GE VERNOVA

# L30 Line Current Differential System

## UR Series Instruction Manual

**L30 revision: 7.2x**

Manual P/N: 1601-9050-AA7

E83849
LISTED
IND.CONT. EQ.
52TL

DISTRIBUTED NETWORK PROTOCOL level 2 dnp PASSED Level Two Conformance Tested

REGISTERED ISO 9001

WORLDWIDE 10 YEAR WARRANTY

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Use this chapter for initial setup of your new L30 Line Current Differential System.

### 1.1.1 CAUTIONS AND WARNINGS

Before attempting to install or use the device, review all safety indicators in this document to help prevent injury, equipment damage, or downtime.

The following safety and equipment symbols are used in this document.

**Indicates a hazardous situation which, if not avoided, will result in death or serious injury.**

**Indicates a hazardous situation which, if not avoided, could result in death or serious injury.**

**Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.**

Indicates practices not related to personal injury.

#### a) GENERAL CAUTIONS AND WARNINGS

The following general safety precautions and warnings apply.

**Ensure that all connections to the product are correct so as to avoid accidental risk of shock and/or fire, for example such as can arise from high voltage connected to low voltage terminals.**

**Follow the requirements of this manual, including adequate wiring size and type, terminal torque settings, voltage, current magnitudes applied, and adequate isolation/clearance in external wiring from high to low voltage circuits.**

**Use the device only for its intended purpose and application.**

**Ensure that all ground paths are uncompromised for safety purposes during device operation and service.**

**Ensure that the control power applied to the device, the AC current, and voltage input match the ratings specified on the relay nameplate. Do not apply current or voltage in excess of the specified limits.**

**Only qualified personnel are to operate the device. Such personnel must be thoroughly familiar with all safety cautions and warnings in this manual and with applicable country, regional, utility, and plant safety regulations.**

**Hazardous voltages can exist in the power supply and at the device connection to current transformers, voltage transformers, control, and test circuit terminals. Make sure all sources of such voltages are isolated prior to attempting work on the device.**

**Hazardous voltages can exist when opening the secondary circuits of live current transformers. Make sure that current transformer secondary circuits are shorted out before making or removing any connection to the current transformer (CT) input terminals of the device.**

**For tests with secondary test equipment, ensure that no other sources of voltages or currents are connected to such equipment and that trip and close commands to the circuit breakers or other switching apparatus are isolated, unless this is required by the test procedure and is specified by appropriate utility/plant procedure.**

**When the device is used to control primary equipment, such as circuit breakers, isolators, and other switching apparatus, all control circuits from the device to the primary equipment must be isolated while personnel are working on or around this primary equipment to prevent any inadvertent command from this device.**

**Use an external disconnect to isolate the mains voltage supply.**

**Personal safety can be affected if the product is physically modified by the end user. Modifications to the product outside of recommended wiring configuration, hardware, or programming boundaries is not recommended end-use practice. Product disassembly and repairs are not permitted. All service needs to be conducted by the factory.**

**LED transmitters are classified as IEC 60825-1 Accessible Emission Limit (AEL) Class 1M. Class 1M devices are considered safe to the unaided eye. Do not view directly with optical instruments.**

1

**NOTICE** This product is rated to Class A emissions levels and is to be used in Utility, Substation Industrial environments. Not to be used near electronic devices rated for Class B levels.

### 1.1.2 INSPECTION PROCEDURE

1. Open the relay packaging and inspect the unit for physical damage.
2. View the rear nameplate and verify that the correct model has been ordered and delivered. The model number is at the top right.

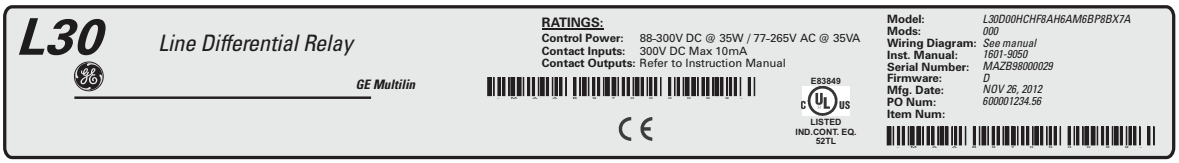


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**Figure 1–1: REAR NAMEPLATE (EXAMPLE)**

3. Ensure that the following items are included:
   - Instruction manual (if ordered)
   - GE EnerVista™ DVD (includes the EnerVista UR Setup software and manuals in PDF format)
   - Mounting screws
4. If there is any noticeable physical damage, or any of the contents listed are missing, contact GE Grid Solutions as follows.

**GE GRID SOLUTIONS CONTACT INFORMATION AND CALL CENTER FOR PRODUCT SUPPORT:**

GE Grid Solutions
650 Markland Street
Markham, Ontario
Canada L6C 0M1

**TELEPHONE**: Worldwide +1 905 927 7070
Europe/Middle East/Africa +34 94 485 88 54
North America toll-free 1 800 547 8629
**FAX**: +1 905 927 5098
**E-MAIL**: Worldwide multilin.tech@ge.com
Europe multilin.tech.euro@ge.com
**HOME PAGE**: http://www.gegridsolutions.com/multilin

For updates to the instruction manual, firmware, and software, visit the GE Grid Solutions website.

### 1.2.1 INTRODUCTION TO THE UR

The GE Universal Relay (UR) series is a new generation of digital, modular, and multifunction equipment that is easily incorporated into automation systems, at both the station and enterprise levels.

### 1.2.2 HARDWARE ARCHITECTURE

#### a) UR BASIC DESIGN

The UR is a digital-based device containing a central processing unit (CPU) that handles multiple types of input and output signals. The UR device can communicate over a local area network (LAN) with an operator interface, a programming device, or another UR device.

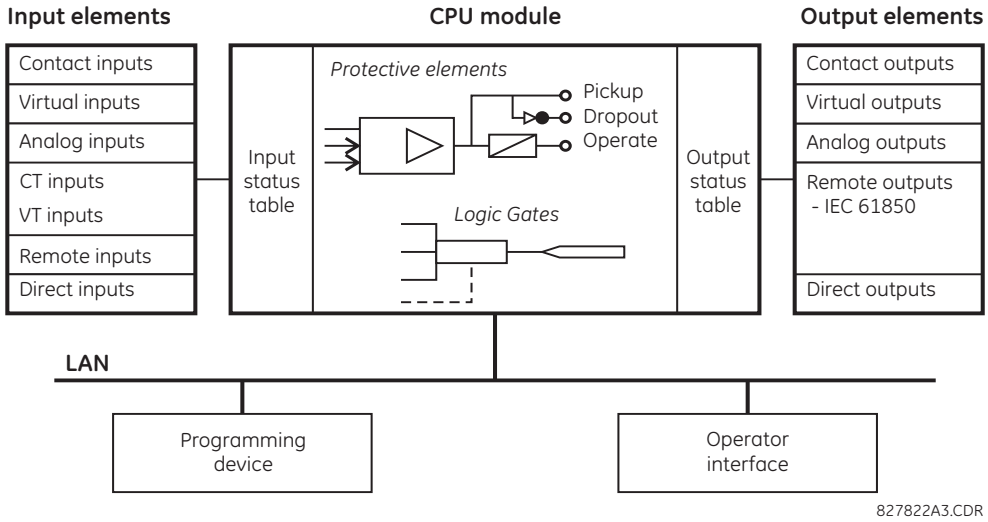



**Figure 1–2: UR BLOCK DIAGRAM**

The **CPU module** contains firmware that provides protection elements in the form of logic algorithms, as well as programmable logic gates, timers, and latches for control features.

**Input elements** accept a variety of analog or digital signals from the field. The UR isolates and converts these signals into logic signals used by the relay.

**Output elements** convert and isolate the logic signals generated by the relay into digital or analog signals that are used to control field devices.

The unit and software are backwards-compatible with UR devices.

#### b) UR SIGNAL TYPES

The **contact inputs and outputs** are digital signals associated with connections to hard-wired contacts. Both 'wet' and 'dry' contacts are supported.

The **virtual inputs and outputs** are digital signals associated with UR-series internal logic signals. Virtual inputs include signals generated by the local user interface. The virtual outputs are outputs of FlexLogic™ equations used to customize the device. Virtual outputs can also serve as virtual inputs to FlexLogic equations.

The **analog inputs and outputs** are signals that are associated with transducers, such as Resistance Temperature Detectors (RTDs).

The **CT and VT inputs** are analog current transformer and voltage transformer signals used to monitor AC power lines. The UR-series relays support 1 A and 5 A CTs.

The **remote inputs and outputs** provide a means of sharing digital point state information between remote UR-series devices. The remote outputs interface to the remote inputs of other UR-series devices. Remote outputs are FlexLogic operands inserted into IEC 61850 GSSE and GOOSE messages.

The **direct inputs and outputs** provide a means of sharing digital point states between a number of UR-series intelligent electronic devices (IEDs) over dedicated fiber, RS422, or G.703 interface. No switching equipment is required as the IEDs are connected directly in a ring or redundant (dual) ring configuration. This feature is optimized for speed and intended for pilot-aided schemes, distributed logic applications, or the extension of the input/output capabilities of a single relay chassis.

### 1.2.3 SOFTWARE ARCHITECTURE

Firmware is the software embedded in the relay in functional modules that can be installed in any relay as required. This is achieved with object-oriented design and programming (OOD/OOP) techniques.

Object-oriented techniques involve the use of *objects* and *classes*. An object is defined as "a logical entity that contains both data and code that manipulates data." A class is the generalized form of similar objects. By using this approach, one can create a protection class with the protection elements as objects of the class, such as time overcurrent, instantaneous overcurrent, current differential, undervoltage, overvoltage, underfrequency, and distance. These objects represent completely self-contained software modules. The same object-class concept can be used for metering, input/output control, software interface, communications, or any functional entity in the system.

Employing OOD/OOP in the software architecture of the L30 achieves the same features as the hardware architecture: modularity, scalability, and flexibility. The application software for any UR-series device (for example, feeder protection, transformer protection, distance protection) is constructed by combining objects from the various functional classes. This results in a common interface across the UR series.

### 1.3.1 SYSTEM REQUIREMENTS

The relay front panel or the EnerVista UR Setup software can be used to communicate with the relay. The software interface is the preferred method to edit settings and view actual values because the computer monitor can display more information.

The minimum system requirements for the EnerVista UR Setup software are as follows:

- Pentium 4 (Core Duo recommended)
- Windows XP with Service Pack 2 (Service Pack 3 recommended), Windows 7, or Windows Server 2008 Release 2 64-bit
- 1 GB of RAM (2 GB recommended)
- 500 MB free hard drive space (1 GB recommended)
- 1024 x 768 display (1280 x 800 recommended)
- Serial port
- Ethernet port of the same type as one of the UR CPU ports or a LAN connection to the UR
- Internet access or a DVD drive

The following qualified modems have been tested to be compatible with the L30 and the EnerVista UR Setup software:

- US Robotics external 56K FaxModem 5686
- US Robotics external Sportster 56K X2
- PCTEL 2304WT V.92 MDC internal modem

### 1.3.2 INSTALLATION

After ensuring that the requirements for using EnerVista UR Setup software are met, install the software from the GE EnerVista DVD. Or download the UR EnerVista software from http://www.gegridsolutions.com/multilin and install it.

To install the UR EnerVista software from the DVD:

1. Insert the GE EnerVista DVD into the DVD drive of your computer.
2. Click the **Install Now** button and follow the instructions.
3. When installation is complete, start the EnerVista Launchpad application.
4. Click the **IED Setup** section of the **Launch Pad** window.

**Figure 1–3: ADDING A UR DEVICE IN LAUNCHPAD WINDOW**

5. In the EnerVista Launch Pad window, click the **Add Product** button and select the appropriate product as follows. Select the **Web** option to ensure the most recent software release, or select **CD** if you do not have an Internet connec-

tion, then click the **Add Now** button to list software items for the product. EnerVista Launchpad obtains the software from the Internet or DVD and automatically starts the installation program.

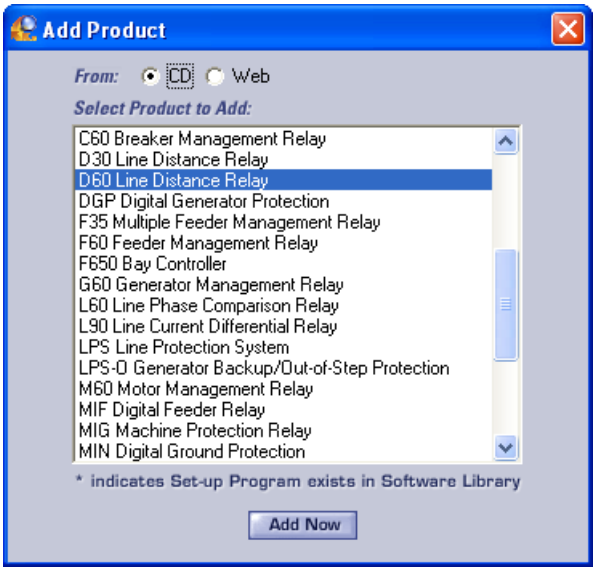



**Figure 1–4: IDENTIFYING THE UR DEVICE TYPE**

6. Select the complete path, including the new directory name, where the EnerVista UR Setup software is to be installed.
7. Click the **Next** button to begin the installation. The files are installed in the directory indicated, and the installation program automatically creates icons and adds an entry to the Windows start menu.
8. Click **Finish** to complete the installation. The UR device is added to the list of installed intelligent electronic devices (IEDs) in the EnerVista Launchpad window, as shown.

**Figure 1–5: UR DEVICE ADDED TO LAUNCHPAD WINDOW**

## 1.3.3 CONFIGURING THE L30 FOR SOFTWARE ACCESS

### a) OVERVIEW

You connect remotely to the L30 through the rear RS485 or Ethernet port with a computer running the EnerVista UR Setup software. The L30 can also be accessed locally with a computer through the front panel RS232 port or the rear Ethernet port using the Quick Connect feature.

- To configure the L30 for remote access via the rear RS485 port, see the Configuring Serial Communications section.
- To configure the L30 for remote access via the rear Ethernet port, see the Configuring Ethernet Communications section.
- To configure the L30 for local access with a computer through either the front RS232 port or rear Ethernet port, see the Using the Quick Connect Feature section.

Implement IP addresses for the computer and a L30 device as follows.

The UR family supports the use of subnetworks as documented in RFC 950, which divides class-based networks into sub-networks (non-CIDR). The classes and IP address ranges are defined as follows.

**Table 1–1: IP ADDRESS CLASSES**

| CLASSES | IP ADDRESS RANGE | DEFAULT SUBNET MASK ADDRESS | UR DEVICES |
|---|---|---|---|
| A | 1.0.0.0 to 127.255.255.255 | 255.0.0.0 | 65,535 or more |
| B | 128.0.0.0 to 191.255.255.255 | 255.255.0.0 | 255 to 65,534 |
| C | 192.0.0.0 to 223.255.255.255 | 255.255.255.0 | 0 to 254 |
| D | 224.0.0.0 to 239.255.255.255 | (Reserved for multicasting) | |
| E | 240.0.0.0 to 255.255.255.255 | (Reserved) | |

Both network and subnet addresses are contained within a range. The number of hosts determines the class and addresses as follows:

- Class A 255.0.0.0 — The first octet (255) specifies the network, the second to fourth octets (0) specify the subnet and host. Use this class when you have more than 65,535 hosts (UR devices).
- Class B 255.255.0.0 — The first two octets (255) specify the network, the third octet (0) specifies the subnet, and the fourth octet (0) specifies the host. Use this class when you have 255 to 65,534 hosts (UR devices).
- Class C 255.255.255.0 — The first three octets (255) specify the network and the last octet (0) specifies the subnet and host. Use this class when you have up to 254 hosts (UR devices).

An example of implementation is one computer and one UR device. Because there is one UR device, class C addressing is required. So we use UR 192.167.2.x with subnet mask 255.255.255.0 and computer 192.167.3.x with subnet mask 255.255.255.0.

For older, non-CIDR routing protocols, such as RIP version 1, follow these restrictions:

- Identical subnet masks — Use a single mask for all subnets within a network
- Contiguous subnets — The subnets must be contiguous and not split among networks. The subnets cannot pass traffic through other networks.

### b) CONFIGURING SERIAL COMMUNICATIONS

A computer with an RS232 port and a serial cable is required. To use the RS485 port at the back of the relay, a GE Multilin F485 converter (or compatible RS232-to-RS485 converter) is required. See the F485 instruction manual for details.

1. Connect the computer to the F485 and the F485 to the RS485 terminal on the back of the UR device, or connect the computer to the RS232 port on the front of the relay.
2. In the EnerVista Launchpad software on the computer, select the UR device to start the software.
3. Click the **Device Setup** button to open the Device Setup window, and click the **Add Site** button to define a new site.
4. Enter a site name in the **Site Name** field. Optionally add a short description of the site along with the display order of devices defined for the site. This example uses “Location 1” as the site name. When done, click the **OK** button. The new site appears in the upper-left list in the EnerVista UR Setup window.
5. Click the **Device Setup** button, then select the new site to re-open the Device Setup window.
6. Click the **Add Device** button to define the new device.
7. Enter a name in the "Device Name” field and a description (optional) of the site.

8. Select “Serial” from the **Interface** drop-down list. This displays a number of interface parameters that must be entered for serial communications.

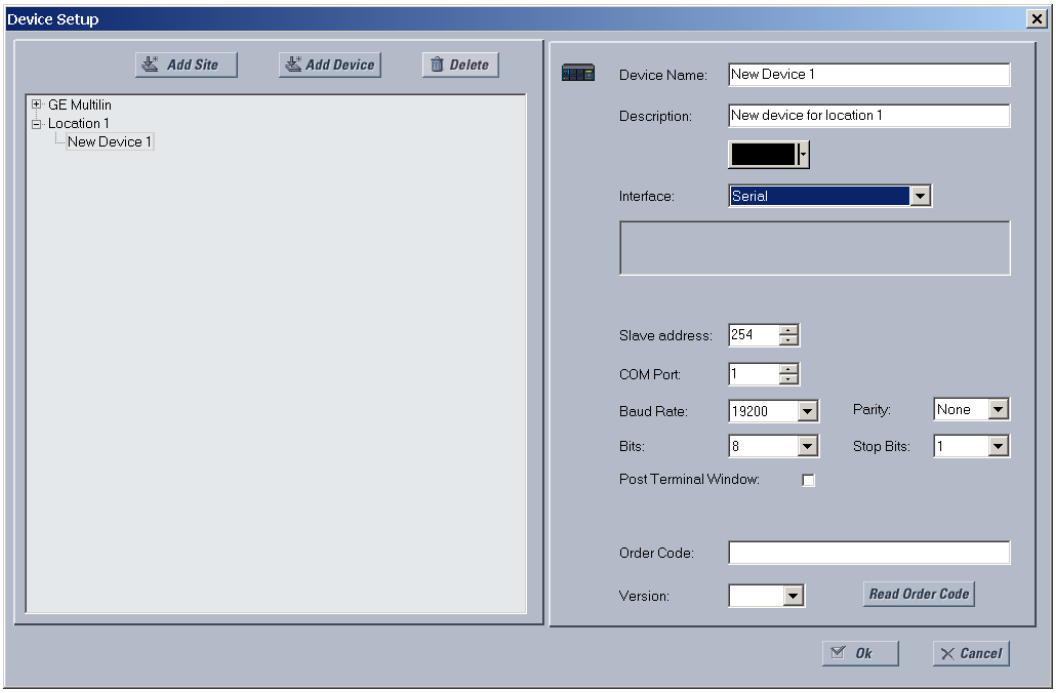



**Figure 1–6: CONFIGURING SERIAL COMMUNICATIONS**

9. Enter the COM port used by the computer, the baud rate, and parity settings from the front panel **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **COMMUNICATIONS** ⇨ **SERIAL PORTS** menu, and the relay slave address setting from the front panel **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **COMMUNICATIONS** ⇨⇩ **MODBUS PROTOCOL** ⇨ **MODBUS SLAVE ADDRESS** menu in their respective fields.
10. Click the **Read Order Code** button to connect to the L30 device and upload the order code. If a communications error occurs, ensure that the EnerVista UR Setup serial communications values entered in the previous step correspond to the relay setting values.
11. Click the **OK** button when the relay order code has been received. The new device is added to the Site List window (or Online window) located in the top left corner of the main EnerVista UR Setup window.

The device has now been configured for RS232 communications. Proceed to the Connecting to the L30 section to begin communication.

### c) CONFIGURING ETHERNET COMMUNICATIONS

Before starting, verify that the Ethernet network cable is properly connected to the Ethernet port on the back of the relay. To setup the relay for Ethernet communications, you define a Site, then add the relay as a Device at that site.The computer and UR device must be on the same subnet.

12. Select the “UR” device from the EnerVista Launchpad to start EnerVista UR Setup.
13. Click the **Device Setup** button to open the Device Setup window, then click the **Add Site** button to define a new site.
14. Enter the desired site name in the “Site Name” field. If desired, a short description of site can also be entered along with the display order of devices defined for the site. In this example, we use “Location 2” as the site name. Click the **OK** button when complete.
15. The new site appears in the upper-left list in the EnerVista UR Setup window. Click the **Device Setup** button then select the new site to re-open the Device Setup window.
16. Click the **Add Device** button to define the new device.
17. Enter the desired name in the “Device Name” field and a description (optional) of the site.

18. Select “Ethernet” from the **Interface** drop-down list. This displays a number of interface parameters that must be entered for proper Ethernet functionality.

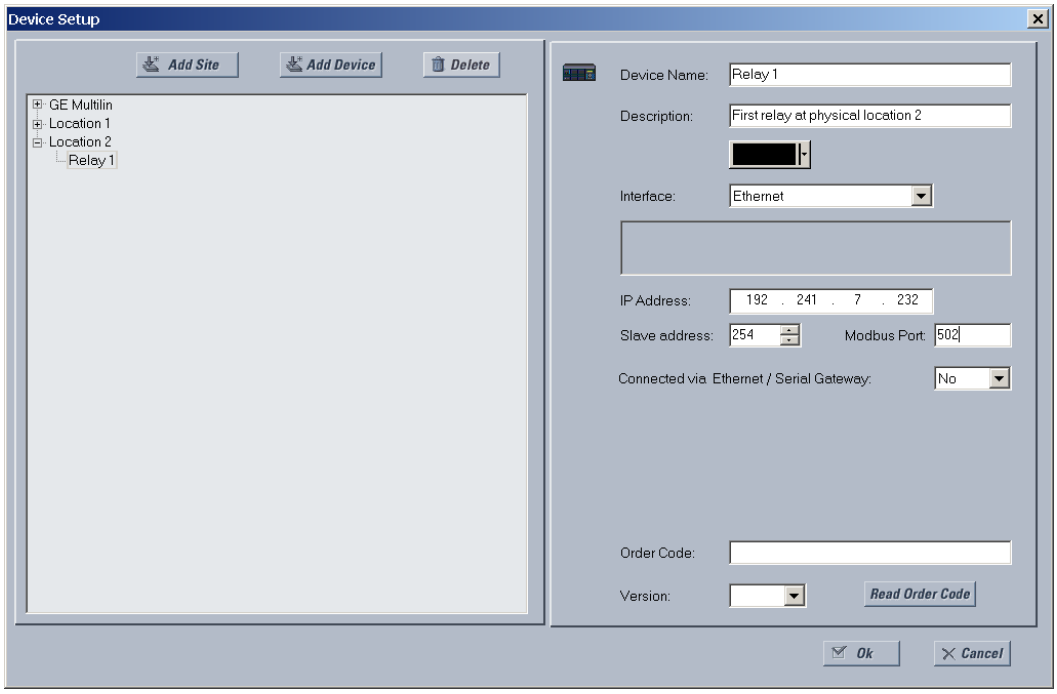



**Figure 1–7: CONFIGURING ETHERNET COMMUNICATIONS**

19. Enter the relay IP address specified in the front panel **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **COMMUNICATIONS** ⇨⇩ **NETWORK** ⇨ **IP ADDRESS** in the “IP Address” field.
20. Enter the relay slave address and Modbus port address values from the respective settings in the front panel **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **COMMUNICATIONS** ⇨⇩ **MODBUS PROTOCOL** menu.
21. Click the **Read Order Code** button to connect to the L30 device and upload the order code. If an communications error occurs, ensure that the three EnerVista UR Setup values entered in the previous steps correspond to the relay setting values.
22. Click **OK** when the relay order code has been received. The new device is added to the Site List window (or Online window) located in the top left corner of the main EnerVista UR Setup window.

The Site Device has now been configured for Ethernet communications. Proceed to the Connecting to the L30 section to begin communications.

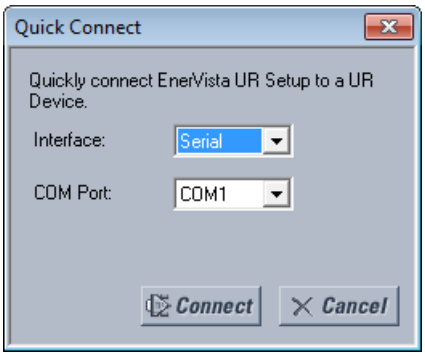
### 1.3.4 USING THE QUICK CONNECT FEATURE

#### a) USING QUICK CONNECT VIA THE FRONT PANEL RS232 PORT

Before starting, verify that the serial cable is properly connected from the computer to the front panel RS232 port with a straight-through 9-pin to 9-pin RS232 cable.

1. Verify that the latest version of the EnerVista UR Setup software is installed (available from the GE EnerVista CD or online from http://www.gegridsolutions.com/multilin). See the Software Installation section if not already installed.
2. Select the “UR” device from the EnerVista Launchpad to start EnerVista UR Setup.

3. Click the **Quick Connect** button to open the Quick Connect dialog box.




4. Select the **Serial** interface and the correct COM Port, then click **Connect**.
5. The EnerVista UR Setup software creates a site named "Quick Connect" with a corresponding device also named "Quick Connect" and displays them at the upper-left of the screen. Expand the sections to view data directly from the L30 device.

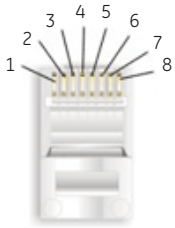
Each time that the EnerVista UR Setup software is initialized, click the **Quick Connect** button to establish direct communications to the L30 device. This ensures that configuration of the EnerVista UR Setup software matches the L30 model number.

### b) USING QUICK CONNECT VIA THE REAR ETHERNET PORTS

To use the Quick Connect feature to access the L30 from a computer through Ethernet, first assign an IP address to the relay from the front panel keyboard.

1. Press the MENU key until the SETTINGS menu displays.
2. Navigate to the **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **COMMUNICATIONS** ⇨⇩ **NETWORK** ⇨ **IP ADDRESS** setting.
3. Enter an IP address, for example "1.1.1.1," and select the ENTER key to save the value.
4. In the same menu, select the **SUBNET IP MASK** setting.
5. Enter a subnet IP address, for example "255.0.0.0," and press the ENTER key to save the value.

Next, use an Ethernet cross-over cable to connect the computer to the rear Ethernet port. In case you need it, the figure shows the pinout for an Ethernet cross-over cable.




| END 1 | | |
|---|---|---|
| Pin | Wire color | Diagram |
| 1 | White/orange | |
| 2 | Orange | |
| 3 | White/green | |
| 4 | Blue | |
| 5 | White/blue | |
| 6 | Green | |
| 7 | White/brown | |
| 8 | Brown | |

| END 2 | | |
|---|---|---|
| Pin | Wire color | Diagram |
| 1 | White/green | |
| 2 | Green | |
| 3 | White/orange | |
| 4 | Blue | |
| 5 | White/blue | |
| 6 | Orange | |
| 7 | White/brown | |
| 8 | Brown | |

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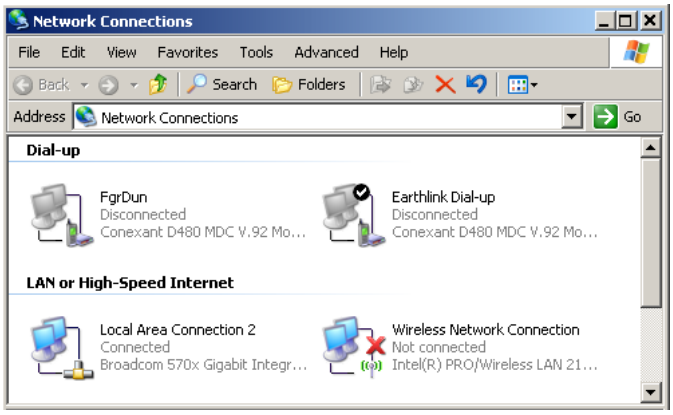
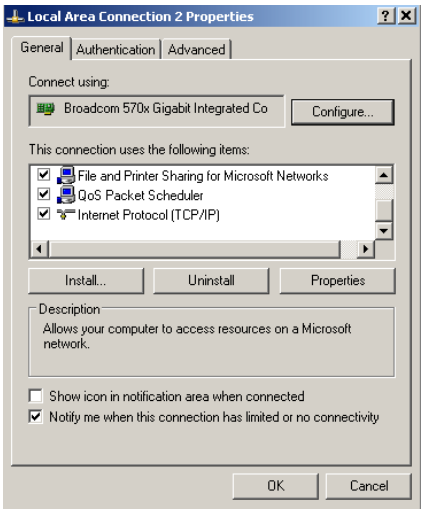
**Figure 1–8: ETHERNET CROSS-OVER CABLE PIN LAYOUT**

Now, assign the computer an IP address compatible with the relay's IP address.

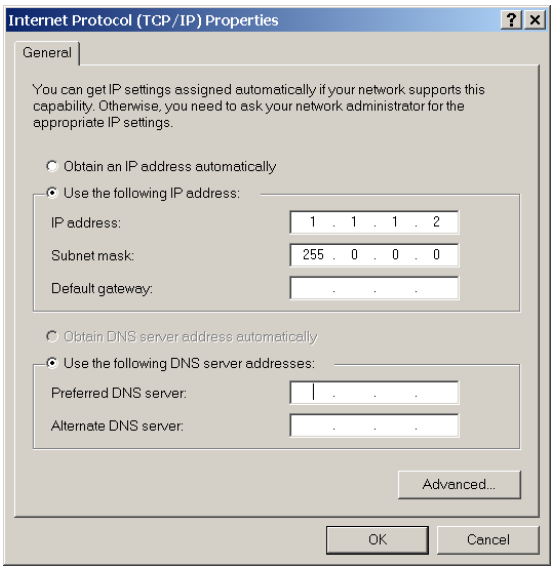
1. From the Windows desktop, right-click the **My Network Places** icon and select **Properties** to open the network connections window.




2. Right-click the **Local Area Connection** icon and select **Properties**.



3. Select the **Internet Protocol (TCP/IP)** item from the list, and click the **Properties** button.




4. Click the “Use the following IP address” box.
5. Enter an **IP address** with the first three numbers the same as the IP address of the L30 relay and the last number different (in this example, 1.1.1.2).
6. Enter a subnet mask equal to the one set in the L30 (in this example, 255.0.0.0).
7. Click the **OK** button to save the values.

Before continuing, test the Ethernet connection.

1. Open a Windows console window by selecting **Start > Run** from the Windows **Start** menu and typing “cmd”.
2. Type the following command, substituting the IP address of 1.1.1.1 with yours:

```
C:\WINNT>ping 1.1.1.1
```

3. If the connection is successful, the system returns four replies similar to the following:

```
Pinging 1.1.1.1 with 32 bytes of data:

Reply from 1.1.1.1: bytes=32 time<10ms TTL=255
Reply from 1.1.1.1: bytes=32 time<10ms TTL=255
Reply from 1.1.1.1: bytes=32 time<10ms TTL=255
Reply from 1.1.1.1: bytes=32 time<10ms TTL=255

Ping statistics for 1.1.1.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip time in milliseconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0 ms
```

4. Note that the values for `time` and `TTL` vary depending on local network configuration.
5. If the following sequence of messages appears when entering the `C:\WINNT>ping 1.1.1.1` command:

```
Pinging 1.1.1.1 with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 1.1.1.1:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
Approximate round trip time in milliseconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0 ms

Pinging 1.1.1.1 with 32 bytes of data:
```

verify the physical connection between the L30 and the computer, and double-check the programmed IP address in the **PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ NETWORK ⇨ IP ADDRESS** setting, then repeat step 2.

6. If the following sequence of messages appears when entering the `C:\WINNT>ping 1.1.1.1` command:

```
Pinging 1.1.1.1 with 32 bytes of data:

Hardware error.
Hardware error.
Hardware error.
Hardware error.

Ping statistics for 1.1.1.1:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
Approximate round trip time in milliseconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0 ms

Pinging 1.1.1.1 with 32 bytes of data:
```

verify the physical connection between the L30 and the computer, and double-check the programmed IP address in the **PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ NETWORK ⇨ IP ADDRESS** setting, then repeat step 2.

7. If the following sequence of messages appears when entering the `C:\WINNT>ping 1.1.1.1` command:

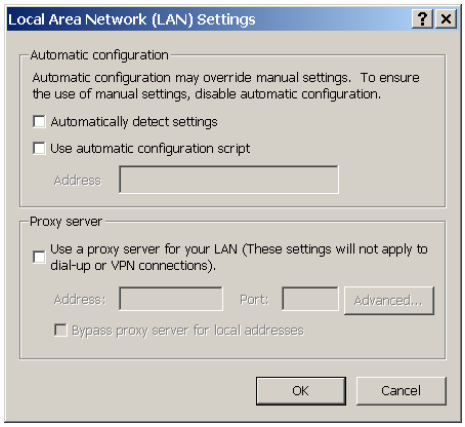
```
Pinging 1.1.1.1 with 32 bytes of data:

Destination host unreachable.
Destination host unreachable.
Destination host unreachable.
Destination host unreachable.

Ping statistics for 1.1.1.1:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
Approximate round trip time in milliseconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0 ms

Pinging 1.1.1.1 with 32 bytes of data:
```

verify the IP address is programmed in the local computer by entering the ipconfig command in the command window.

```
C:\WINNT>ipconfig

Windows IP Configuration

Ethernet adapter <F4FE223E-5EB6-4BFB-9E34-1BD7BE7F59FF>:

        Connection-specific DNS suffix. . :
        IP Address. . . . . . . . . . . . : 0.0.0.0
        Subnet Mask . . . . . . . . . . . : 0.0.0.0
        Default Gateway . . . . . . . . . :

Ethernet adapter Local Area Connection:

        Connection-specific DNS suffix  . :
        IP Address. . . . . . . . . . . . : 1.1.1.2
        Subnet Mask . . . . . . . . . . . : 255.0.0.0
        Default Gateway . . . . . . . . . :

C:\WINNT>
```

Before using the Quick Connect feature through the Ethernet port, disable any configured proxy settings in Internet Explorer.

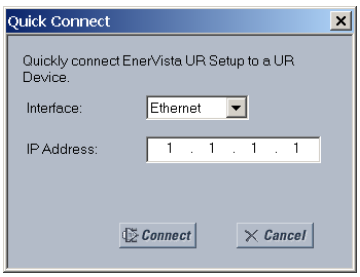
1. Start the Internet Explorer software.
2. Select the **Tools > Internet Options** menu item and click the **Connections** tab.
3. Click on the **LAN Settings** button to open the following window.




4. Ensure that the “Use a proxy server for your LAN” box is not checked.

If this computer is used to connect to the Internet, re-enable any proxy server settings after the computer has been disconnected from the L30 relay.

1. Start the Internet Explorer software.
2. Select the “UR” device from the EnerVista Launchpad to start EnerVista UR Setup.
3. Click the **Quick Connect** button to open the Quick Connect dialog box.

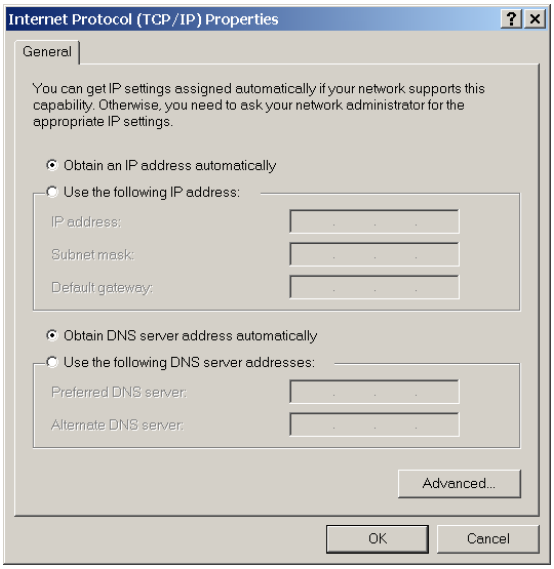


4. Select the **Ethernet** interface and enter the IP address assigned to the L30, then click the **Connect** button. The EnerVista UR Setup software creates a site named “Quick Connect” with a corresponding device also named “Quick Connect” and displays them at the upper-left of the screen.
5. Expand the sections to view data directly from the L30 device.

Each time the EnerVista UR Setup software is initialized, click the **Quick Connect** button to establish direct communications to the L30. This ensures that configuration of the EnerVista UR Setup software matches the L30 model number.

When direct communications with the L30 via Ethernet is complete, make the following changes:

1. From the Windows desktop, right-click the **My Network Places** icon and select **Properties** to open the network connections window.
2. Right-click the **Local Area Connection** icon and select the **Properties** item.
3. Select the **Internet Protocol (TCP/IP)** item from the list provided and click the **Properties** button.
4. Set the computer to “Obtain a relay address automatically” as shown.




If this computer is used to connect to the Internet, re-enable any proxy server settings after the computer has been disconnected from the L30 relay.

**AUTOMATIC DISCOVERY OF ETHERNET DEVICES**

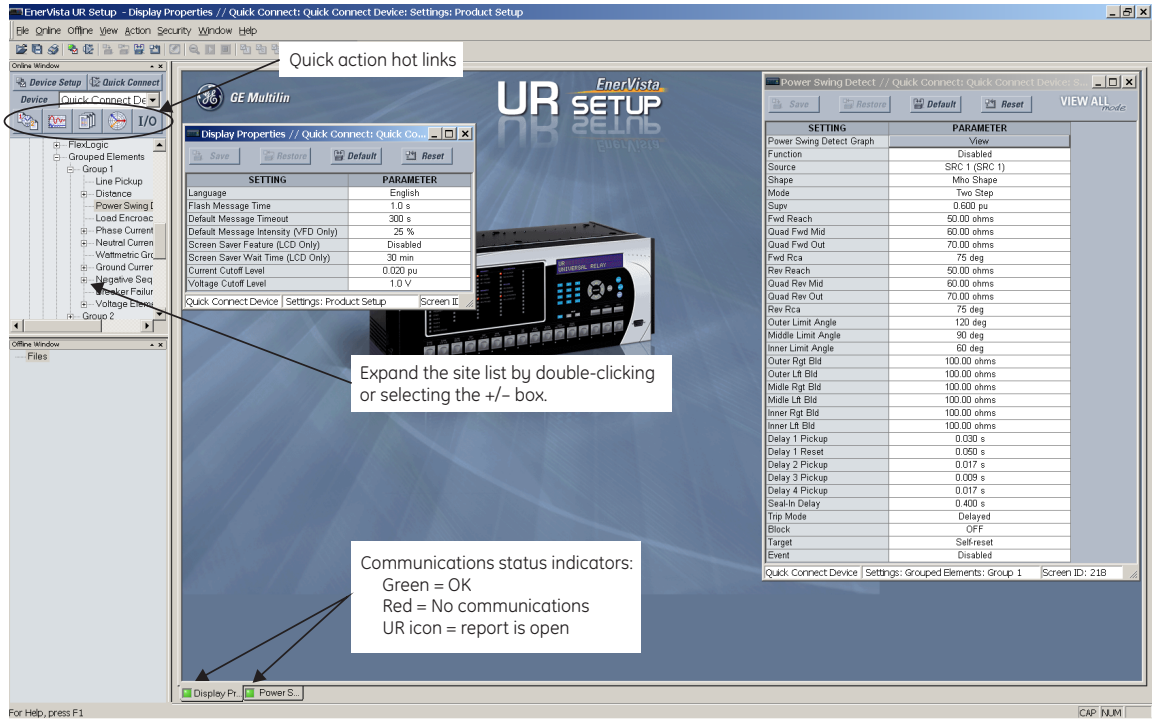
The EnerVista UR Setup software can automatically discover and communicate to all UR-series IEDs located on an Ethernet network.

Using the Quick Connect feature, a single click of the mouse triggers the software to automatically detect any UR-series relays located on the network. The EnerVista UR Setup software then proceeds to configure all settings and order code options in the **Device Setup** menu. This feature allows the user to identify and interrogate all UR-series devices at a location.

### 1.3.5 CONNECTING TO THE L30 RELAY

When unable to connect because of an "ACCESS VIOLATION," access **Device Setup** and refresh the order code for the device.

1. Open the Display Properties window through the Site List tree as shown. The Display Properties window opens with a status indicator on the lower left of the EnerVista UR Setup window.




842743A3.CDR

2. If the status indicator is red, verify that the Ethernet network cable is properly connected to the Ethernet port on the back of the relay and that the relay has been properly setup for communications (steps A and B earlier).

   If a relay icon appears in place of the status indicator, than a report (such as an oscillography or event record) is open. Close the report to re-display the green status indicator.

3. The Display Properties settings can now be edited, printed, or changed.

NOTE

See chapter 4 in this manual or the EnerVista UR Setup Help File for information about the using the EnerVista UR Setup software interface.

### QUICK ACTION HOT LINKS

The EnerVista UR Setup software has several quick action buttons to provide instant access to several functions that are often performed when using L30 relays. From the online window, users can select the relay to interrogate from a pull-down window, then click the button for the action they want to perform. The following quick action functions are available:

- View the L30 event record
- View the last recorded oscillography record
- View the status of all L30 inputs and outputs
- View all of the L30 metering values
- View the L30 protection summary
- Generate a service report

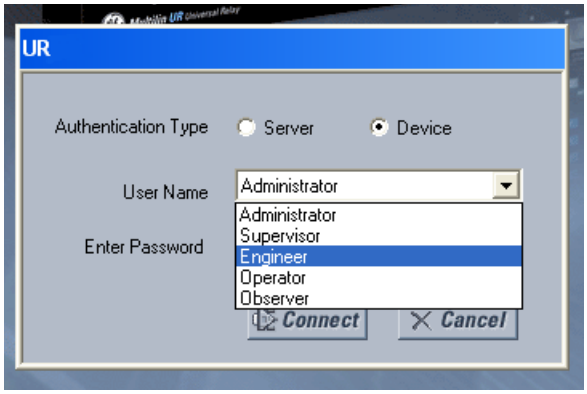
### 1.3.6 SETTING UP CYBERSENTRY AND CHANGING DEFAULT PASSWORD

If and when first using CyberSentry security, use the following procedure for set up.

1. Log in to the relay as Administrator by using the Value keys on the front panel or through EnerVista connected serially (so that no IP address is required). If logging in through EnerVista choose Device authentication. Enter the default password "ChangeMe1#". Note that the "Lock relay" setting needs to be disabled in the **Security > Supervisory** menu. When this setting is disabled, configuration and firmware upgrade are possible. By default, this setting is disabled.
2. Enable the Supervisor role if you have a need for it.
3. Make any required changes in configuration, such as setting a valid IP address for communication over Ethernet.
4. Log out of the Administrator account by choosing None.

Next, device or server authentication can be chosen on the login screen, but the choice is available only in EnerVista. Use device authentication to log in using the five pre-configured roles (Administrator, Supervisor, Engineer, Operator, Observer, or Administrator and Supervisor when device authentication is disabled). When using a serial connection, only device authentication is supported. When server authentication is required, characteristics for communication with a RADIUS server must be configured on the UR. This is possible only through the EnerVista software. The RADIUS server itself also must be configured. The appendix called RADIUS Server gives an example of how to setup a simple RADIUS server. Once both the RADIUS server and the parameters for connecting UR to the server have been configured, you can choose server authentication on the login screen of EnerVista.

**Figure 1–9: LOGIN SCREEN FOR CYBERSENTRY**




During the commissioning phase, you have the option to bypass the use of passwords. Do so by enabling the **BYPASS ACCESS** setting under **SETTINGS > PRODUCT SETUP > SECURITY > SUPERVISORY**. Be sure to disable this bypass setting after commissioning the device.

You can change the password for any role either from the front panel or through EnerVista.

If using EnerVista, navigate to **Settings > Product Setup > Security**. Change the **Local Administrator Password**, for example. It is strongly recommended that the password for the Administrator be changed from the default. Changing the passwords for the other three roles is optional.

### 1.4.1 MOUNTING AND WIRING

See Chapter 3: Hardware for mounting and wiring instructions.

### 1.4.2 COMMUNICATIONS

The EnerVista UR Setup software communicates to the relay via the faceplate RS232 port or the rear panel RS485 / Ethernet ports. To communicate via the faceplate RS232 port, a standard straight-through serial cable is used. The DB-9 male end is connected to the relay and the DB-9 or DB-25 female end is connected to the computer COM2 port as described in the CPU Communication Ports section of chapter 3.

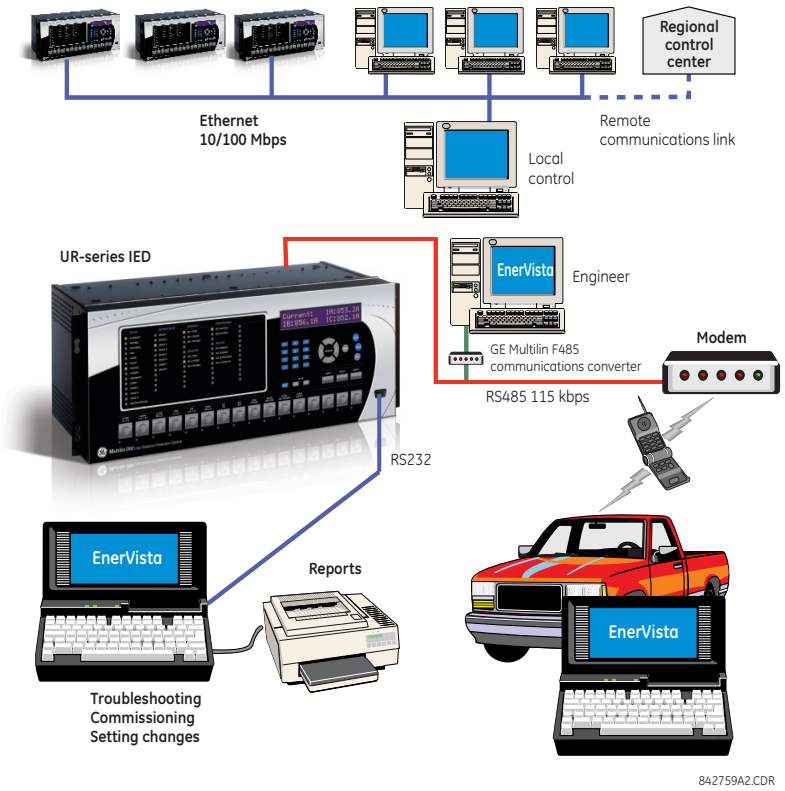



**Figure 1–10: RELAY COMMUNICATION OPTIONS**

To communicate through the L30 rear RS485 port from a computer RS232 port, the GE Multilin RS232/RS485 converter box is required. This device (catalog number F485) connects to the computer using a straight-through serial cable. A shielded twisted-pair (20, 22, or 24 AWG) connects the F485 converter to the L30 rear communications port. The converter terminals (+, –, GND) are connected to the L30 communication module (+, –, COM) terminals. See the CPU Communication Ports section in chapter 3 for details. The line is terminated with an R-C network (that is, 120 Ω, 1 nF) as described in the chapter 3.

### 1.4.3 FACEPLATE DISPLAY

All messages are displayed on a backlit liquid crystal display (LCD) to make them visible under poor lighting conditions. While the keypad and display are not actively being used, the display defaults to user-defined messages. Any high-priority event-driven message automatically overrides the default message and appears on the display.

Settings files conversion from previous firmware versions is supported.

### 1.5.1 FACEPLATE KEYPAD

Display messages are organized into pages under the following headings: actual values, settings, commands, and targets. The MENU key navigates through these pages. Each heading page is divided further into logical subgroups.

The MESSAGE keys navigate through the subgroups. The VALUE keys increment or decrement numerical setting values when in programming mode. These keys also scroll through alphanumeric values in the text edit mode. Alternatively, values can be entered with the numeric keypad.

The decimal key initiates and advances to the next character in text edit mode or enters a decimal point.

The HELP key can be pressed at any time for context-sensitive help messages.

The ENTER key stores altered setting values.

When entering an IP address on the front panel, key in the first sequence of the number, then press the • key for the decimal place. For example, for 127.0.0.1, press 127, then •, then 0, then •, then 0, then •, then 1. To save the address, press the ENTER key.

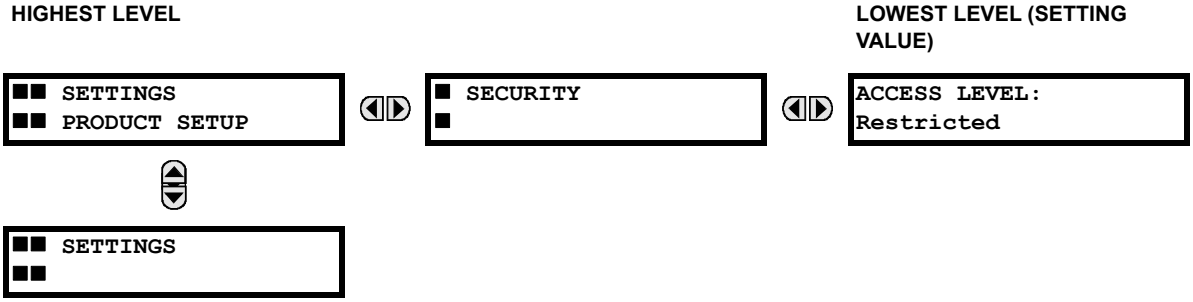
### 1.5.2 MENU NAVIGATION

Press the MENU key to select a header display page (top-level menu). The header title appears momentarily followed by a header display page menu item. Each press of the MENU key advances through the following main heading pages:

- Actual values
- Settings
- Commands
- Targets
- User displays (when enabled)

### 1.5.3 MENU HIERARCHY

The setting and actual value messages are arranged hierarchically. The header display pages are indicated by double scroll bar characters (■■), while sub-header pages are indicated by single scroll bar characters (■). The header display pages represent the highest level of the hierarchy and the sub-header display pages fall below this level. The MESSAGE UP and DOWN keys move within a group of headers, sub-headers, setting values, or actual values. Continually pressing the MESSAGE RIGHT key from a header display displays specific information for the header category. Conversely, continually pressing the MESSAGE LEFT key from a setting value or actual value display returns to the header display.



### 1.5.4 RELAY ACTIVATION

The relay is in the default “Not Programmed” state when it leaves the factory. When powered up successfully, the Trouble LED is on and the In Service LED off. The relay in the “Not Programmed” state blocks signaling of any output relay. These conditions remain until the relay is explicitly put in the “Programmed” state.

Select the menu message **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ INSTALLATION ⇨ RELAY SETTINGS**

```
RELAY SETTINGS:
Not Programmed
```

1. To put the relay in the “Programmed” state, press either of the VALUE keys once and then press ENTER. The faceplate Trouble LED turns off and the In Service LED turns on.

The settings for the relay can be programmed manually (see Chapter 5) via the faceplate keypad or remotely via the EnerVista UR Setup software (see the EnerVista UR Setup help file).

### 1.5.5 RELAY PASSWORDS

#### a) PASSWORD SECURITY

It is recommended that passwords be set for each security level and assigned to specific personnel. There are two user security access levels, COMMAND and SETTING.

**1. COMMAND**

The COMMAND access level restricts the user from making any settings changes, but allows the user to perform the following operations:

- Change state of virtual inputs
- Clear event records
- Clear oscillography records
- Operate user-programmable pushbuttons

**2. SETTING**

The SETTING access level allows the user to make any changes to any of the setting values.

NOTE

See the Changing Settings section in Chapter 4 for complete instructions on setting security-level passwords.

#### b) CYBERSENTRY

When the CyberSentry option is purchased, advanced security services are available, using either device authentication or server authentication using RADIUS. When this option is purchased, the basic password security is disabled automatically. For more information, see the CyberSentry content in the *Security* section of the next chapter.

### 1.5.6 FLEXLOGIC CUSTOMIZATION

FlexLogic equation editing is required for setting user-defined logic for customizing the relay operations. See the FlexLogic section in Chapter 5.

The L30 requires minimal maintenance after it is commissioned into service. Since the L30 is a microprocessor-based relay, its characteristics do not change over time. As such, no further functional tests are required. Expected service life is 20 years for UR devices manufactured June 2014 or later when applied in a controlled indoors environment and electrical conditions within specification.

The L30 performs a number of continual self-tests and takes the necessary action in case of any major errors (see the Relay Self-Tests section in chapter 7). However, it is recommended that L30 maintenance be scheduled with other system maintenance. This maintenance can involve in-service, out-of-service, or unscheduled maintenance.

In-service maintenance:

1. Visual verification of the analog values integrity, such as voltage and current (in comparison to other devices on the corresponding system).
2. Visual verification of active alarms, relay display messages, and LED indications.
3. LED test.
4. Visual inspection for any damage, corrosion, dust, or loose wires.
5. Event recorder file download with further events analysis.

Out-of-service maintenance:

1. Check wiring connections for firmness.
2. Analog values (currents, voltages, RTDs, analog inputs) injection test and metering accuracy verification. Calibrated test equipment is required.
3. Protection elements setting verification (analog values injection or visual verification of setting file entries against relay settings schedule).
4. Contact inputs and outputs verification. This test can be conducted by direct change of state forcing or as part of the system functional testing.
5. Visual inspection for any damage, corrosion, or dust.
6. Event recorder file download with further events analysis.
7. LED Test and pushbutton continuity check.

Unscheduled maintenance, such as a disturbance causing system interruption:

1. View the event recorder and oscillography or fault report for correct operation of inputs, outputs, and elements.

If the relay or one of its modules is of concern, contact GE Multilin for service.

### 2.1.1 OVERVIEW



The L30 Line Current Differential System is a digital current differential relay system with an integral communications channel interface.

The L30 is intended to provide complete protection for transmission lines of any voltage level. Both three phase and single phase tripping schemes are available. Models of the L30 are available for application on both two and three terminal lines. The L30 uses per phase differential at 64 kbps transmitting two phaselets per cycle. The current differential scheme is based on innovative patented techniques developed by GE. The L30 algorithms are based on the Fourier transform–phaselet approach and an adaptive statistical restraint. The restraint is similar to a traditional percentage differential scheme, but is adaptive based on relay measurements. When used with a 64 kbps channel, the innovative *phaselets* approach yields an operating time of 1.0 to 1.5 cycles (typical). The adaptive statistical restraint approach provides both more sensitive and more accurate fault sensing. This allows the L30 to detect relatively higher impedance single line to ground faults that existing systems may not. The basic current differential element operates on current input only. Long lines with significant capacitance can benefit from charging current compensation if terminal voltage measurements are applied to the relay. The voltage input is also used for some protection and monitoring features such as directional elements, fault locator, metering, and distance backup.

The L30 is designed to operate over different communications links with various degrees of noise encountered in power systems and communications environments. Since correct operation of the relay is completely dependent on data received from the remote end, special attention must be paid to information validation. The L30 incorporates a high degree of security by using a 32-bit CRC (cyclic redundancy code) inter-relay communications packet.

Several options are available for communication. A faceplate RS232 port can be used to connect to a computer for the programming of settings and the monitoring of actual values. The RS232 port has a fixed baud rate of 19.2 kbps. The rear RS485 port allows independent access by operating and engineering staff. It can be connected to system computers with baud rates up to 115.2 kbps. All serial ports use the Modbus RTU protocol. The IEC 60870-5-103 protocol is supported on the RS485 interface. IEC 60870-5-103, DNP, and Modbus cannot be enabled simultaneously on this interface. Also only one of the DNP, IEC 60870-5-103, and IEC 60870-5-104 protocols can be enabled at any time on the relay. When the IEC 60870-5-103 protocol is chosen, the RS485 port has a fixed even parity and the baud rate can be either 9.6 kbps or 19.2 kbps. The 100Base-FX or 100Base-T Ethernet interface provides fast, reliable communications in noisy environments. The Ethernet port supports IEC 61850, IEC 61850-90-5, Modbus/TCP, and TFTP protocols, PTP (according to IEEE Std. 1588-2008 or IEC 61588), and allows access to the relay via any standard web browser (L30 web pages). The IEC 60870-5-104 protocol is supported on the Ethernet port. The Ethernet port also supports the Parallel Redundancy Protocol (PRP) of IEC 62439-3 (clause 4, 2012) when purchased as an option.

In addition to current differential protection, the relay provides multiple backup protection for phase and ground faults. For overcurrent protection, the time overcurrent curves may be selected from a selection of standard curve shapes or a custom FlexCurve™ for optimum co-ordination.

The L30 incorporates charging current compensation for applications on very long transmission lines without loss of sensitivity. The line capacitive current is removed from the terminal phasors.

For breaker-and-a-half or ring applications, the L30 design provides secure operation during external faults with possible CT saturation.

Voltage, current, and power metering is built into the relay as a standard feature. Current parameters are available as total waveform RMS magnitude, or as fundamental frequency only RMS magnitude and angle (phasor).

Settings and actual values can be accessed from the front panel or EnerVista software.

The following single line diagram illustrates the relay functionality using American National Standards Institute (ANSI) device numbers.

**Table 2–1: ANSI DEVICE NUMBERS AND FUNCTIONS**

| DEVICE NUMBER | FUNCTION |
|---|---|
| 25 | Synchrocheck |
| 27P | Phase undervoltage |
| 27X | Auxiliary undervoltage |
| 49 | Thermal overload protection |
| 50BF | Breaker failure |

| DEVICE NUMBER | FUNCTION |
|---|---|
| 51P | Phase time overcurrent |
| 51_2 | Negative-sequence time overcurrent |
| 52 | AC circuit breaker |
| 59P | Phase overvoltage |
| 59_2 | Negative-sequence overvoltage |

### Table 2–1: ANSI DEVICE NUMBERS AND FUNCTIONS

| DEVICE NUMBER | FUNCTION |
|---|---|
| 50DD | Current disturbance detector |
| 50G | Ground instantaneous overcurrent |
| 50N | Neutral instantaneous overcurrent |
| 50P | Phase instantaneous overcurrent |
| 50_2 | Negative-sequence instantaneous overcurrent |
| 51G | Ground time overcurrent |
| 51N | Neutral time overcurrent |

| DEVICE NUMBER | FUNCTION |
|---|---|
| 59X | Auxiliary overvoltage |
| 67N | Neutral directional overcurrent |
| 67P | Phase directional overcurrent |
| 79 | Automatic recloser |
| 81U | Underfrequency |
| 87L | Segregated line current differential |
| 87LG | Line ground current differential |

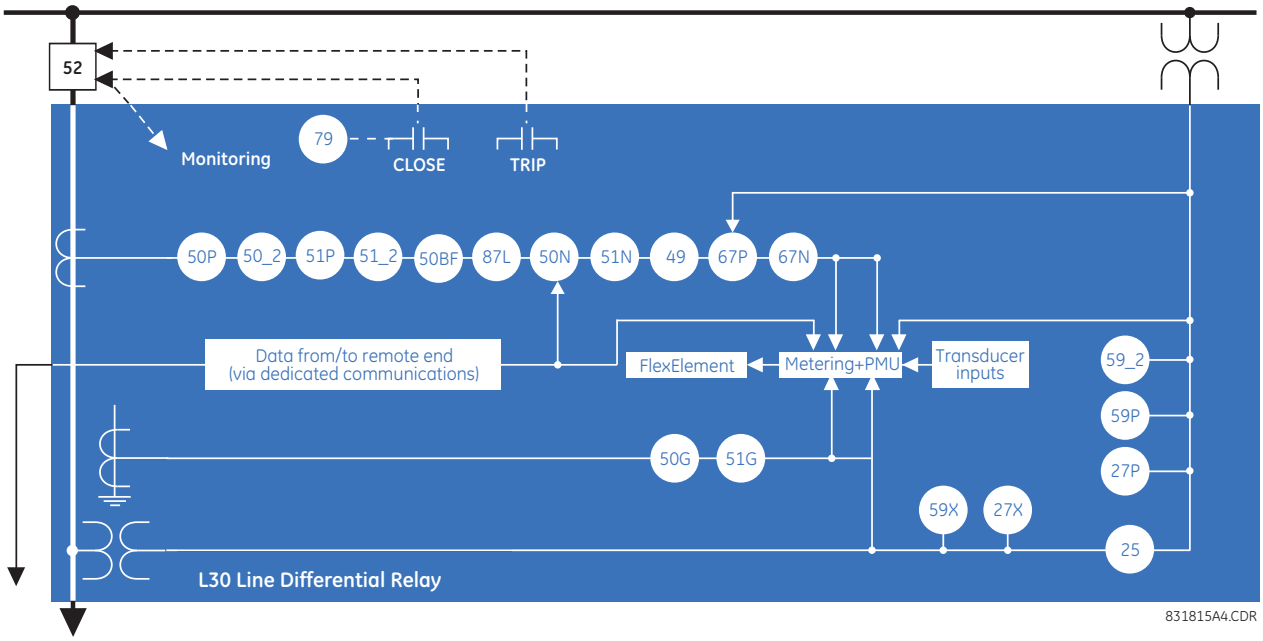



**Figure 2–1: SINGLE LINE DIAGRAM**

### Table 2–2: OTHER DEVICE FUNCTIONS

| FUNCTION |
|---|
| Breaker arcing current ($I^2t$) |
| Breaker control |
| Contact inputs (up to 96) |
| Contact outputs (up to 64) |
| Control pushbuttons |
| CT failure detector |
| CyberSentry™ security |
| Data logger |
| Digital counters (8) |
| Digital elements (48) |
| Direct inputs (8 per pilot channel) |
| Disconnect switches |
| DNP 3.0 or IEC 60870-5-104 protocol |

| FUNCTION |
|---|
| Fault locator and fault reporting |
| FlexElements™ (8) |
| FlexLogic equations |
| IEC 60870-5-103 communications (optional) |
| IEC 61850 communications (optional) |
| Channel tests |
| Metering:Current, voltage, power, frequency, power factor, 87L current, local and remote phasors |
| Modbus communications |
| Modbus user map |
| Non-volatile latches |
| Non-volatile selector switch |
| Open pole detector |
| Oscillography |

| FUNCTION |
|---|
| Stub bus |
| Synchrophasor (PMU) |
| Time synchronization over IRIG-B or IEEE 1588 |
| Time synchronization over SNTP |
| Transducer inputs and outputs |
| User-definable displays |
| User-programmable LEDs |
| User-programmable pushbuttons |
| User-programmable self-tests |
| Virtual inputs (64) |
| Virtual outputs (96) |
| VT fuse failure |

**Table 2–2: OTHER DEVICE FUNCTIONS**

| FUNCTION | FUNCTION | FUNCTION |
|---|---|---|
| Event recorder | Setting groups (6) | |

## 2.1.2 FEATURES



**LINE CURRENT DIFFERENTIAL:**

- Phase segregated, high-speed digital current differential system
- Overhead and underground AC transmission lines, series compensated lines
- Two-terminal and three-terminal line applications
- Zero-sequence removal for application on lines with tapped transformers connected in a grounded wye on the line side
- GE phaselets approach based on the Discrete Fourier Transform with 64 samples per cycle and transmitting two time-stamped phaselets per cycle
- Adaptive restraint approach improving sensitivity and accuracy of fault sensing
- Accommodates in-zone transformer with a magnitude and phase compensation and second harmonic inhibit during transformer magnetizing inrush
- Continuous clock synchronization via the distributed synchronization technique
- Increased transient stability through DC decaying offset removal
- Accommodates up to five times CT ratio differences
- Peer-to-peer (master-master) architecture changing to master-slave via DTT (if channel fails) at 64 kbps
- Charging current compensation
- Interfaces direct fiber, multiplexed RS422, IEEE C37.94, and G.703 connections with relay ID check
- Per-phase line differential protection direct transfer trip plus eight user-assigned pilot signals via the communications channel
- Secure 32-bit CRC protection against communications errors
- Channel asymmetry (up to 10 ms) compensation using GPS satellite-controlled clock

**BACKUP PROTECTION:**

- DTT provision for pilot schemes
- Two-element time overcurrent and two-element instantaneous overcurrent directional phase overcurrent protection
- Two-element time overcurrent and two-element instantaneous overcurrent directional zero-sequence protection
- Two-element time overcurrent and two-element instantaneous overcurrent negative-sequence overcurrent protection
- Undervoltage and overvoltage protection

**ADDITIONAL PROTECTION:**

- Breaker failure protection
- Stub bus protection
- VT and CT supervision
- GE Multilin *sources* approach allowing grouping of different CTs and VTs from multiple input channels
- Open pole detection
- Breaker trip coil supervision and *seal-in* of trip command
- FlexLogic allowing creation of user-defined distributed protection and control logic

**CONTROL:**

- One and two breaker configuration for breaker-and-a-half and ring bus schemes, pushbutton control from the relay
- Auto-reclosing and synchrochecking

- Breaker arcing current

**MONITORING:**

- Oscillography of current, voltage, FlexLogic operands, and digital signals (1 × 128 cycles to 31 × 8 cycles configurable)
- Events recorder: 1024 events
- Fault locator

**METERING:**

- Actual 87L remote phasors, differential current, channel delay, and channel asymmetry at all line terminals of line current differential protection
- Line current, voltage, real power, reactive power, apparent power, power factor, and frequency

**COMMUNICATIONS:**

- Front panel RS232 port: 19.2 kbps
- Rear RS485 port: up to 115 kbps
- Rear 100Base-FX Ethernet port supporting the IEC 61850 protocol

### 2.1.3 SECURITY

The following security features are available:

- Password security — Basic security present in the default offering of the product
- EnerVista security — Role-based access to various EnerVista software screens and configuration elements. The feature is available in the default offering of the product and only in the EnerVista software.
- CyberSentry security — Advanced security options available as a software option. When purchased, the options are automatically enabled, and the default Password security and EnerVista security are disabled.

Changing the password, or any other setting, does not take the relay out of service. The relay is taken out of service when a settings file is written to it.

#### a) ENERVISTA SECURITY

The EnerVista security management system is a role-based access control (RBAC) system that allows an administrator to manage the privileges of multiple users. This allows for access control of UR devices by multiple personnel within a substation and conforms to the principles of RBAC as defined in ANSI INCITS 359-2004. The EnerVista security management system is disabled by default to allow the administrator direct access to the EnerVista software after installation. It is recommended that security be enabled before placing the device in service.

Basic password or enhanced CyberSentry security applies, depending on purchase.

#### b) PASSWORD SECURITY

Password security is a basic security feature present in the default offering of the product.

Two levels of password security are provided: command and setting.

The following operations are under command password supervision:

- Operating the breakers via faceplate keypad
- Changing the state of virtual inputs
- Clearing the event records
- Clearing the oscillography records
- Clearing fault reports
- Changing the date and time
- Clearing the breaker arcing current
- Clearing the data logger
- Clearing the user-programmable pushbutton states

The following operations are under setting password supervision:

- Changing any setting
- Test mode operation

The L30 supports password entry from a local or remote connection. Local access is defined as any access to settings or commands via the faceplate interface. This includes both keypad entry and the through the faceplate RS232 port. Remote access is defined as any access to settings or commands via any rear communications port. This includes both Ethernet and RS485 connections. Any changes to the local or remote passwords enables this functionality.



When entering a settings or command password via EnerVista or any serial interface, the user must enter the corresponding connection password. If the connection is to the back of the L30, the remote password must be used. If the connection is to the RS232 port of the faceplate, the local password applies.

Password access events are logged in the Event Recorder.

### c) CYBERSENTRY SECURITY

CyberSentry Embedded Security is a software option that provides advanced security services. When this option is purchased, the basic password security is disabled automatically.

CyberSentry provides security through the following features:

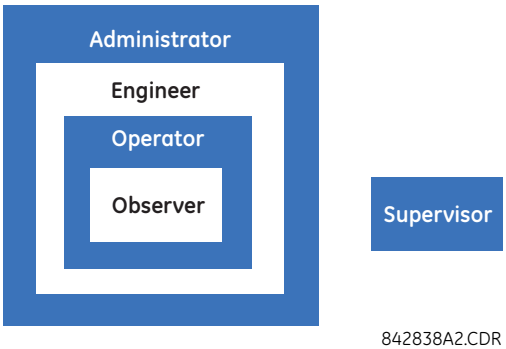
- An Authentication, Authorization, Accounting (AAA) Remote Authentication Dial-In User Service (RADIUS) client that is centrally managed, enables user attribution, provides accounting of all user activities, and uses secure standards-based strong cryptography for authentication and credential protection.
- A Role-Based Access Control (RBAC) system that provides a permission model that allows access to UR device operations and configurations based on specific roles and individual user accounts configured on the AAA server (that is, Administrator, Supervisor, Engineer, Operator, Observer).
- Security event reporting through the Syslog protocol for supporting Security Information Event Management (SIEM) systems for centralized cybersecurity monitoring.
- Strong encryption of all access and configuration network messages between the EnerVista software and UR devices using the Secure Shell (SSH) protocol, the Advanced Encryption Standard (AES), and 128-bit keys in Galois Counter Mode (GCM) as specified in the U.S. National Security Agency Suite B extension for SSH and approved by the National Institute of Standards and Technology (NIST) FIPS-140-2 standards for cryptographic systems.

#### CYBERSENTRY USER ROLES

CyberSentry user roles (Administrator, Engineer, Operator, Supervisor, Observer) limit the levels of access to various UR device functions. This means that the EnerVista software allows for access to functionality based on the user's logged in role.

**Example:** Administrative functions can be segmented away from common operator functions, or engineering type access, all of which are defined by separate roles, as shown in the following figure, so that access of UR devices by multiple personnel within a substation is allowed.

**Figure 2–2: CYBERSENTRY USER ROLES**




The table lists the roles that are supported and their corresponding capabilities.

### Table 2–3: PERMISSIONS BY USER ROLE FOR CYBERSENTRY

| Roles | Administrator | Engineer | Operator | Supervisor | Observer |
|---|---|---|---|---|---|
| | Complete access | Complete access except for CyberSentry Security | Command menu | Authorizes writing | Default role |
| **Device Definition** | R | R | R | R | R |
| **Settings** | | | | | |
| \|---------- **Product Setup** | | | | | |
| \|---------- Security (CyberSentry) | RW | R | R | R | R |
| \|---------- Supervisory | see table notes | R | R | see table notes | R |
| \|---------- Display Properties | RW | RW | R | R | R |
| \|---------- Clear relay records (settings) | RW | RW | R | R | R |
| \|---------- Communications | RW | RW | R | R | R |
| \|---------- Modbus user map | RW | RW | R | R | R |
| \|---------- Real Time Clock | RW | RW | R | R | R |
| \|---------- Oscillography | RW | RW | R | R | R |
| \|---------- Data Logger | RW | RW | R | R | R |
| \|---------- Demand | RW | RW | R | R | R |
| \|---------- User Programmable LEDs | RW | RW | R | R | R |
| \|---------- User Programmable self test | RW | RW | R | R | R |
| \|---------- Control Pushbuttons | RW | RW | R | R | R |
| \|---------- User programmable Pushbuttons | RW | RW | R | R | R |
| \|---------- Flex states | RW | RW | R | R | R |
| \|---------- User definable dis-plays | RW | RW | R | R | R |
| \|---------- Direct I/O | RW | RW | R | R | R |
| \|---------- Tele-protection | RW | RW | R | R | R |
| \|---------- Installation | RW | RW | R | R | R |
| \|---------- **System Setup** | RW | RW | R | R | R |
| \|---------- **FlexLogic** | RW | RW | R | R | R |
| \|---------- **Grouped Elements** | RW | RW | R | R | R |
| \|---------- **Control Elements** | RW | RW | R | R | R |
| \|---------- **Inputs / Outputs** | RW | RW | R | R | R |
| \|---------- Contact Input | RW | RW | R | R | R |
| \|---------- Contact Input thresh-old | RW | RW | R | R | R |
| \|---------- Virtual Inputs | RW | RW | R | R | R |
| \|---------- Contact Output | RW | RW | R | R | R |
| \|---------- Virtual Output | RW | RW | R | R | R |
| \|---------- Remote Devices | RW | RW | R | R | R |
| \|---------- Remote Inputs | RW | RW | R | R | R |
| \|---------- Remote DPS input | RW | RW | R | R | R |
| \|---------- Remote Output DNA Bit Pair | RW | RW | R | R | R |
| \|---------- Remote Output user Bit Pair | RW | RW | R | R | R |
| \|---------- Resetting | RW | RW | R | R | R |

| Roles | Administrator | Engineer | Operator | Supervisor | Observer |
|---|---|---|---|---|---|
| \|---------- Direct Inputs | RW | RW | R | R | R |
| \|---------- Direct Outputs | RW | RW | R | R | R |
| \|---------- Teleprotection | RW | RW | R | R | R |
| \|---------- Direct Analogs | RW | RW | R | R | R |
| \|---------- Direct Integers | RW | RW | R | R | R |
| \|---------- IEC61850 GOOSE Analogs | RW | RW | R | R | R |
| \|---------- IEC61850 GOOSE Integers | RW | RW | R | R | R |
| \|---------- **Transducer I/O** | RW | RW | R | R | R |
| \|---------- **Testing** | RW | RW | R | R | R |
| \|---------- **Front Panel Labels Designer** | NA | NA | NA | NA | NA |
| \|---------- **Protection Summary** | NA | NA | NA | NA | NA |
| **Commands** | RW | RW | RW | R | R |
| \|---------- **Virtual Inputs** | RW | RW | RW | R | R |
| \|---------- **Clear Records** | RW | RW | RW | R | R |
| \|---------- **Set date and time** | RW | RW | RW | R | R |
| **User Displays** | R | R | R | R | R |
| **Targets** | R | R | R | R | R |
| **Actual Values** | R | R | R | R | R |
| \|---------- Front Panel Labels Designer | R | R | R | R | R |
| \|---------- Status | R | R | R | R | R |
| \|---------- Metereing | R | R | R | R | R |
| \|---------- Transducer I/O | R | R | R | R | R |
| \|---------- Records | R | R | R | R | R |
| \|---------- Product Info | R | R | R | R | R |
| **Maintenance** | RW | RW | R | R | R |
| \|---------- Modbus Analyzer | NA | NA | NA | NA | NA |
| \|---------- Change Front Panel | RW | RW | RW | R | R |
| \|---------- Update Firmware | Yes | No | No | No | No |
| \|---------- Retrieve File | Yes | No | No | No | No |

**Table Notes:**

1. RW = read and write access
2. R = read access
3. Supervisor = RW (default), Administrator = R (default), Administrator = RW (only if Supervisor role is disabled)
4. NA = the permission is not enforced by CyberSentry Security

**CYBERSENTRY USER AUTHENTICATION**

There are two types of authentication supported by CyberSentry that can be used to access the UR device:

- Device Authentication (local UR device authenticates)
- Server Authentication (RADIUS server authenticates)

The EnerVista software allows access to functionality that is determined by the user role, which comes either from the local UR device or RADIUS server.

The EnerVista software has a device authentication option on the login screen for accessing the UR device. When the "Device" button is selected, the UR uses its local authentication database and not the RADIUS server to authenticate the user. In this case, it uses its built-in roles (Administrator, Engineer, Supervisor, Observer, Operator, or Administrator and Supervisor when Device Authentication is disabled) as login names and the associated passwords are stored on the UR device. As such, when using the local accounts, access is not user-attributable.

In cases where user attributable access is required especially to facilitate auditable processes for compliance reasons, use RADIUS authentication only.

When the "Server" Authentication Type option is selected, the UR uses the RADIUS server and not its local authentication database to authenticate the user.

No password or security information are displayed in plain text by the EnerVista software or UR device, nor are they ever transmitted without cryptographic protection.

**CyberSentry Server Authentication**

The UR has been designed to automatically direct authentication requests based on user names. In this respect, local account names on the UR are considered as reserved, and not used on a RADIUS server.

The UR automatically detects whether an authentication request is to be handled remotely or locally. As there are only five local accounts possible on the UR, if the user ID credential does not match one of the five local accounts, the UR automatically forwards the request to a RADIUS server when one is provided.

If a RADIUS server is provided, but is unreachable over the network, server authentication requests are denied. In this situation, use local UR accounts to gain access to the UR system.

### 2.1.4 IEC 870-5-103 PROTOCOL

IEC 870-5-103 is a companion standard to IEC 870-5 suit of standards for transmission protocols. It defines messages and procedures for interoperability between protection equipment and devices of a control system in a substation for communicating on a serial line.

The IEC 60870-5-103 is an unbalanced (master-slave) protocol for coded-bit serial communication, exchanging information with a control system. In the context of this protocol, the protection equipment is the slave and the control system is the master. The communication is based on a point to point principle. The master must be able to interpret the IEC 60870-5-103 communication messages.

The UR implementation of IEC 60870-5-103 consists of the following functions:

- Report binary inputs
- Report analog values (measurands)
- Commands
- Time synchronization

The RS485 port supports IEC 60870-5-103.

### 2.2.1 OVERVIEW

The L30 is available as a 19-inch rack horizontal mount or reduced-size (¾) vertical unit and consists of the following modules: power supply, CPU, CT/VT, contact input and output, transducer input and output, and inter-relay communications. Each of these modules can be supplied in a number of configurations specified at the time of ordering. The information required to completely specify the relay is provided in the following tables (see chapter 3 for full details of relay modules).

NOTE

Order codes are subject to change without notice. See the ordering page at http://www.gegridsolutions.com/multilin/order.htm for the latest options.



The order code structure is dependent on the mounting option (horizontal or vertical) and the type of CT/VT modules (enhanced diagnostic CT/VT modules or HardFiber™ process bus modules). The order code options are described in the following sub-sections.

### 2.2.2 ORDER CODES WITH ENHANCED CT/VT MODULES

The order codes for the horizontal mount units are shown below.

**Table 2–4: L30 ORDER CODES (HORIZONTAL UNITS)**

| | L30 - * ** - * * * - F ** - H ** - L ** - N ** - S ** - U ** - W/X ** | |
|---|---|---|
| **BASE UNIT** | L30 | Base Unit |
| **CPU** | T | RS485 and Three Multi-mode fiber 100Base-FX (SFP with LC) |
| | U | RS485 and Two Multi-mode fiber 100Base-FX (SFP with LC), One 10/100Base-T (SFP with RJ45) |
| | V | RS485 and Three 10/100Base-T (SFP with RJ45) |
| **SOFTWARE** | 00 | No software options |
| | 03 | IEC 61850 |
| | 06 | One phasor measurement unit (PMU) |
| | 07 | IEC 61850 and one phasor measurement unit (PMU) |
| | 18 | Synchrocheck, three-pole autoreclose |
| | 19 | Synchrocheck, three-pole autoreclose, one phasor measurement unit (PMU) |
| | 24 | In-zone transformer protection |
| | 25 | In-zone transformer protection and IEC 61850 |
| | 26 | In-zone transformer protection and one phasor measurement unit (PMU) |
| | 27 | In-zone transformer protection, IEC 61850, and one phasor measurement unit (PMU) |
| | A0 | CyberSentry Lvl 1 |
| | A3 | CyberSentry Lvl 1 and IEC 61850 |
| | A6 | CyberSentry Lvl 1 and phasor measurement unit (PMU) |
| | A7 | CyberSentry Lvl 1 and IEC 61850 and phasor measurement unit (PMU) |
| | AI | CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck |
| | AJ | CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck and one PMU |
| | AO | CyberSentry Lvl 1 and In-zone transformer protection |
| | AP | CyberSentry Lvl 1 and IEC 61850 and In-zone transformer protection |
| | AQ | CyberSentry Lvl 1 and phasor measurement unit (PMU) and In-zone transformer protection |
| | AR | CyberSentry Lvl 1 and IEC 61850 and (PMU) and In-zone transformer protection |
| | B0 | IEEE 1588 |
| | B3 | IEEE 1588 and IEC 61850 |
| | B6 | IEEE 1588 and phasor measurement unit (PMU) |
| | B7 | IEEE 1588 and IEC 61850 and phasor measurement unit (PMU) |
| | BI | IEEE 1588 and three-pole autoreclose and synchrocheck |
| | BJ | IEEE 1588 and three-pole autoreclose and synchrocheck and one PMU |
| | BO | IEEE 1588 and In-zone transformer protection |
| | BP | IEEE 1588 and IEC 61850 and In-zone transformer protection |
| | BQ | IEEE 1588 and phasor measurement unit (PMU) and In-zone transformer protection |
| | BR | IEEE 1588 and IEC 61850 and (PMU) and In-zone transformer protection |
| | C0 | Parallel Redundancy Protocol (PRP) |
| | C3 | PRP and IEC 61850 |
| | C6 | PRP and PMU |
| | C7 | PRP, IEC 61850, and PMU |
| | CI | PRP, three-pole autoreclose, synchrocheck |
| | CJ | PRP, three-pole autoreclose, PMU, synchrocheck |
| | CO | PRP and in-zone transformer protection |
| | CP | PRP, in-zone transformer protection, and IEC 61850 |
| | CQ | PRP, in-zone transformer protection, and PMU |
| | CR | PRP, in-zone transformer protection, IEC 61850, and PMU |
| | D0 | IEEE 1588 and CyberSentry Lvl 1 |
| | D3 | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 |
| | D6 | IEEE 1588 and CyberSentry Lvl 1 and phasor measurement unit (PMU) |
| | D7 | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and phasor measurement unit (PMU) |
| | DI | IEEE 1588 and CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck |
| | DJ | IEEE 1588 and CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck and PMU |
| | DO | IEEE 1588 and CyberSentry Lvl 1 and In-zone transformer protection |
| | DP | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and In-zone transformer protection |
| | DQ | IEEE 1588 and CyberSentry Lvl 1 and one PMU and In-zone transformer protection |
| | DR | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and PMU and In-zone transformer protection |
| | E0 | IEEE 1588 and PRP |
| | E3 | IEEE 1588, PRP, IEC 61850 |
| | E6 | IEEE 1588, PRP, and PMU |
| | E7 | IEEE 1588, PRP, IEC 61850, and PMU |
| | EI | IEEE 1588, PRP, three-pole autoreclose, synchrocheck |
| | EJ | IEEE 1588, PRP, three-pole autoreclose, PMU, synchrocheck |
| | EO | IEEE 1588, PRP, and in-zone transformer protection |
| | EP | IEEE 1588, PRP, in-zone transformer protection, and IEC 61850 |
| | EQ | IEEE 1588, PRP, in-zone transformer protection, and PMU |
| | ER | IEEE 1588, PRP, in-zone transformer protection, IEC 61850, and PMU |
| | F0 | PRP and CyberSentry Lvl 1 |
| | F3 | PRP, CyberSentry Lvl 1, and IEC 61850 |
| | F6 | PRP, CyberSentry Lvl 1, and PMU |
| | F7 | PRP, CyberSentry Lvl 1, IEC 61850, and PMU |
| | FI | PRP, CyberSentry Lvl 1, three-pole autoreclose, synchrocheck |
| | FJ | PRP, CyberSentry Lvl 1, three-pole autoreclose, PMU, synchrocheck |
| | FO | PRP, CyberSentry Lvl 1, in-zone transformer protection |
| | FP | PRP, CyberSentry Lvl 1, in-zone transformer protection, and IEC 61850 |
| | FQ | PRP, CyberSentry Lvl 1, in-zone transformer protection, and PMU |
| | FR | PRP, CyberSentry Lvl 1, in-zone transformer protection, IEC 61850, and PMU |
| | G0 | IEEE 1588, PRP, and CyberSentry Lvl 1 |
| | G3 | IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850 |
| | G6 | IEEE 1588, PRP, CyberSentry Lvl 1, and PMU |
| | G7 | IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and PMU |
| | GI | IEEE 1588, PRP, CyberSentry Lvl 1, three-pole autoreclose, synchrocheck |
| | GJ | IEEE 1588, PRP, CyberSentry Lvl 1, three-pole autoreclose, PMU, synchrocheck |
| | GO | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection |
| | GP | IEEE 1588 PRP, CyberSentry Lvl 1, in-zone transformer protection, and IEC 61850 |
| | GQ | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection, and PMU |
| | GR | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection, IEC 61850, and PMU |
| | J0 | IEC 60870-5-103 |
| | J3 | IEC 60870-5-103 + IEC 61850 |

## Table 2–4: L30 ORDER CODES (HORIZONTAL UNITS)

| | L30 - * ** - * * - F ** - H ** - L ** - N ** - S ** - U ** - W/X ** | |
|---|---|---|
| **BASE UNIT** | L30 | Full Size Horizontal Mount<br>Base Unit |
| | J6 | IEC 60870-5-103 + PMU |
| | J7 | IEC 60870-5-103 + IEC 61850 + PMU |
| | JI | IEC 60870-5-103 + three-pole autoreclose + synchrocheck |
| | JJ | IEC 60870-5-103 + three-pole autoreclose + PMU + synchrocheck |
| | JO | IEC 60870-5-103 + in-zone transformer protection |
| | JP | IEC 60870-5-103 + in-zone transformer protection + IEC 61850 |
| | JQ | IEC 60870-5-103 + in-zone transformer protection + PMU |
| | JR | IEC 60870-5-103 + in-zone transformer protection + IEC 61850 + PMU |
| | K0 | IEEE1588 + PRP + IEC 60870-5-103 |
| | K3 | IEEE1588 + PRP + IEC 60870-5-103 + IEC 61850 |
| | K6 | IEEE1588 + PRP + IEC 60870-5-103 + PMU |
| | K7 | IEEE1588 + PRP + IEC 60870-5-103 + IEC 61850 + PMU |
| | KI | IEEE1588 + PRP + IEC 60870-5-103 + three-pole autoreclose + synchrocheck |
| | KJ | IEEE1588 + PRP + IEC 60870-5-103 + three-pole autoreclose + PMU + synchrocheck |
| | KO | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection |
| | KP | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + IEC 61850 |
| | KQ | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + PMU |
| | KR | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + IEC 61850 + PMU |
| | L0 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + |
| | L3 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + IEC 61850 |
| | L6 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + PMU |
| | L7 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + IEC 61850 + PMU |
| | LI | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + three-pole autoreclose + synchrocheck |
| | LJ | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + three-pole autoreclose + PMU + synchrocheck |
| | LO | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection |
| | LP | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + IEC 61850 |
| | LQ | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + PMU |
| | LR | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + IEC 61850 + PMU |
| **MOUNT/COATING** | H | Horizontal (19" rack) |
| | A | Horizontal (19" rack) with harsh environmental coating |
| **FACEPLATE/ DISPLAY** | C | English display |
| | D | French display |
| | R | Russian display |
| | P | English display with 4 small and 12 large programmable pushbuttons |
| | G | French display with 4 small and 12 large programmable pushbuttons |
| | S | Russian display with 4 small and 12 large programmable pushbuttons |
| | K | Enhanced front panel with English display |
| | M | Enhanced front panel with French display |
| | Q | Enhanced front panel with Russian display |
| | U | Enhanced front panel with Chinese display |
| | L | Enhanced front panel with English display and user-programmable pushbuttons |
| | N | Enhanced front panel with French display and user-programmable pushbuttons |
| | T | Enhanced front panel with Russian display and user-programmable pushbuttons |
| | V | Enhanced front panel with Chinese display and user-programmable pushbuttons |
| | W | Enhanced front panel with Turkish display |
| | Y | Enhanced front panel with Turkish display and user-programmable pushbuttons |
| | I | Enhanced front panel with German display |
| | J | Enhanced front panel with German display and user-programmable pushbuttons |
| **POWER SUPPLY** | H | 125 / 250 V AC/DC power supply |
| **(redundant supply must** | H | 125 / 250 V AC/DC with redundant 125 / 250 V AC/DC power supply RH |
| **be same type as main supply)** | L | 24 to 48 V (DC only) power supply |
| | L | 24 to 48 V (DC only) with redundant 24 to 48 V DC power supply RL |
| **CT/VT DSP** | 8L | Standard 4CT/4VT with enhanced diagnostics (required for PMU option) |
| | 8N | Standard 8CT with enhanced diagnostics (required for PMU option) |
| **DIGITAL INPUTS/OUTPUTS** | XX | No Module |
| | 4A | 4 Solid-State (no monitoring) MOSFET outputs |
| | 4B | 4 Solid-State (voltage with optional current) MOSFET outputs |
| | 4C | 4 Solid-State (current with optional voltage) MOSFET outputs |
| | 4D | 16 digital inputs with Auto-Burnishing (maximum of three modules within a case) |
| | 4L | 14 Form-A (no monitoring) Latching outputs |
| | 67 | 8 Form-A (no monitoring) outputs |
| | 6A | 2 Form-A (voltage with optional current) and 2 Form-C outputs, 8 digital inputs |
| | 6B | 2 Form-A (voltage with optional current) and 4 Form-C outputs, 4 digital inputs |
| | 6C | 8 Form-C outputs |
| | 6D | 16 digital inputs |
| | 6E | 4 Form-C outputs, 8 digital inputs |
| | 6F | 8 Fast Form-C outputs |
| | 6G | 4 Form-A (voltage with optional current) outputs, 8 digital inputs |
| | 6H | 6 Form-A (voltage with optional current) outputs, 4 digital inputs |
| | 6K | 4 Form-C and 4 Fast Form-C outputs |
| | 6L | 2 Form-A (current with optional voltage) and 2 Form-C outputs, 8 digital inputs |
| | 6M | 2 Form-A (current with optional voltage) and 4 Form-C outputs, 4 digital inputs |
| | 6N | 4 Form-A (current with optional voltage) outputs, 8 digital inputs |
| | 6P | 6 Form-A (current with optional voltage) outputs, 4 digital inputs |
| | 6R | 2 Form-A (no monitoring) and 2 Form-C outputs, 8 digital inputs |
| | 6S | 2 Form-A (no monitoring) and 4 Form-C outputs, 4 digital inputs |
| | 6T | 4 Form-A (no monitoring) outputs, 8 digital inputs |
| | 6U | 6 Form-A (no monitoring) outputs, 4 digital inputs |
| | 6V | 2 Form-A outputs, 1 Form-C output, 1 Form-A latching output, 8 digital inputs |
| **TRANSDUCER** | 5A | 4 DCmA inputs, 4 DCmA outputs (only one 5A or 5D module is allowed) |
| **INPUTS/OUTPUTS** | 5C | 8 RTD inputs |
| **(select a maximum of 3 per unit)** | 5D | 4 RTD inputs, 4 DCmA outputs (only one 5A or 5D module is allowed) |
| | 5E | 4 RTD inputs, 4 DCmA inputs |
| | 5F | 8 DCmA inputs |
| **INTER-RELAY COMMUNICATIONS** | 2A | C37.94SM, 1300 nm single-mode, ELED, 1 channel single-mode |
| **(select a maximum of 1 per unit)** | 2B | C37.94SM, 1300 nm single-mode, ELED, 2 channel single-mode |
| | 2H | IEEE C37.94, 820 nm, 128 kbps, multimode, LED, 2 Channels |
| | 2I | Channel 1 - IEEE C37.94, MM, 64/128 kbps; Channel 2 - 1300 nm, single-mode, Laser |
| | 2J | Channel 1 - IEEE C37.94, MM, 64/128 kbps; Channel 2 - 1550 nm, single-mode, Laser |
| | 72 | 1550 nm, single-mode, Laser, 1 Channel |
| | 73 | 1550 nm, single-mode, Laser, 2 Channel |
| | 76 | IEEE C37.94, 820 nm, 64 kbps, multimode, LED, 1 Channel |
| | 77 | IEEE C37.94, 820 nm, 64 kbps, multimode, LED, 2 Channels |
| | 7A | 820 nm, multimode, LED, 1 Channel |
| | 7B | 1300 nm, multimode, LED, 1 Channel |
| | 7C | 1300 nm, single-mode, ELED, 1 Channel |
| | 7D | 1300 nm, single-mode, LASER, 1 Channel |
| | 7F | Channel 1 - G.703; Channel 2 - 1300 nm, multimode |
| | 7G | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode ELED |
| | 7H | 820 nm, multimode, LED, 2 Channels |
| | 7I | 1300 nm, multimode, LED, 2 Channels |
| | 7J | 1300 nm, single-mode, ELED, 2 Channels |
| | 7K | 1300 nm, single-mode, Laser, 2 Channels |
| | 7M | Channel 1 - RS422; Channel 2 - 1300 nm, multimode, LED |
| | 7N | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, ELED |
| | 7P | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, Laser |
| | 7Q | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode Laser |
| | 7R | G.703, 1 Channel |
| | 7S | G.703, 2 Channels |
| | 7T | RS422, 1 Channel |
| | 7V | RS422, 2 Channels, 2 Clock Inputs |
| | 7W | RS422, 2 Channels |

The order codes for the reduced size vertical mount units are shown below.

## Table 2–5: L30 ORDER CODES (REDUCED SIZE VERTICAL UNITS)

| | L30 | - | * | ** | - | * | * | * | - | F | ** | - | H | ** | - | L | ** | - | N | ** | - | R | ** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BASE UNIT** | L30 | | | | | | | | | | | | | | | | | | | | | | | Base Unit |
| **CPU** | | | T | | | | | | | | | | | | | | | | | | | | | RS485 and Three Multi-mode fiber 100Base-FX (SFP with LC) |
| | | | U | | | | | | | | | | | | | | | | | | | | | RS485 and Two Multi-mode fiber 100Base-FX (SFP with LC), One 10/100Base-T (SFP with RJ45) |
| | | | V | | | | | | | | | | | | | | | | | | | | | RS485 and Three 10/100Base-T (SFP with RJ45) |
| **SOFTWARE** | | | | 00 | | | | | | | | | | | | | | | | | | | | No software options |
| | | | | 03 | | | | | | | | | | | | | | | | | | | | IEC 61850 |
| | | | | 06 | | | | | | | | | | | | | | | | | | | | Phasor measurement unit (PMU) |
| | | | | 07 | | | | | | | | | | | | | | | | | | | | IEC 61850 and phasor measurement unit (PMU) |
| | | | | 18 | | | | | | | | | | | | | | | | | | | | Synchrocheck, three-pole autoreclose |
| | | | | 19 | | | | | | | | | | | | | | | | | | | | Synchrocheck, three-pole autoreclose, one phasor measurement unit (PMU) |
| | | | | 24 | | | | | | | | | | | | | | | | | | | | In-zone transformer protection |
| | | | | 25 | | | | | | | | | | | | | | | | | | | | In-zone transformer protection and IEC 61850 |
| | | | | 26 | | | | | | | | | | | | | | | | | | | | In-zone transformer protection and one phasor measurement unit (PMU) |
| | | | | 27 | | | | | | | | | | | | | | | | | | | | In-zone transformer protection, IEC 61850, and one phasor measurement unit (PMU) |
| | | | | A0 | | | | | | | | | | | | | | | | | | | | CyberSentry Lvl 1 |
| | | | | A3 | | | | | | | | | | | | | | | | | | | | CyberSentry Lvl 1 and IEC 61850 |
| | | | | A6 | | | | | | | | | | | | | | | | | | | | CyberSentry Lvl 1 and phasor measurement unit (PMU) |
| | | | | A7 | | | | | | | | | | | | | | | | | | | | CyberSentry Lvl 1 and IEC 61850 and phasor measurement unit (PMU) |
| | | | | AI | | | | | | | | | | | | | | | | | | | | CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck |
| | | | | AJ | | | | | | | | | | | | | | | | | | | | CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck and one PMU |
| | | | | AO | | | | | | | | | | | | | | | | | | | | CyberSentry Lvl 1 and In-zone transformer protection |
| | | | | AP | | | | | | | | | | | | | | | | | | | | CyberSentry Lvl 1 and IEC 61850 and In-zone transformer protection |
| | | | | AQ | | | | | | | | | | | | | | | | | | | | CyberSentry Lvl 1 and phasor measurement unit (PMU) and In-zone transformer protection |
| | | | | AR | | | | | | | | | | | | | | | | | | | | CyberSentry Lvl 1 and IEC 61850 and (PMU) and In-zone transformer protection |
| | | | | B0 | | | | | | | | | | | | | | | | | | | | IEEE 1588 |
| | | | | B3 | | | | | | | | | | | | | | | | | | | | IEEE 1588 and IEC 61850 |
| | | | | B6 | | | | | | | | | | | | | | | | | | | | IEEE 1588 and phasor measurement unit (PMU) |
| | | | | B7 | | | | | | | | | | | | | | | | | | | | IEEE 1588 and IEC 61850 and phasor measurement unit (PMU) |
| | | | | BI | | | | | | | | | | | | | | | | | | | | IEEE 1588 and three-pole autoreclose and synchrocheck |
| | | | | BJ | | | | | | | | | | | | | | | | | | | | IEEE 1588 and three-pole autoreclose and synchrocheck and one PMU |
| | | | | BO | | | | | | | | | | | | | | | | | | | | IEEE 1588 and In-zone transformer protection |
| | | | | BP | | | | | | | | | | | | | | | | | | | | IEEE 1588 and IEC 61850 and In-zone transformer protection |
| | | | | BQ | | | | | | | | | | | | | | | | | | | | IEEE 1588 and phasor measurement unit (PMU) and In-zone transformer protection |
| | | | | BR | | | | | | | | | | | | | | | | | | | | IEEE 1588 and IEC 61850 and (PMU) and In-zone transformer protection |
| | | | | C0 | | | | | | | | | | | | | | | | | | | | Parallel Redundancy Protocol (PRP) |
| | | | | C3 | | | | | | | | | | | | | | | | | | | | PRP and IEC 61850 |
| | | | | C6 | | | | | | | | | | | | | | | | | | | | PRP and PMU |
| | | | | C7 | | | | | | | | | | | | | | | | | | | | PRP, IEC 61850, and PMU |
| | | | | CI | | | | | | | | | | | | | | | | | | | | PRP, three-pole autoreclose, synchrocheck |
| | | | | CJ | | | | | | | | | | | | | | | | | | | | PRP, three-pole autoreclose, PMU, synchrocheck |
| | | | | CO | | | | | | | | | | | | | | | | | | | | PRP and in-zone transformer protection |
| | | | | CP | | | | | | | | | | | | | | | | | | | | PRP, in-zone transformer protection, and IEC 61850 |
| | | | | CQ | | | | | | | | | | | | | | | | | | | | PRP, in-zone transformer protection, and PMU |
| | | | | CR | | | | | | | | | | | | | | | | | | | | PRP, in-zone transformer protection, IEC 61850, and PMU |
| | | | | D0 | | | | | | | | | | | | | | | | | | | | IEEE 1588 and CyberSentry Lvl 1 |
| | | | | D3 | | | | | | | | | | | | | | | | | | | | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 |
| | | | | D6 | | | | | | | | | | | | | | | | | | | | IEEE 1588 and CyberSentry Lvl 1 and phasor measurement unit (PMU) |
| | | | | D7 | | | | | | | | | | | | | | | | | | | | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and phasor measurement unit (PMU) |
| | | | | DI | | | | | | | | | | | | | | | | | | | | IEEE 1588 and CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck |
| | | | | DJ | | | | | | | | | | | | | | | | | | | | IEEE 1588 and CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck and PMU |
| | | | | DO | | | | | | | | | | | | | | | | | | | | IEEE 1588 and CyberSentry Lvl 1 and In-zone transformer protection |
| | | | | DP | | | | | | | | | | | | | | | | | | | | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and In-zone transformer protection |
| | | | | DQ | | | | | | | | | | | | | | | | | | | | IEEE 1588 and CyberSentry Lvl 1 and one PMU and In-zone transformer protection |
| | | | | DR | | | | | | | | | | | | | | | | | | | | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and PMU and In-zone transformer protection |
| | | | | E0 | | | | | | | | | | | | | | | | | | | | IEEE 1588 and PRP |
| | | | | E3 | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, IEC 61850 |
| | | | | E6 | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, and PMU |
| | | | | E7 | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, IEC 61850, and PMU |
| | | | | EI | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, three-pole autoreclose, synchrocheck |
| | | | | EJ | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, three-pole autoreclose, PMU, synchrocheck |
| | | | | EO | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, and in-zone transformer protection |
| | | | | EP | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, in-zone transformer protection, and IEC 61850 |
| | | | | EQ | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, in-zone transformer protection, and PMU |
| | | | | ER | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, in-zone transformer protection, IEC 61850, and PMU |
| | | | | F0 | | | | | | | | | | | | | | | | | | | | PRP and CyberSentry Lvl 1 |
| | | | | F3 | | | | | | | | | | | | | | | | | | | | PRP, CyberSentry Lvl 1, and IEC 61850 |
| | | | | F6 | | | | | | | | | | | | | | | | | | | | PRP, CyberSentry Lvl  1, and PMU |
| | | | | F7 | | | | | | | | | | | | | | | | | | | | PRP, CyberSentry Lvl 1, IEC 61850, and PMU |
| | | | | FI | | | | | | | | | | | | | | | | | | | | PRP, CyberSentry Lvl 1, three-pole autoreclose, synchrocheck |
| | | | | FJ | | | | | | | | | | | | | | | | | | | | PRP, CyberSentry Lvl 1, three-pole autoreclose, PMU, synchrocheck |
| | | | | FO | | | | | | | | | | | | | | | | | | | | PRP, CyberSentry Lvl 1, in-zone transformer protection |
| | | | | FP | | | | | | | | | | | | | | | | | | | | PRP, CyberSentry Lvl 1, in-zone transformer protection, and IEC 61850 |
| | | | | FQ | | | | | | | | | | | | | | | | | | | | PRP, CyberSentry Lvl 1, in-zone transformer protection, and PMU |
| | | | | FR | | | | | | | | | | | | | | | | | | | | PRP, CyberSentry Lvl 1, in-zone transformer protection, IEC 61850, and PMU |
| | | | | G0 | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, and CyberSentry Lvl 1 |
| | | | | G3 | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850 |
| | | | | G6 | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, CyberSentry Lvl 1, and PMU |
| | | | | G7 | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and PMU |
| | | | | GI | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, CyberSentry Lvl 1, three-pole autoreclose, synchrocheck |
| | | | | GJ | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, CyberSentry Lvl 1, three-pole autoreclose, PMU, synchrocheck |
| | | | | GO | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection |
| | | | | GP | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection, and IEC 61850 |
| | | | | GQ | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection, and PMU |
| | | | | GR | | | | | | | | | | | | | | | | | | | | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection, IEC 61850, and PMU |
| | | | | J0 | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 |
| | | | | J3 | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEC 61850 |
| | | | | J6 | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + PMU |
| | | | | J7 | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEC 61850 + PMU |
| | | | | JI | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + three-pole autoreclose + synchrocheck |
| | | | | JJ | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + three-pole autoreclose + PMU + synchrocheck |
| | | | | JO | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + in-zone transformer protection |
| | | | | JP | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + in-zone transformer protection + IEC 61850 |
| | | | | JQ | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + in-zone transformer protection + PMU |
| | | | | JR | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + in-zone transformer protection + IEC 61850 + PMU |
| | | | | K0 | | | | | | | | | | | | | | | | | | | | IEEE1588 + PRP + IEC 60870-5-103 |
| | | | | K3 | | | | | | | | | | | | | | | | | | | | IEEE1588 + PRP + IEC 60870-5-103 + IEC 61850 |
| | | | | K6 | | | | | | | | | | | | | | | | | | | | IEEE1588 + PRP + IEC 60870-5-103 + PMU |
| | | | | K7 | | | | | | | | | | | | | | | | | | | | IEEE1588 + PRP + IEC 60870-5-103 + IEC 61850 + PMU |
| | | | | KI | | | | | | | | | | | | | | | | | | | | IEEE1588 + PRP + IEC 60870-5-103 + three-pole autoreclose + synchrocheck |
| | | | | KJ | | | | | | | | | | | | | | | | | | | | IEEE1588 + PRP + IEC 60870-5-103 + three-pole autoreclose + PMU + synchrocheck |
| | | | | KO | | | | | | | | | | | | | | | | | | | | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection |
| | | | | KP | | | | | | | | | | | | | | | | | | | | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + IEC 61850 |
| | | | | KQ | | | | | | | | | | | | | | | | | | | | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + PMU |
| | | | | KR | | | | | | | | | | | | | | | | | | | | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + IEC 61850 + PMU |
| | | | | L0 | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + |
| | | | | L3 | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + IEC 61850 |
| | | | | L6 | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + PMU |
| | | | | L7 | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + IEC 61850 + PMU |
| | | | | LI | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + three-pole autoreclose + synchrocheck |
| | | | | LJ | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + three-pole autoreclose + PMU + synchrocheck |
| | | | | LO | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection |
| | | | | LP | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + IEC 61850 |
| | | | | LQ | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + PMU |
| | | | | LR | | | | | | | | | | | | | | | | | | | | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + IEC 61850 + PMU |
| **MOUNT/COATING** | | | | | | V | | | | | | | | | | | | | | | | | | Vertical (3/4 rack) |
| | | | | | | B | | | | | | | | | | | | | | | | | | Vertical (3/4 rack) with harsh environmental coating |
| **FACEPLATE/ DISPLAY** | | | | | | | F | | | | | | | | | | | | | | | | | English display |
| | | | | | | | D | | | | | | | | | | | | | | | | | French display |
| | | | | | | | R | | | | | | | | | | | | | | | | | Russian display |
| | | | | | | | K | | | | | | | | | | | | | | | | | Enhanced front panel with English display |

## Table 2–5: L30 ORDER CODES (REDUCED SIZE VERTICAL UNITS)

| | L30 - * ** - * * * - F ** - H ** - L ** - N ** - R ** | |
|---|---|---|
| | M | Enhanced front panel with French display |
| | Q | Enhanced front panel with Russian display |
| | U | Enhanced front panel with Chinese display |
| | L | Enhanced front panel with English display and user-programmable pushbuttons |
| | N | Enhanced front panel with French display and user-programmable pushbuttons |
| | T | Enhanced front panel with Russian display and user-programmable pushbuttons |
| | V | Enhanced front panel with Chinese display and user-programmable pushbuttons |
| | W | Enhanced front panel with Turkish display |
| | Y | Enhanced front panel with Turkish display and user-programmable pushbuttons |
| | I | Enhanced front panel with German display |
| | J | Enhanced front panel with German display and user-programmable pushbuttons |
| **POWER SUPPLY** | H | 125 / 250 V AC/DC power supply |
| | L | 24 to 48 V (DC only) power supply |
| **CT/VT DSP** | 8L | Standard 4CT/4VT with enhanced diagnostics (required for PMU option) |
| | 8N | Standard 8CT with enhanced diagnostics (required for PMU option) |
| **DIGITAL INPUTS/OUTPUTS** | XX XX XX | No Module |
| | 4A 4A 4A | 4 Solid-State (no monitoring) MOSFET outputs |
| | 4B 4B 4B | 4 Solid-State (voltage with optional current) MOSFET outputs |
| | 4C 4C 4C | 4 Solid-State (current with optional voltage) MOSFET outputs |
| | 4D 4D 4D | 16 digital inputs with Auto-Burnishing (maximum of three modules within a case) |
| | 4L 4L 4L | 14 Form-A (no monitoring) Latching outputs |
| | 67 67 67 | 8 Form-A (no monitoring) outputs |
| | 6A 6A 6A | 2 Form-A (voltage with optional current) and 2 Form-C outputs, 8 digital inputs |
| | 6B 6B 6B | 2 Form-A (voltage with optional current) and 4 Form-C outputs, 4 digital inputs |
| | 6C 6C 6C | 8 Form-C outputs |
| | 6D 6D 6D | 16 digital inputs |
| | 6E 6E 6E | 4 Form-C outputs, 8 digital inputs |
| | 6F 6F 6F | 8 Fast Form-C outputs |
| | 6G 6G 6G | 4 Form-A (voltage with optional current) outputs, 8 digital inputs |
| | 6H 6H 6H | 6 Form-A (voltage with optional current) outputs, 4 digital inputs |
| | 6K 6K 6K | 4 Form-C and 4 Fast Form-C outputs |
| | 6L 6L 6L | 2 Form-A (current with optional voltage) and 2 Form-C outputs, 8 digital inputs |
| | 6M 6M 6M | 2 Form-A (current with optional voltage) and 4 Form-C outputs, 4 digital inputs |
| | 6N 6N 6N | 4 Form-A (current with optional voltage) outputs, 8 digital inputs |
| | 6P 6P 6P | 6 Form-A (current with optional voltage) outputs, 4 digital inputs |
| | 6R 6R 6R | 2 Form-A (no monitoring) and 2 Form-C outputs, 8 digital inputs |
| | 6S 6S 6S | 2 Form-A (no monitoring) and 4 Form-C outputs, 4 digital inputs |
| | 6T 6T 6T | 4 Form-A (no monitoring) outputs, 8 digital inputs |
| | 6U 6U 6U | 6 Form-A (no monitoring) outputs, 4 digital inputs |
| | 6V 6V 6V | 2 Form-A outputs, 1 Form-C output, 1 Form-A latching output, 8 digital inputs |
| **TRANSDUCER INPUTS/OUTPUTS (select a maximum of 3 per unit)** | 5A 5A 5A | 4 DCmA inputs, 4 DCmA outputs (only one 5A or 5D module is allowed) |
| | 5C 5C 5C | 8 RTD inputs |
| | 5D 5D 5D | 4 RTD inputs, 4 DCmA outputs (only one 5A or 5D module is allowed) |
| | 5E 5E 5E | 4 RTD inputs, 4 DCmA inputs |
| | 5F 5F 5F | 8 DCmA inputs |
| **INTER-RELAY COMMUNICATIONS (select a maximum of 1 per unit)** | 2A | C37.94SM, 1300 nm single-mode, ELED, 1 channel single-mode |
| | 2B | C37.94SM, 1300 nm single-mode, ELED, 2 channel single-mode |
| | 2H | IEEE C37.94, 820 nm, 128 kbps, multimode, LED, 2 Channels |
| | 2I | Channel 1 - IEEE C37.94, MM, 64/128 kbps; Channel 2 - 1300 nm, single-mode, Laser |
| | 2J | Channel 1 - IEEE C37.94, MM, 64/128 kbps; Channel 2 - 1550 nm, single-mode, Laser |
| | 72 | 1550 nm, single-mode, Laser, 1 Channel |
| | 73 | 1550 nm, single-mode, Laser, 2 Channel |
| | 76 | IEEE C37.94, 820 nm, 64 kbps, multimode, LED, 1 Channel |
| | 77 | IEEE C37.94, 820 nm, 64 kbps, multimode, LED, 2 Channels |
| | 7A | 820 nm, multimode, LED, 1 Channel |
| | 7B | 1300 nm, multimode, LED, 1 Channel |
| | 7C | 1300 nm, single-mode, ELED, 1 Channel |
| | 7D | 1300 nm, single-mode, Laser, 1 Channel |
| | 7F | Channel 1 - G.703; Channel 2 - 1300 nm, multimode |
| | 7G | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode ELED |
| | 7H | 820 nm, multimode, LED, 2 Channels |
| | 7I | 1300 nm, multimode, LED, 2 Channels |
| | 7J | 1300 nm, single-mode, ELED, 2 Channels |
| | 7K | 1300 nm, single-mode, Laser, 2 Channels |
| | 7M | Channel 1 - RS422; Channel 2 - 1300 nm, multimode, LED |
| | 7N | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, ELED |
| | 7P | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, Laser |
| | 7Q | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode Laser |
| | 7R | G.703, 1 Channel |
| | 7S | G.703, 2 Channels |
| | 7T | RS422, 1 Channel |
| | 7V | RS422, 2 Channels, 2 Clock Inputs |
| | 7W | RS422, 2 Channels |

### 2.2.3 ORDER CODES WITH PROCESS BUS MODULES

The order codes for the horizontal mount units with the process bus module are shown below.

## Table 2–6: L30 ORDER CODES (HORIZONTAL UNITS WITH PROCESS BUS)

| | L30 - * ** - * * * - F ** - H ** - L ** - N ** - S ** - W/X ** | |
|---|---|---|
| **BASE UNIT** | L30 | Base Unit |
| **CPU** | T | RS485 and Three Multi-mode fiber 100Base-FX (SFP with LC) |
| | U | RS485 and Two Multi-mode fiber 100Base-FX (SFP with LC), One 10/100Base-T (SFP with RJ45) |
| | V | RS485 and Three 10/100Base-T (SFP with RJ45) |
| **SOFTWARE** | 00 | No software options |
| | 03 | IEC 61850 |
| | 06 | One phasor measurement unit (PMU) |
| | 07 | IEC 61850 and one phasor measurement unit (PMU) |
| | 18 | Synchrocheck, three-pole autoreclose |
| | 19 | Synchrocheck, three-pole autoreclose, one phasor measurement unit (PMU) |
| | 24 | In-zone transformer protection |
| | 25 | In-zone transformer protection and IEC 61850 |
| | 26 | In-zone transformer protection and one phasor measurement unit (PMU) |
| | 27 | In-zone transformer protection, IEC 61850, and one phasor measurement unit (PMU) |
| | A0 | CyberSentry Lvl 1 |
| | A3 | CyberSentry Lvl 1 and IEC 61850 |
| | A6 | CyberSentry Lvl 1 and phasor measurement unit (PMU) |
| | A7 | CyberSentry Lvl 1 and IEC 61850 and phasor measurement unit (PMU) |
| | AI | CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck |
| | AJ | CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck and one PMU |
| | AO | CyberSentry Lvl 1 and In-zone transformer protection |
| | AP | CyberSentry Lvl 1 and IEC 61850 and In-zone transformer protection |
| | AQ | CyberSentry Lvl 1 and phasor measurement unit (PMU) and In-zone transformer protection |
| | AR | CyberSentry Lvl 1 and IEC 61850 and (PMU) and In-zone transformer protection |
| | B0 | IEEE 1588 |
| | B3 | IEEE 1588 and IEC 61850 |
| | B6 | IEEE 1588 and phasor measurement unit (PMU) |
| | B7 | IEEE 1588 and IEC 61850 and phasor measurement unit (PMU) |
| | BI | IEEE 1588 and three-pole autoreclose and synchrocheck |
| | BJ | IEEE 1588 and three-pole autoreclose and synchrocheck and one PMU |
| | BO | IEEE 1588 and In-zone transformer protection |
| | BP | IEEE 1588 and IEC 61850 and In-zone transformer protection |
| | BQ | IEEE 1588 and phasor measurement unit (PMU) and In-zone transformer protection |
| | BR | IEEE 1588 and IEC 61850 and (PMU) and In-zone transformer protection |
| | C0 | Parallel Redundancy Protocol (PRP) |
| | C3 | PRP and IEC 61850 |
| | C6 | PRP and PMU |
| | C7 | PRP, IEC 61850, and PMU |
| | CI | PRP, three-pole autoreclose, synchrocheck |

## Table 2–6: L30 ORDER CODES (HORIZONTAL UNITS WITH PROCESS BUS)

| | L30 - * ** - * * * - F ** - H ** - L ** - N ** - S ** - W/X ** | |
|---|---|---|
| **BASE UNIT** | L30 | Base Unit |
| | CJ | PRP, three-pole autoreclose, PMU, synchrocheck |
| | CO | PRP and in-zone transformer protection |
| | CP | PRP, in-zone transformer protection, and IEC 61850 |
| | CQ | PRP, in-zone transformer protection, and PMU |
| | CR | PRP, in-zone transformer protection, IEC 61850, and PMU |
| | D0 | IEEE 1588 and CyberSentry Lvl 1 |
| | D3 | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 |
| | D6 | IEEE 1588 and CyberSentry Lvl 1 and phasor measurement unit (PMU) |
| | D7 | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and phasor measurement unit (PMU) |
| | DI | IEEE 1588 and CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck |
| | DJ | IEEE 1588 and CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck and PMU |
| | DO | IEEE 1588 and CyberSentry Lvl 1 and In-zone transformer protection |
| | DP | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and In-zone transformer protection |
| | DQ | IEEE 1588 and CyberSentry Lvl 1 and one PMU and In-zone transformer protection |
| | DR | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and PMU and In-zone transformer protection |
| | E0 | IEEE 1588 and PRP |
| | E3 | IEEE 1588, PRP, IEC 61850 |
| | E6 | IEEE 1588, PRP, and PMU |
| | E7 | IEEE 1588, PRP, IEC 61850, and PMU |
| | EI | IEEE 1588, PRP, three-pole autoreclose, synchrocheck |
| | EJ | IEEE 1588, PRP, three-pole autoreclose, PMU, synchrocheck |
| | EO | IEEE 1588, PRP, and in-zone transformer protection |
| | EP | IEEE 1588, PRP, in-zone transformer protection, and IEC 61850 |
| | EQ | IEEE 1588, PRP, in-zone transformer protection, and PMU |
| | ER | IEEE 1588, PRP, in-zone transformer protection, IEC 61850, and PMU |
| | F0 | PRP and CyberSentry Lvl 1 |
| | F3 | PRP, CyberSentry Lvl 1, and IEC 61850 |
| | F6 | PRP, CyberSentry Lvl 1, and PMU |
| | F7 | PRP, CyberSentry Lvl 1, IEC 61850, and PMU |
| | FI | PRP, CyberSentry Lvl 1, three-pole autoreclose, synchrocheck |
| | FJ | PRP, CyberSentry Lvl 1, three-pole autoreclose, PMU, synchrocheck |
| | FO | PRP, CyberSentry Lvl 1, in-zone transformer protection |
| | FP | PRP, CyberSentry Lvl 1, in-zone transformer protection, and IEC 61850 |
| | FQ | PRP, CyberSentry Lvl 1, in-zone transformer protection, and PMU |
| | FR | PRP, CyberSentry Lvl 1, in-zone transformer protection, IEC 61850, and PMU |
| | G0 | IEEE 1588, PRP, and CyberSentry Lvl 1 |
| | G3 | IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850 |
| | G6 | IEEE 1588, PRP, CyberSentry Lvl 1, and PMU |
| | G7 | IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and PMU |
| | GI | IEEE 1588, PRP, CyberSentry Lvl 1, three-pole autoreclose, synchrocheck |
| | GJ | IEEE 1588, PRP, CyberSentry Lvl 1, three-pole autoreclose, PMU, synchrocheck |
| | GO | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection |
| | GP | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection, and IEC 61850 |
| | GQ | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection, and PMU |
| | GR | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection, IEC 61850, and PMU |
| | J0 | IEC 60870-5-103 |
| | J3 | IEC 60870-5-103 + IEC 61850 |
| | J6 | IEC 60870-5-103 + PMU |
| | J7 | IEC 60870-5-103 + IEC 61850 + PMU |
| | JI | IEC 60870-5-103 + three-pole autoreclose + synchrocheck |
| | JJ | IEC 60870-5-103 + three-pole autoreclose + PMU + synchrocheck |
| | JO | IEC 60870-5-103 + in-zone transformer protection |
| | JP | IEC 60870-5-103 + in-zone transformer protection + IEC 61850 |
| | JQ | IEC 60870-5-103 + in-zone transformer protection + PMU |
| | JR | IEC 60870-5-103 + in-zone transformer protection + IEC 61850 + PMU |
| | K0 | IEEE1588 + PRP + IEC 60870-5-103 |
| | K3 | IEEE1588 + PRP + IEC 60870-5-103 + IEC 61850 |
| | K6 | IEEE1588 + PRP + IEC 60870-5-103 + PMU |
| | K7 | IEEE1588 + PRP + IEC 60870-5-103 + IEC 61850 + PMU |
| | KI | IEEE1588 + PRP + IEC 60870-5-103 + three-pole autoreclose + synchrocheck |
| | KJ | IEEE1588 + PRP + IEC 60870-5-103 + three-pole autoreclose + PMU + synchrocheck |
| | KO | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection |
| | KP | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + IEC 61850 |
| | KQ | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + PMU |
| | KR | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + IEC 61850 + PMU |
| | L0 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + |
| | L3 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + IEC 61850 |
| | L6 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + PMU |
| | L7 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + IEC 61850 + PMU |
| | LI | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + three-pole autoreclose + synchrocheck |
| | LJ | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + three-pole autoreclose + PMU + synchrocheck |
| | LO | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection |
| | LP | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + IEC 61850 |
| | LQ | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + PMU |
| | LR | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + IEC 61850 + PMU |
| **MOUNT/COATING** | H | Horizontal (19" rack) |
| | A | Horizontal (19" rack) with harsh environmental coating |
| **FACEPLATE/ DISPLAY** | C | English display |
| | D | French display |
| | R | Russian display |
| | P | English display with 4 small and 12 large programmable pushbuttons |
| | G | French display with 4 small and 12 large programmable pushbuttons |
| | S | Russian display with 4 small and 12 large programmable pushbuttons |
| | K | Enhanced front panel with English display |
| | M | Enhanced front panel with French display |
| | Q | Enhanced front panel with Russian display |
| | U | Enhanced front panel with Chinese display |
| | L | Enhanced front panel with English display and user-programmable pushbuttons |
| | N | Enhanced front panel with French display and user-programmable pushbuttons |
| | T | Enhanced front panel with Russian display and user-programmable pushbuttons |
| | V | Enhanced front panel with Chinese display and user-programmable pushbuttons |
| | W | Enhanced front panel with Turkish display |
| | Y | Enhanced front panel with Turkish display and user-programmable pushbuttons |
| | I | Enhanced front panel with German display |
| | J | Enhanced front panel with German display and user-programmable pushbuttons |
| **POWER SUPPLY (redundant supply must be same type as main supply)** | H | 125 / 250 V AC/DC power supply |
| | H | 125 / 250 V AC/DC with redundant 125 / 250 V AC/DC power supply |
| | L | 24 to 48 V (DC only) power supply |
| | L | 24 to 48 V (DC only) with redundant 24 to 48 V DC power supply |
| **PROCESS BUS MODULE** | 81 | Eight-port digital process bus module |
| **DIGITAL INPUTS/OUTPUTS** | XX | No Module |
| | 4A | 4 Solid-State (no monitoring) MOSFET outputs |
| | 4B | 4 Solid-State (voltage with optional current) MOSFET outputs |
| | 4C | 4 Solid-State (current with optional voltage) MOSFET outputs |
| | 4D | 16 digital inputs with Auto-Burnishing (maximum of three modules within a case) |
| | 4L | 14 Form-A (no monitoring) Latching outputs |
| | 67 | 8 Form-A (no monitoring) outputs |
| | 6A | 2 Form-A (voltage with optional current) and 2 Form-C outputs, 8 digital inputs |
| | 6B | 2 Form-A (voltage with optional current) and 4 Form-C outputs, 4 digital inputs |
| | 6C | 8 Form-C outputs |
| | 6D | 16 digital inputs |
| | 6E | 4 Form-C outputs, 8 digital inputs |
| | 6F | 8 Fast Form-C outputs |
| | 6G | 4 Form-A (voltage with optional current) outputs, 8 digital inputs |
| | 6H | 6 Form-A (voltage with optional current) outputs, 4 digital inputs |
| | 6K | 4 Form-C and 4 Fast Form-C outputs |
| | 6L | 2 Form-A (current with optional voltage) and 2 Form-C outputs, 8 digital inputs |
| | 6M | 2 Form-A (current with optional voltage) and 4 Form-C outputs, 4 digital inputs |
| | 6N | 4 Form-A (current with optional voltage) outputs, 8 digital inputs |
| | 6P | 6 Form-A (current with optional voltage) outputs, 4 digital inputs |
| | 6R | 2 Form-A (no monitoring) and 2 Form-C outputs, 8 digital inputs |
| | 6S | 2 Form-A (no monitoring) and 4 Form-C outputs, 4 digital inputs |
| | 6T | 4 Form-A (no monitoring) outputs, 8 digital inputs |

## Table 2–6: L30 ORDER CODES (HORIZONTAL UNITS WITH PROCESS BUS)

| | L30 - * ** - * * * - F ** - H ** - L ** - N ** - S ** - W/X ** | |
|---|---|---|
| **BASE UNIT** | L30 | Base Unit |
| | 6U 6U | 6 Form-A (no monitoring) outputs, 4 digital inputs |
| | 6V 6V | 2 Form-A outputs, 1 Form-C output, 1 Form-A latching output, 8 digital inputs |
| **INTER-RELAY COMMUNICATIONS (select a maximum of 1 per unit)** | 2A | C37.94SM, 1300 nm single-mode, ELED, 1 channel single-mode |
| | 2B | C37.94SM, 1300 nm single-mode, ELED, 2 channel single-mode |
| | 2H | IEEE C37.94, 820 nm, 128 kbps, multimode, LED, 2 Channels |
| | 2I | Channel 1 - IEEE C37.94, MM, 64/128 kbps; Channel 2 - 1300 nm, single-mode, Laser |
| | 2J | Channel 1 - IEEE C37.94, MM, 64/128 kbps; Channel 2 - 1550 nm, single-mode, Laser |
| | 72 | 1550 nm, single-mode, Laser, 1 Channel |
| | 73 | 1550 nm, single-mode, Laser, 2 Channel |
| | 76 | IEEE C37.94, 820 nm, 64 kbps, multimode, LED, 1 Channel |
| | 77 | IEEE C37.94, 820 nm, 64 kbps, multimode, LED, 2 Channels |
| | 7A | 820 nm, multimode, LED, 1 Channel |
| | 7B | 1300 nm, multimode, LED, 1 Channel |
| | 7C | 1300 nm, single-mode, ELED, 1 Channel |
| | 7D | 1300 nm, single-mode, Laser, 1 Channel |
| | 7F | Channel 1 - G.703; Channel 2 - 1300 nm, multimode |
| | 7G | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode ELED |
| | 7H | 820 nm, multimode, LED, 2 Channels |
| | 7I | 1300 nm, multimode, LED, 2 Channels |
| | 7J | 1300 nm, single-mode, ELED, 2 Channels |
| | 7K | 1300 nm, single-mode, Laser, 2 Channels |
| | 7M | Channel 1 - RS422; Channel 2 - 1300 nm, multimode, LED |
| | 7N | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, ELED |
| | 7P | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, Laser |
| | 7Q | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode Laser |
| | 7R | G.703, 1 Channel |
| | 7S | G.703, 2 Channels |
| | 7T | RS422, 1 Channel |
| | 7V | RS422, 2 Channels, 2 Clock Inputs |
| | 7W | RS422, 2 Channels |

The order codes for the reduced size vertical mount units with the process bus module are shown below.

## Table 2–7: L30 ORDER CODES (REDUCED SIZE VERTICAL UNITS WITH PROCESS BUS)

| | L30 - * ** - * * * - F ** - H ** - L ** - N ** - R ** | |
|---|---|---|
| **BASE UNIT** | L30 | Base Unit |
| **CPU** | T | RS485 and Three Multi-mode fiber 100Base-FX (SFP with LC) |
| | U | RS485 and Two Multi-mode fiber 100Base-FX (SFP with LC), One 10/100Base-T (SFP with RJ45) |
| | V | RS485 and Three 10/100Base-T (SFP with RJ45) |
| **SOFTWARE** | 00 | No software options |
| | 03 | IEC 61850 |
| | 06 | Phasor measurement unit (PMU) |
| | 07 | IEC 61850 and phasor measurement unit (PMU) |
| | 18 | Synchrocheck, three-pole autoreclose |
| | 19 | Synchrocheck, three-pole autoreclose, one phasor measurement unit (PMU) |
| | 24 | In-zone transformer protection |
| | 25 | In-zone transformer protection and IEC 61850 |
| | 26 | In-zone transformer protection and one phasor measurement unit (PMU) |
| | 27 | In-zone transformer protection, IEC 61850, and one phasor measurement unit (PMU) |
| | A0 | CyberSentry Lvl 1 |
| | A3 | CyberSentry Lvl 1 and IEC 61850 |
| | A6 | CyberSentry Lvl 1 and phasor measurement unit (PMU) |
| | A7 | CyberSentry Lvl 1 and IEC 61850 and phasor measurement unit (PMU) |
| | AI | CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck |
| | AJ | CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck and one PMU |
| | AO | CyberSentry Lvl 1 and In-zone transformer protection |
| | AP | CyberSentry Lvl 1 and IEC 61850 and In-zone transformer protection |
| | AQ | CyberSentry Lvl 1 and phasor measurement unit (PMU) and In-zone transformer protection |
| | AR | CyberSentry Lvl 1 and IEC 61850 and (PMU) and In-zone transformer protection |
| | B0 | IEEE 1588 |
| | B3 | IEEE 1588 and IEC 61850 |
| | B6 | IEEE 1588 and phasor measurement unit (PMU) |
| | B7 | IEEE 1588 and IEC 61850 and phasor measurement unit (PMU) |
| | BI | IEEE 1588 and three-pole autoreclose and synchrocheck |
| | BJ | IEEE 1588 and three-pole autoreclose and synchrocheck and one PMU |
| | BO | IEEE 1588 and In-zone transformer protection |
| | BP | IEEE 1588 and IEC 61850 and In-zone transformer protection |
| | BQ | IEEE 1588 and phasor measurement unit (PMU) and In-zone transformer protection |
| | BR | IEEE 1588 and IEC 61850 and (PMU) and In-zone transformer protection |
| | C0 | Parallel Redundancy Protocol (PRP) |
| | C3 | PRP and IEC 61850 |
| | C6 | PRP and PMU |
| | C7 | PRP, IEC 61850, and PMU |
| | CI | PRP, three-pole autoreclose, synchrocheck |
| | CJ | PRP, three-pole autoreclose, PMU, synchrocheck |
| | CO | PRP and in-zone transformer protection |
| | CP | PRP, in-zone transformer protection, and IEC 61850 |
| | CQ | PRP, in-zone transformer protection, and PMU |
| | CR | PRP, in-zone transformer protection, IEC 61850, and PMU |
| | D0 | IEEE 1588 and CyberSentry Lvl 1 |
| | D3 | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 |
| | D6 | IEEE 1588 and CyberSentry Lvl 1 and phasor measurement unit (PMU) |
| | D7 | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and phasor measurement unit (PMU) |
| | DI | IEEE 1588 and CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck |
| | DJ | IEEE 1588 and CyberSentry Lvl 1 and three-pole autoreclose and synchrocheck and PMU |
| | DO | IEEE 1588 and CyberSentry Lvl 1 and In-zone transformer protection |
| | DP | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and In-zone transformer protection |
| | DQ | IEEE 1588 and CyberSentry Lvl 1 and one PMU and In-zone transformer protection |
| | DR | IEEE 1588 and CyberSentry Lvl 1 and IEC 61850 and PMU and In-zone transformer protection |
| | E0 | IEEE 1588 and PRP |
| | E3 | IEEE 1588, PRP, IEC 61850 |
| | E6 | IEEE 1588, PRP, and PMU |
| | E7 | IEEE 1588, PRP, IEC 61850, and PMU |
| | EI | IEEE 1588, PRP, three-pole autoreclose, and synchrocheck |
| | EJ | IEEE 1588, PRP, three-pole autoreclose, PMU, and synchrocheck |
| | EO | IEEE 1588, PRP, and in-zone transformer protection |
| | EP | IEEE 1588, PRP, in-zone transformer protection, and IEC 61850 |
| | EQ | IEEE 1588, PRP, in-zone transformer protection, and PMU |
| | ER | IEEE 1588, PRP, in-zone transformer protection, IEC 61850, and PMU |
| | F0 | PRP and CyberSentry Lvl 1 |
| | F3 | PRP, CyberSentry Lvl 1, and IEC 61850 |
| | F6 | PRP, CyberSentry Lvl 1, and PMU |
| | F7 | PRP, CyberSentry Lvl 1, IEC 61850, and PMU |
| | FI | PRP, CyberSentry Lvl 1, three-pole autoreclose, synchrocheck |
| | FJ | PRP, CyberSentry Lvl 1, three-pole autoreclose, PMU, synchrocheck |
| | FO | PRP, CyberSentry Lvl 1, in-zone transformer protection |
| | FP | PRP, CyberSentry Lvl 1, in-zone transformer protection, and IEC 61850 |
| | FQ | PRP, CyberSentry Lvl 1, in-zone transformer protection, and PMU |
| | FR | PRP, CyberSentry Lvl 1, in-zone transformer protection, IEC 61850, and PMU |
| | G0 | IEEE 1588, PRP, and CyberSentry Lvl 1 |
| | G3 | IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850 |
| | G6 | IEEE 1588, PRP, CyberSentry Lvl 1, and PMU |
| | G7 | IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and PMU |
| | GI | IEEE 1588, PRP, CyberSentry Lvl 1, three-pole autoreclose, synchrocheck |
| | GJ | IEEE 1588, PRP, CyberSentry Lvl 1, three-pole autoreclose, PMU, synchrocheck |
| | GO | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection |
| | GP | IEEE 1588 PRP, CyberSentry Lvl 1, in-zone transformer protection, and IEC 61850 |
| | GQ | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection, and PMU |
| | GR | IEEE 1588, PRP, CyberSentry Lvl 1, in-zone transformer protection, IEC 61850, and PMU |
| | J0 | IEC 60870-5-103 |
| | J3 | IEC 60870-5-103 + IEC 61850 |
| | J6 | IEC 60870-5-103 + PMU |

## Table 2–7: L30 ORDER CODES (REDUCED SIZE VERTICAL UNITS WITH PROCESS BUS)

| L30 - * ** - * * * - F ** - H ** - L ** - N ** - R ** | |
|---|---|
| | Reduced Size Vertical Mount |
| J7 | IEC 60870-5-103 + IEC 61850 + PMU |
| JI | IEC 60870-5-103 + three-pole autoreclose + synchrocheck |
| JJ | IEC 60870-5-103 + three-pole autoreclose + PMU + synchrocheck |
| JO | IEC 60870-5-103 + in-zone transformer protection |
| JP | IEC 60870-5-103 + in-zone transformer protection + IEC 61850 |
| JQ | IEC 60870-5-103 + in-zone transformer protection + PMU |
| JR | IEC 60870-5-103 + in-zone transformer protection + IEC 61850 + PMU |
| K0 | IEEE1588 + PRP + IEC 60870-5-103 |
| K3 | IEEE1588 + PRP + IEC 60870-5-103 + IEC 61850 |
| K6 | IEEE1588 + PRP + IEC 60870-5-103 + PMU |
| K7 | IEEE1588 + PRP + IEC 60870-5-103 + IEC 61850 + PMU |
| KI | IEEE1588 + PRP + IEC 60870-5-103 + three-pole autoreclose + synchrocheck |
| KJ | IEEE1588 + PRP + IEC 60870-5-103 + three-pole autoreclose + PMU + synchrocheck |
| KO | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection |
| KP | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + IEC 61850 |
| KQ | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + PMU |
| KR | IEEE1588 + PRP + IEC 60870-5-103 + in-zone transformer protection + IEC 61850 + PMU |
| L0 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + |
| L3 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + IEC 61850 |
| L6 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + PMU |
| L7 | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + IEC 61850 + PMU |
| LI | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + three-pole autoreclose + synchrocheck |
| LJ | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + three-pole autoreclose + PMU + synchrocheck |
| LO | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection |
| LP | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + IEC 61850 |
| LQ | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + PMU |
| LR | IEC 60870-5-103 + IEEE1588 + PRP + CyberSentry Lvl 1 + in-zone transformer protection + IEC 61850 + PMU |
| **MOUNT/COATING** | |
| V | Vertical (3/4 rack) |
| B | Vertical (3/4 rack) with harsh environmental coating |
| **FACEPLATE/ DISPLAY** | |
| F | English display |
| D | French display |
| R | Russian display |
| K | Enhanced front panel with English display |
| M | Enhanced front panel with French display |
| Q | Enhanced front panel with Russian display |
| U | Enhanced front panel with Chinese display |
| L | Enhanced front panel with English display and user-programmable pushbuttons |
| N | Enhanced front panel with French display and user-programmable pushbuttons |
| T | Enhanced front panel with Russian display and user-programmable pushbuttons |
| V | Enhanced front panel with Chinese display and user-programmable pushbuttons |
| W | Enhanced front panel with Turkish display |
| Y | Enhanced front panel with Turkish display and user-programmable pushbuttons |
| I | Enhanced front panel with German display |
| J | Enhanced front panel with German display and user-programmable pushbuttons |
| **POWER SUPPLY** | |
| H | 125 / 250 V AC/DC power supply |
| L | 24 to 48 V (DC only) power supply |
| **PROCESS BUS MODULE** | |
| 81 | Eight-port digital process bus module |
| **DIGITAL INPUTS/OUTPUTS** | |
| XX | No Module |
| 4A | 4 Solid-State (no monitoring) MOSFET outputs |
| 4B | 4 Solid-State (voltage with optional current) MOSFET outputs |
| 4C | 4 Solid-State (current with optional voltage) MOSFET outputs |
| 4D | 16 digital inputs with Auto-Burnishing (maximum of three modules within a case) |
| 4L | 14 Form-A (no monitoring) Latching outputs |
| 67 | 8 Form-A (no monitoring) outputs |
| 6A | 2 Form-A (voltage with optional current) and 2 Form-C outputs, 8 digital inputs |
| 6B | 2 Form-A (voltage with optional current) and 4 Form-C outputs, 4 digital inputs |
| 6C | 8 Form-C outputs |
| 6D | 16 digital inputs |
| 6E | 4 Form-C outputs, 8 digital inputs |
| 6F | 8 Fast Form-C outputs |
| 6G | 4 Form-A (voltage with optional current) outputs, 8 digital inputs |
| 6H | 6 Form-A (voltage with optional current) outputs, 4 digital inputs |
| 6K | 4 Form-C and 4 Fast Form-C outputs |
| 6L | 2 Form-A (current with optional voltage) and 2 Form-C outputs, 8 digital inputs |
| 6M | 2 Form-A (current with optional voltage) and 4 Form-C outputs, 4 digital inputs |
| 6N | 4 Form-A (current with optional voltage) outputs, 8 digital inputs |
| 6P | 6 Form-A (current with optional voltage) outputs, 4 digital inputs |
| 6R | 2 Form-A (no monitoring) and 2 Form-C outputs, 8 digital inputs |
| 6S | 2 Form-A (no monitoring) and 4 Form-C outputs, 4 digital inputs |
| 6T | 4 Form-A (no monitoring) outputs, 8 digital inputs |
| 6U | 6 Form-A (no monitoring) outputs, 4 digital inputs |
| 6V | 2 Form-A outputs, 1 Form-C output, 1 Form-A latching output, 8 digital inputs |
| **INTER-RELAY COMMUNICATIONS (select a maximum of 1 per unit)** | |
| 2A | C37.94SM, 1300 nm single-mode, ELED, 1 channel single-mode |
| 2B | C37.94SM, 1300 nm single-mode, ELED, 2 channel single-mode |
| 2H | IEEE C37.94, 820 nm, 128 kbps, multimode, LED, 2 Channels |
| 2I | Channel 1 - IEEE C37.94, MM, 64/128 kbps; Channel 2 - 1300 nm, single-mode, Laser |
| 2J | Channel 1 - IEEE C37.94, MM, 64/128 kbps; Channel 2 - 1500 nm, single-mode, Laser |
| 72 | 1550 nm, single-mode, Laser, 1 Channel |
| 73 | 1550 nm, single-mode, Laser, 2 Channel |
| 76 | IEEE C37.94, 820 nm, 64 kbps, multimode, LED, 1 Channel |
| 77 | IEEE C37.94, 820 nm, 64 kbps, multimode, LED, 2 Channels |
| 7A | 820 nm, multimode, LED, 1 Channel |
| 7B | 1300 nm, multimode, LED, 1 Channel |
| 7C | 1300 nm, single-mode, ELED, 1 Channel |
| 7D | 1300 nm, single-mode, Laser, 1 Channel |
| 7F | Channel 1 - G.703; Channel 2 - 1300 nm, multimode |
| 7G | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode ELED |
| 7H | 820 nm, multimode, LED, 2 Channels |
| 7I | 1300 nm, multimode, LED, 2 Channels |
| 7J | 1300 nm, single-mode, ELED, 2 Channels |
| 7K | 1300 nm, single-mode, Laser, 2 Channels |
| 7M | Channel 1 - RS422; Channel 2 - 1300 nm, multimode, LED |
| 7N | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, ELED |
| 7P | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, Laser |
| 7Q | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode Laser |
| 7R | G.703, 1 Channel |
| 7S | G.703, 2 Channels |
| 7T | RS422, 1 Channel |
| 7V | RS422, 2 Channels, 2 Clock Inputs |
| 7W | RS422, 2 Channels |

### 2.2.4 REPLACEMENT MODULES

Replacement modules can be ordered separately. When ordering a replacement CPU module or faceplate, provide the serial number of your existing unit.

NOTE

Not all replacement modules may be applicable to the L30 relay. Only the modules specified in the order codes are available as replacement modules.

Replacement module codes are subject to change without notice. See the ordering page at http://www.gegridsolutions.com/multilin/order.htm for the latest options.

The replacement module order codes for the horizontal mount units are shown below.

**Table 2–8: ORDER CODES FOR REPLACEMENT MODULES, HORIZONTAL UNITS**

| UR | - | ** | - | * | |
|---|---|---|---|---|---|
| **POWER SUPPLY** | \| | SH | A | \| | 125 / 300 V AC/DC |
| **redundant supply only available in horizontal units and must be same type as main supply, for example must swap both power supplies when switching from RH to SH** | \| | SL | A | \| | 24 to 48 V (DC only) |
| **CPU** | \| | T | | \| | RS485 with 3 100Base-FX Ethernet, multimode, SFP with LC |
| | \| | U | | \| | RS485 with 1 100Base-T Ethernet, SFP RJ-45 + 2 100Base-FX Ethernet, multimode, SFP with LC |
| | \| | V | | \| | RS485 with 3 100Base-T Ethernet, SFP with RJ-45 |
| **FACEPLATE/DISPLAY** | \| | 3C | | \| | Horizontal faceplate with keypad and English display |
| | \| | 3D | | \| | Horizontal faceplate with keypad and French display |
| | \| | 3R | | \| | Horizontal faceplate with keypad and Russian display |
| | \| | 3A | | \| | Horizontal faceplate with keypad and Chinese display |
| | \| | 3P | | \| | Horizontal faceplate with keypad, user-programmable pushbuttons, and English display |
| | \| | 3G | | \| | Horizontal faceplate with keypad, user-programmable pushbuttons, and French display |
| | \| | 3S | | \| | Horizontal faceplate with keypad, user-programmable pushbuttons, and Russian display |
| | \| | 3B | | \| | Horizontal faceplate with keypad, user-programmable pushbuttons, and Chinese display |
| | \| | 3K | | \| | Enhanced front panel with English display |
| | \| | 3M | | \| | Enhanced front panel with French display |
| | \| | 3Q | | \| | Enhanced front panel with Russian display |
| | \| | 3U | | \| | Enhanced front panel with Chinese display |
| | \| | 3L | | \| | Enhanced front panel with English display and user-programmable pushbuttons |
| | \| | 3N | | \| | Enhanced front panel with French display and user-programmable pushbuttons |
| | \| | 3T | | \| | Enhanced front panel with Russian display and user-programmable pushbuttons |
| | \| | 3V | | \| | Enhanced front panel with Chinese display and user-programmable pushbuttons |
| | \| | 3I | | \| | Enhanced front panel with German display |
| | \| | 3J | | \| | Enhanced front panel with German display and user-programmable pushbuttons |
| **CONTACT INPUTS AND OUTPUTS** | \| | 4A | | \| | 4 Solid-State (no monitoring) MOSFET outputs |
| | \| | 4B | | \| | 4 Solid-State (voltage with optional current) MOSFET outputs |
| | \| | 4C | | \| | 4 Solid-State (current with optional voltage) MOSFET outputs |
| | \| | 4D | | \| | 16 contact inputs with Auto-Burnishing |
| | \| | 4L | | \| | 14 Form-A (no monitoring) Latching outputs |
| | \| | 67 | | \| | 8 Form-A (no monitoring) outputs |
| | \| | 6A | | \| | 2 Form-A (voltage with optional current) and 2 Form-C outputs, 8 contact inputs |
| | \| | 6B | | \| | 2 Form-A (voltage with optional current) and 4 Form-C outputs, 4 contact inputs |
| | \| | 6C | | \| | 8 Form-C outputs |
| | \| | 6D | | \| | 16 contact inputs |
| | \| | 6E | | \| | 4 Form-C outputs, 8 contact inputs |
| | \| | 6F | | \| | 8 Fast Form-C outputs |
| | \| | 6G | | \| | 4 Form-A (voltage with optional current) outputs, 8 contact inputs |
| | \| | 6H | | \| | 6 Form-A (voltage with optional current) outputs, 4 contact inputs |
| | \| | 6K | | \| | 4 Form-C and 4 Fast Form-C outputs |
| | \| | 6L | | \| | 2 Form-A (current with optional voltage) and 2 Form-C outputs, 8 contact inputs |
| | \| | 6M | | \| | 2 Form-A (current with optional voltage) and 4 Form-C outputs, 4 contact inputs |
| | \| | 6N | | \| | 4 Form-A (current with optional voltage) outputs, 8 contact inputs |
| | \| | 6P | | \| | 6 Form-A (current with optional voltage) outputs, 4 contact inputs |
| | \| | 6R | | \| | 2 Form-A (no monitoring) and 2 Form-C outputs, 8 contact inputs |
| | \| | 6S | | \| | 2 Form-A (no monitoring) and 4 Form-C outputs, 4 contact inputs |
| | \| | 6T | | \| | 4 Form-A (no monitoring) outputs, 8 contact inputs |
| | \| | 6U | | \| | 6 Form-A (no monitoring) outputs, 4 contact inputs |
| | \| | 6V | | \| | 2 Form-A outputs, 1 Form-C output, 2 Form-A (no monitoring) latching outputs, 8 contact inputs |
| **CT/VT MODULES** | \| | 8L | | \| | Standard 4CT/4VT with enhanced diagnostics |
| **(NOT AVAILABLE FOR THE C30)** | \| | 8N | | \| | Standard 8CT with enhanced diagnostics |
| | \| | 8M | | \| | Sensitive Ground 4CT/4VT with enhanced diagnostics |
| | \| | 8R | | \| | Sensitive Ground 8CT with enhanced diagnostics |
| **INTER-RELAY COMMUNICATIONS** | \| | 2A | | \| | C37.94SM, 1300 nm single-mode, ELED, 1 channel single-mode |
| | \| | 2B | | \| | C37.94SM, 1300 nm single-mode, ELED, 2 channel single-mode |
| | \| | 2H | | \| | IEEE C37.94, 820 nm, 128 kbps, multimode, LED, 2 Channels |
| | \| | 2I | | \| | Channel 1 - IEEE C37.94, multimode, 64/128 kbps; Channel 2 - 1300 nm, single-mode, Laser |
| | \| | 2J | | \| | Channel 1 - IEEE C37.94, multimode, 64/128 kbps; Channel 2 - 1550 nm, single-mode, Laser |
| | \| | 72 | | \| | 1550 nm, single-mode, Laser, 1 Channel |
| | \| | 73 | | \| | 1550 nm, single-mode, Laser, 2 Channel |
| | \| | 76 | | \| | IEEE C37.94, 820 nm, multimode, LED, 1 Channel |
| | \| | 77 | | \| | IEEE C37.94, 820 nm, multimode, LED, 2 Channels |
| | \| | 7A | | \| | 820 nm, multimode, LED, 1 Channel |
| | \| | 7B | | \| | 1300 nm, multimode, LED, 1 Channel |
| | \| | 7C | | \| | 1300 nm, single-mode, ELED, 1 Channel |
| | \| | 7D | | \| | 1300 nm, single-mode, Laser, 1 Channel |
| | \| | 7F | | \| | Channel 1 - G.703; Channel 2 - 1300 nm, multimode |
| | \| | 7G | | \| | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode ELED |
| | \| | 7H | | \| | 820 nm, multimode, LED, 2 Channels |
| | \| | 7I | | \| | 1300 nm, multimode, LED, 2 Channels |
| | \| | 7J | | \| | 1300 nm, single-mode, ELED, 2 Channels |
| | \| | 7K | | \| | 1300 nm, single-mode, Laser, 2 Channels |
| | \| | 7M | | \| | Channel 1 - RS422; Channel 2 - 1300 nm, multimode, LED |
| | \| | 7N | | \| | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, ELED |
| | \| | 7P | | \| | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, Laser |
| | \| | 7Q | | \| | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode Laser |
| | \| | 7R | | \| | G.703, 1 Channel |
| | \| | 7S | | \| | G.703, 2 Channels |
| | \| | 7T | | \| | RS422, 1 Channel |
| | \| | 7W | | \| | RS422, 2 Channels |

The replacement module order codes for the reduced-size vertical mount units are shown below.

## Table 2–9: ORDER CODES FOR REPLACEMENT MODULES, VERTICAL UNITS

| UR | - | ** | - | * | |
|---|---|---|---|---|---|
| **POWER SUPPLY** | | SH | B | | 125 / 300 V AC/DC |
| | | SL | B | | 24 to 48 V (DC only) |
| **CPU** | | T | | | RS485 with 3 100Base-FX Ethernet, multimode, SFP with LC |
| | | U | | | RS485 with 1 100Base-T Ethernet, SFP RJ-45 + 2 100Base-FX Ethernet, multimode, SFP with LC |
| | | V | | | RS485 with 3 100Base-T Ethernet, SFP with RJ-45 |
| **FACEPLATE/DISPLAY** | | 3F | | | Vertical faceplate with keypad and English display |
| | | 3D | | | Vertical faceplate with keypad and French display |
| | | 3R | | | Vertical faceplate with keypad and Russian display |
| | | 3A | | | Vertical faceplate with keypad and Chinese display |
| | | 3K | | | Enhanced front panel with English display |
| | | 3M | | | Enhanced front panel with French display |
| | | 3Q | | | Enhanced front panel with Russian display |
| | | 3U | | | Enhanced front panel with Chinese display |
| | | 3L | | | Enhanced front panel with English display and user-programmable pushbuttons |
| | | 3N | | | Enhanced front panel with French display and user-programmable pushbuttons |
| | | 3T | | | Enhanced front panel with Russian display and user-programmable pushbuttons |
| | | 3V | | | Enhanced front panel with Chinese display and user-programmable pushbuttons |
| | | 3I | | | Enhanced front panel with German display |
| | | 3J | | | Enhanced front panel with German display and user-programmable pushbuttons |
| **CONTACT INPUTS/OUTPUTS** | | 4A | | | 4 Solid-State (no monitoring) MOSFET outputs |
| | | 4B | | | 4 Solid-State (voltage with optional current) MOSFET outputs |
| | | 4C | | | 4 Solid-State (current with optional voltage) MOSFET outputs |
| | | 4D | | | 16 contact inputs with Auto-Burnishing |
| | | 4L | | | 14 Form-A (no monitoring) Latching outputs |
| | | 67 | | | 8 Form-A (no monitoring) outputs |
| | | 6A | | | 2 Form-A (voltage with optional current) and 2 Form-C outputs, 8 contact inputs |
| | | 6B | | | 2 Form-A (voltage with optional current) and 4 Form-C outputs, 4 contact inputs |
| | | 6C | | | 8 Form-C outputs |
| | | 6D | | | 16 contact inputs |
| | | 6E | | | 4 Form-C outputs, 8 contact inputs |
| | | 6F | | | 8 Fast Form-C outputs |
| | | 6G | | | 4 Form-A (voltage with optional current) outputs, 8 contact inputs |
| | | 6H | | | 6 Form-A (voltage with optional current) outputs, 4 contact inputs |
| | | 6K | | | 4 Form-C and 4 Fast Form-C outputs |
| | | 6L | | | 2 Form-A (current with optional voltage) and 2 Form-C outputs, 8 contact inputs |
| | | 6M | | | 2 Form-A (current with optional voltage) and 4 Form-C outputs, 4 contact inputs |
| | | 6N | | | 4 Form-A (current with optional voltage) outputs, 8 contact inputs |
| | | 6P | | | 6 Form-A (current with optional voltage) outputs, 4 contact inputs |
| | | 6R | | | 2 Form-A (no monitoring) and 2 Form-C outputs, 8 contact inputs |
| | | 6S | | | 2 Form-A (no monitoring) and 4 Form-C outputs, 4 contact inputs |
| | | 6T | | | 4 Form-A (no monitoring) outputs, 8 contact inputs |
| | | 6U | | | 6 Form-A (no monitoring) outputs, 4 contact inputs |
| | | 6V | | | 2 Form-A outputs, 1 Form-C output, 2 Form-A (no monitoring) latching outputs, 8 contact inputs |
| **CT/VT MODULES** | | 8L | | | Standard 4CT/4VT with enhanced diagnostics |
| **(NOT AVAILABLE FOR THE C30)** | | 8N | | | Standard 8CT with enhanced diagnostics |
| | | 8M | | | Sensitive Ground 4CT/4VT with enhanced diagnostics |
| | | 8R | | | Sensitive Ground 8CT with enhanced diagnostics |
| **INTER-RELAY COMMUNICATIONS** | | 2A | | | C37.94SM, 1300 nm single-mode, ELED, 1 channel single-mode |
| | | 2B | | | C37.94SM, 1300 nm single-mode, ELED, 2 channel single-mode |
| | | 2H | | | IEEE C37.94, 820 nm, 128 kbps, multimode, LED, 2 Channels |
| | | 2I | | | Channel 1 - IEEE C37.94, multimode, 64/128 kbps; Channel 2 - 1300 nm, single-mode, Laser |
| | | 2J | | | Channel 1 - IEEE C37.94, multimode, 64/128 kbps; Channel 2 - 1550 nm, single-mode, Laser |
| | | 72 | | | 1550 nm, single-mode, Laser, 1 Channel |
| | | 73 | | | 1550 nm, single-mode, Laser, 2 Channel |
| | | 76 | | | IEEE C37.94, 820 nm, 64 kbps, multimode, LED, 1 Channel |
| | | 77 | | | IEEE C37.94, 820 nm, 64 kbps, multimode, LED, 2 Channels |
| | | 7A | | | 820 nm, multimode, LED, 1 Channel |
| | | 7B | | | 1300 nm, multimode, LED, 1 Channel |
| | | 7C | | | 1300 nm, single-mode, ELED, 1 Channel |
| | | 7D | | | 1300 nm, single-mode, Laser, 1 Channel |
| | | 7F | | | Channel 1 - G.703; Channel 2 - 1300 nm, multimode |
| | | 7G | | | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode ELED |
| | | 7H | | | 820 nm, multimode, LED, 2 Channels |
| | | 7I | | | 1300 nm, multimode, LED, 2 Channels |
| | | 7J | | | 1300 nm, single-mode, ELED, 2 Channels |
| | | 7K | | | 1300 nm, single-mode, Laser, 2 Channels |
| | | 7M | | | Channel 1 - RS422; Channel 2 - 1300 nm, multimode, LED |
| | | 7N | | | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, ELED |
| | | 7P | | | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, Laser |
| | | 7Q | | | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode Laser |
| | | 7R | | | G.703, 1 Channel |
| | | 7S | | | G.703, 2 Channels |
| | | 7T | | | RS422, 1 Channel |
| | | 7W | | | RS422, 2 Channels |

### 2.3.1 UR SIGNAL PROCESSING

The UR series relays are microprocessor-based protective relays that are designed to measure power system conditions directly via CT and VT inputs and via other sources of information, such as analog inputs, communications inputs and contact inputs. The following figure shows the overall signal processing in URs.



An analog low pass anti-aliasing filter with a 3 dB corner frequency is set at 2.4 kHz and is used for current and voltage analog filtering as well as signal conditioning. The same filtering is applied for phase, ground currents, phase-to-phase (when applicable), and auxiliary voltages. The 2.4 kHz cut-off frequency applies to both 50 Hz and 60 Hz applications and fixed in the hardware, and thus is not dependent on the system nominal frequency setting.

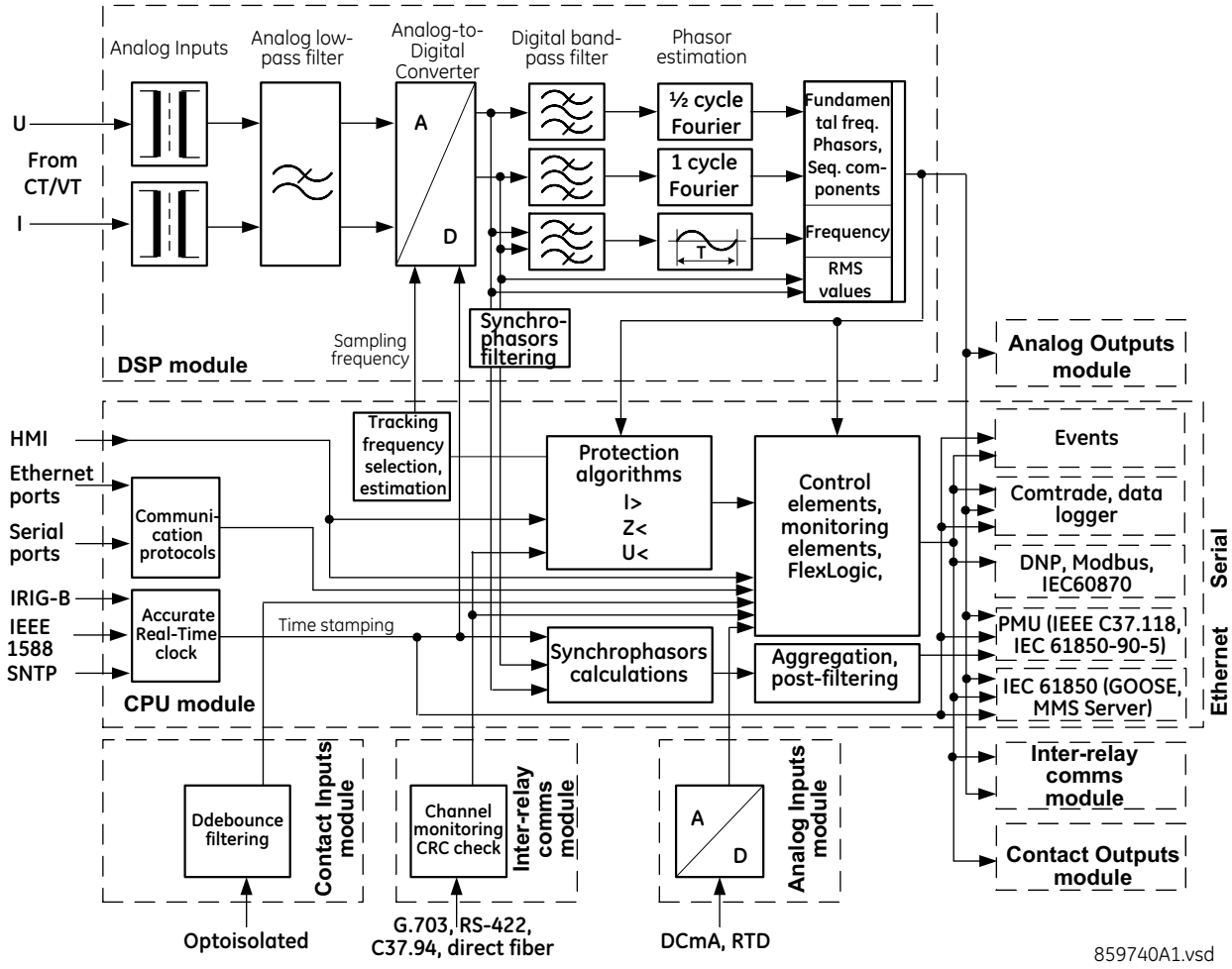



**Figure 2–3: UR SIGNAL PROCESSING**

The UR samples its AC signals at 64 samples per cycle, that is, at 3840 Hz in 60 Hz systems, and 3200 Hz in 50 Hz systems. The sampling rate is dynamically adjusted to the actual system frequency by an accurate and fast frequency tracking system.

The A/D converter has the following ranges of AC signals:

Voltages:

$$\pm\sqrt{2}\cdot 260(V) \qquad \textbf{(EQ 2.1)}$$

Currents:

$$\pm\sqrt{2}\cdot 46 rated(A) \quad \textbf{(EQ 2.2)}$$

Current harmonics are estimated based on raw samples with the use of the full-cycle Fourier filter. Harmonics 2nd through 25th are estimated.

True RMS value for the current is calculated on a per-phase basis. The true RMS can be used for demand recording or as an input signal to Time Overcurrent function, if the latter is intended for thermal protection. The true RMS is calculated as per the widely accepted definition:

$$I_{RMS(t)} = \sqrt{\frac{1}{T}\int_{(t-T)}^{t} i^2(t)dt} \quad \textbf{(EQ 2.3)}$$

RMS values include harmonics, inter-harmonics, DC components, and so on, along with fundamental frequency values. The true RMS value reflects thermal effects of the current and is used for the thermal related monitoring and protection functions.

Protection and control functions respond to phasors of the fundamental and/or harmonic frequency components (magnitudes and angles), with an exception for some functions that have an option for RMS or fundamental measurements, or some function responding to RMS only. This type of response is explained typically in each element's section in the instruction manual.

Currents are pre-filtered using a Finite Impulse Response (FIR) digital filter. The filter is designed to reject DC components and low-frequency distortions, without amplifying high-frequency noise. This filter is referred to as a modified MIMIC filter, which provides excellent filtering and overall balance between speed and accuracy of filtering. The filter is cascaded with the full-cycle Fourier filter for the current phasor estimation.

Voltages are pre-filtered using a patented Finite Impulse Response (FIR) digital filter. The filter has been optimized to reject voltage transformers specific distortions, such as Capacitive Voltage Transformer (CVT) noise and high-frequency oscillatory components. The filter is cascaded with the half-cycle Fourier filter for the voltage phasor estimation.

The URs measure power system frequency using the Clarke transformation by estimating the period of the waveform from two consecutive zero-crossings in the same direction (negative-to-positive). Voltage or current samples are pre-filtered using a Finite Impulse Response (FIR) digital filter to remove high frequency noise contained in the signal. The period is used after several security conditions are met, such as true RMS signal must be above 6% nominal for a certain time and others. If these security conditions are not met, the last valid measurement is used for a specific time after which the UR reverts to nominal system frequency.

Synchrophasors are calculated using a patented convolution integral algorithm. This algorithm allows use of the same time stamped samples, which are used for protection and taken at the same sampling frequency. This allows URs to use one sampling clock for both protection algorithms and synchrophasors.

Synchrophasors on firmware versions 7.23 and up have been tested and certified to meet IEEE C37.118-2011 and C37.118.1a-2014 standards for both metering and protection classes with outputs available up to 60 synchrophasors per second for the metering class and 120 synchrophasors per second for the protection class. Synchrophasors measurement are also available via IEC 61850-90-5 protocol.

Contact inputs threshold is settable in the firmware with 17, 33, 84, 166 VDC settings available. Inputs are scanned every 0.5 ms and can be conditioned for the critical applications, using debounce time timer, settable from 0.0 ms to 16.0 ms. Contact inputs with auto-burnishing are available as well, when external contacts are exposed to the contamination in a harsh industrial environment.

All measured values are available in the UR metering section on the front panel and via communications protocols. Measured analog values and binary signals can be captured in COMTRADE format with sampling rates from 8 to 64 samples per power cycle. Analog values can be captured with Data Logger, allowing much slower rates extended over long period of time.

Other advanced UR order code options are available to support IEC 61850 Ed2.0 (including fast GOOSE, MMS server, 61850 services, ICD/CID/IID files, and so on), IEEE 1588 (IEEE C37.238 power profile) based time synchronization, CyberSentry (advanced cyber security), the Parallel Redundancy Protocol (PRP), IEC 60870-5-103, and so on.

### 2.4.1 INTER-RELAY COMMUNICATIONS

Dedicated inter-relay communications may operate over 64 kbps digital channels or dedicated fiber optic channels. Available interfaces include:

- RS422 at 64 kbps
- G.703 at 64 kbps
- Dedicated fiber optics at 64 kbps. The fiber optic options include:
  - 820 nm multi-mode fiber with an LED transmitter
  - 1300 nm multi-mode fiber with an LED transmitter
  - 1300 nm single-mode fiber with an ELED transmitter
  - 1300 nm single-mode fiber with a laser transmitter
  - 1550 nm single-mode fiber with a laser transmitter
  - IEEE C37.94 820 nm multi-mode fiber with an LED transmitter

All fiber optic options use an ST connector. L30 models are available for use on two or three terminal lines. A two terminal line application requires one bidirectional channel. However, in two terminal line applications, it is also possible to use an L30 relay with two bidirectional channels. The second bidirectional channel will provide a redundant backup channel with automatic switchover if the first channel fails.

The L30 current differential relay is designed to function in a peer-to-peer or master-to-master architecture. In the peer-to-peer architecture, all relays in the system are identical and perform identical functions in the current differential scheme. In order for every relay on the line to be a peer, each relay must be able to communicate with all of the other relays. If there is a failure in communications among the relays, the relays revert to a master-to-slave architecture on a three-terminal system, with the master as the relay that has current phasors from all terminals. Using two different operational modes increases the dependability of the current differential scheme on a three-terminal system by reducing reliance on communications.

The main difference between a master and a slave L30 is that only a master relay performs the actual current differential calculation, and only a master relay communicates with the relays at all other terminals of the protected line.

At least one master L30 relay must have live communications to all other terminals in the current differential scheme; the other L30 relays on that line may operate as slave relays. All master relays in the scheme will be equal, and each will perform all functions. Each L30 relay in the scheme will determine if it is a master by comparing the number of terminals on the line to the number of active communication channels.

The slave terminals only communicate with the master; there is no slave-to-slave communications path. As a result, a slave L30 relay cannot calculate the differential current. When a master L30 relay issues a local trip signal, it also sends a direct transfer trip (DTT) signal to all of the other L30 relays on the protected line.

If a slave L30 relay issues a trip from one of its backup functions, it can send a transfer trip signal to its master and other slave relays if such option is designated. Because a slave cannot communicate with all the relays in the differential scheme, the master will then “broadcast” the direct transfer trip (DTT) signal to all other terminals.

The slave L30 Relay performs the following functions:

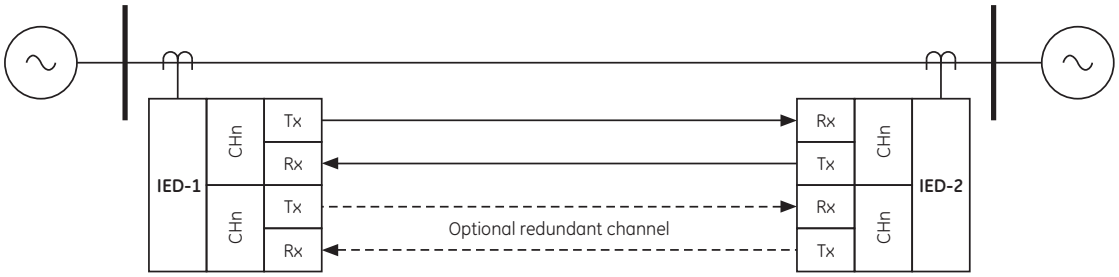
- Samples currents and voltages
- Removes DC offset from the current via the mimic algorithm
- Creates phaselets
- Calculates sum of squares data
- Transmits current data to all master L30 relays
- Performs all local relaying functions
- Receives current differential DTT and Direct Input signals from all other L30 relays
- Transmits direct output signals to all communicating relays
- Sends synchronization information of local clock to all other L30 clocks

The master L30 relay performs the following functions:

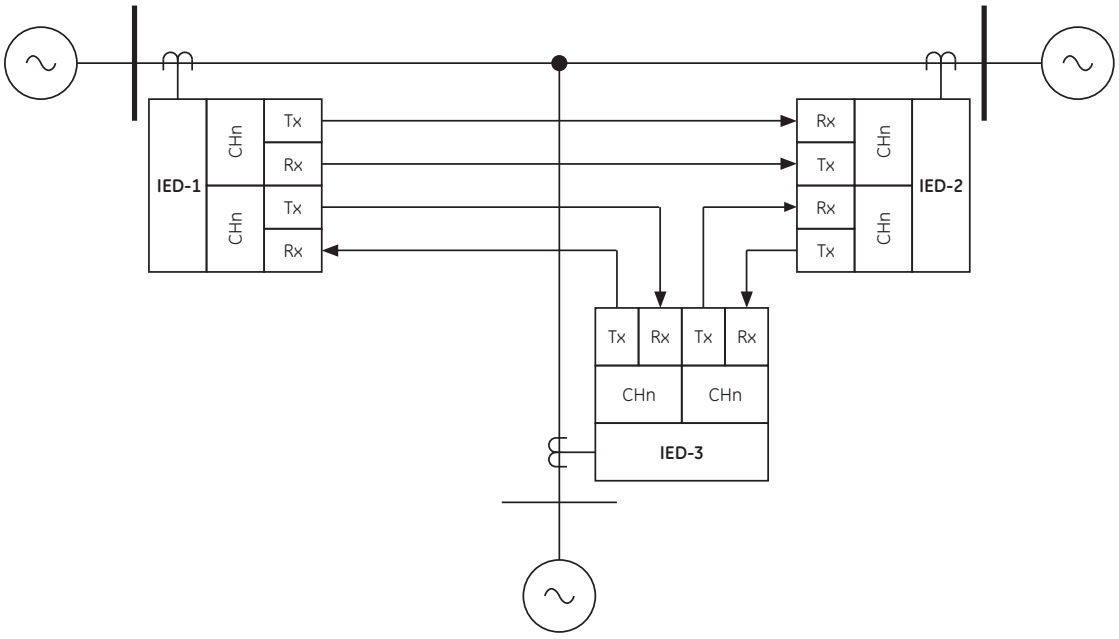
- Performs all functions of a slave L30
- Receives current phasor information from all relays
- Performs the current differential algorithm
- Sends a current differential DTT signal to all L30 relays on the protected line

In the peer-to-peer mode, all L30 relays act as masters.






Typical two-terminal application




Typical three-terminal application

831009A5.CDR

**Figure 2–4: COMMUNICATIONS PATHS**

### 2.4.2 CHANNEL MONITOR

The L30 has logic to detect that the communications channel is deteriorating or has failed completely. This can provide an alarm indication and disable the current differential protection. Note that a failure of the communications from the master to a slave does not prevent the master from performing the current differential algorithm; failure of the communications from a slave to the master will prevent the master from performing the correct current differential logic. Channel propagation delay is being continuously measured and adjusted according to changes in the communications path. Every relay on the protection system can assigned an unique ID to prevent advertent loopbacks at multiplexed channels.

### 2.4.3 LOOPBACK TEST

This option allows the user to test the relay at one terminal of the line by *looping* the transmitter output to the receiver input; at the same time, the signal sent to the remote will not change. A local loopback feature is included in the relay to simplify single ended testing.



### 2.4.4 DIRECT TRANSFER TRIPPING

The L30 includes provision for sending and receiving a single-pole direct transfer trip (DTT) signal from current differential protection between the L30 relays at the line terminals using the pilot communications channel. The user may also initiate an additional eight pilot signals with an L30 communications channel to create trip, block, or signaling logic. A FlexLogic operand, an external contact closure, or a signal over the LAN communication channels can be assigned for that logic.

NOTE

The operating times include the activation time of a trip rated form-A output contact unless otherwise indicated. FlexLogic operands of a given element are 4 ms faster. Take this into account when using FlexLogic to interconnect with other protection or control elements of the relay, building FlexLogic equations, or interfacing with other IEDs or power system devices via communications or different output contacts. If not specified, the operate times given here are for a 60 Hz system at nominal system frequency. Operate times for a 50 Hz system are 1.2 times longer. Timer Accuracy is specified as a percentage of the total operating time that is the sum of the Operate Time and settable Pickup Delay.

### LINE CURRENT DIFFERENTIAL (87L)

Application: 2 or 3 terminal line, series compensated line, tapped line, with charging current compensation

Characteristic: Dual slope percent differential

Pickup current level: 0.20 to 4.00 pu in steps of 0.01

CT Tap (CT mismatch factor): 0.20 to 5.00 in steps of 0.01

Slope # 1: 1 to 50%

Slope # 2: 1 to 70%

Breakpoint between slopes: 0.0 to 20.0 pu in steps of 0.1

Level accuracy: ±3% of reading of the maximum circuit current

DTT: Direct Transfer Trip (1 and 3 pole) to remote L90

Operating Time: 1.0 to 1.5 power cycles duration

Asymmetrical channel delay compensation using GPS: asymmetry up to 10 ms

In-zone transformer group compensation: 0 to 330° in steps of 30°

Inrush inhibit level: 1.0 to 40.0%$f_0$ in steps of 0.1

Inrush inhibit mode: per-phase, 2-out-of-3, average

Zero-sequence current differential (87LG):

- 87LG pickup level: 0.05 to 1.00 pu in steps of 0.01
- 87LG slope: 1 to 50%
- 87LG pickup delay: 0.00 to 5.00 s in steps of 0.01
- 87LG operate time: 1.5 to 2.5 cycles

### PHASE/NEUTRAL/GROUND TOC

Current: Phasor or RMS

Pickup level: 0.000 to 30.000 pu in steps of 0.001

Dropout level: 97% of pickup

Level accuracy:

- 0.1 to 2.0 × CT: ±0.5% of reading or ±0.4% of rated (whichever is greater)
- > 2.0 × CT: ±1.5% of reading > 2.0 × CT rating

Timing characteristics: IEEE Moderately/Very/Extremely Inverse; IEC (and BS) A/B/C and Short Inverse; GE IAC Inverse, Short/Very/Extremely Inverse; $I^2t$; FlexCurves™ (programmable); (Curve multiplier 0.00 to 600.00 in steps of 0.01 s)
Definite Time (Time delay = 0.00 to 600.00 in steps of 0.01 s)

Reset type: Instantaneous/Timed (per IEEE)

Curve timing accuracy at 1.03 to 20 x pickup: ±3.5% of operate time or ±½ cycle (whichever is greater) from pickup to operate

Voltage restraint: modifies pickup current for voltage in the range of 0.1<V<0.9 VT Nominal in a fixed linear relationship

### PHASE/NEUTRAL/GROUND IOC

Pickup level: 0.000 to 30.000 pu in steps of 0.001

Dropout level: 97% of pickup

Level accuracy:

- 0.1 to 2.0 × CT rating: ±0.5% of reading or ±0.4% of rated (whichever is greater)
- > 2.0 × CT rating ±1.5% of reading

Overreach: <2%

Pickup delay: 0.00 to 600.00 s in steps of 0.01

Reset delay: 0.00 to 600.00 s in steps of 0.01

Operate time: <16 ms at 3 × pickup at 60 Hz (Phase IOC)
<20 ms at 3 × pickup at 60 Hz (Neutral IOC)
<25 ms at 3 x pickup at 60 H (Ground IOC)

Timer accuracy: ±3.5% of operate time or ±1/4 cycle (whichever is greater)

### NEGATIVE SEQUENCE TOC

| | |
|---|---|
| Current: | Phasor |
| Pickup level: | 0.000 to 30.000 pu in steps of 0.001 |
| Dropout level: | 97% of pickup |
| Level accuracy: | ±0.5% of reading or ±0.4% of rated (whichever is greater) from 0.1 to 2.0 x CT rating ±1.5% of reading > 2.0 x CT rating |
| Timing characteristics: | IEEE Moderately/Very/Extremely Inverse; IEC (and BS) A/B/C and Short Inverse; GE IAC Inverse, Short/Very/Extremely Inverse; $I^2t$; FlexCurves™ (programmable) (Curve multiplier = 0.00 to 600.00 in steps of 0.01 s); Definite Time (Time delay = 0.00 to 600.00 in steps of 0.01 s) |
| Reset type: | Instantaneous/Timed (per IEEE) and Linear |
| Curve timing accuracy at 1.03 to 20 x pickup: | ±3.5% of operate time or ±½ cycle (whichever is greater) from pickup to operate |

### NEGATIVE SEQUENCE IOC

| | |
|---|---|
| Current: | Phasor |
| Pickup level: | 0.000 to 30.000 pu in steps of 0.001 |
| Dropout level: | 97% of pickup |
| Level accuracy: | 0.1 to 2.0 × CT rating: ±0.5% of reading or ±0.4% of rated (whichever is greater); > 2.0 × CT rating: ±1.5% of reading |
| Overreach: | <2% |
| Pickup delay: | 0.00 to 600.00 s in steps of 0.01 |
| Reset delay: | 0.00 to 600.00 s in steps of 0.01 |
| Operate time: | <20 ms at 3 × pickup at 60 Hz |
| Timer accuracy: | ±3% of operate time or ±1/4 cycle (whichever is greater) |

### PHASE DIRECTIONAL OVERCURRENT

| | |
|---|---|
| Relay connection: | 90° (quadrature) |
| Quadrature voltage: | ABC phase seq.: phase A ($V_{BC}$), phase B ($V_{CA}$), phase C ($V_{AB}$); ACB phase seq.: phase A ($V_{CB}$), phase B ($V_{AC}$), phase C ($V_{BA}$) |

Polarizing voltage threshold: 0.000 to 3.000 pu in steps of 0.001

Current sensitivity threshold: 0.05 pu

| | |
|---|---|
| Characteristic angle: | 0 to 359° in steps of 1 |
| Angle accuracy: | ±2° |

Operation time (FlexLogic operands):

Tripping (reverse load, forward fault):< 12 ms, typically

Blocking (forward load, reverse fault):< 8 ms, typically

### NEUTRAL DIRECTIONAL OVERCURRENT

| | |
|---|---|
| Directionality: | Co-existing forward and reverse |
| Polarizing: | Voltage, Current, Dual, Dual-V, Dual-I |
| Polarizing voltage: | V_0 or VX |
| Polarizing current: | IG |
| Operating current: | I_0 |
| Level sensing: | 3 × (\|I_0\| – *K* × \|I_1\|), IG Independent for forward and reverse |
| Restraint, *K*: | 0.000 to 0.500 in steps of 0.001 |
| Characteristic angle: | –90 to 90° in steps of 1 |
| Limit angle: | 40 to 90° in steps of 1, independent for forward and reverse |
| Angle accuracy: | ±2° |
| Offset impedance: | 0.00 to 250.00 Ω in steps of 0.01 |
| Pickup level: | 0.002 to 30.000 pu in steps of 0.01 |
| Dropout level: | 97 to 98% |
| Operation time: | <16 ms at 3 × pickup at 60 Hz |

### PHASE UNDERVOLTAGE

| | |
|---|---|
| Voltage: | Phasor only |
| Pickup level: | 0.000 to 3.000 pu in steps of 0.001 |
| Dropout level: | 102% of pickup |
| Level accuracy: | ±0.5% of reading from 10 to 208 V |
| Timing characteristics: | GE IAV Inverse (Curve multiplier 0.00 to 600.00 in steps of 0.01 s) Definite Time (Time delay = 0.00 to 600.00 in steps of 0.01 s) |
| Curve timing accuracy at <0.90 x pickup: | ±3.5% of operate time or ±1/2 cycle (whichever is greater) from pickup to operate |
| Operate time: | <30 ms at 0.9 pickup at 60 Hz for Definite Time mode |

### AUXILIARY UNDERVOLTAGE

| | |
|---|---|
| Pickup level: | 0.000 to 3.000 pu in steps of 0.001 |
| Dropout level: | 103% of pickup |
| Level accuracy: | ±0.5% of reading from 10 to 208 V |
| Timing characteristics: | GE IAV Inverse (Curve multiplier = 0.00 to 600.00 in steps of 0.01 s); Definite Time (Time delay = 0.00 to 600.00 in steps of 0.01 s) |
| Curve timing accuracy at <0.90 x pickup: | ±3.5% of operate time or ±1/2 cycle (whichever is greater) from pickup to operate |
| Operate time: | <30 ms at 0.9 pickup at 60 Hz for Definite Time mode |

### PHASE OVERVOLTAGE

| | |
|---|---|
| Voltage: | Phasor only |
| Pickup level: | 0.000 to 3.000 pu in steps of 0.001 |
| Dropout level: | 98% of pickup |
| Level accuracy: | ±0.5% of reading from 10 to 208 V |
| Pickup delay: | 0.00 to 600.00 in steps of 0.01 s |
| Operate time: | <30 ms at 1.10 × pickup at 60 Hz |
| Timer accuracy: | ±3% of operate time or ±1/4 cycle (whichever is greater) |

### AUXILIARY OVERVOLTAGE

| | |
|---|---|
| Pickup level: | 0.000 to 3.000 pu in steps of 0.001 |
| Dropout level: | 97% of pickup |
| Level accuracy: | ±0.5% of reading from 10 to 208 V |
| Pickup delay: | 0 to 600.00 s in steps of 0.01 |
| Reset delay: | 0 to 600.00 s in steps of 0.01 |
| Timer accuracy: | ±3% of operate time or ±1/4 cycle (whichever is greater) |
| Operate time: | <30 ms at 1.10 × pickup at 60 Hz |

### NEGATIVE SEQUENCE OVERVOLTAGE

| | |
|---|---|
| Pickup level: | 0.000 to 1.250 pu in steps of 0.001 |
| Dropout level: | 97% of pickup |
| Level accuracy: | ±0.5% of reading from 10 to 208 V |
| Pickup delay: | 0 to 600.00 s in steps of 0.01 |
| Reset delay: | 0 to 600.00 s in steps of 0.01 |
| Timer accuracy: | ±3% of operate time or ±20 ms, whichever is greater |
| Operate time: | <30 ms at 1.10 × pickup at 60 Hz |

### UNDERFREQUENCY

| | |
|---|---|
| Minimum signal: | 0.10 to 1.25 pu in steps of 0.01 |
| Pickup level: | 20.00 to 65.00 Hz in steps of 0.01 |
| Dropout level: | pickup + 0.03 Hz |
| Level accuracy: | ±0.001 Hz |
| Time delay: | 0 to 65.535 s in steps of 0.001 |
| Timer accuracy: | ±3% of operate time or ±1/4 cycle (whichever is greater) |
| Operate time: | typically 4 cycles at 0.1 Hz/s change<br>typically 3.5 cycles at 0.3 Hz/s change<br>typically 3 cycles at 0.5 Hz/s change |

Typical times are average operate times including variables such as frequency change instance, test method, etc., and may vary by ±0.5 cycles.

### BREAKER FAILURE

| | |
|---|---|
| Mode: | 1-pole, 3-pole |
| Current supervision: | phase, neutral current |
| Current supv. pickup: | 0.001 to 30.000 pu in steps of 0.001 |
| Current supv. dropout: | 97% of pickup |
| Current supv. accuracy: | |
| 0.1 to 2.0 × CT rating: | ±0.75% of reading or ±2% of rated (whichever is greater) |
| above 2 × CT rating: | ±2.5% of reading |

### BREAKER ARCING CURRENT

| | |
|---|---|
| Principle: | accumulates breaker duty ($I^2t$) and measures fault duration |
| Initiation: | programmable per phase from any FlexLogic operand |

Compensation for auxiliary relays: 0 to 65.535 s in steps of 0.001

| | |
|---|---|
| Alarm threshold: | 0 to 50000 $kA^2$-cycle in steps of 1 |
| Fault duration accuracy: | 0.25 of a power cycle |
| Availability: | 1 per CT bank with a minimum of 2 |

### SYNCHROCHECK

| | |
|---|---|
| Max voltage difference: | 0 to 400000 V in steps of 1 |
| Max angle difference: | 0 to 100° in steps of 1 |
| Max freq. difference: | 0.00 to 2.00 Hz in steps of 0.01 |

Hysteresis for max. freq. diff.: 0.00 to 0.10 Hz in steps of 0.01

| | |
|---|---|
| Dead source function: | None, LV1 & DV2, DV1 & LV2, DV1 or DV2, DV1 xor DV2, DV1 & DV2 (L = Live, D = Dead) |

### AUTORECLOSURE

Single breaker applications, 3-pole tripping schemes

Up to 4 reclose attempts before lockout

Independent dead time setting before each shot

Possibility of changing protection settings after each shot with FlexLogic

### THERMAL OVERLOAD PROTECTION

Thermal overload curves: IEC 255-8 curve

| | |
|---|---|
| Base current: | 0.20 to 3.00 pu in steps of 0.01 |
| Overload ($k$) factor: | 1.00 to 1.20 pu in steps of 0.05 |
| Trip time constant: | 0 to 1000 min. in steps of 1 |
| Reset time constant: | 0 to 1000 min. in steps of 1 |
| Minimum reset time: | 0 to 1000 min. in steps of 1 |

Timer accuracy (cold curve): ±100 ms or 2%, whichever is greater

Timer accuracy (hot curve): ±500 ms or 2%, whichever is greater for $I_p < 0.9 \times k \times I_b$ and $I / (k \times I_b) > 1.1$

### TRIP BUS (TRIP WITHOUT FLEXLOGIC)

| | |
|---|---|
| Number of elements: | 6 |
| Number of inputs: | 16 |
| Operate time: | <2 ms at 60 Hz |
| Timer accuracy: | ±3% or 10 ms, whichever is greater |

## 2.5.2 USER-PROGRAMMABLE ELEMENTS

### FLEXLOGIC

| | |
|---|---|
| Programming language: | Reverse Polish Notation with graphical visualization (keypad programmable) |
| Lines of code: | 512 |
| Internal variables: | 64 |
| Supported operations: | NOT, XOR, OR (2 to 16 inputs), AND (2 to 16 inputs), NOR (2 to 16 inputs), NAND (2 to 16 inputs), latch (reset-dominant), edge detectors, timers |
| Inputs: | any logical variable, contact, or virtual input |
| Number of timers: | 32 |
| Pickup delay: | 0 to 60000 (ms, sec., min.) in steps of 1 |
| Dropout delay: | 0 to 60000 (ms, sec., min.) in steps of 1 |
| Timer accuracy: | ±0.1% of operate time or ±1/8 cycle, whichever is greater |

### FLEXCURVES™

| | |
|---|---|
| Number: | 4 (A through D) |
| Reset points: | 40 (0 through 1 of pickup) |
| Operate points: | 80 (1 through 20 of pickup) |
| Time delay: | 0 to 65535 ms in steps of 1 |

### FLEX STATES

| | |
|---|---|
| Number: | up to 256 logical variables grouped under 16 Modbus addresses |
| Programmability: | any logical variable, contact, or virtual input |

### FLEXELEMENTS™

| | |
|---|---|
| Number of elements: | 8 |
| Operating signal: | any analog actual value, or two values in differential mode |
| Operating signal mode: | signed or absolute value |
| Operating mode: | level, delta |
| Comparator direction: | over, under |
| Pickup level: | –90.000 to 90.000 pu in steps of 0.001 |
| Hysteresis: | 0.1 to 50.0% in steps of 0.1 |
| Delta dt: | 20 ms to 60 days |
| Pickup & dropout delay: | 0.000 to 65.535 s in steps of 0.001 |

### NON-VOLATILE LATCHES

| | |
|---|---|
| Type: | set-dominant or reset-dominant |
| Number: | 16 (individually programmed) |
| Output: | stored in non-volatile memory |
| Execution sequence: | as input prior to protection, control, and FlexLogic |

### USER-PROGRAMMABLE LEDs

| | |
|---|---|
| Number: | 48 plus trip and alarm |
| Programmability: | from any logical variable, contact, or virtual input |
| Reset mode: | self-reset or latched |

### LED TEST

| | |
|---|---|
| Initiation: | from any contact input or user-programmable condition |
| Number of tests: | 3, interruptible at any time |
| Duration of full test: | approximately 3 minutes |
| Test sequence 1: | all LEDs on |
| Test sequence 2: | all LEDs off, one LED at a time on for 1 s |
| Test sequence 3: | all LEDs on, one LED at a time off for 1 s |

### USER-DEFINABLE DISPLAYS

| | |
|---|---|
| Number of displays: | 16 |
| Lines of display: | 2 × 20 alphanumeric characters |
| Parameters: | up to 5, any Modbus register addresses |
| Invoking and scrolling: | keypad, or any user-programmable condition, including pushbuttons |

### CONTROL PUSHBUTTONS

| | |
|---|---|
| Number of pushbuttons: | 7 |
| Operation: | drive FlexLogic operands |

### USER-PROGRAMMABLE PUSHBUTTONS (OPTIONAL)

| | |
|---|---|
| Number of pushbuttons: | 12 on basic front panel<br>16 on enhanced horizontal front panel<br>6 on enhanced vertical front panel |
| Mode: | self-reset, latched |
| Display message: | 2 lines of 20 characters each |
| Drop-out timer: | 0.00 to 60.00 s in steps of 0.05 |
| Autoreset timer: | 0.2 to 600.0 s in steps of 0.1 |
| Hold timer: | 0.0 to 10.0 s in steps of 0.1 |

### SELECTOR SWITCH

| | |
|---|---|
| Number of elements: | 2 |
| Upper position limit: | 1 to 7 in steps of 1 |
| Selecting mode: | time-out or acknowledge |
| Time-out timer: | 3.0 to 60.0 s in steps of 0.1 |
| Control inputs: | step-up and 3-bit |
| Power-up mode: | restore from non-volatile memory or synchronize to a 3-bit control input or synch/restore mode |

### DIGITAL ELEMENTS

| | |
|---|---|
| Number of elements: | 48 |
| Operating signal: | any FlexLogic operand |
| Pickup delay: | 0.000 to 999999.999 s in steps of 0.001 |
| Dropout delay: | 0.000 to 999999.999 s in steps of 0.001 |
| Timing accuracy: | ±3% or ±4 ms, whichever is greater |

## 2.5.3 MONITORING

### OSCILLOGRAPHY

| | |
|---|---|
| Number of records: | 3 to 64, configurable |
| Sampling rate: | 8, 16, 32, or 64 samples per power cycle, configurable |
| Triggers: | any FlexLogic operand, configurable |
| Trigger position: | 0 to 100%, configurable |
| Recorded data: | raw AC input channels<br>up to 64 configured digital channels, representing any FlexLogic operand<br>up to 16 configured analog channels, representing any measured analog value |
| Data storage: | in non-volatile memory |
| Format: | COMTRADE IEEE C37.111 (1999 or 2013) |

### EVENT RECORDER

| | |
|---|---|
| Capacity: | 1024 events |
| Time-tag: | to 1 microsecond |
| Triggers: | any FlexLogic operand, configurable |
| Data storage: | in non-volatile memory |

### DATA LOGGER

| | |
|---|---|
| Number of channels: | 1 to 16 |
| Parameters: | any available analog actual value |
| Sampling rate: | 15 to 3600000 ms in steps of 1 |
| Trigger: | any FlexLogic operand |
| Mode: | continuous or triggered |
| Storage capacity: | (NN is dependent on memory) |
| | 1-second rate:<br>01 channel for NN days<br>16 channels for NN days<br>↓<br>60-minute rate:<br>01 channel for NN days<br>16 channels for NN days |

### FAULT LOCATOR

Number of independent fault locators: 1

| | |
|---|---|
| Method: | single-ended |
| Voltage source: | wye-connected VTs, delta-connected VTs and neutral voltage, delta-connected VTs and zero-sequence current (approximation) |
| Maximum accuracy if: | fault resistance is zero and fault currents from all line terminals are approximately in phase (single-ended method) |
| Relay accuracy: | ±1.5% (V > 10 V, I > 0.2 pu), single-ended method |
| Worst-case accuracy: | |
| $VT_{\%error}$ + | user data |
| $CT_{\%error}$ + | user data |
| $Z_{Line\%error}$ + | user data |
| $METHOD_{error}$ + 1.5% | single-ended method |

See Theory of Operation chapter, Fault Locator section

### PHASOR MEASUREMENT UNIT

| | |
|---|---|
| Output format: | per IEEE C37.118-2011, C37.118.1a-2014, or IEC 61850-90-5 standard |
| Number of channels: | 14 synchrophasors, 8 analogs, 16 digitals |
| TVE (total vector error) | <1% |
| Triggering: | frequency, voltage, current, power, rate of change of frequency, user-defined |
| Reporting rate: | 1, 2, 5, 10, 12, 15, 20, 25, 30, 50, or 60 times per second for P and M class, and 100 or 120 times per second for P class only |
| Number of clients: | One over TCP/IP port and one over UDP/IP per aggregator |
| AC ranges: | As indicated in appropriate specifications sections |
| Network reporting format: | 16-bit integer (for IEEE C37.118) or 32-bit IEEE floating point numbers |
| Network reporting style: | rectangular (real and imaginary for IEEE C37.188) or polar (magnitude and angle) coordinates |
| Post-filtering: | none, 3-point, 5-point, 7-point |
| Calibration: | ±5° (angle) and ±5% (magnitude) |

## 2.5.4 METERING

### RMS CURRENT: PHASE, NEUTRAL, AND GROUND

Accuracy at

| | |
|---|---|
| 0.1 to 2.0 × CT rating: | ±0.25% of reading or ±0.1% of rated (whichever is greater) |
| > 2.0 × CT rating: | ±1.0% of reading |

### RMS VOLTAGE

| | |
|---|---|
| Accuracy: | ±0.5% of reading from 10 to 208 V |

### REAL POWER (WATTS)

Accuracy at 0.1 to 1.5 x CT rating and 0.8 to 1.2 x VT rating: ±1.0% of reading at $-1.0 \le PF < -0.8$ and $0.8 < PF \le 10$

### REACTIVE POWER (VARS)

Accuracy at 0.1 to 1.5 x CT rating and 0.8 to 1.2 x VT rating: ±1.0% of reading at $-0.2 \le PF \le 0.2$

### APPARENT POWER (VA)

Accuracy at 0.1 to 1.5 x CT rating and 0.8 to 1.2 x VT rating: ±1.0% of reading

### FREQUENCY

Accuracy for 45 to 65Hz input at

| | |
|---|---|
| V = 0.8 to 1.2 pu: | ±0.001 Hz (when voltage signal is used for frequency measurement) |
| I = 0.1 to 0.25 pu: | ±0.02 Hz (when current signal is used for frequency measurement) |
| I > 0.25 pu: | ±0.005 Hz (when current signal is used for frequency measurement) |

## 2.5.5 INPUTS

### AC CURRENT

CT rated primary: 1 to 50000 A
CT rated secondary: 1 A or 5 A by connection
Relay burden: < 0.2 VA at rated secondary
Conversion range:
Standard CT: 0.02 to 46 × CT rating RMS symmetrical
Sensitive Ground CT module: 0.002 to 4.6 × CT rating RMS symmetrical
Current withstand: 20 ms at 250 times rated
1 sec at 100 times rated
continuous 4xInom
Short circuit rating:150000 RMS symmetrical amperes, 250 V maximum (primary current to external CT)

### AC VOLTAGE

VT rated secondary: 25.0 to 240.0 V
VT ratio: 1.00 to 24000.00
Relay burden: < 0.25 VA at 120 V
Conversion range: 1 to 275 V
Voltage withstand: continuous at 260 V to neutral
1 min/hr at 420 V to neutral

### FREQUENCY

Nominal frequency setting:25 to 60 Hz
Sampling frequency: 64 samples per power cycle
Tracking frequency range:45 to 65 Hz

### CONTACT INPUTS

Dry contacts: 1000 Ω maximum
Wet contacts: 300 V DC maximum
Selectable thresholds: 17 V, 33 V, 84 V, 166 V
Tolerance: ±10%
Contacts per common return: 4
Recognition time: < 1 ms
Debounce time: 0.0 to 16.0 ms in steps of 0.5
Continuous current draw:4 mA (when energized)

### CONTACT INPUTS WITH AUTO-BURNISHING

Dry contacts: 1000 Ω maximum
Wet contacts: 300 V DC maximum
Selectable thresholds: 17 V, 33 V, 84 V, 166 V
Tolerance: ±10%
Contacts per common return: 2
Recognition time: < 1 ms
Debounce time: 0.0 to 16.0 ms in steps of 0.5
Continuous current draw:4 mA (when energized)
Auto-burnish impulse current: 50 to 70 mA
Duration of auto-burnish impulse: 25 to 50 ms

### DCMA INPUTS

Current input (mA DC): 0 to –1, 0 to +1, –1 to +1, 0 to 5, 0 to 10, 0 to 20, 4 to 20 (programmable)
Input impedance: 379 Ω ±10%
Conversion range: –1 to + 20 mA DC
Accuracy: ±0.2% of full scale
Type: Passive

### RTD INPUTS

Types (3-wire): 100 Ω Platinum, 100 & 120 Ω Nickel, 10 Ω Copper
Sensing current: 5 mA
Range: –50 to +250°C
Accuracy: ±2°C
Isolation: 36 V pk-pk

### IRIG-B INPUT

IRIG formats accepted: B000…B007, B120…B127
IRIG control bits: IEEE Std C37.118.1-2011
Amplitude modulation: 1 to 10 V pk-pk
DC shift: TTL–Compatible
Input impedance: 50 kΩ
Isolation: 2 kV

### REMOTE INPUTS (IEC 61850 GSSE/GOOSE)

Input points: 32, configured from 64 incoming bit pairs
Remote devices: 16
Default states on loss of comms.: On, Off, Latest/Off, Latest/On
Remote DPS inputs: 5

## 2.5.6 POWER SUPPLY

### LOW RANGE

Nominal DC voltage: 24 to 48 V
Minimum DC voltage: 20 V
Maximum DC voltage: 60 V for RL power supply module (obsolete), 75 V for SL power supply module
Voltage loss hold-up: 200 ms duration at maximum load
NOTE: Low range is DC only.

### HIGH RANGE

Nominal DC voltage: 125 to 250 V
Minimum DC voltage: 88 V
Maximum DC voltage: 300 V
Nominal AC voltage: 100 to 240 V at 50/60 Hz
Minimum AC voltage: 88 V at 25 to 100 Hz
Maximum AC voltage: 265 V at 25 to 100 Hz
Voltage loss hold-up: 200 ms duration at maximum load

### ALL RANGES

Volt withstand: 2 × Highest Nominal Voltage for 10 ms

Power consumption: typical = 15 to 20 W/VA
maximum = 45 W/VA
contact factory for exact order code consumption

### INTERNAL FUSE

RATINGS

Low range power supply: 8 A / 250 V
High range power supply: 4 A / 250 V

INTERRUPTING CAPACITY

AC: 100 000 A RMS symmetrical
DC: 10 000 A



## 2.5.7 OUTPUTS

### FORM-A RELAY

Make and carry for 0.2 s: 30 A as per ANSI C37.90

Carry continuous: 6 A

Break (DC inductive, L/R = 40 ms):

| VOLTAGE | CURRENT |
|---|---|
| 24 V | 1 A |
| 48 V | 0.5 A |
| 125 V | 0.3 A |
| 250 V | 0.2 A |

Operate time: < 4 ms

Contact material: silver alloy

### LATCHING RELAY

Make and carry for 0.2 s: 30 A as per ANSI C37.90

Carry continuous: 6 A as per IEEE C37.90

Break (DC resistive as per IEC 61810-1):

| VOLTAGE | CURRENT |
|---|---|
| 24 V | 6 A |
| 48 V | 1.6 A |
| 125 V | 0.4 A |
| 250 V | 0.2 A |

Operate time: < 4 ms

Contact material: silver alloy

Control: separate operate and reset inputs

Control mode: operate-dominant or reset-dominant

### FORM-A VOLTAGE MONITOR

Applicable voltage: approx. 15 to 250 V DC

Trickle current: approx. 1 to 2.5 mA

### FORM-A CURRENT MONITOR

Threshold current: approx. 80 to 100 mA

### FORM-C AND CRITICAL FAILURE RELAY

Make and carry for 0.2 s: 30 A as per ANSI C37.90

Carry continuous: 8 A

Break (DC inductive, L/R = 40 ms):

| VOLTAGE | CURRENT |
|---|---|
| 24 V | 1 A |
| 48 V | 0.5 A |
| 125 V | 0.3 A |
| 250 V | 0.2 A |

Operate time: < 8 ms

Contact material: silver alloy

### FAST FORM-C RELAY

Make and carry: 0.1 A max. (resistive load)

Minimum load impedance:

| INPUT VOLTAGE | IMPEDANCE | |
|---|---|---|
| | 2 W RESISTOR | 1 W RESISTOR |
| 250 V DC | 20 KΩ | 50 KΩ |
| 120 V DC | 5 KΩ | 2 KΩ |
| 48 V DC | 2 KΩ | 2 KΩ |
| 24 V DC | 2 KΩ | 2 KΩ |

Note: values for 24 V and 48 V are the same due to a required 95% voltage drop across the load impedance.

Operate time: < 0.6 ms

Internal Limiting Resistor: 100 Ω, 2 W

### SOLID-STATE OUTPUT RELAY

Operate and release time: <100 µs

Maximum voltage: 265 V DC

Maximum leakage current in off state (excluding voltage monitor circuit current): 100 µA

Maximum continuous current: 5 A at 45°C; 4 A at 65°C

Make and carry:
for 0.2 s: 30 A as per ANSI C37.90
for 0.03 s 300 A

Breaking capacity:

| | UL508 | Utility application (autoreclose scheme) | Industrial application |
|---|---|---|---|
| **Operations/ interval** | 5000 ops / 1 s-On, 9 s-Off | 5 ops / 0.2 s-On, 0.2 s-Off within 1 minute | 10000 ops / 0.2 s-On, 30 s-Off |
| | 1000 ops / 0.5 s-On, 0.5 s-Off | | |
| **Break capability (0 to 250 V DC)** | 3.2 A L/R = 10 ms | 10 A L/R = 40 ms | 10 A L/R = 40 ms |
| | 1.6 A L/R = 20 ms | | |
| | 0.8 A L/R = 40 ms | | |

### CONTROL POWER EXTERNAL OUTPUT (FOR DRY CONTACT INPUT)

Capacity: 100 mA DC at 48 V DC

Isolation: ±300 Vpk

### REMOTE OUTPUTS (IEC 61850 GSSE/GOOSE)

Standard output points: 32

User output points: 32

### DCMA OUTPUTS

Range: –1 to 1 mA, 0 to 1 mA, 4 to 20 mA

Max. load resistance: 12 kΩ for –1 to 1 mA range
12 kΩ for 0 to 1 mA range
600 Ω for 4 to 20 mA range

Accuracy: ±0.75% of full-scale for 0 to 1 mA range
±0.5% of full-scale for –1 to 1 mA range
±0.75% of full-scale for 0 to 20 mA range

99% Settling time to a step change: 100 ms

Isolation: 1.5 kV

Driving signal: any FlexAnalog quantity

Upper and lower limit for the driving signal: –90 to 90 pu in steps of 0.001

## 2.5.8 COMMUNICATION PROTOCOLS

### RS232

Front port: 19.2 kbps, Modbus RTU

### RS485

1 rear port: Up to 115 kbps, Modbus RTU, DNP 3, IEC 60870-5-103

Typical distance: 1200 m

Isolation: 2 kV, isolated together at 36 Vpk

### FIBER ETHERNET PORT

Operates with 50/125 µm and 62.5/125 µm multimode fiber

| PARAMETER | FIBER TYPE |
|---|---|
| | 100 MB MULTI-MODE |
| Wavelength | 1310 nm |
| Connector | LC |
| Transmit power | –20 dBm |
| Receiver sensitivity | –30 dBm |
| Power budget | 10 dB |
| Maximum input power | –14 dBm |
| Typical distance | 2 km |
| Full duplex | yes |
| Redundancy | yes |

### ETHERNET (10/100 MB TWISTED PAIR)

Modes: 10 MB, 10/100 MB (auto-detect)

Connector: RJ45

### SIMPLE NETWORK TIME PROTOCOL (SNTP)

clock synchronization error: <10 ms (typical)

### PRECISION TIME PROTOCOL (PTP)

PTP IEEE Std 1588-2008 (version 2)

Power Profile (PP) per IEEE Standard PC37.238-2011

Slave-only ordinary clock

Peer delay measurement mechanism

### PARALLEL REDUNDANCY PROTOCOL (PRP) (IEC 62439-3 CLAUSE 4, 2012)

Ethernet ports used: 2 and 3

Networks supported: 10/100 MB Ethernet

### OTHER

TFTP, HTTP, IEC 60870-5-104, Ethernet Global Data (EGD)

### SHIELDED TWISTED-PAIR INTERFACE OPTIONS

| INTERFACE TYPE | TYPICAL DISTANCE |
|---|---|
| RS422 | 1200 m |
| G.703 | 100 m |

NOTE RS422 distance is based on transmitter power and does not take into consideration the clock source provided by the user.

### LINK POWER BUDGET AND MAXIMUM OPTICAL INPUT POWER

The following specifications apply to filter interface modules implemented from January 2012.

| EMITTER, FIBER TYPE | CABLE TYPE | TRANSMIT POWER | RECEIVED SENSITIVITY | POWER BUDGET | MAXIMUM OPTICAL INPUT POWER |
|---|---|---|---|---|---|
| 820 nm, Multimode | 62.5/125 µm | -16 dBm | -32 dBm | 16 dBm | -8 dBm |
| | 50/125 µm | -20 dBm | | 12 dBm | |
| 1300 nm, Multimode | 62.5/125 µm | -16 dBm | -32 dBm | 16 dBm | -8 dBm |
| | 50/125 µm | -20 dBm | | 12 dBm | |
| 1300 nm, Single mode | 9/125 µm | -15 dBm | -32 dBm | 17 dBm | -8 dBm |
| 1300 nm Laser, Single mode | 9/125 µm | 0 dBm | -34 dBm | 34 dBm | -8 dBm |
| 1550 nm Laser, Single mode | 9/125 µm | 5 dBm | -34 dBm | 39 dBm | -10 dBm |

The following specifications apply to filter interface modules implemented before January 2012.

| EMITTER, FIBER TYPE | TRANSMIT POWER | RECEIVED SENSITIVITY | POWER BUDGET | MAX. OPTICAL INPUT POWER |
|---|---|---|---|---|
| 820 nm LED, Multimode | –20 dBm | –30 dBm | 10 dB | –7.6 dBm |
| 1300 nm LED, Multimode | –21 dBm | –30 dBm | 9 dB | –11 dBm |
| 1300 nm ELED, Single mode | –23 dBm | –32 dBm | 9 dB | –14 dBm |
| 1300 nm Laser, Single mode | –1 dBm | –30 dBm | 29 dB | –14 dBm |
| 1550 nm Laser, Single mode | +5 dBm | –30 dBm | 35 dB | –14 dBm |

NOTE These power budgets are calculated from the manufacturer's worst-case transmitter power and worst case receiver sensitivity.

NOTE The power budgets for the 1300 nm ELED are calculated from the manufacturer's transmitter power and receiver sensitivity at ambient temperature. At extreme temperatures these values deviate based on component tolerance. On average, the output power decreases as the temperature is increased by a factor 1dB / 5°C.

### TYPICAL LINK DISTANCE

| EMITTER TYPE | CABLE TYPE | CONNECTOR TYPE | TYPICAL DISTANCE | |
|---|---|---|---|---|
| | | | BEFORE JANUARY 2012 | FROM JANUARY 2012 |
| 820 nm LED, multimode | 62.5/125 µm | ST | 1.65 km | 2 km |
| | 50/125 µm | ST | 1.65 km | 2 km |

| EMITTER TYPE | CABLE TYPE | CONNECTOR TYPE | TYPICAL DISTANCE | |
|---|---|---|---|---|
| | | | BEFORE JANUARY 2012 | FROM JANUARY 2012 |
| 1300 nm LED, multimode | 62.5/125 µm | ST | 4 km | 5 km |
| | 50/125 µm | ST | 4 km | 5 km |
| 1300 nm ELED, single mode | 9/125 µm | ST | 11.4 km | 20 km |
| 1300 nm Laser, single mode | 9/125 µm | ST | 64 km | 65 km |
| 1550 nm Laser, single mode | 9/125 µm | ST | 105 km | 125 km |

NOTE

Typical distances listed are based on the following assumptions for system loss. As actual losses vary from one installation to another, the distance covered by your system may vary.

**CONNECTOR LOSSES (TOTAL OF BOTH ENDS)**

ST connector 0.7 dB (each)

**FIBER LOSSES**

820 nm multimode 3 dB/km

1300 nm multimode 1 dB/km

1300 nm single mode 0.35 dB/km

1550 nm single mode 0.25 dB/km

Splice losses: One splice every 2 km, at 0.05 dB loss per splice.

**SYSTEM MARGIN**

3 dB additional loss added to calculations to compensate for all other losses.

Compensated difference in transmitting and receiving (channel asymmetry) channel delays using GPS satellite clock: 10 ms

## 2.5.10 ENVIRONMENTAL

### AMBIENT TEMPERATURES

Maximum operating range: –40 to 85°C

Continuous operating range: –40 to 60°C[1]

1 Based on IEC 60068-2-1 and IEC 60068-2-2, Variant Bd and Ad for 16 hrs. The UR can operate up to a surrounding ambient of 85°C, however operating outside the recommended continuous temperature range for extended periods can result in MTBF degradation and decrease the response time of the LCD.

### HUMIDITY

Humidity: operating up to 95% (non-condensing) at 55°C (as per IEC60068-2-30 variant 1, 6 days).

### OTHER

Altitude: 2000 m (maximum)

Pollution degree: II

Overvoltage category: II

Ingress protection: IP20 front, IP10 back (basic front panel and Rev. 1 enhanced front panel)

IP40 front, IP10 back (Rev. 2 enhanced front panel)

IP54 front with IP54 mounting collar accessory (Rev. 2 enhanced front panel)

Noise: 0 dB

### L30 TYPE TESTS

| TEST | REFERENCE STANDARD | TEST LEVEL |
|---|---|---|
| Dielectric voltage withstand | EN 60255-5 | 2.2 kV |
| Impulse voltage withstand | EN 60255-5 | 5 kV |
| Damped oscillatory | IEC 61000-4-18 / IEC 60255-22-1 | 2.5 kV CM, 1 kV DM |
| Electrostatic discharge | EN 61000-4-2 / IEC 60255-22-2 | Level 3 |
| RF immunity | EN 61000-4-3 / IEC 60255-22-3 | Level 3 |
| Fast transient disturbance | EN 61000-4-4 / IEC 60255-22-4 | Class A and B |
| Surge immunity | EN 61000-4-5 / IEC 60255-22-5 | Level 3 and 4 |
| Conducted RF immunity | EN 61000-4-6 / IEC 60255-22-6 | Level 3 |
| Power frequency immunity | EN 61000-4-7 / IEC 60255-22-7 | Class A and B |
| Voltage interruption and ripple DC | IEC 60255-11 | 12% ripple, 200 ms interrupts |
| Radiated and conducted emissions | CISPR11 / CISPR22 / IEC 60255-25 | Class A |
| Sinusoidal vibration | IEC 60255-21-1 | Class 1 |
| Shock and bump | IEC 60255-21-2 | Class 1 |
| Seismic | IEC 60255-21-3 | Class 1 |
| Power magnetic immunity | IEC 61000-4-8 | Level 5 |
| Pulse magnetic immunity | IEC 61000-4-9 | Level 4 |
| Damped magnetic immunity | IEC 61000-4-10 | Level 4 |
| Voltage dip and interruption | IEC 61000-4-11 | 0, 40, 70, 80% dips; 250 / 300 cycle interrupts |
| Damped oscillatory | IEC 61000-4-12 | 2.5 kV CM, 1 kV DM |
| Conducted RF immunity, 0 to 150 kHz | IEC 61000-4-16 | Level 4 |
| Voltage ripple | IEC 61000-4-17 | 15% ripple |
| Ingress protection | IEC 60529 | IP20 front, IP10 back |
| Cold | IEC 60068-2-1 | –40°C for 16 hours |
| Hot | IEC 60068-2-2 | 85°C for 16 hours |
| Humidity | IEC 60068-2-30 | 6 days, variant 1 |
| Damped oscillatory | IEEE/ANSI C37.90.1 | 2.5 kV, 1 MHz |
| RF immunity | IEEE/ANSI C37.90.2 | 20 V/m, 80 MHz to 1 GHz |
| Safety | UL 508 | e83849 NKCR |
| Safety | UL C22.2-14 | e83849 NKCR7 |
| Safety | UL 1053 | e83849 NKCR |
| Safety | IEC 60255-27 | Insulation: class 1, Pollution degree: 2, Over voltage cat II |



### THERMAL

Products go through an environmental test based upon an Accepted Quality Level (AQL) sampling process.

## 2.5.13 APPROVALS

### APPROVALS

| COMPLIANCE | APPLICABLE COUNCIL DIRECTIVE | ACCORDING TO |
|---|---|---|
| CE | Low voltage directive | EN 60255-5 |
| | EMC directive | EN 60255-26 / EN 50263 |
| | | EN 61000-6-5 |
| C-UL-US | --- | UL 508 |
| | | UL 1053 |
| | | C22.2 No. 14 |

## 2.5.14 MAINTENANCE

### MOUNTING

Attach mounting brackets using 20 inch-pounds (±2 inch-pounds) of torque.

### CLEANING

Normally, cleaning is not required; but for situations where dust has accumulated on the faceplate display, a dry cloth can be used.

**NOTICE**

To avoid deterioration of electrolytic capacitors, power up units that are stored in a de-energized state once per year, for one hour continuously.

### a) HORIZONTAL UNITS

The L30 Line Current Differential System is available as a 19-inch rack horizontal mount unit with a removable faceplate. The faceplate can be specified as either basic or enhanced at the time of ordering. The enhanced faceplate contains additional user-programmable pushbuttons and LED indicators.

The modular design allows the relay to be easily upgraded or repaired by a qualified service person. The faceplate is hinged to allow easy access to the removable modules, and is itself removable to allow mounting on doors with limited rear depth.

In November 2017, GE began transitioning to Rev. 2 of the enhanced horizontal front panel. This panel can be identified by the use of a screw instead of a knob to close the panel. It can conform to an IP54 rating with the IP54 mounting collar purchased separately. The IP54 mounting collar can be used in panel-mount installations, not 19-inch rack-mount installations. The IP54 mounting collar cannot be used with Rev. 1 enhanced front panels.



The case dimensions are shown below, along with panel cutout details for panel mounting. When planning the location of your panel cutout, ensure that provision is made for the faceplate to swing open without interference to or from adjacent equipment.

The relay must be mounted such that the faceplate sits semi-flush with the panel or switchgear door, allowing the operator access to the keypad and the RS232 communications port. The relay is secured to the panel with the use of four screws supplied with the relay.

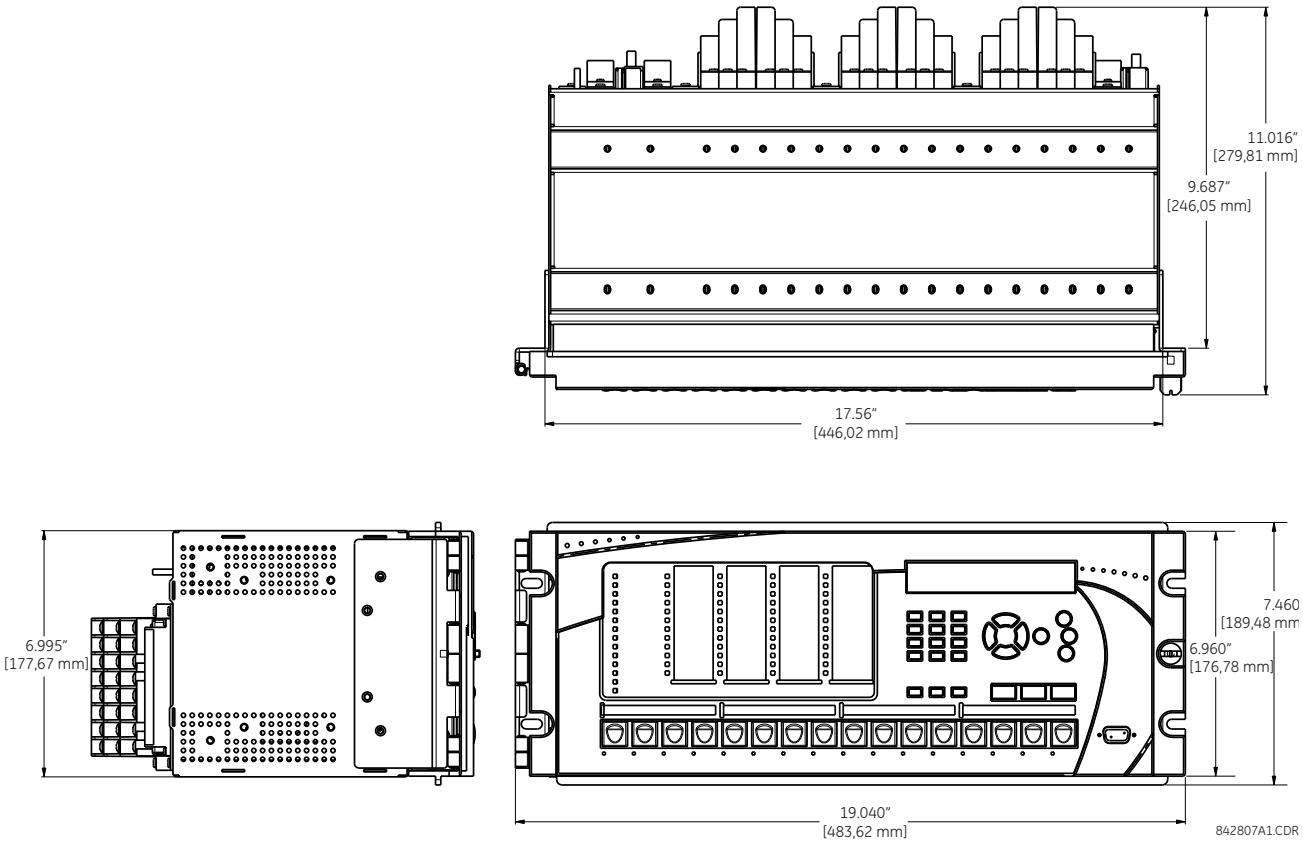



**Figure 3–1: HORIZONTAL DIMENSIONS (REV. 1 ENHANCED FRONT PANEL)**

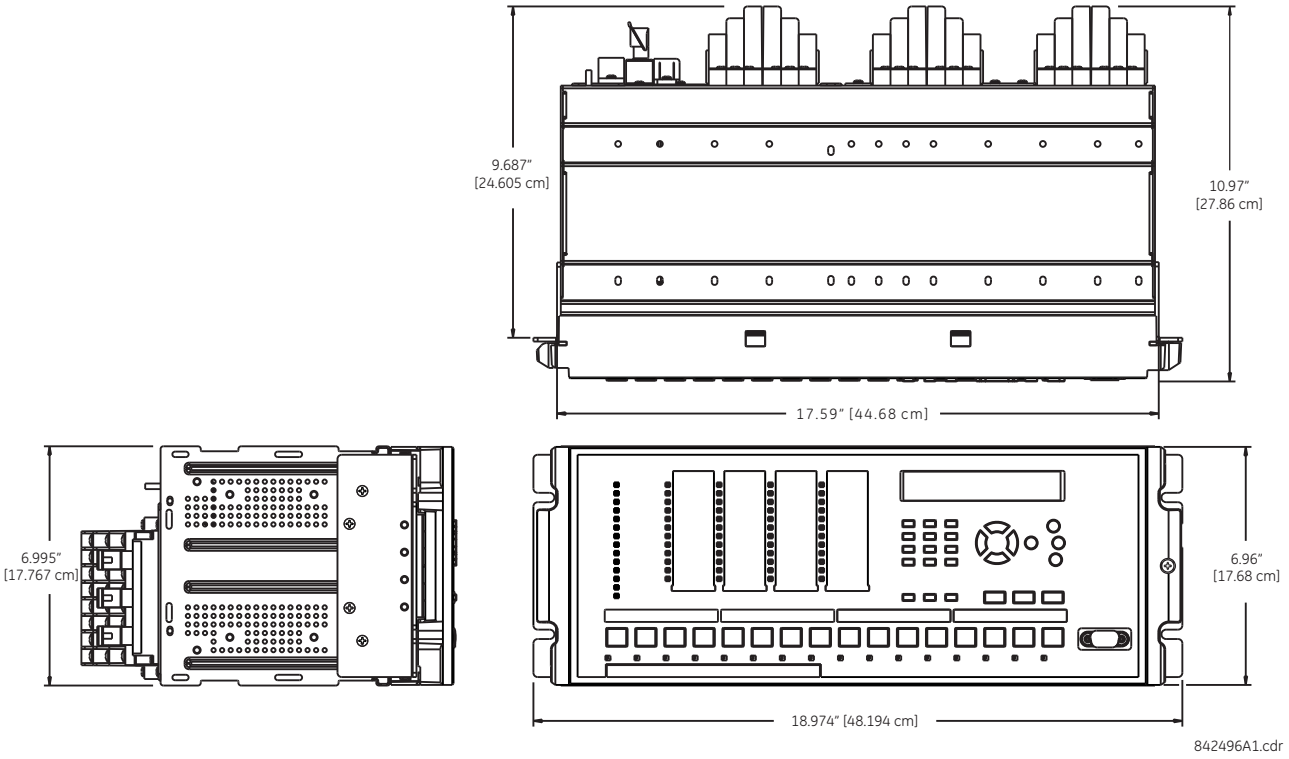



**Figure 3–2: HORIZONTAL DIMENSIONS (REV. 2 ENHANCED FRONT PANEL)**

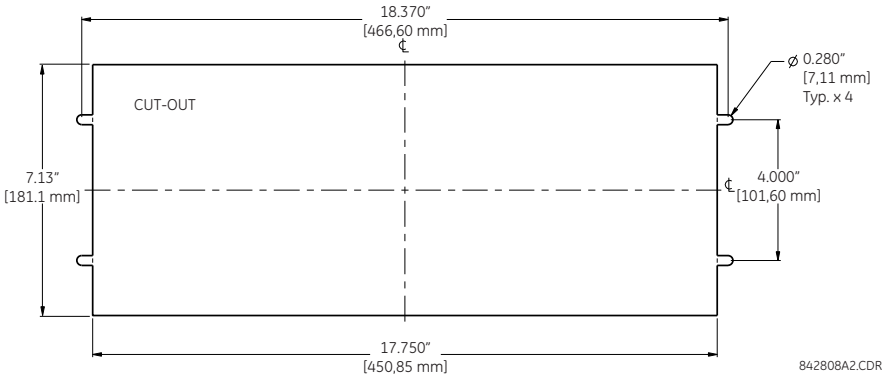



**Figure 3–3: HORIZONTAL MOUNTING (ENHANCED FRONT PANEL)**

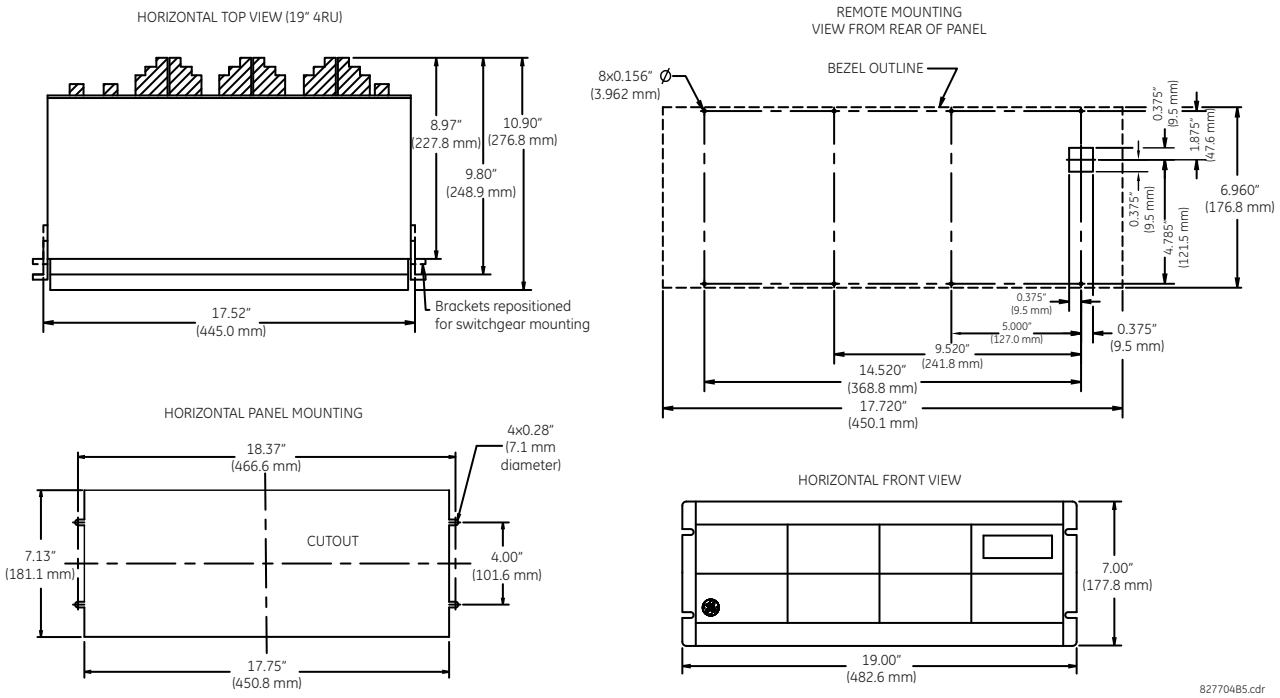



**Figure 3–4: HORIZONTAL DIMENSIONS (BASIC FRONT PANEL)**

### b) VERTICAL UNITS

The L30 Line Current Differential System is available as a reduced size (¾) vertical mount unit, with a removable faceplate. The faceplate can be specified as either basic or enhanced at the time of ordering. The enhanced faceplate contains additional user-programmable pushbuttons and LED indicators.

The modular design allows the relay to be easily upgraded or repaired by a qualified service person. The faceplate is hinged to allow easy access to the removable modules, and is itself removable to allow mounting on doors with limited rear depth.

The case dimensions are shown below, along with panel cutout details for panel mounting. When planning the location of your panel cutout, ensure that provision is made for the faceplate to swing open without interference to or from adjacent equipment.

The relay must be mounted such that the faceplate sits semi-flush with the panel or switchgear door, allowing the operator access to the keypad and the RS232 communications port. The relay is secured to the panel with the use of four screws supplied with the relay.

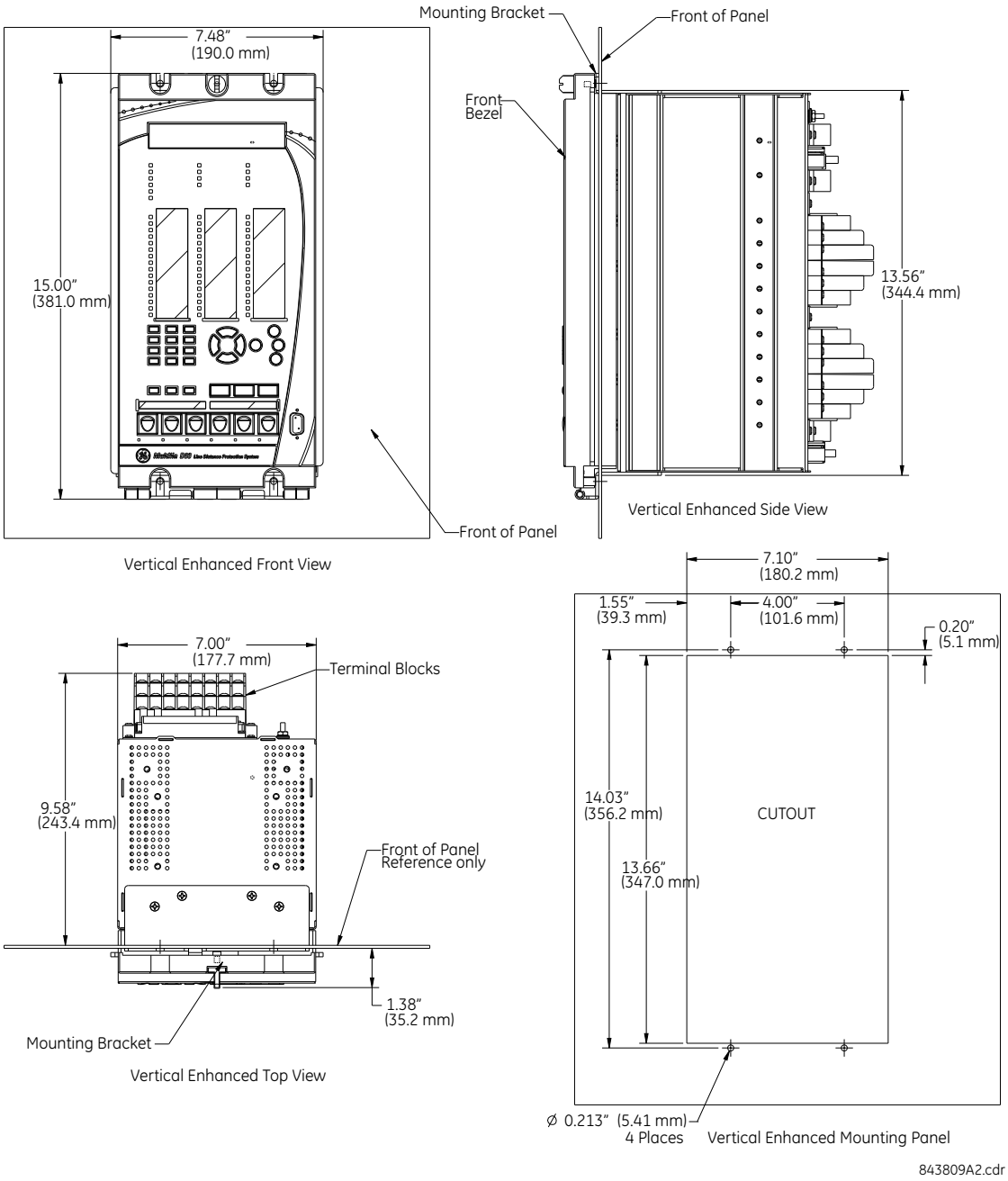



**Figure 3–5: L30 VERTICAL DIMENSIONS (ENHANCED PANEL)**

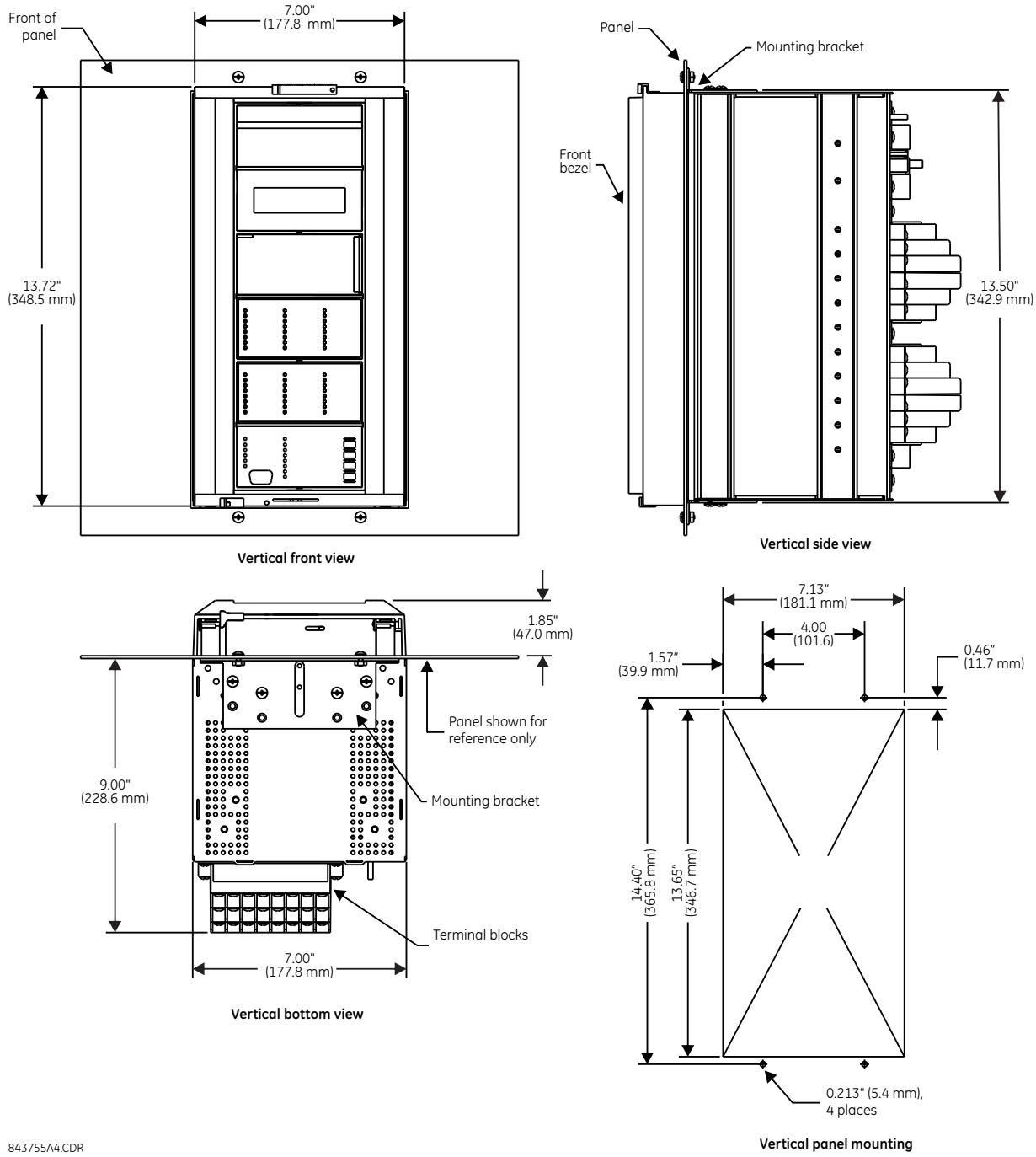



**Figure 3–6: L30 VERTICAL MOUNTING AND DIMENSIONS (BASIC PANEL)**

For side mounting L30 devices with the enhanced front panel, see the following documents available on the UR DVD and the GE Grid Solutions website:

- GEK-113180: UR-Series UR-V Side-Mounting Front Panel Assembly Instructions
- GEK-113181: Connecting a Remote UR-V Enhanced Front Panel to a Vertical UR Device Instruction Sheet
- GEK-113182: Connecting a Remote UR-V Enhanced Front Panel to a Vertically-Mounted Horizontal UR Device Instruction Sheet

For side mounting L30 devices with the basic front panel, use the following figures.

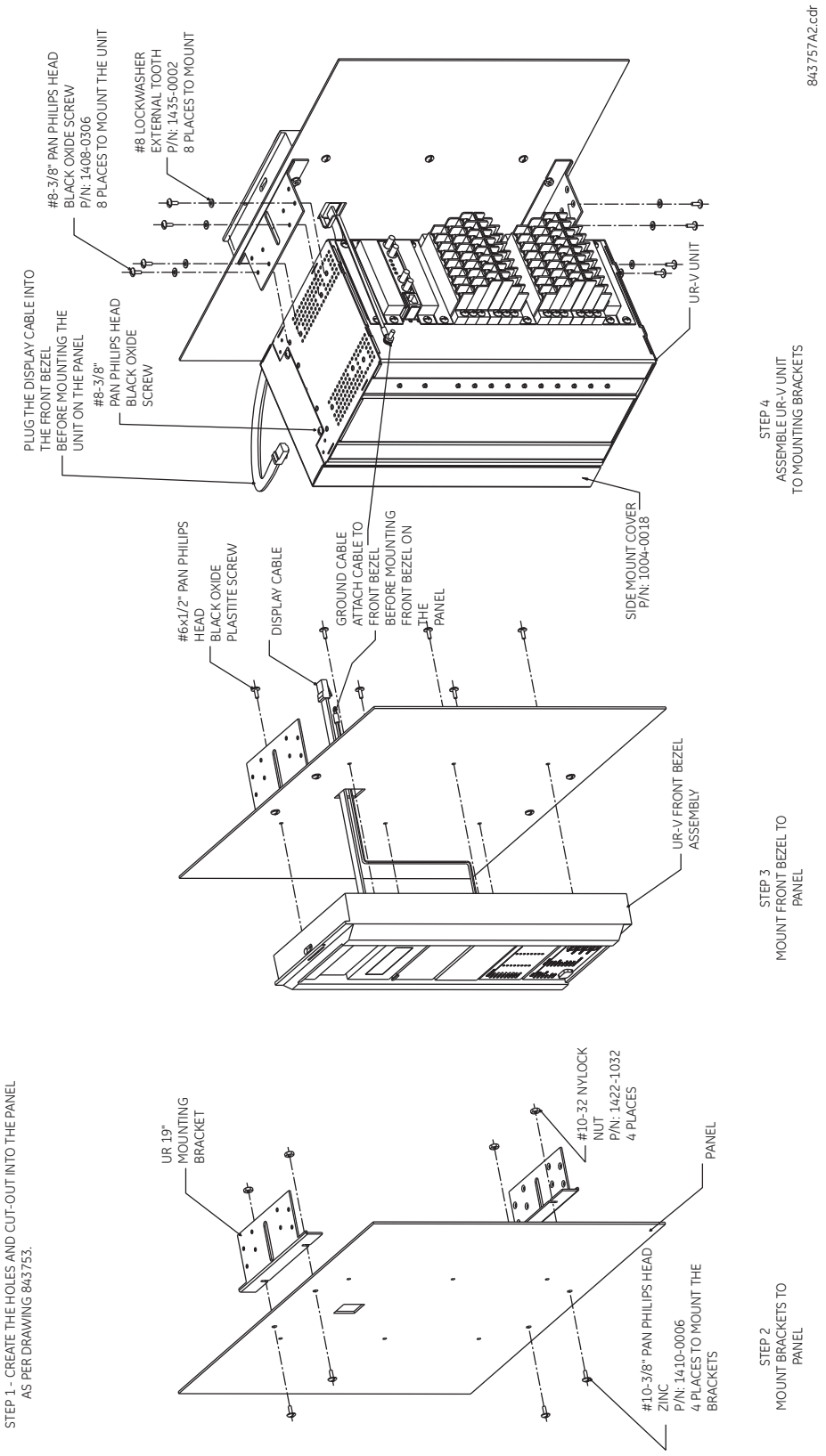



**Figure 3–7: L30 VERTICAL SIDE MOUNTING INSTALLATION (BASIC PANEL)**

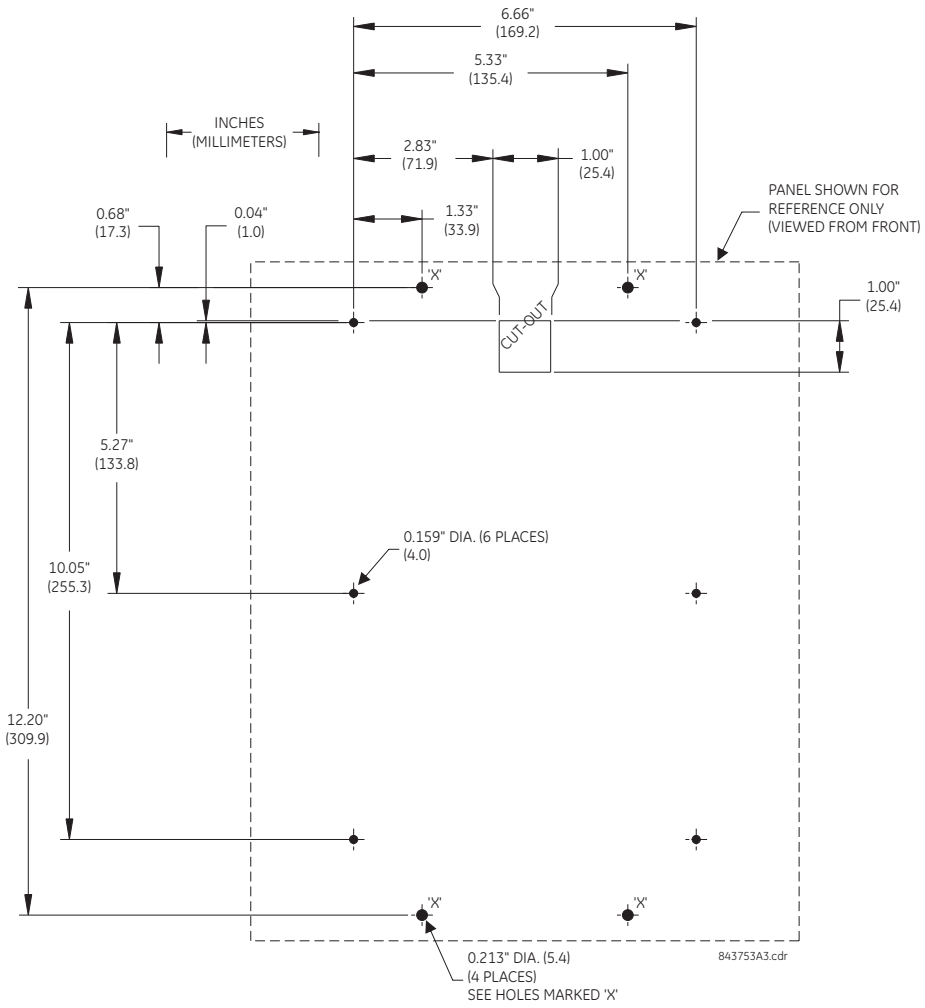



**Figure 3–8: L30 VERTICAL SIDE MOUNTING REAR DIMENSIONS (BASIC PANEL)**

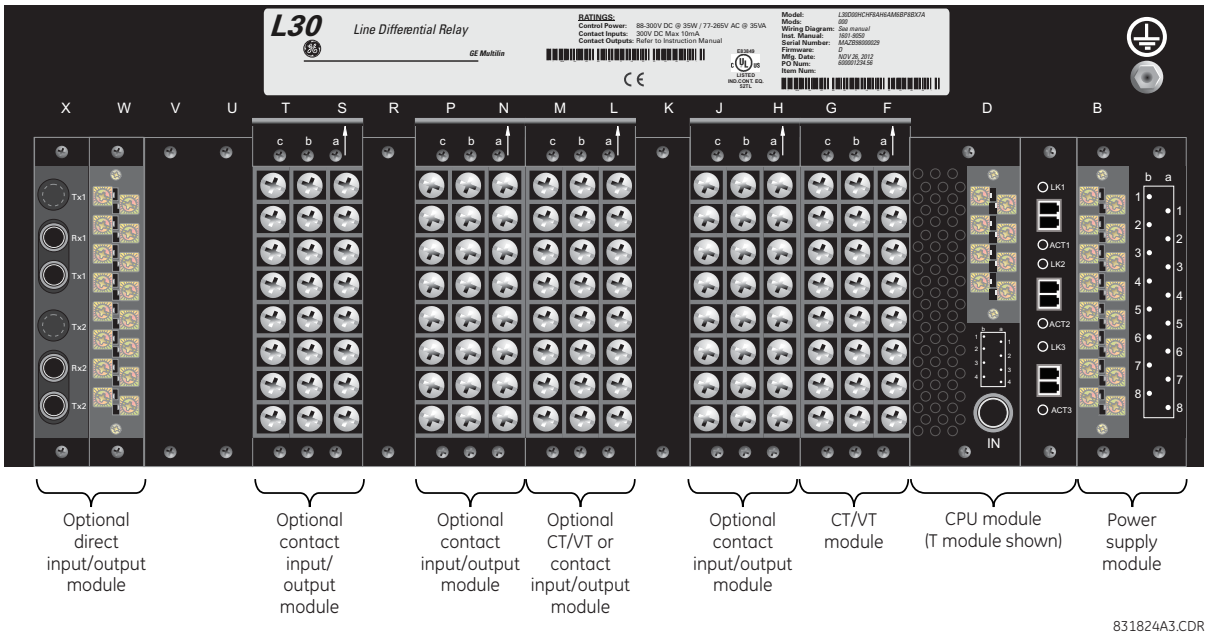



**Figure 3–9: REAR TERMINAL VIEW**

**WARNING**

**Do not touch any rear terminals while the relay is energized.**

**NOTICE**

The small form-factor pluggable ports (SFPs) are pluggable transceivers. Do not use non-validated transceivers or install validated transceivers in the wrong Ethernet slot, else damage can occur.

The relay follows a convention with respect to terminal number assignments which are three characters long assigned in order by module slot position, row number, and column letter. Two-slot wide modules take their slot designation from the first slot position (nearest to CPU module) which is indicated by an arrow marker on the terminal block. See the following figure for an example of rear terminal assignments.

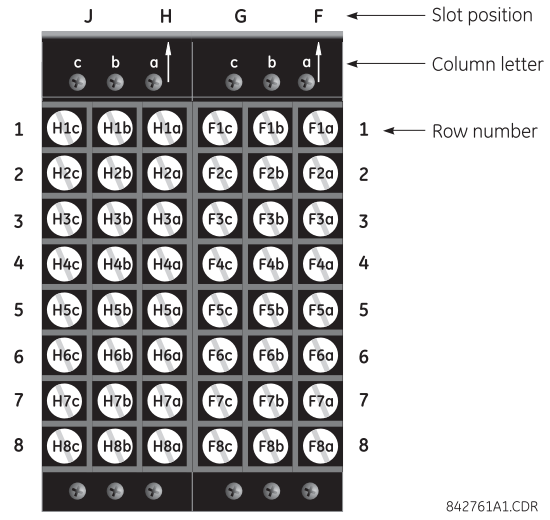



**Figure 3–10: EXAMPLE OF MODULES IN F AND H SLOTS**

The torque used to connect the terminal blocks to the back of the relay chassis (screws a, b, c shown) is 9 inch-pounds. For the connections to the terminal blocks (rows 1 to 8), use a minimum of 17 inch-pounds. During manufacturing, the power supply and CPU modules are installed in slots B and D of the chassis with 13 inch-pounds of torque on the screws at the top and bottom of the modules.

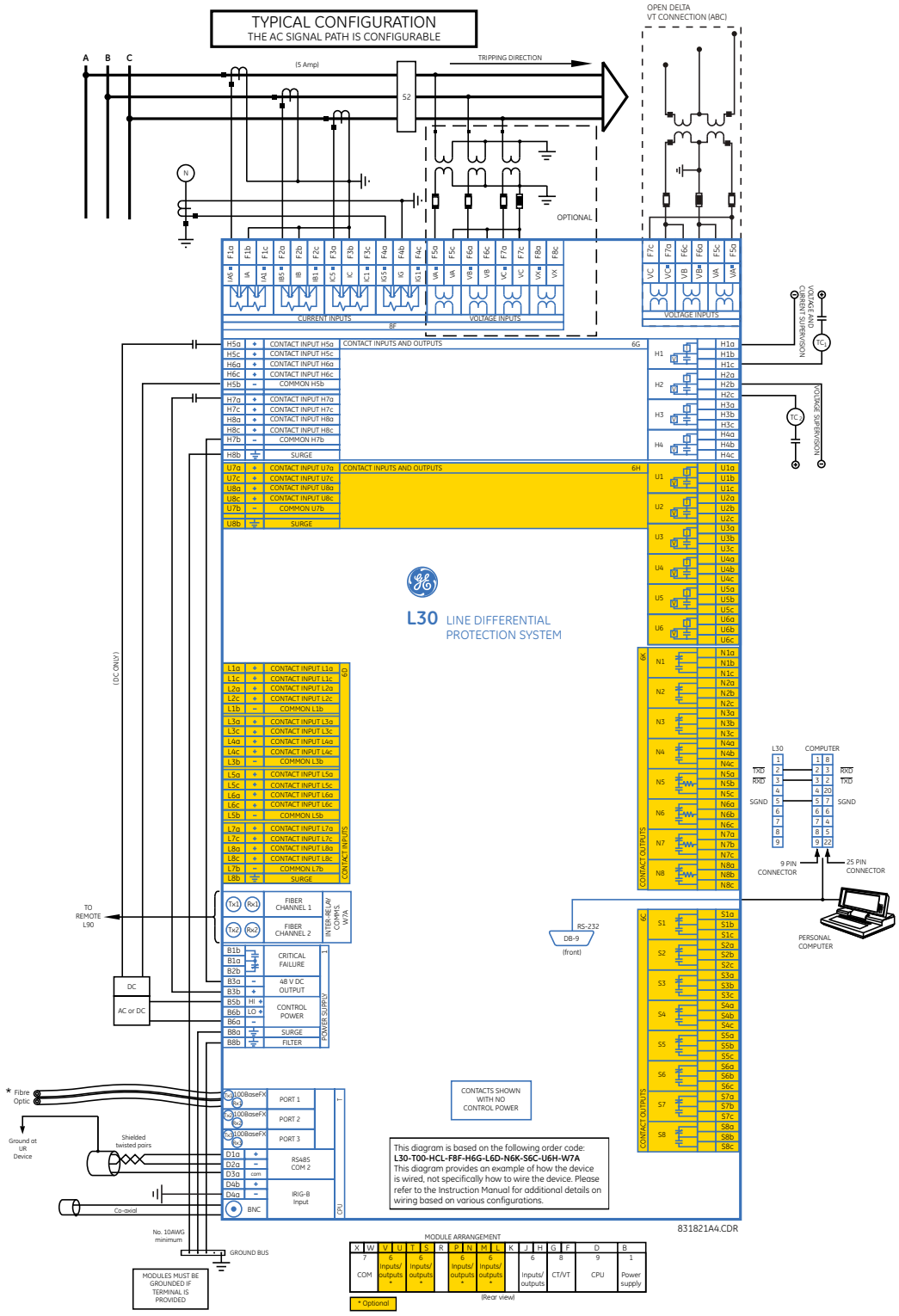



Figure 3–11: TYPICAL WIRING DIAGRAM (T MODULE SHOWN FOR CPU)

### 3.2.2 DIELECTRIC STRENGTH

The dielectric strength of the UR-series module hardware is shown in the following table:

**Table 3–1: DIELECTRIC STRENGTH OF UR-SERIES MODULE HARDWARE**

| MODULE TYPE | MODULE FUNCTION | TERMINALS | | DIELECTRIC STRENGTH (AC) |
|---|---|---|---|---|
| | | FROM | TO | |
| 1 | Power supply | High (+); Low (+); (–) | Chassis | 2000 V AC for 1 minute |
| 1 | Power supply | 48 V DC (+) and (–) | Chassis | 2000 V AC for 1 minute |
| 1 | Power supply | Relay terminals except terminals 8a and 8b | Chassis | 2000 V AC for 1 minute |
| 2 | Reserved | N/A | N/A | N/A |
| 3 | Reserved | N/A | N/A | N/A |
| 4 | Digital contact inputs/ outputs | All | Chassis | 2000 V AC for 1 minute |
| 5 | Analog inputs/outputs | All except 8b | Chassis | < 50 V DC |
| 6 | Digital contact inputs/ outputs | All | Chassis | 2000 V AC for 1 minute |
| 7 | G.703 | All except 2b, 3a, 7b, 8a | Chassis | 2000 V AC for 1 minute |
| | RS422 | All except 6a, 7b, 8a | Chassis | < 50 V DC |
| 8 | CT/VT | All | Chassis | 2000 V AC for 1 minute |
| 9 | CPU | All | Chassis | 2000 V AC for 1 minute |

**NOTICE**

Filter networks and transient protection clamps are used in the hardware to prevent damage caused by high peak voltage transients, radio frequency interference (RFI), and electromagnetic interference (EMI). These protective components can be damaged by application of the ANSI/IEEE C37.90 specified test voltage for a period longer than the specified one minute.

### 3.2.3 CONTROL POWER

**NOTICE**

Control power supplied to the relay must be connected to the matching power supply range of the relay. If voltage is applied to the wrong terminals, damage can occur.

The L30 relay, like almost all electronic relays, contains electrolytic capacitors. These capacitors are well-known to deteriorate over time if voltage is not applied periodically. Deterioration can be avoided by powering up the relay at least once a year.

The power supply module can be ordered for two possible voltage ranges, and the UR can be ordered with or without a redundant power supply module option. Each range has a dedicated input connection for proper operation. The ranges are as shown below (see the Specifications section of chapter 2 for details):

- Low (LO) range: 24 to 48 V (DC only) nominal.
- High (HI) range: 125 to 250 V nominal.

The power supply module provides power to the relay and supplies power for dry contact input connections.

The power supply module provides 48 V DC power for dry contact input connections and a critical failure relay (see the Typical Wiring Diagram earlier). The critical failure relay is a form-C device that is energized once control power is applied and the relay has successfully booted up with no critical self-test failures. If on-going self-test diagnostic checks detect a critical failure (see the Self-Test Errors section in chapter 7) or control power is lost, the relay is de-energize.

For high reliability systems, the L30 has a redundant option in which two L30 power supplies are placed in parallel on the bus. If one of the power supplies become faulted, the second power supply assumes the full load of the relay without any interruptions. Each power supply has a green LED on the front of the module to indicate it is functional. The critical fail relay of the module also indicates a faulted power supply.

An LED on the front of the control power module shows the status of the power supply:

| LED INDICATION | POWER SUPPLY |
|---|---|
| CONTINUOUS ON | OK |
| ON / OFF CYCLING | Failure |
| OFF | Failure |

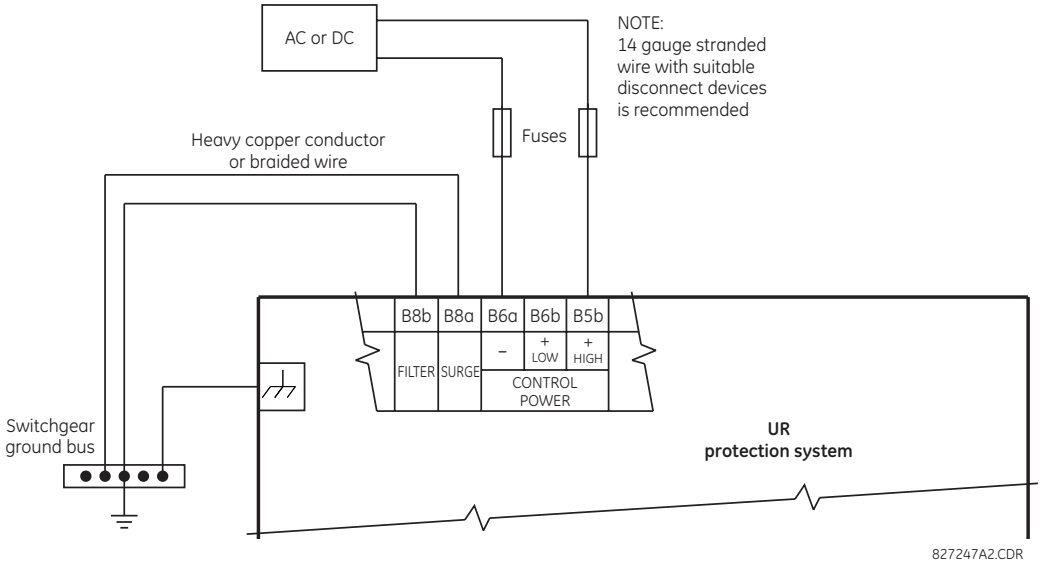



**Figure 3–12: CONTROL POWER CONNECTION**

### a) NON-VOLATILE DATA STORAGE

Non-volatile data is temporary data required after a power cycle for relay state, such as latch status before reboot. The relay saves this data in non-volatile storage every two minutes or when a state change occurs.

If a state change occurs just before a power down (less than two minutes) and the relay power is cycled, some temporary data can be saved and the prior state is retained at power up. Otherwise, a two-minute powered on period after a state change ensures that all temporary state changes required after reboot have been saved. A command also is available to initiate saving of data in the compact flash memory using **Commands > Relay Maintenance > Save Volatile Data**.

## 3.2.4 CT AND VT MODULES

A CT/VT module can have voltage or current inputs on channels 1 through 4 inclusive, or channels 5 through 8 inclusive. Channels 1 and 5 are intended for connection to phase A, and are labeled as such in the relay. Likewise, channels 2 and 6 are intended for connection to phase B, and channels 3 and 7 are intended for connection to phase C.

Channels 4 and 8 are intended for connection to a single-phase source. For voltage inputs, these channel are labelled as auxiliary voltage (VX). For current inputs, these channels are intended for connection to a CT between system neutral and ground, and are labelled as ground current (IG).

**NOTICE** Verify that the connection made to the relay terminals for nominal current of 1 A or 5 A matches the secondary rating of the connected CTs. Unmatched CTs can result in equipment damage or inadequate protection.

To connect the module, size 12 American Wire Gauge (AWG) is commonly used; the maximum size is 10 AWG.

CT/VT modules can be ordered with a standard ground current input that is the same as the phase current input. Each AC current input has an isolating transformer and an automatic shorting mechanism that shorts the input when the module is withdrawn from the chassis. There are no internal ground connections on the current inputs. Current transformers with 1 to 50000 A primaries and 1 A or 5 A secondaries can be used.

The above modules have enhanced diagnostics that can automatically detect CT/VT hardware failure and take the relay out of service.

CT connections for both ABC and ACB phase rotations are identical as shown in the Typical Wiring Diagram.

The exact placement of a zero-sequence core balance CT to detect ground fault current is shown as follows. Twisted-pair cabling on the zero-sequence CT is recommended.

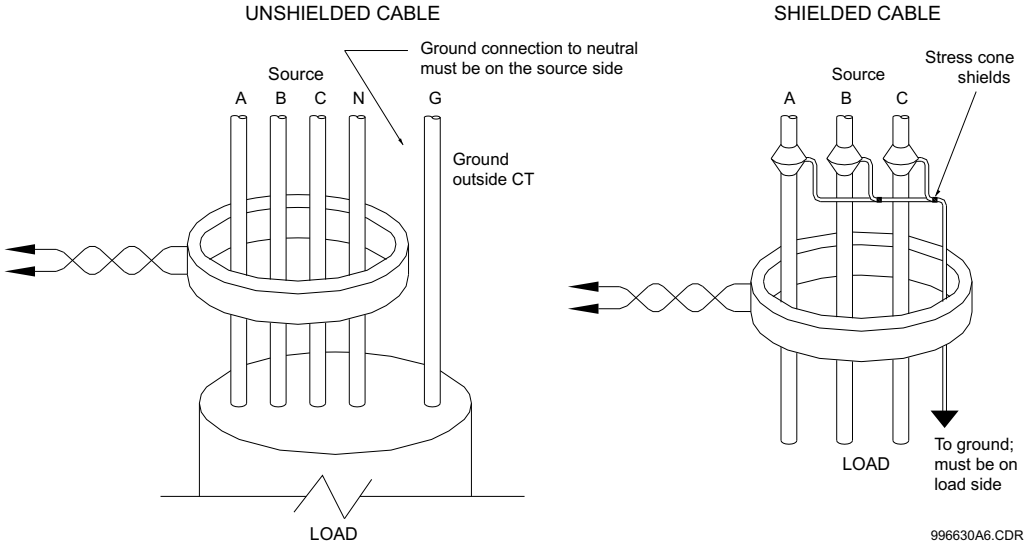
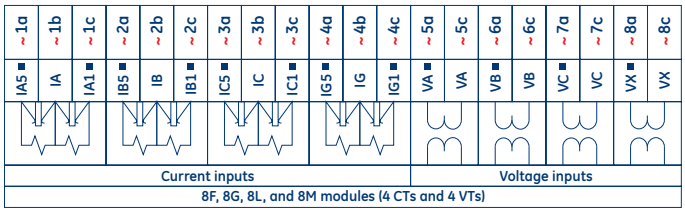



**Figure 3–13: ZERO-SEQUENCE CORE BALANCE CT INSTALLATION**

The phase voltage channels are used for most metering and protection purposes. The auxiliary voltage channel is used as input for the synchrocheck and volts-per-hertz features.

NOTE

Substitute the tilde "~" symbol with the slot position of the module in the following figure.



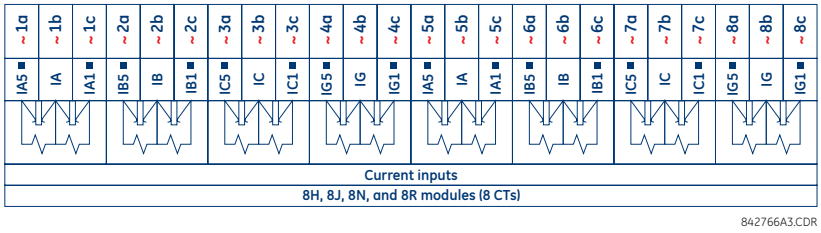




**Figure 3–14: CT/VT MODULE WIRING**

### 3.2.5 PROCESS BUS MODULES

The L30 can be ordered with a process bus interface module. This module is designed to interface with the GE Multilin HardFiber system, allowing bidirectional IEC 61850 fiber optic communications with up to eight HardFiber merging units, known as Bricks. The HardFiber system has been designed to integrate seamlessly with the existing UR-series applications, including protection functions, FlexLogic, metering, and communications.

The IEC 61850 process bus system offers the following benefits:

- Reduces labor associated with design, installation, and testing of protection and control applications using the L30 by reducing the number of individual copper terminations
- Integrates seamlessly with existing L30 applications, since the IEC 61850 process bus interface module replaces the traditional CT/VT modules
- Communicates using open standard IEC 61850 messaging

For additional details on the HardFiber system, see GE publication GEK-113658: HardFiber Process Bus System Instruction Manual.



### 3.2.6 CONTACT INPUTS AND OUTPUTS

Every contact input/output module has 24 terminal connections. They are arranged as three terminals per row, with eight rows in total. A given row of three terminals can be used for the outputs of one relay. For example, for form-C relay outputs, the terminals connect to the normally open (NO), normally closed (NC), and common contacts of the relay. For a form-A output, there are options of using current or voltage detection for feature supervision, depending on the module ordered. The terminal configuration for contact inputs is different for the two applications.

The contact inputs are grouped with a common return. The input/output modules have two versions of grouping: four inputs per common return and two inputs per common return. When a contact input/output module is ordered, four inputs per common is used. If the inputs must be isolated per row, then two inputs per common return should be selected (4D module).

The tables and diagrams on the following pages illustrate the module types (6A, etc.) and contact arrangements that can be ordered for the relay. Since an entire row is used for a single contact output, the name is assigned using the module slot position and row number. However, since there are two contact inputs per row, these names are assigned by module slot position, row number, and column position.

Some form-A / solid-state relay outputs include circuits to monitor the DC voltage across the output contact when it is open, and the DC current through the output contact when it is closed. Each of the monitors contains a level detector whose output is set to logic “On” when the current in the circuit is above the threshold setting. The voltage monitor is set to “On” when there is a voltage across open contact (the detector allows a current of about 1 to 2.5 mA), and the current monitor is set to “On” when the current flowing through the closed contact exceeds about 80 to 100 mA. The voltage monitor is intended to check the health of the overall trip circuit, and the current monitor can be used to seal-in the output contact until an external contact has interrupted current flow. If enabled, the current monitoring can be used as a seal-in signal to ensure that the form-A contact does not attempt to break the energized inductive coil circuit and weld the output contacts.

Block diagrams are shown as follows for form-A and solid-state relay outputs with optional voltage monitor, optional current monitor, and with no monitoring. The actual values shown for contact output 1 are the same for all contact outputs. Form-A contact output with or without a current or voltage monitoring option is not polarity sensitive. The polarity shown in the figure is required for solid-state contact output connection.

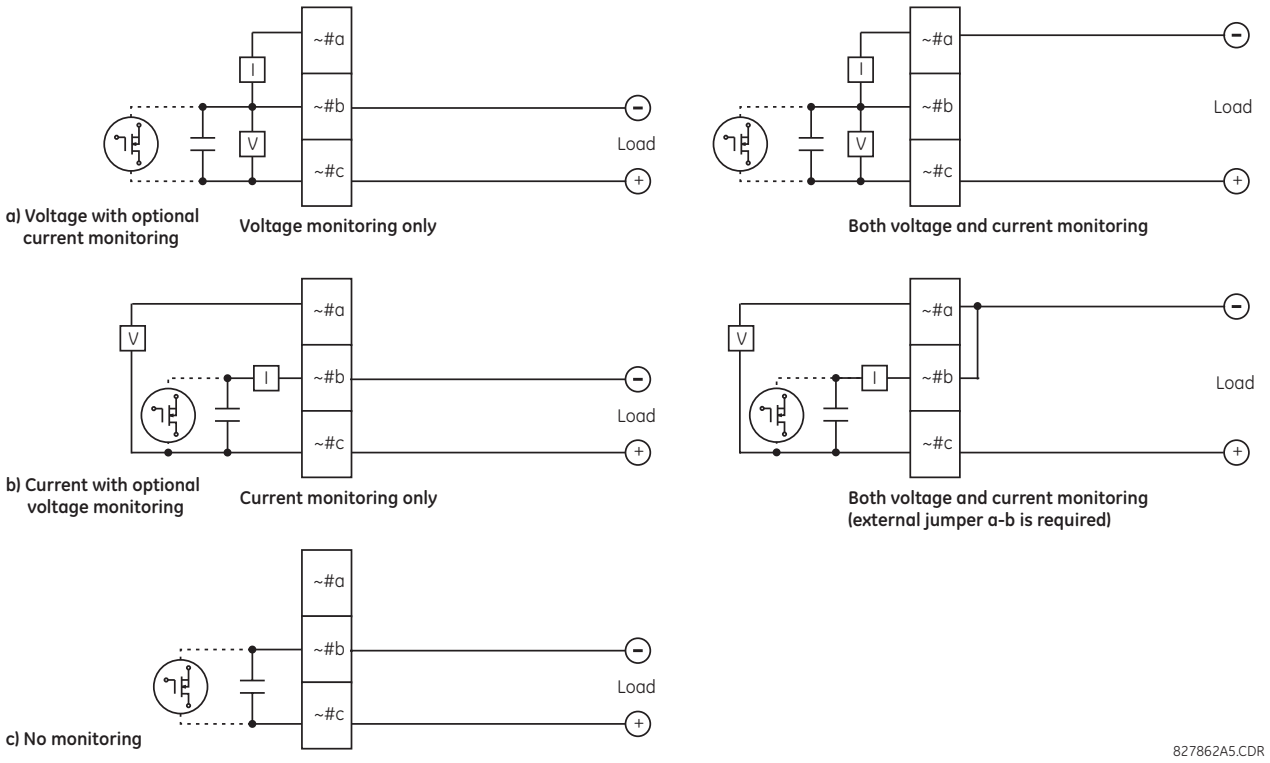



**Figure 3–15: FORM-A AND SOLID-STATE CONTACT OUTPUTS WITH VOLTAGE AND CURRENT MONITORING**

The operation of voltage and current monitors is reflected with the corresponding FlexLogic operands (CONT OP # VON, CONT OP # VOFF, and CONT OP # ION) which can be used in protection, control, and alarm logic. The typical application of the voltage monitor is breaker trip circuit integrity monitoring; a typical application of the current monitor is seal-in of the control command.

See the Digital Elements section of chapter 5 for an example of how form-A and solid-state relay contacts can be applied for breaker trip circuit integrity monitoring.

**WARNING** **Consider relay contacts unsafe to touch when the unit is energized.**

NOTE **USE OF FORM-A AND SOLID-STATE RELAY OUTPUTS IN HIGH IMPEDANCE CIRCUITS**

For form-A and solid-state relay output contacts internally equipped with a voltage measuring circuit across the contact, the circuit has an impedance that can cause a problem when used in conjunction with external high input impedance monitoring equipment such as modern relay test set trigger circuits. These monitoring circuits may continue to read the form-A contact as being closed after it has closed and subsequently opened, when measured as an impedance.

The solution is to use the voltage measuring trigger input of the relay test set, and connect the form-A contact through a voltage-dropping resistor to a DC voltage source. If the 48 V DC output of the power supply is used as a source, a 500 Ω, 10 W resistor is appropriate. In this configuration, the voltage across either the form-A contact or the resistor can be used to monitor the state of the output.

NOTE Wherever a tilde "~" symbol appears, substitute with the slot position of the module; wherever a number sign "#" appears, substitute the contact number.

**NOTICE** When current monitoring is used to seal-in the form-A and solid-state relay contact outputs, the FlexLogic operand driving the contact output should be given a reset delay of 10 ms to prevent damage of the output contact (in situations when the element initiating the contact output is bouncing, at values in the region of the pickup value).

### Table 3–2: CONTACT INPUT AND OUTPUT MODULE ASSIGNMENTS

| ~6A MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-C |
| ~4 | Form-C |
| ~5a, ~5c | 2 Inputs |
| ~6a, ~6c | 2 Inputs |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6B MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-C |
| ~4 | Form-C |
| ~5 | Form-C |
| ~6 | Form-C |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6C MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1 | Form-C |
| ~2 | Form-C |
| ~3 | Form-C |
| ~4 | Form-C |
| ~5 | Form-C |
| ~6 | Form-C |
| ~7 | Form-C |
| ~8 | Form-C |

| ~6D MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1a, ~1c | 2 Inputs |
| ~2a, ~2c | 2 Inputs |
| ~3a, ~3c | 2 Inputs |
| ~4a, ~4c | 2 Inputs |
| ~5a, ~5c | 2 Inputs |
| ~6a, ~6c | 2 Inputs |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6E MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-C |
| ~2 | Form-C |
| ~3 | Form-C |
| ~4 | Form-C |
| ~5a, ~5c | 2 Inputs |
| ~6a, ~6c | 2 Inputs |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6F MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1 | Fast Form-C |
| ~2 | Fast Form-C |
| ~3 | Fast Form-C |
| ~4 | Fast Form-C |
| ~5 | Fast Form-C |
| ~6 | Fast Form-C |
| ~7 | Fast Form-C |
| ~8 | Fast Form-C |

| ~6G MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-A |
| ~4 | Form-A |
| ~5a, ~5c | 2 Inputs |
| ~6a, ~6c | 2 Inputs |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6H MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-A |
| ~4 | Form-A |
| ~5 | Form-A |
| ~6 | Form-A |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6K MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1 | Form-C |
| ~2 | Form-C |
| ~3 | Form-C |
| ~4 | Form-C |
| ~5 | Fast Form-C |
| ~6 | Fast Form-C |
| ~7 | Fast Form-C |
| ~8 | Fast Form-C |

| ~6L MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-C |
| ~4 | Form-C |
| ~5a, ~5c | 2 Inputs |
| ~6a, ~6c | 2 Inputs |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6M MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-C |
| ~4 | Form-C |
| ~5 | Form-C |
| ~6 | Form-C |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6N MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-A |
| ~4 | Form-A |
| ~5a, ~5c | 2 Inputs |
| ~6a, ~6c | 2 Inputs |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6P MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-A |
| ~4 | Form-A |
| ~5 | Form-A |
| ~6 | Form-A |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6R MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-C |
| ~4 | Form-C |
| ~5a, ~5c | 2 Inputs |
| ~6a, ~6c | 2 Inputs |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6S MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-C |
| ~4 | Form-C |
| ~5 | Form-C |
| ~6 | Form-C |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6T MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-A |
| ~4 | Form-A |
| ~5a, ~5c | 2 Inputs |
| ~6a, ~6c | 2 Inputs |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6U MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-A |
| ~4 | Form-A |
| ~5 | Form-A |
| ~6 | Form-A |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~6V MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-C |
| ~4 | 2 Outputs |
| ~5a, ~5c | 2 Inputs |
| ~6a, ~6c | 2 Inputs |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~67 MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1 | Form-A |
| ~2 | Form-A |
| ~3 | Form-A |
| ~4 | Form-A |
| ~5 | Form-A |
| ~6 | Form-A |
| ~7 | Form-A |
| ~8 | Form-A |

| ~4A MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1 | Not Used |
| ~2 | Solid-State |
| ~3 | Not Used |
| ~4 | Solid-State |
| ~5 | Not Used |
| ~6 | Solid-State |
| ~7 | Not Used |
| ~8 | Solid-State |

| ~4B MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1 | Not Used |
| ~2 | Solid-State |
| ~3 | Not Used |
| ~4 | Solid-State |
| ~5 | Not Used |
| ~6 | Solid-State |
| ~7 | Not Used |
| ~8 | Solid-State |

| ~4C MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1 | Not Used |
| ~2 | Solid-State |
| ~3 | Not Used |
| ~4 | Solid-State |
| ~5 | Not Used |
| ~6 | Solid-State |
| ~7 | Not Used |
| ~8 | Solid-State |

| ~4D MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1a, ~1c | 2 Inputs |
| ~2a, ~2c | 2 Inputs |
| ~3a, ~3c | 2 Inputs |
| ~4a, ~4c | 2 Inputs |
| ~5a, ~5c | 2 Inputs |
| ~6a, ~6c | 2 Inputs |
| ~7a, ~7c | 2 Inputs |
| ~8a, ~8c | 2 Inputs |

| ~4L MODULE | |
|---|---|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1 | 2 Outputs |
| ~2 | 2 Outputs |
| ~3 | 2 Outputs |
| ~4 | 2 Outputs |
| ~5 | 2 Outputs |
| ~6 | 2 Outputs |
| ~7 | 2 Outputs |
| ~8 | Not Used |

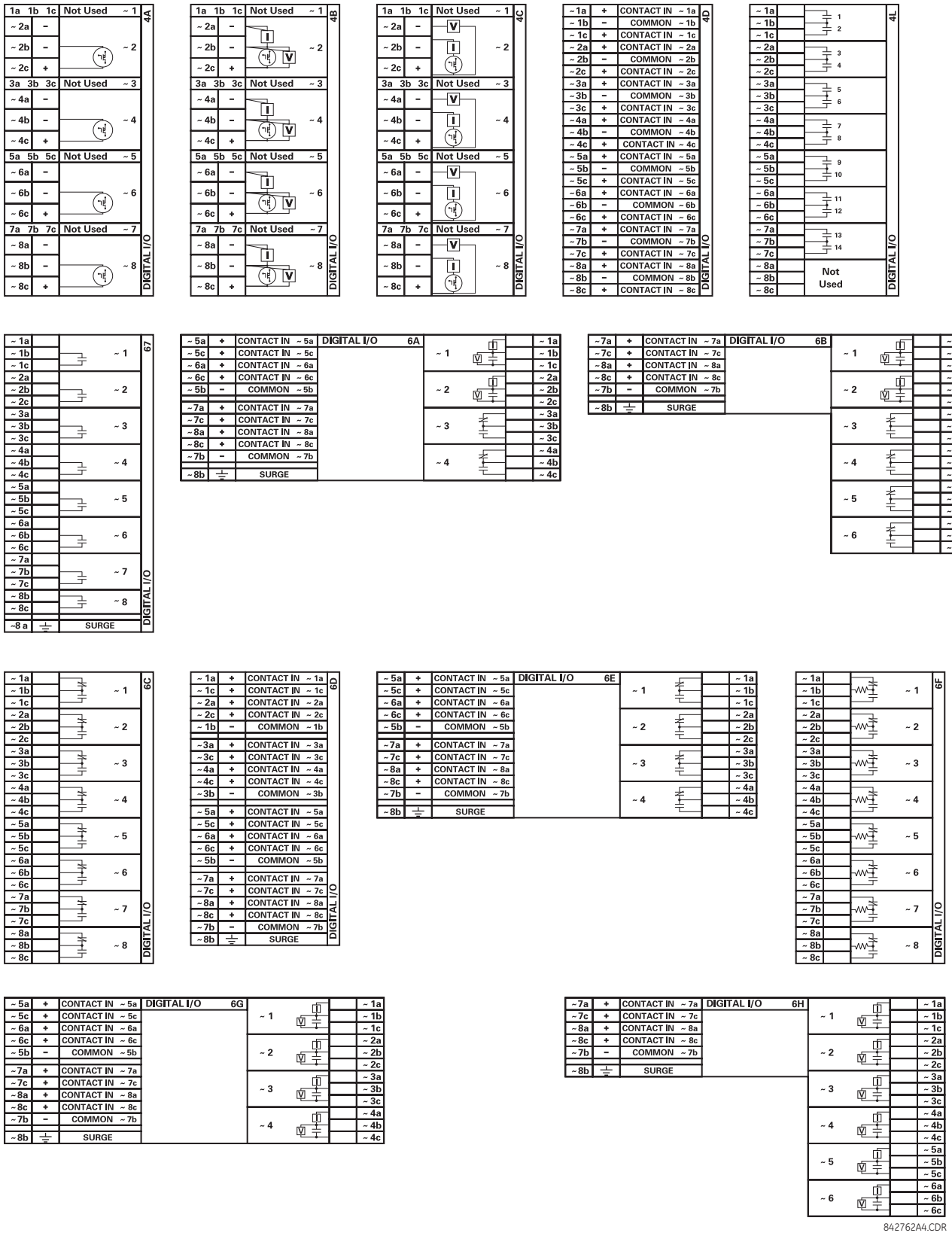



**Figure 3–16: CONTACT INPUT AND OUTPUT MODULE WIRING (1 of 2)**

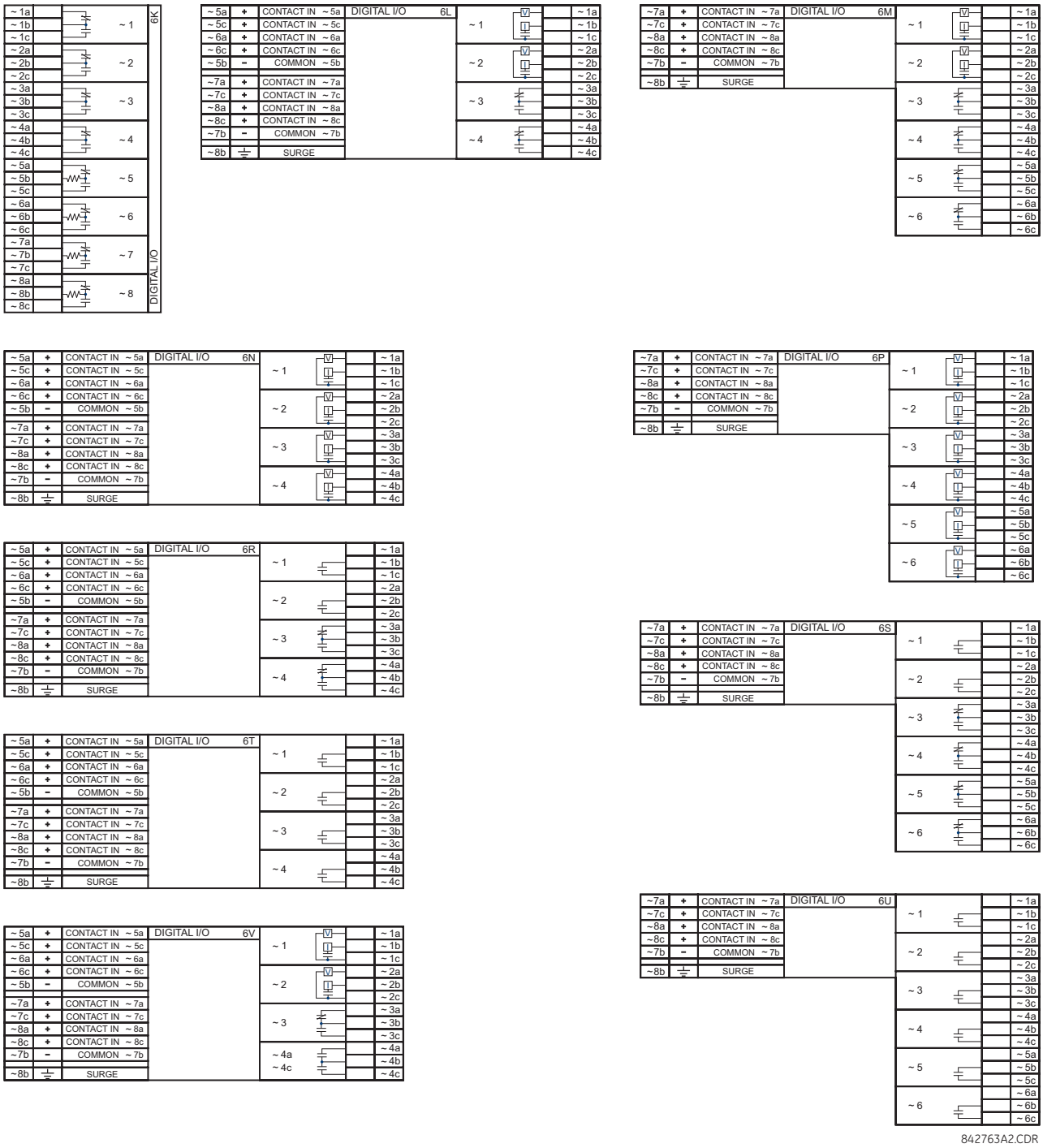



**Figure 3–17: CONTACT INPUT AND OUTPUT MODULE WIRING (2 of 2)**

**NOTICE** For proper functionality, observe the polarity shown in the figures for all contact input and output connections.

### CONTACT INPUTS

A dry contact has one side connected to terminal B3b. This is the positive 48 V DC voltage rail supplied by the power supply module. The other side of the dry contact is connected to the required contact input terminal. Each contact input group has its own common (negative) terminal which must be connected to the DC negative terminal (B3a) of the power supply module. When a dry contact closes, a current of 1 to 3 mA flows through the associated circuit.

A wet contact has one side connected to the positive terminal of an external DC power supply. The other side of this contact is connected to the required contact input terminal. If a wet contact is used, then the negative side of the external source must be connected to the relay common (negative) terminal of each contact group. The maximum external source voltage for this arrangement is 300 V DC.

The voltage threshold at which each group of four contact inputs detects a closed contact input is programmable as 17 V DC for 24 V sources, 33 V DC for 48 V sources, 84 V DC for 110 to 125 V sources, and 166 V DC for 250 V sources.



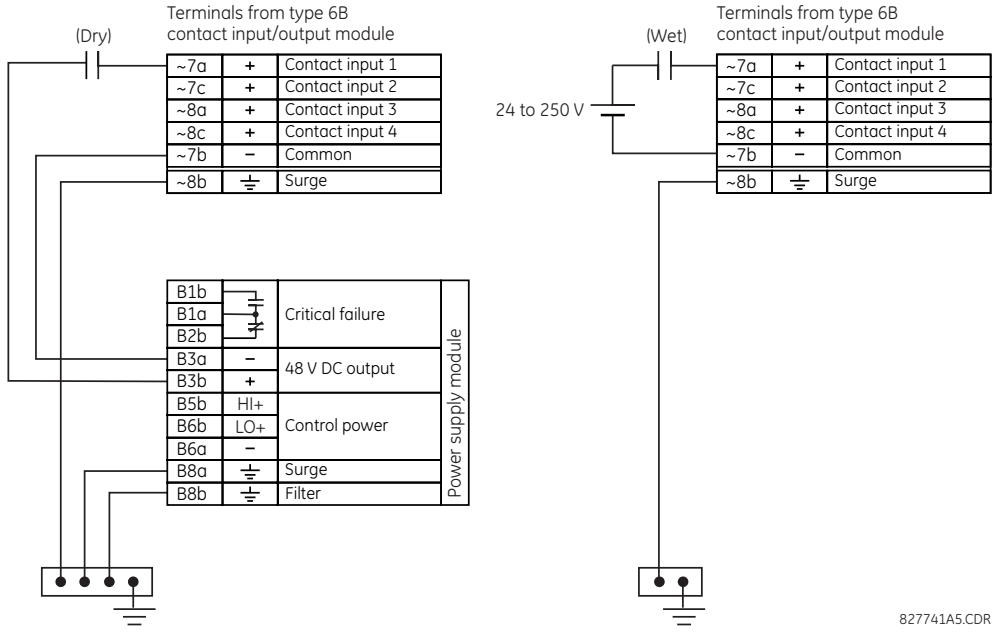



**Figure 3–18: DRY AND WET CONTACT INPUT CONNECTIONS**

NOTE

Wherever a tilde "~" symbol appears, substitute with the slot position of the module.

There is no provision in the relay to detect a DC ground fault on 48 V DC control power external output. We recommend using an external DC supply.

### GENERAL APPLICATION CONSIDERATIONS

Contacts outputs of protective relays, auxiliary contacts from breakers, disconnectors and other devices, are generally connected to contacts inputs of protective relays. In some situations, the contact outputs of some protective relays can have high impedance connected across it. When such a contact output is connected across a L30 contact input, it can spuriously operate the L30 input even when the output is open, if there is a substantial distributed capacitance (represented by C1) present in the wiring between the output and the L30 input and the debounce time setting in the L30 relay is low enough. This false assertion of the contact input, when there is inadvertent ground present at the DC positive terminal, can be prevented by inserting a resistor across the L30 input.

The following figure shows a typical DC circuit, with battery ground detection, of contact input. The contact output has parallel impedance across it (represented by R1).

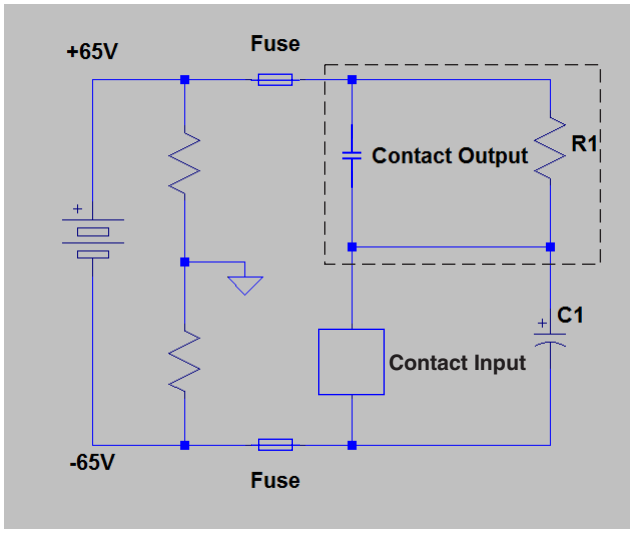



**Figure 3–19: TYPICAL CONTACT INPUT DC CIRCUIT**

The presence of the impedance path (R1) across the contact output allows the stray (distributed) capacitance C1 to charge as shown, thus developing a voltage across the contact input enough to momentarily operate the input while the capacitance discharges in the presence of DC ground on the positive terminal of the battery.

The duration of the discharge depends on the value of the distributed capacitance, the initial voltage of the distributed capacitance, and the input impedance of the contact input. If the duration is greater than the debounce time setting, then the contact input operates.

The application example that follows describes how to mitigate this problem by connecting a resistor across the contact input, as shown in the next figure, or by adjusting the debounce time setting to a value greater than the discharge time to prevent spurious operation of the contact input only if the voltage (with output open) across the contact input due to trickle current is less than the threshold voltage. This operation of contact inputs also can be prevented by using the Auto-Burnish contact inputs or contact inputs with active impedance.

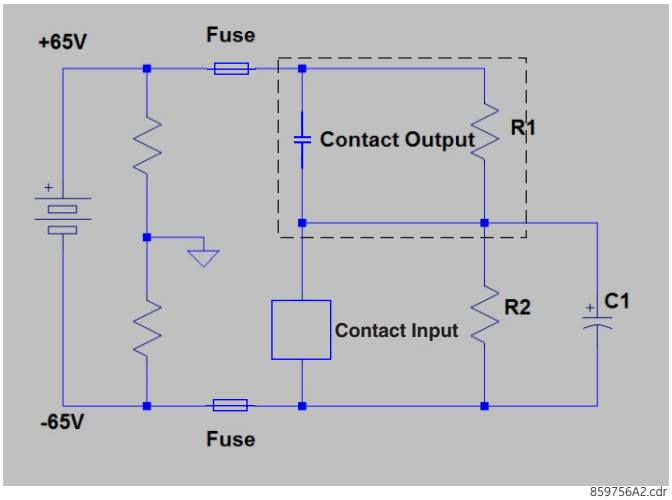



**Figure 3–20: CONTACT INPUT CONNECTED TO A CONTACT OUTPUT WITH RESISTOR (R2) ACROSS THE INPUT**

### APPLICATION EXAMPLE

This example is for illustrative purposes only and the calculations present the worst-case scenario. In practice, the value of debounce time can be lower.

Contact input ON state impedance used in the calculation of the discharge period is based on the following table.

**Table 3–3: DISCHARGE PERIOD**

| BATTERY VOLTAGE (V) | INPUT IMPEDANCE (KΩ) |
|---|---|
| 130 | 50 |
| 250 | 97 |

Debounce time setting = 2 ms

Assume a stray capacitance of 0.1 µF.

Assume an initial voltage across the stray capacitance "Vinitial" = 19 V (Vthreshold - 65 V), where Vthreshold = 84 V. The initial voltage Vinitial depends on values of impedance of R1 and contact inputs when the contact input is OFF (non-activated state).

Therefore, discharge time constant (τ) =50 kΩ *0.1 µF = 5 ms.

Discharge period t is calculated from the following equation:

$$Vthreshold = (Vbatt - VInitial) *e^{(-t/\tau)}$$

$$84 = -149 *e^{(t/0.005)} \quad \textbf{(EQ 3.1)}$$

$$T = -0.005 * \ln (84/149) = 0.0029 \text{ s}$$

Therefore, in this example the contact inputs operate.

To prevent this operation, the debounce time must be increased to 4 ms (set debounce time as per the following table) or insert a resistor less than or equal to "R" as calculated later.

**Table 3–4: TYPICAL DEBOUNCE TIME SETTING**

| STRAY CAPACITANCE (µF) | BATTERY VOLTAGE (V) | DEBOUNCE TIME (MS) |
|---|---|---|
| 0.05 | 130 | 2 |
| 0.1 | 130 | 4 |
| 0.2 | 130 | 6 |
| 0.05 | 250 | 3 |
| 0.1 | 250 | 6 |
| 0.2 | 250 | 11 |

The value of this resistor "R" is calculated as follows:

1. Determine the minimum voltage (V threshold) required to turn on the input. This is determined by direct measurement or referenced in the input specifications.
2. Calculate the resistance necessary to limit the voltage to 1/3 V threshold (when the contact is OFF, the non-activated state) as follows:

   $$R = (Vthreshold / 3) / (2 \text{ mA}) \quad \textbf{(EQ 3.2)}$$

   The 2 mA current is used in case the contact input is connected across the GE Form A contact output with voltage monitoring. Otherwise use the amperage of the active circuit connected to the contact input when its contact output is open and the voltage across the contact input is third trigger threshold to calculate the resistor value.
3. When the contact is ON (operate state), the battery voltage appears across the resistor. The wattage rating of the resistor is then:

   $$PR = 1.3 * (Vbatt)^2 / R \text{ Watts} \quad \textbf{(EQ 3.3)}$$
4. Applying the following equation to our example:

   $$R = 84 \text{ V} / 3*(1 / 2 \text{ mA}) = 14 \text{ k}\Omega$$

   $$PR = 1.57 \text{ Watts} \quad \textbf{(EQ 3.4)}$$
5. Calculating the voltage across the contact input with the Burden Resistor, Voltage across the contact Input:

Vresistor = 2 mA * 14 Kohm = 28 V

Vresistor < contact input threshold (84 V) **(EQ 3.5)**

In conclusion, in this example, the contact input does NOT operate falsely with the Burden Resistor across its input AND when a battery ground is present.

### USE OF CONTACT INPUTS WITH AUTO-BURNISHING

The contact inputs sense a change of the state of the external device contact based on the measured current. When external devices are located in a harsh industrial environment (either outdoor or indoor), their contacts can be exposed to various types of contamination. Normally, there is a thin film of insulating sulfidation, oxidation, or contaminates on the surface of the contacts, sometimes making it difficult or impossible to detect a change of the state. This film must be removed to establish circuit continuity – an impulse of higher than normal current can accomplish this.

The contact inputs with auto-burnish create a high current impulse when the threshold is reached to burn off this oxidation layer as a maintenance to the contacts. Afterwards the contact input current is reduced to a steady-state current. The impulse has a 5 second delay after a contact input changes state.



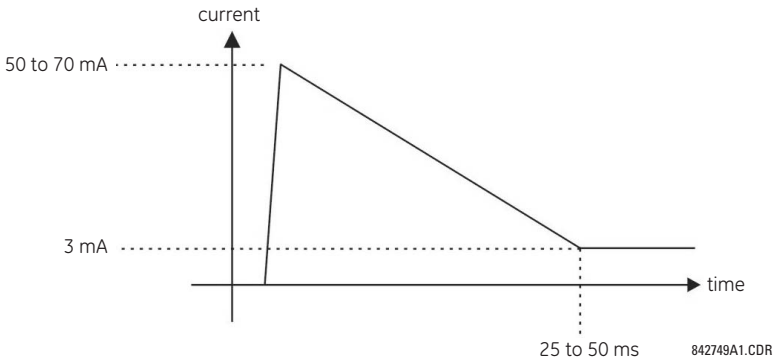
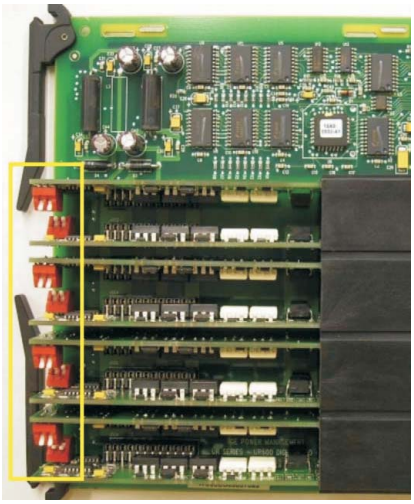



**Figure 3–21: CURRENT THROUGH CONTACT INPUTS WITH AUTO-BURNISHING**

Regular contact inputs limit current to less than 3 mA to reduce station battery burden. In contrast, contact inputs with auto-burnishing allow currents up to 50 to 70 mA at the first instance when the change of state was sensed. Then, within 25 to 50 ms, this current is slowly reduced to 3 mA as indicated above. The 50 to 70 mA peak current burns any film on the contacts, allowing for proper sensing of state changes. If the external device contact is bouncing, the auto-burnishing starts when external device contact bouncing is over.

Another important difference between the auto-burnishing input module and the regular input modules is that only two contact inputs have common ground, as opposed to four contact inputs sharing one common ground (refer to the Contact Input and Output Module Wiring diagrams). This is beneficial when connecting contact inputs to separate voltage sources. Consequently, the threshold voltage setting is also defined per group of two contact inputs.

The auto-burnish feature can be disabled or enabled using the DIP switches found on each daughter card. There is a DIP switch for each contact, for a total of 16 inputs.



CONTACT INPUT 1 AUTO-BURNISH = OFF
CONTACT INPUT 2 AUTO-BURNISH = OFF

CONTACT INPUT 1 AUTO-BURNISH = ON
CONTACT INPUT 2 AUTO-BURNISH = OFF

CONTACT INPUT 1 AUTO-BURNISH = OFF
CONTACT INPUT 2 AUTO-BURNISH = ON

CONTACT INPUT 1 AUTO-BURNISH = ON
CONTACT INPUT 2 AUTO-BURNISH = ON

842751A1.CDR

**Figure 3–22: AUTO-BURNISH DIP SWITCHES**

NOTE

The auto-burnish circuitry has an internal fuse for safety purposes. During regular maintenance, check the auto-burnish functionality using an oscilloscope.

### USE OF CONTACT INPUTS WITH ACTIVE IMPEDANCE

Contact inputs susceptible to parasitic capacitance caused by long cable runs affected by switching surges from external circuits can result in inadvertent activation of contact inputs with the external contact open. In this case, GE recommends using the digital I/O module with active impedance circuit.

Active impedance contact input can tolerate external cable capacitance of up to 0.2 µF, without entering the ON state for more than 2 ms. The contact input debounce time can still be set above 2 ms for added security to prevent contact input activations cause by external transient ON states.

An active impedance contact input is normally in Low impedance mode during OFF contact state (non-activated condition). During Low impedance state contact input impedance is maintained at 10 K Ohms impedance to allow fast discharge of the stray capacitance of the long cables.

When the contact input voltage exceeds the set threshold, active impedance maintains 10 K Ohms impedance value. If voltage starts rapidly decreasing, this indicates that stray capacitance is being discharged through the contact input. If, however, voltage stabilizes above the set threshold, the input impedance is switched to High impedance mode of 100 K Ohms. This value reduces the input current to <3 mA, and contact input switched to the ON state (operated state).

The figure shows the active impedance contact input V-I characteristic. Different thresholds with their corresponding characteristics are shown by color. The contact input is in the ON (operated) state if the input voltage is to the right of the colored threshold band (+/-10% tolerance), and the contact input is in the OFF (non-activated) state when input voltage is to the left of the band. A contact input is in LOW state during non-operated system condition, and actively switches to HIGH state upon detection of input voltage above the settable threshold.

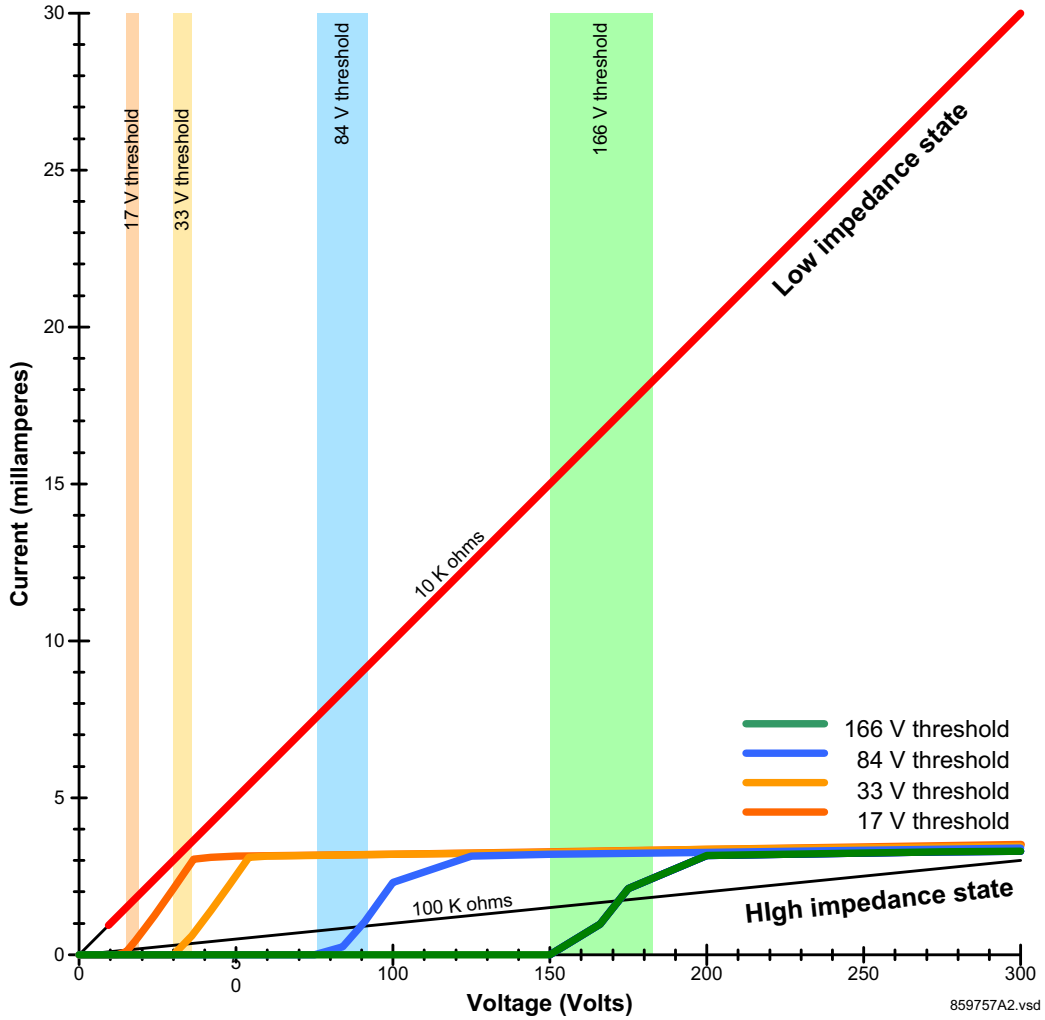



**Figure 3–23: ACTIVE IMPEDANCE CONTACT INPUT V-I CHARACTERISTIC**

### 3.2.7 TRANSDUCER INPUTS AND OUTPUTS

Transducer input modules can receive input signals from external DCmA output transducers (DCmA In) or resistance temperature detectors (RTDs). Hardware and software are provided to receive signals from these external transducers and convert these signals into a digital format for use as required.

Transducer output modules provide DC current outputs in several standard DCmA ranges. Software is provided to configure virtually any analog quantity used in the relay to drive the analog outputs.

Every transducer input/output module has a total of 24 terminal connections. These connections are arranged as three terminals per row with a total of eight rows. A given row can be used for either inputs or outputs, with terminals in column "a" having positive polarity and terminals in column "c" having negative polarity. Since an entire row is used for a single input/output channel, the name of the channel is assigned using the module slot position and row number.

Each module also requires that a connection from an external ground bus be made to terminal 8b. The current outputs require a twisted-pair shielded cable, where the shield is grounded at one end only. The following figure illustrates the transducer module types (5A, 5C, 5D, 5E, and 5F) and channel arrangements that can be ordered for the relay.

NOTE

Wherever a tilde “~” symbol appears, substitute with the slot position of the module.

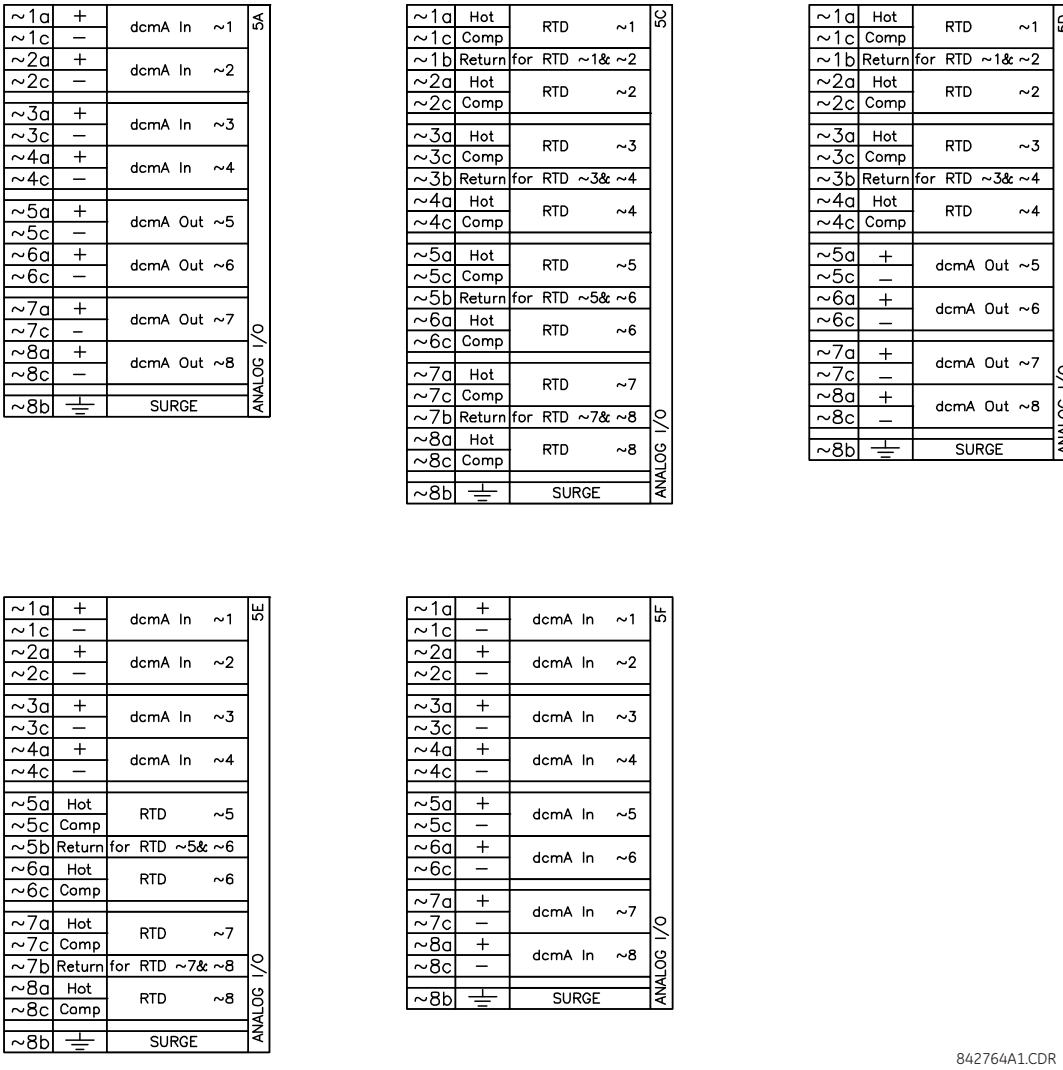



**Figure 3–24: TRANSDUCER INPUT/OUTPUT MODULE WIRING**

The following figure show how to connect RTDs.

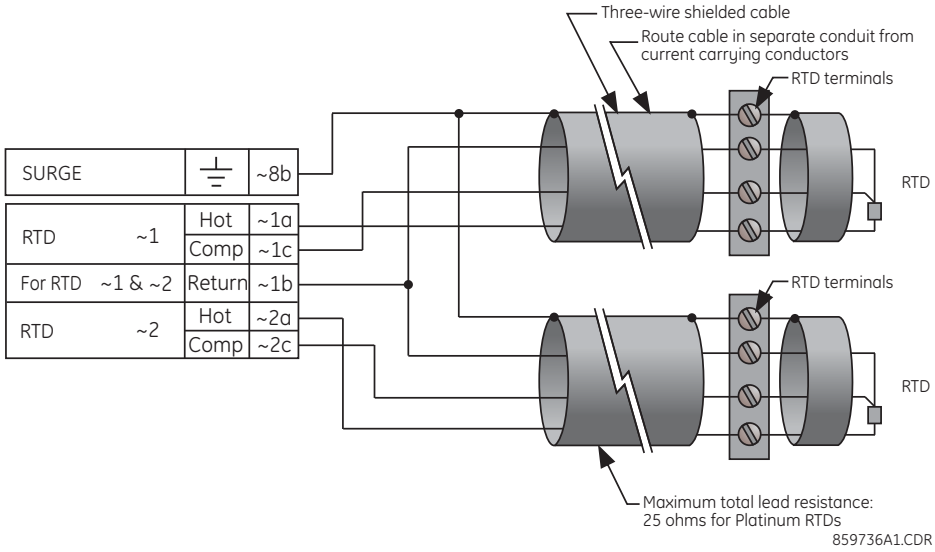



**Figure 3–25: RTD CONNECTION**

### 3.2.8 RS232 FACEPLATE PORT

A 9-pin RS232C serial port is located on the L30 faceplate for programming with a computer. All that is required to use this interface is a computer running the EnerVista UR Setup software provided with the relay. Cabling for the RS232 port is shown in the following figure for both 9-pin and 25-pin connectors.

NOTE

The baud rate for this port is fixed at 19200 bps.

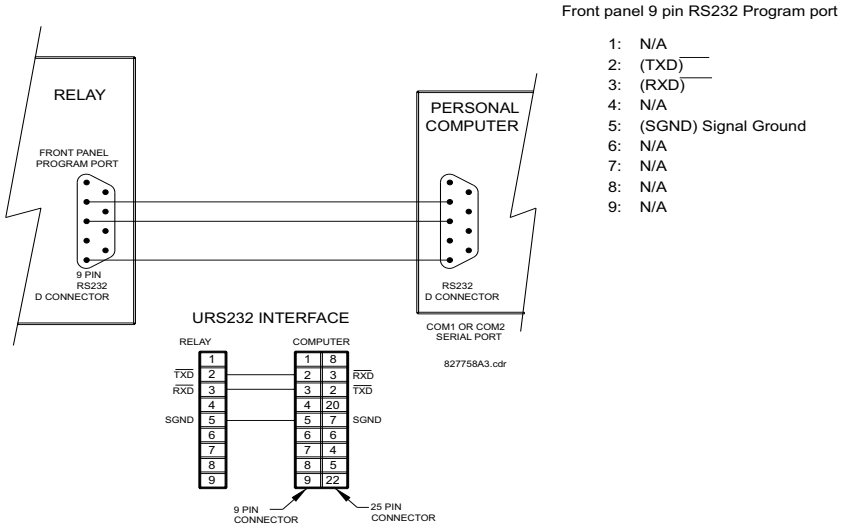



**Figure 3–26: RS232 FACEPLATE PORT CONNECTION**

### 3.2.9 CPU COMMUNICATION PORTS

#### a) OVERVIEW

In addition to the faceplate RS232 port, the L30 provides a rear RS485 communication port.

The CPU modules do not require a surge ground connection.

If using a Process Bus Module and IRIG-B as the synchronizing source, GE recommends moving the grounding from the IRIG-B generator to UR terminal D4a in order to better protect the IRIG-B input from long bursts of transient noise.

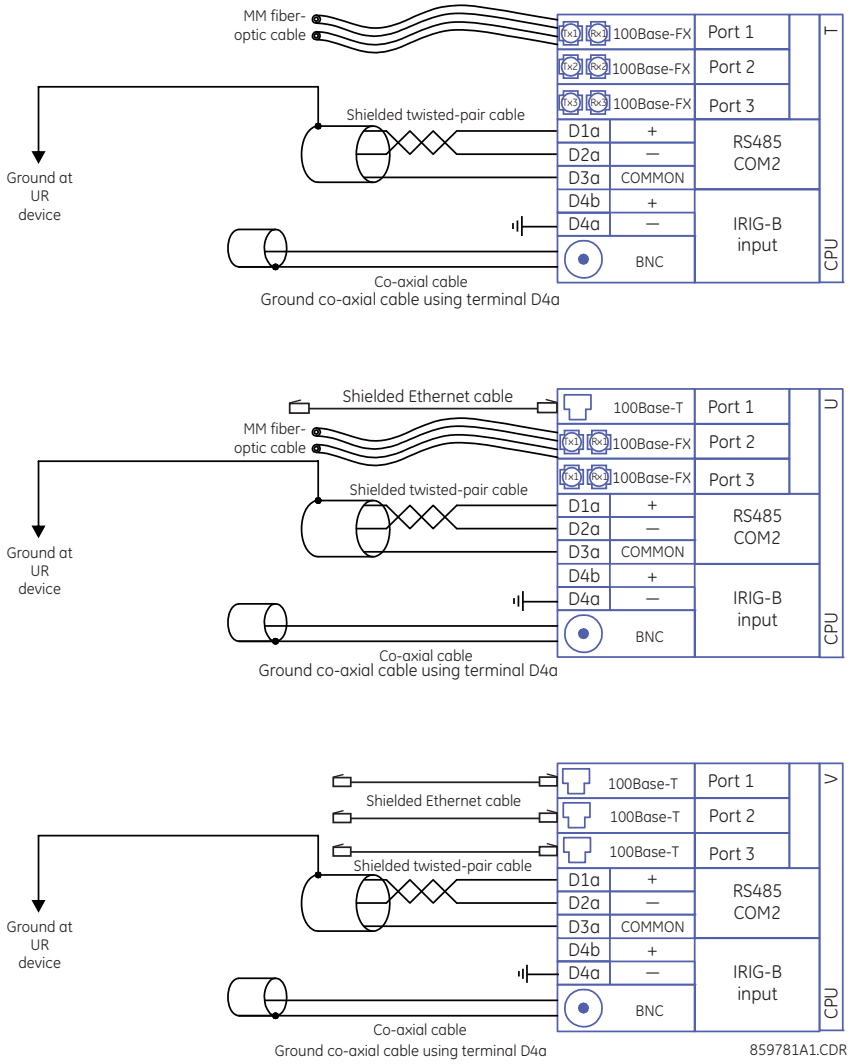



**Figure 3–27: CPU MODULE WIRING WHEN USING PROCESS BUS MODULE**

If not using a Process Bus Module, the following IRIG-B cable and ground connection is appropriate.

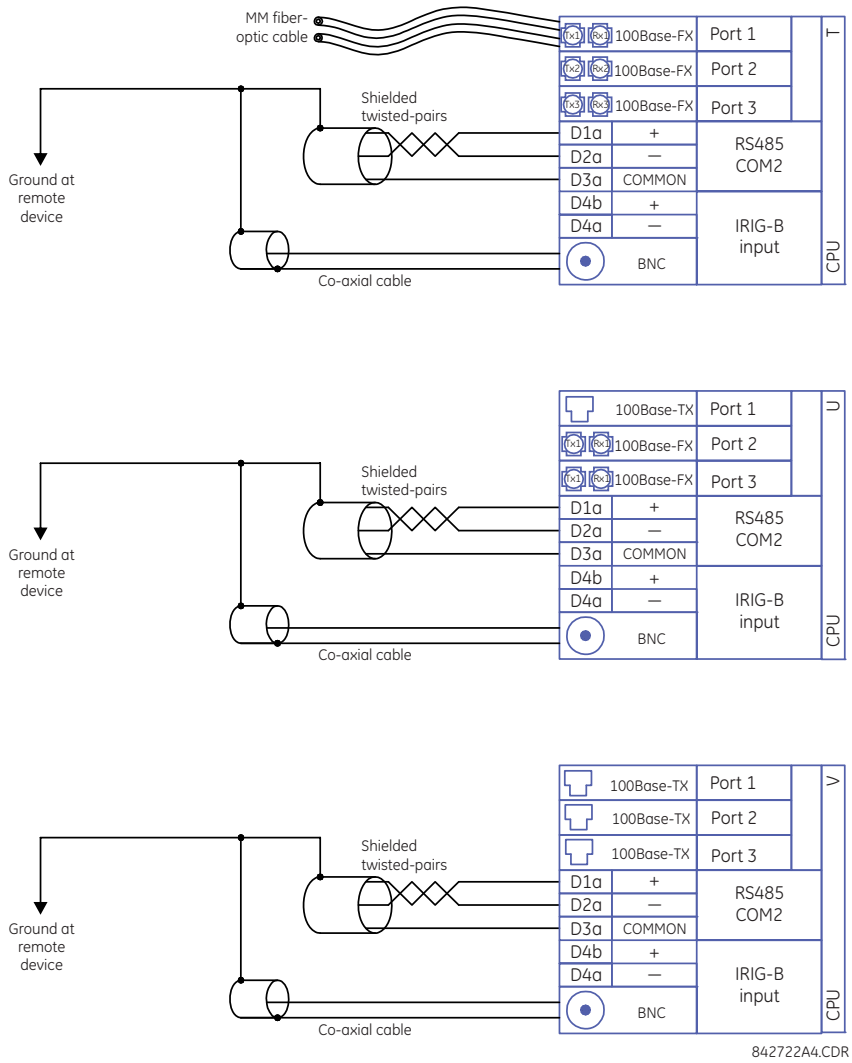



**Figure 3–28: CPU MODULE WIRING FOR IRIG-B WITHOUT PROCESS BUS MODULE**

### b) RS485 PORTS

RS485 data transmission and reception are accomplished over a single twisted pair with transmit and receive data alternating over the same two wires. Through the use of the port, continuous monitoring and control from a remote computer, SCADA system, or PLC is possible.

To minimize errors from noise, the use of shielded twisted pair wire is recommended. Correct polarity must also be observed. For instance, the relays must be connected with all RS485 "+" terminals connected together, and all RS485 "–" terminals connected together. Though data is transmitted over a two-wire twisted pair, all RS485 devices require a shared reference, or common voltage. This common voltage is implied to be a power supply common. Some systems allow the shield (drain wire) to be used as common wire and to connect directly to the L30 COM terminal (#3); others function correctly only if the common wire is connected to the L30 COM terminal, but insulated from the shield.

To avoid loop currents, ground the shield at only one point. If other system considerations require the shield to be grounded at more than one point, install resistors (typically 100 ohms) between the shield and ground at each grounding point. Each relay needs to be daisy-chained to the next one in the link. A maximum of 32 relays can be connected in this manner without exceeding driver capability. For larger systems, additional serial channels must be added. It is also possible to use commercially available repeaters to have more than 32 relays on a single channel. Avoid star or stub connections entirely.

Lightning strikes and ground surge currents can cause large momentary voltage differences between remote ends of the communication link. For this reason, surge protection devices are internally provided at both communication ports. An isolated power supply with an optocoupled data interface also acts to reduce noise coupling. To ensure maximum reliability, all equipment should have similar transient protection devices installed.

Terminate both ends of the RS485 circuit with an impedance as shown below.

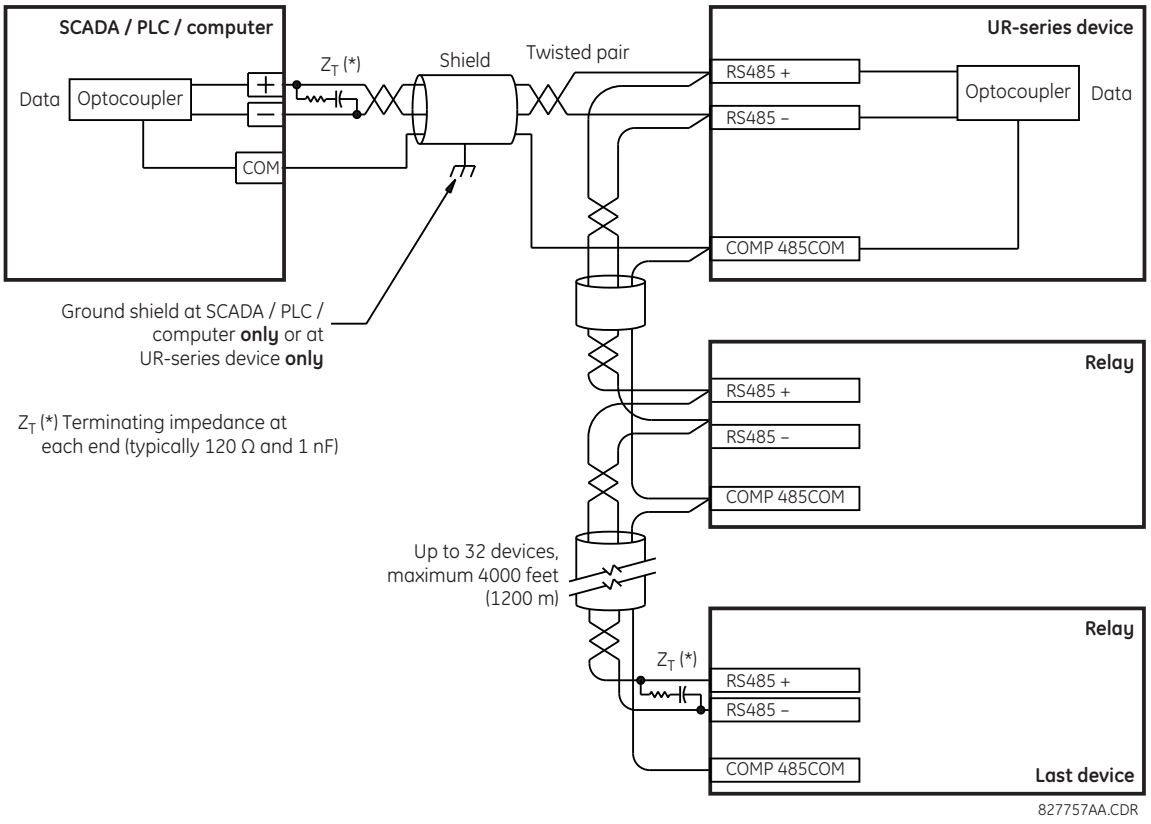



**Figure 3–29: RS485 SERIAL CONNECTION**

### c) 100BASE-FX FIBER OPTIC PORTS

Ensure that the dust covers are installed when the fiber is not in use. Dirty or scratched connectors can lead to high losses on a fiber link.

The fiber optic communication ports allow for fast and efficient communications between relays at 100 Mbps. Optical fiber can be connected to the relay supporting a wavelength of 1310 nm in multi-mode.

### 3.2.10 IRIG-B

IRIG-B is a standard time code format that allows stamping of events to be synchronized among connected devices. The IRIG-B code allows time accuracies of up to 100 ns. Using the IRIG-B input, the L30 operates an internal oscillator with 1 µs resolution and accuracy. The IRIG time code formats are serial, pulse width-modulated codes that can be either DC level shifted or amplitude modulated (AM). The GE MultiSync 100 1588 GPS Clock as well as third-party equipment are available for generating the IRIG-B signal; this equipment can use a global positioning system (GPS) satellite system to obtain the time reference so that devices at different geographic locations can be synchronized.



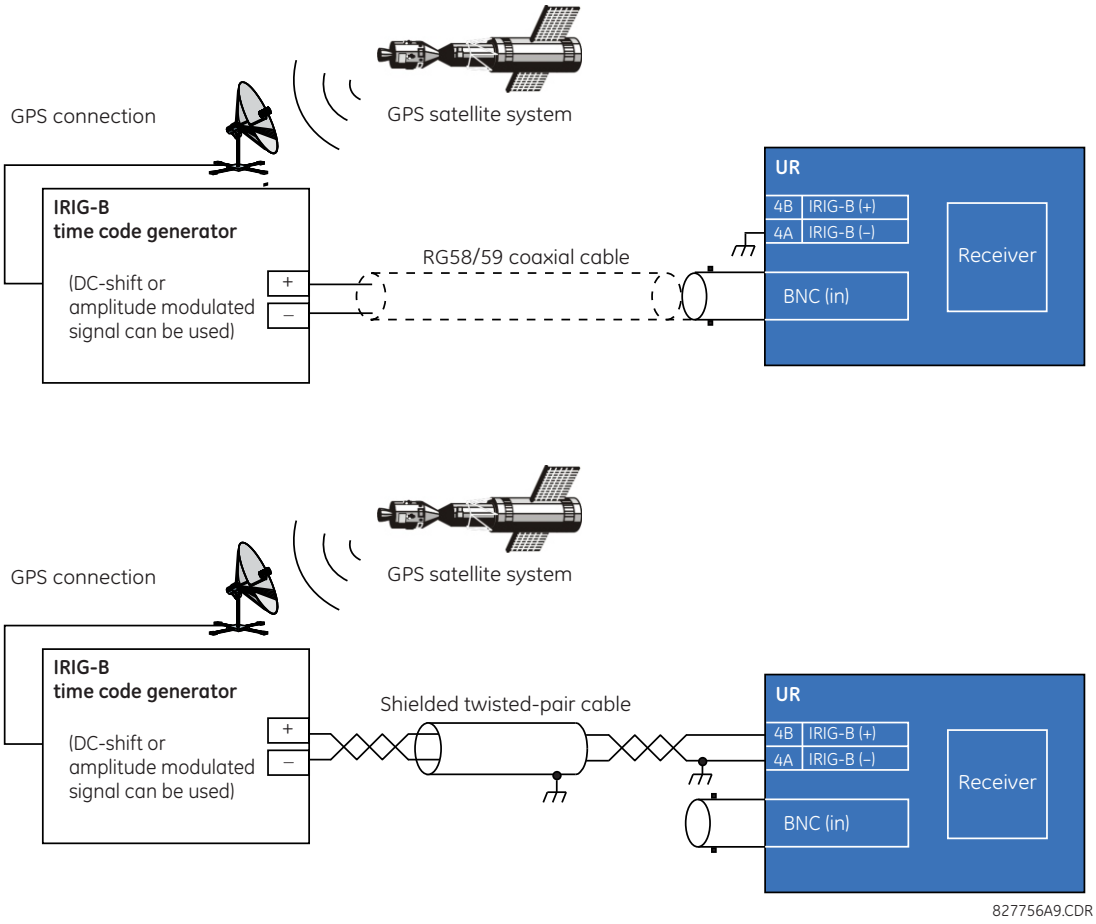



**Figure 3–30: OPTIONS FOR THE IRIG-B CONNECTION**

NOTE

Using an amplitude modulated receiver causes errors up to 1 ms in event time-stamping.

The L30 is intended for use with external clocks that set the IRIG-B control bits according to IEEE Std C37.118.1-2011. When used with a source that sets the IRIG-B control bits according to IEEE Std 1344-1995, the source must have the sign of its local time offset setting reversed, and if daylight savings time (DST) is used, the source's DST start and DST stop date settings must be interchanged.

NOTE

When IRIG-B is used as the time synchronization source for synchrophasors, the DC level shifted option must be used in order to achieve the 1% Total Vector Error specified by the standard. If amplitude modulated IRIG-B is used, it results in a 20 to 25 degree error in the synchrophasor angle measurement. The IEEE 1588 Precision Time Protocol can also be used to achieve accurate time synchronization for synchrophasor calculation.

### 3.3.1 DESCRIPTION

A special inter-relay communications module is available for the L30. This module is plugged into slot "W" in horizontally mounted units and slot "R" in vertically mounted units. Inter-relay channel communications is not the same as 10/100Base-F interface communications (available as an option with the CPU module). Channel communication is used for sharing data among relays.

The inter-relay communications modules are available with several interfaces and some are outlined here in more detail. Those that apply depend on options purchased. The options are outlined in the Inter-Relay Communications section of the Order Code tables in Chapter 2.

All of the fiber modules use ST type connectors. For two-terminal applications, each L30 relay requires at least one communications channel.



NOTE

The current differential function must be "Enabled" for the communications module to properly operate. Refer to **SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ LINE DIFFERENTIAL ⇨ CURRENT DIFFERENTIAL** menu.

The fiber optic modules (7A to 7W) are designed for back-to-back connections of UR-series relays only. For connections to higher-order systems, use the 72 to 77 modules or the 2A and 2B modules.

**⚠CAUTION** **Observing any fiber transmitter output can injure the eye.**

### 3.3.2 FIBER: LED AND ELED TRANSMITTERS

The following figure shows the configuration for the 7A, 7B, 7C, 7H, 7I, and 7J fiber-only modules.

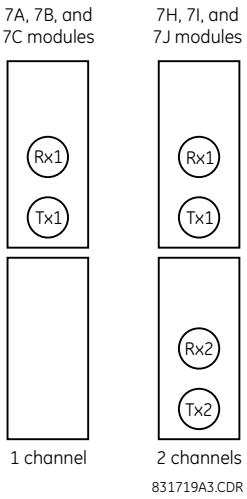



**Figure 3–31: LED AND ELED FIBER MODULES**

### 3.3.3 FIBER-LASER TRANSMITTERS

The following figure shows the configuration for the 72, 73, 7D, and 7K fiber-laser modules.

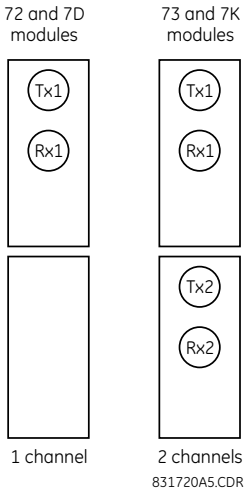



**Figure 3–32: 7X LASER FIBER MODULES**

The following figure shows configuration for the 2I and 2J fiber-laser module.

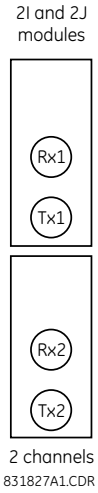



**Figure 3–33: 2I AND 2J LASER FIBER MODULE**

**CAUTION** **Observing any fiber transmitter output can injure the eye.**

**NOTICE** When using a laser Interface, attenuators can be necessary to ensure that you do not exceed the maximum optical input power to the receiver.

### a) DESCRIPTION

The following figure shows the 64K ITU G.703 co-directional interface configuration.

NOTE

The G.703 module is fixed at 64 kbps. The **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DIRECT I/O ⇨⇩ DIRECT I/O DATA RATE** setting is not applicable to this module.

AWG 24 twisted shielded pair is recommended for external connections, with the shield grounded only at one end. Connecting the shield to pin X1a or X6a grounds the shield since these pins are internally connected to ground. Thus, if pin X1a or X6a is used to ground the shield at one end, do not ground the shield at the other end. This interface module is protected by surge suppression devices.



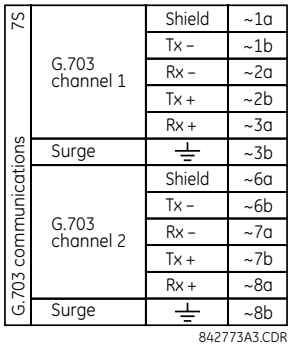



**Figure 3–34: G.703 INTERFACE CONFIGURATION**

The following figure shows the typical pin interconnection between two G.703 interfaces. For the actual physical arrangement of these pins, see the Rear Terminal Layout section earlier in this chapter. All pin interconnections are to be maintained for a connection to a multiplexer.

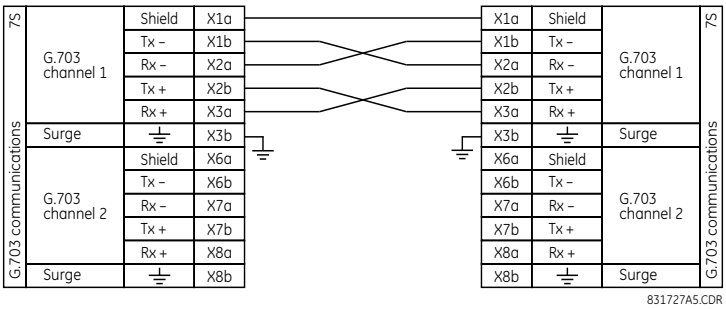



**Figure 3–35: TYPICAL PIN INTERCONNECTION BETWEEN TWO G.703 INTERFACES**

NOTE

Pin nomenclature can differ from one manufacturer to another. Therefore, it is not uncommon to see pinouts numbered TxA, TxB, RxA and RxB. In such cases, it can be assumed that "A" is equivalent to "+" and "B" is equivalent to "–".

### b) G.703 SELECTION SWITCH PROCEDURES

1. With the power to the relay off, remove the G.703 module (7R or 7S) as follows. Record the original location of the module to help ensure that the same or replacement module is inserted into the correct slot.
2. Simultaneously pull the ejector/inserter clips located at the top and at the bottom of each module in order to release the module for removal.
3. Remove the module cover screw.
4. Remove the top cover by sliding it towards the rear and then lift it upwards.
5. Set the timing selection switches (channel 1, channel 2) to the desired timing modes.

6. Replace the top cover and the cover screw.
7. Re-insert the G.703 module. Take care to ensure that the **correct** module type is inserted into the **correct** slot position. The ejector/inserter clips located at the top and at the bottom of each module must be in the disengaged position as the module is smoothly inserted into the slot. Once the clips have cleared the raised edge of the chassis, engage the clips simultaneously. When the clips have locked into position, the module is fully inserted.

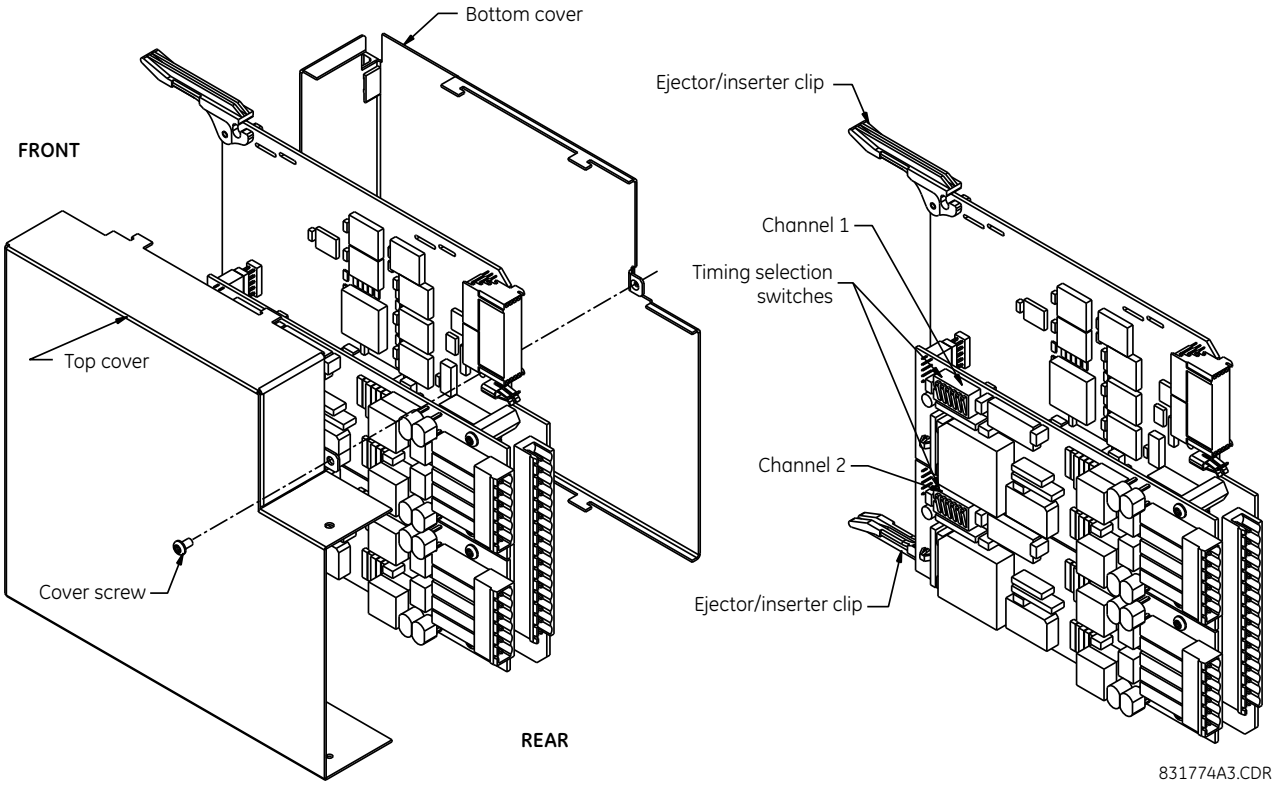



**Figure 3–36: G.703 TIMING SELECTION SWITCH SETTING**

**Table 3–5: G.703 TIMING SELECTIONS**

| SWITCHES | FUNCTION |
|---|---|
| S1 | OFF → octet timing disabled<br>ON → octet timing 8 kHz |
| S5 and S6 | S5 = OFF and S6 = OFF → loop timing mode<br>S5 = ON and S6 = OFF → internal timing mode<br>S5 = OFF and S6 = ON → minimum remote loopback mode<br>S5 = ON and S6 = ON → dual loopback mode |

### c) G.703 OCTET TIMING

If octet timing is enabled (ON), this 8 kHz signal is asserted during the violation of bit 8 (LSB) necessary for connecting to higher order systems. When L30s are connected back-to-back, octet timing is disabled (OFF).

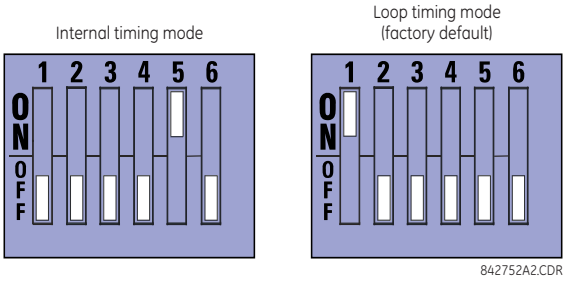
### d) G.703 TIMING MODES

There are two timing modes for the G.703 module: internal timing mode and loop timing mode (default).

- **Internal Timing Mode:** The system clock is generated internally. Therefore, the G.703 timing selection should be in the internal timing mode for back-to-back (UR-to-UR) connections. For back-to-back connections, set for octet timing (S1 = OFF) and timing mode to internal timing (S5 = ON and S6 = OFF).
- **Loop Timing Mode:** The system clock is derived from the received line signal. Therefore, the G.703 timing selection should be in loop timing mode for connections to higher order systems. For connection to a higher order system (UR-

to-multiplexer, factory defaults), set to octet timing (S1 = ON) and set timing mode to loop timing (S5 = OFF and S6 = OFF).

The switch settings for the internal and loop timing modes are shown below:






### e) G.703 TEST MODES

In *minimum remote loopback* mode, the multiplexer is enabled to return the data from the external interface without any processing to assist in diagnosing G.703 line-side problems irrespective of clock rate. Data enters from the G.703 inputs, passes through the data stabilization latch which also restores the proper signal polarity, passes through the multiplexer and then returns to the transmitter. The differential received data is processed and passed to the G.703 transmitter module after which point the data is discarded. The G.703 receiver module is fully functional and continues to process data and passes it to the differential Manchester transmitter module. Since timing is returned as it is received, the timing source is expected to be from the G.703 line side of the interface.

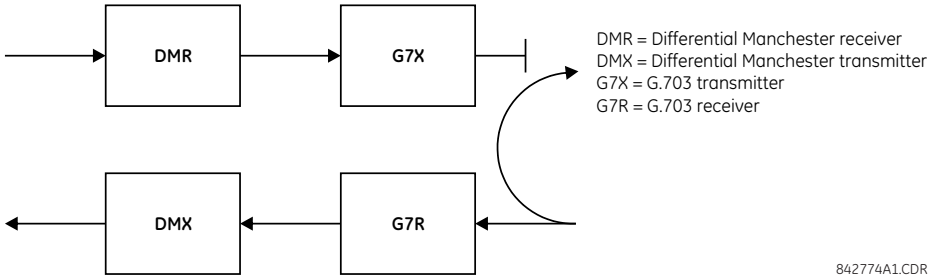



**Figure 3–37: G.703 MINIMUM REMOTE LOOPBACK MODE**

In *dual loopback mode*, the multiplexers are active and the functions of the circuit are divided into two with each receiver/transmitter pair linked together to deconstruct and then reconstruct their respective signals. Differential Manchester data enters the Differential Manchester receiver module and then is returned to the differential Manchester transmitter module. Likewise, G.703 data enters the G.703 receiver module and is passed through to the G.703 transmitter module to be returned as G.703 data. Because of the complete split in the communications path and because, in each case, the clocks are extracted and reconstructed with the outgoing data, in this mode there must be two independent sources of timing. One source lies on the G.703 line side of the interface while the other lies on the differential Manchester side of the interface.

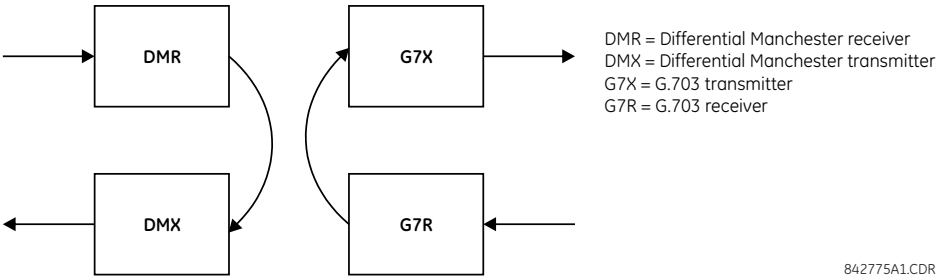



**Figure 3–38: G.703 DUAL LOOPBACK MODE**

### a) DESCRIPTION

There are three RS422 inter-relay communications modules available: single-channel RS422 (module 7T), dual-channel RS422 (module 7W), and dual-channel dual-clock RS422 (module 7V). The modules can be configured to run at 64 or 128 kbps. AWG 24 twisted shielded pair cable is recommended for external connections. These modules are protected by optically-isolated surge suppression devices.

NOTE

The two-channel two-clock RS422 interface (module 7V) is intended for use with two independent channel banks with two independent clocks. It is intended for situations where a single clock for both channels is not acceptable.

The shield pins (6a and 7b) are internally connected to the ground pin (8a). Proper shield termination is as follows:

- Site 1: Terminate shield to pins 6a or 7b or both.
- Site 2: Terminate shield to COM pin 2b.

Match the clock terminating impedance with the impedance of the line.

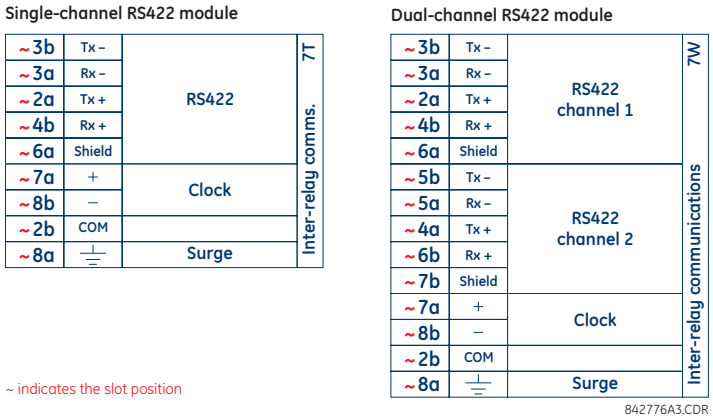



**Figure 3–39: RS422 INTERFACE CONNECTIONS**

The following figure shows the typical pin interconnection between two single-channel RS422 interfaces installed in slot W. All pin interconnections are to be maintained for a connection to a multiplexer.

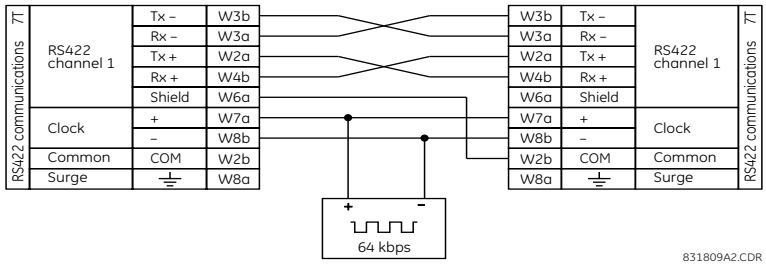



**Figure 3–40: TYPICAL PIN INTERCONNECTION BETWEEN TWO RS422 INTERFACES**

### b) TWO-CHANNEL APPLICATION VIA MULTIPLEXERS

The RS422 interface can be used for single channel or two channel applications over SONET/SDH or multiplexed systems. When used in single-channel applications, the RS422 interface links to higher order systems in a typical fashion observing transmit (Tx), receive (Rx), and send timing (ST) connections. However, when used in two-channel applications, certain criteria must be followed since there is one clock input for the two RS422 channels. The system functions correctly when the following connections are observed and your data module has a terminal timing feature. Terminal timing is a common feature to most synchronous data units that allows the module to accept timing from an external source. Using the terminal timing feature, two channel applications can be achieved if these connections are followed: The send timing outputs from

the multiplexer (data module 1), connects to the clock inputs of the UR–RS422 interface in the usual fashion. In addition, the send timing outputs of data module 1 is also paralleled to the terminal timing inputs of data module 2. By using this configuration, the timing for both data modules and both UR–RS422 channels are derived from a single clock source. As a result, data sampling for both of the UR–RS422 channels is synchronized via the send timing leads on data module 1 as shown below. If the terminal timing feature is not available or this type of connection is not desired, the G.703 interface is a viable option that does not impose timing restrictions.

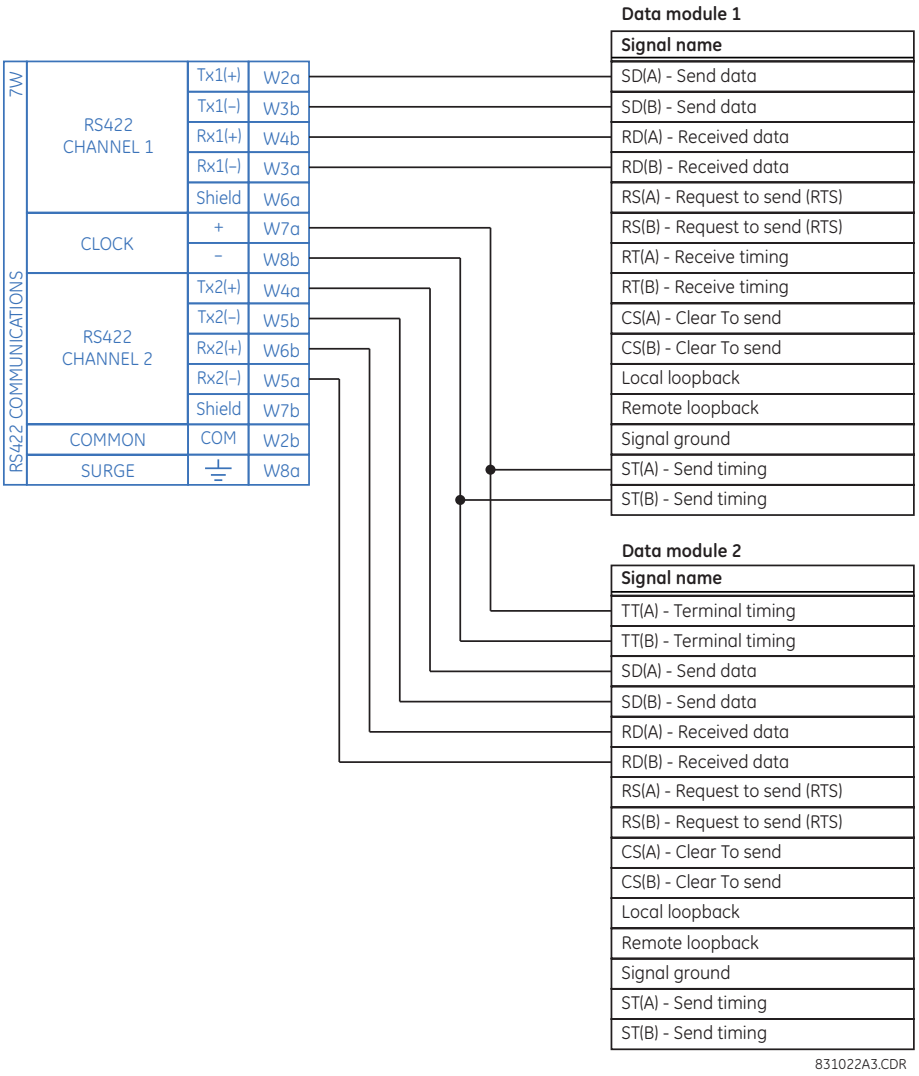



**Figure 3–41: TIMING CONFIGURATION FOR RS422 TWO-CHANNEL, THREE-TERMINAL APPLICATION**

Data module 1 provides timing to the L30 RS422 interface via the ST(A) and ST(B) outputs. Data module 1 also provides timing to data module 2 TT(A) and TT(B) inputs via the ST(A) and AT(B) outputs. The data module pin numbers have been omitted in the figure above since they vary by manufacturer.

### c) TRANSMIT TIMING

The RS422 interface accepts one clock input for transmit timing. It is important that the rising edge of the 64 kHz transmit timing clock of the multiplexer interface is sampling the data in the center of the transmit data window. Therefore, it is important to confirm clock and data transitions to ensure proper system operation. For example, the following figure shows the positive edge of the Tx clock in the center of the Tx data bit.

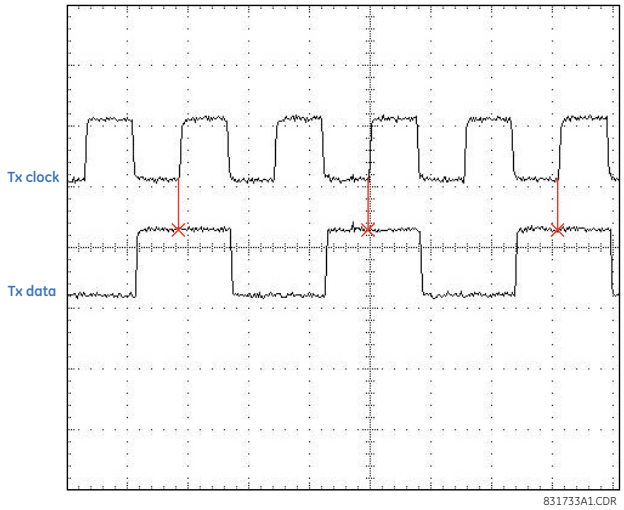



Figure 3–42: CLOCK AND DATA TRANSITIONS

### d) RECEIVE TIMING

The RS422 interface utilizes NRZI-MARK modulation code and; therefore, does not rely on an Rx clock to recapture data. NRZI-MARK is an edge-type, invertible, self-clocking code.

To recover the Rx clock from the data-stream, an integrated DPLL (digital phase lock loop) circuit is utilized. The DPLL is driven by an internal clock, which is 16-times over-sampled, and uses this clock along with the data-stream to generate a data clock that can be used as the SCC (serial communication controller) receive clock.

## 3.3.6 TWO-CHANNEL TWO-CLOCK RS422 INTERFACE

The two-channel two-clock RS422 interface (module 7V) is for use with the synchrophasor feature. The figure shows the module connections.

| 7V | | | |
|---|---|---|---|
| RS422 communications | RS422 channel 1 | Tx – | ~3b |
| | | Rx – | ~3a |
| | | Tx + | ~2a |
| | | Rx + | ~4b |
| | | Shield | ~6a |
| | RS422 channel 2 | Tx – | ~5b |
| | | Rx – | ~5a |
| | | Tx + | ~4a |
| | | Rx + | ~6b |
| | | Shield | ~7b |
| | Channel 1 clock | Tx – | ~7a |
| | | Rx – | ~8b |
| | Channel 2 clock | Tx – | ~1b |
| | | Rx – | ~1a |
| | Common | COM | ~2b |
| | Surge | ⏚ | ~8a |

842802A2.CDR

Figure 3–43: TWO-CHANNEL TWO-CLOCK RS422 INTERFACE CONNECTIONS

## 3.3.7 RS422 AND FIBER INTERFACE

The following figure shows the combined RS422 plus fiberoptic interface configuration at 64K baud. The 7L, 7M, 7N, 7P, and 74 modules are used in two-terminal with a redundant channel or three-terminal configurations where channel 1 is employed via the RS422 interface (possibly with a multiplexer) and channel 2 via direct fiber.

AWG 20-24 twisted shielded pair is recommended for external RS422 connections and ground the shield only at one end. For the direct fiber channel, address power budget issues properly.

**NOTICE** When using a LASER Interface, attenuators can be necessary to ensure that you do not exceed maximum optical input power to the receiver.

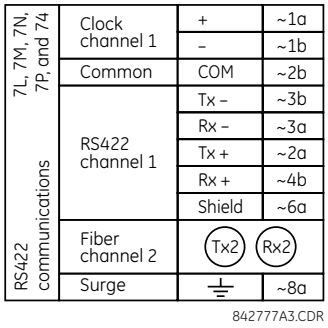



**Figure 3–44: RS422 AND FIBER INTERFACE CONNECTION**

Connections shown above are for multiplexers configured as DCE (data communications equipment) units.

### 3.3.8 G.703 AND FIBER INTERFACE

The figure below shows the combined G.703 plus fiberoptic interface configuration at 64 kbps. The 7E, 7F, 7G, 7Q, and 75 modules are used in configurations where channel 1 is employed via the G.703 interface (possibly with a multiplexer) and channel 2 via direct fiber. AWG 24 twisted shielded pair is recommended for external G.703 connections connecting the shield to pin 1a at one end only. For the direct fiber channel, address power budget issues properly. See previous sections for additional details on the G.703 and fiber interfaces.

**NOTICE** When using a laser Interface, attenuators can be necessary to ensure that you do not exceed the maximum optical input power to the receiver.

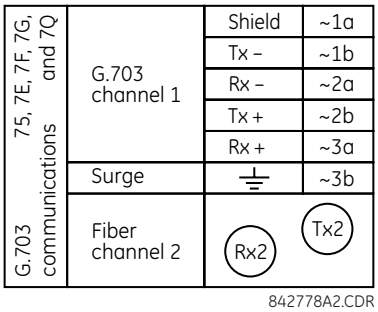



**Figure 3–45: G.703 AND FIBER INTERFACE CONNECTION**

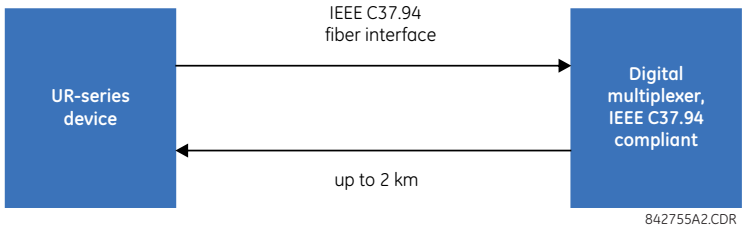
### 3.3.9 IEEE C37.94 INTERFACE

The UR-series IEEE C37.94 communication modules (modules types 2I, 2J, 76, and 77) are designed to interface with IEEE C37.94 compliant digital multiplexers or an IEEE C37.94 compliant interface converter for use with direct input and output applications. The IEEE C37.94 standard defines a point-to-point optical link for synchronous data between a multiplexer and a teleprotection device. This data is typically 64 kbps, but the standard provides for speeds up to 64*n* kbps, where *n* = 1, 2,..., 12. The UR-series C37.94 communication modules are either 64 kbps (with *n* fixed at 1) or 128 kbps (with *n* fixed at 2). The frame is a valid International Telecommunications Union (ITU-T) recommended G.704 pattern from the standpoint of framing and data rate. The frame is 256 bits and is repeated at a frame rate of 8000 Hz, with a resultant bit rate of 2048 kbps.

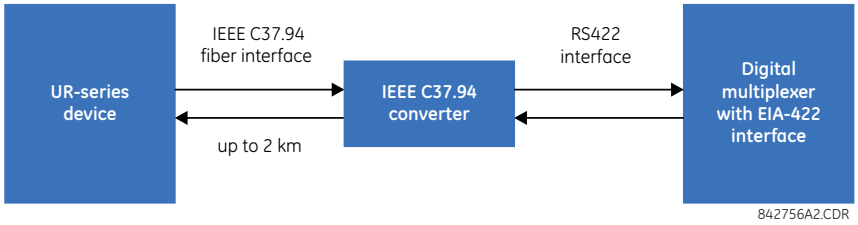
The specifications for the module are as follows:.

- IEEE standard: C37.94 for 2 × 64 kbps optical fiber interface (for 76 and 77 modules)
- Fiber optic cable type: 50 nm or 62.5 µm core diameter optical fiber
- Fiber optic mode: multimode
- Fiber optic cable length: up to 2 km
- Fiber optic connector: type ST
- Wavelength: 820 ±40 nm
- Connection: as per all fiber optic connections, a Tx-to-Rx connection is required

The UR-series C37.94 communication module can be connected directly to any compliant digital multiplexer that supports the IEEE C37.94 standard shown as follows.

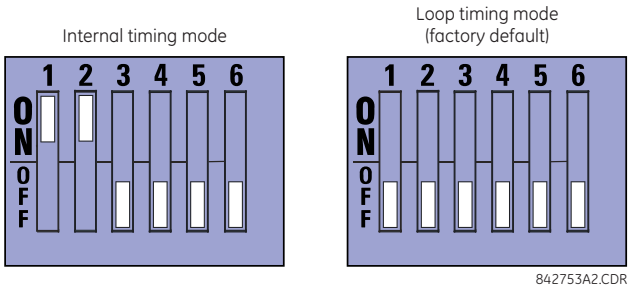



The UR-series C37.94 communication module can be connected to the electrical interface (G.703, RS422, or X.21) of a non-compliant digital multiplexer via an optical-to-electrical interface converter that supports the IEEE C37.94 standard, shown as follows.




In 2008, GE Grid Solutions released revised modules 76 and 77 for C37.94 communication to enable multi-ended fault location functionality with firmware 5.60 release and higher. All modules 76 and 77 shipped the change support this feature and are fully backward compatible with firmware releases below 5.60. For customers using firmware release 5.60 and higher, the module can be identified with "Rev D" printed on the module and is to be used on all ends of L30 communication for two and three terminal applications. Failure to use it at all ends results in intermittent communication alarms. For customers using firmware revisions below 5.60, it is not required to match the revision of the modules installed.

The UR-series C37.94 communication module has six switches to set the clock configuration. The following figure shows the functions of these control switches.



For the internal timing mode, the system clock is generated internally. Therefore, the timing switch selection should be internal timing for relay 1 and loop timed for relay 2. There must be only one timing source configured.

For the looped timing mode, the system clock is derived from the received line signal. Therefore, the timing selection should be in loop timing mode for connections to higher order systems.

The IEEE C37.94 communications module cover removal procedure is as follows:

1. With power to the relay off, remove the IEEE C37.94 module (type 2I, 2J, 76 or 77 module) as follows. Record the original location of the module to help ensure that the same or replacement module is inserted into the correct slot.
2. Simultaneously pull the ejector/inserter clips located at the top and at the bottom of each module in order to release the module for removal.
3. Remove the module cover screw.
4. Remove the top cover by sliding it towards the rear and then lift it upwards.
5. Set the timing selection switches (channel 1, channel 2) to the desired timing modes (see description above).
6. Replace the top cover and the cover screw.
7. Re-insert the IEEE C37.94 module. Take care to ensure that the **correct** module type is inserted into the **correct** slot position. The ejector/inserter clips located at the top and at the bottom of each module must be in the disengaged position as the module is smoothly inserted into the slot. Once the clips have cleared the raised edge of the chassis, engage the clips simultaneously. When the clips have locked into position, the module is fully inserted.

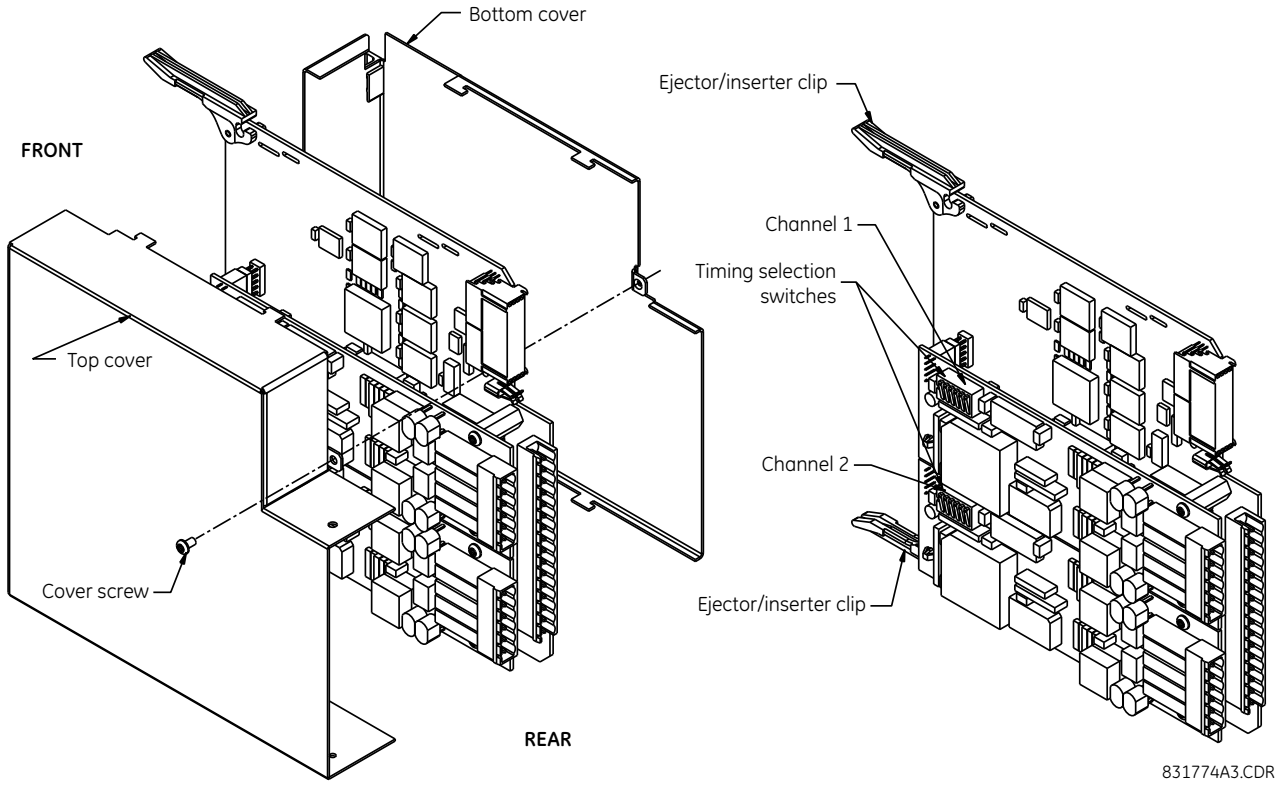



**Figure 3–46: IEEE C37.94 TIMING SELECTION SWITCH SETTING**

Modules shipped since January 2012 have status LEDs that indicate the status of the DIP switches, as shown in the following figure.

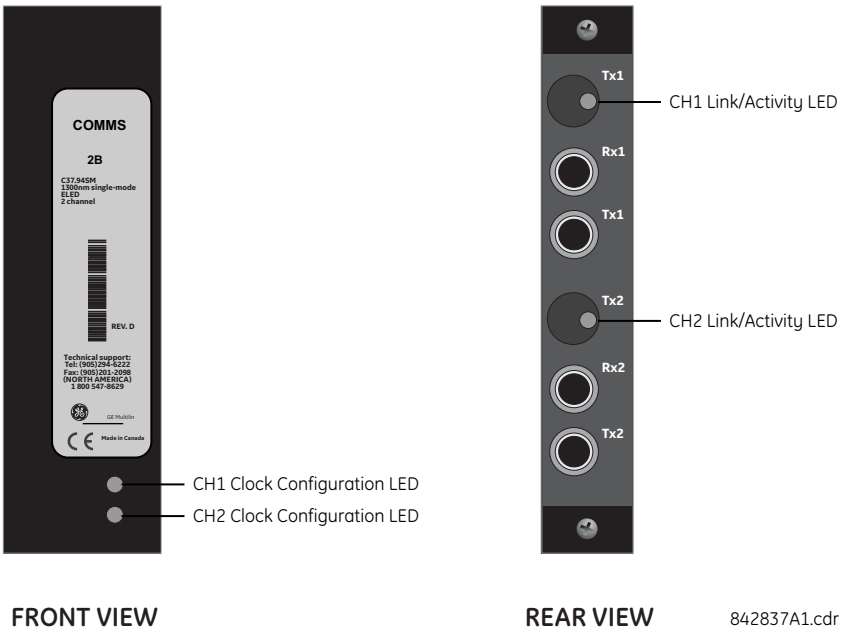



**Figure 3–47: STATUS LEDS**

The clock configuration LED status is as follows:

- Flashing green — loop timing mode while receiving a valid data packet
- Flashing yellow — internal mode while receiving a valid data packet
- Solid red — (switch to) internal timing mode while not receiving a valid data packet

The link/activity LED status is as follows:

- Flashing green — FPGA is receiving a valid data packet
- Solid yellow — FPGA is receiving a "yellow bit" and remains yellow for each "yellow bit"
- Solid red — FPGA is not receiving a valid packet or the packet received is invalid

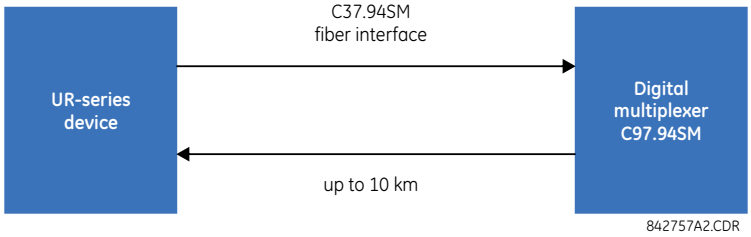
### 3.3.10 C37.94SM INTERFACE

The UR-series C37.94SM communication modules (2A and 2B) are designed to interface with modified IEEE C37.94 compliant digital multiplexers or IEEE C37.94 compliant interface converters that have been converted from 820 nm multi-mode fiber optics to 1300 nm ELED single-mode fiber optics. The IEEE C37.94 standard defines a point-to-point optical link for synchronous data between a multiplexer and a teleprotection device. This data is typically 64 kbps, but the standard provides for speeds up to 64*n* kbps, where *n* = 1, 2,…, 12. The UR-series C37.94SM communication module is 64 kbps only with *n* fixed at 1. The frame is a valid International Telecommunications Union (ITU-T) recommended G.704 pattern from the standpoint of framing and data rate. The frame is 256 bits and is repeated at a frame rate of 8000 Hz, with a resultant bit rate of 2048 kbps.

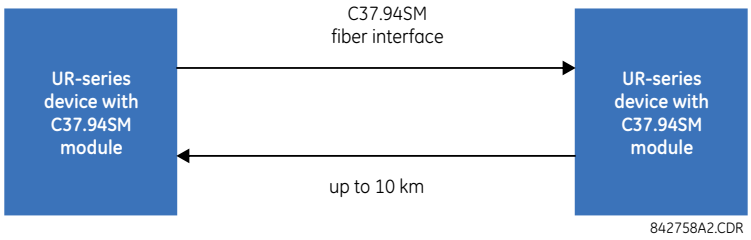
The specifications for the module are as follows:

- Emulated IEEE standard: emulates C37.94 for 1 × 64 kbps optical fiber interface (modules set to *n* = 1 or 64 kbps)
- Fiber optic cable type: 9/125 μm core diameter optical fiber
- Fiber optic mode: single-mode, ELED compatible with HP HFBR-1315T transmitter and HP HFBR-2316T receiver
- Fiber optic cable length: up to 11.4 km
- Fiber optic connector: type ST
- Wavelength: 1300 ±40 nm
- Connection: as per all fiber optic connections, a Tx-to-Rx connection is required

The UR-series C37.94SM communication module can be connected *directly* to any compliant digital multiplexer that supports C37.94SM as shown below.

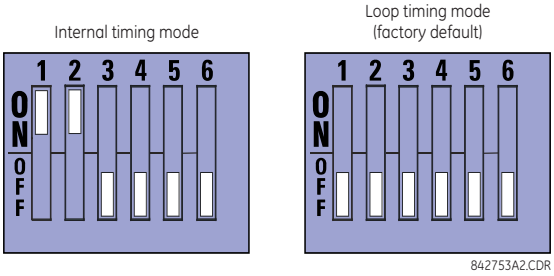



It can also can be connected **directly** to any other UR-series relay with a C37.94SM module as shown below.




In 2008, GE Grid Solutions released revised modules 2A and 2B for C37.94SM communication to enable multi-ended fault location functionality with firmware 5.60 release and higher. All modules 2A and 2B shipped since the change support this feature and are fully backward compatible with firmware releases below 5.60. For customers using firmware release 5.60 and higher, the module can be identified with "Rev D" printed on the module and is to be used on all ends of L30 communication for two and three terminal applications. Failure to use it at all ends results in intermittent communication alarms. For customers using firmware revisions below 5.60, it is not required to match the revision of the modules installed.

The UR-series C37.94SM communication module has six switches that are used to set the clock configuration. The functions of these control switches are shown below.




For the internal timing mode, the system clock is generated internally. Therefore, the timing switch selection should be internal timing for relay 1 and loop timed for relay 2. There must be only one timing source configured.

For the looped timing mode, the system clock is derived from the received line signal. Therefore, the timing selection should be in loop timing mode for connections to higher order systems.

The C37.94SM communications module cover removal procedure is as follows:

1. With power to the relay off, remove the C37.94SM module (modules 2A or 2B) as follows. Record the original location of the module to help ensure that the same or replacement module is inserted into the correct slot.
2. Simultaneously pull the ejector/inserter clips located at the top and at the bottom of each module in order to release the module for removal.
3. Remove the module cover screw.
4. Remove the top cover by sliding it towards the rear and then lift it upwards.
5. Set the timing selection switches (channel 1, channel 2) to the desired timing modes (see description above).
6. Replace the top cover and the cover screw.
7. Re-insert the C37.94SM module. Take care to ensure that the **correct** module type is inserted into the **correct** slot position. The ejector/inserter clips located at the top and at the bottom of each module must be in the disengaged position as the module is smoothly inserted into the slot. Once the clips have cleared the raised edge of the chassis, engage the clips simultaneously. When the clips have locked into position, the module is fully inserted.

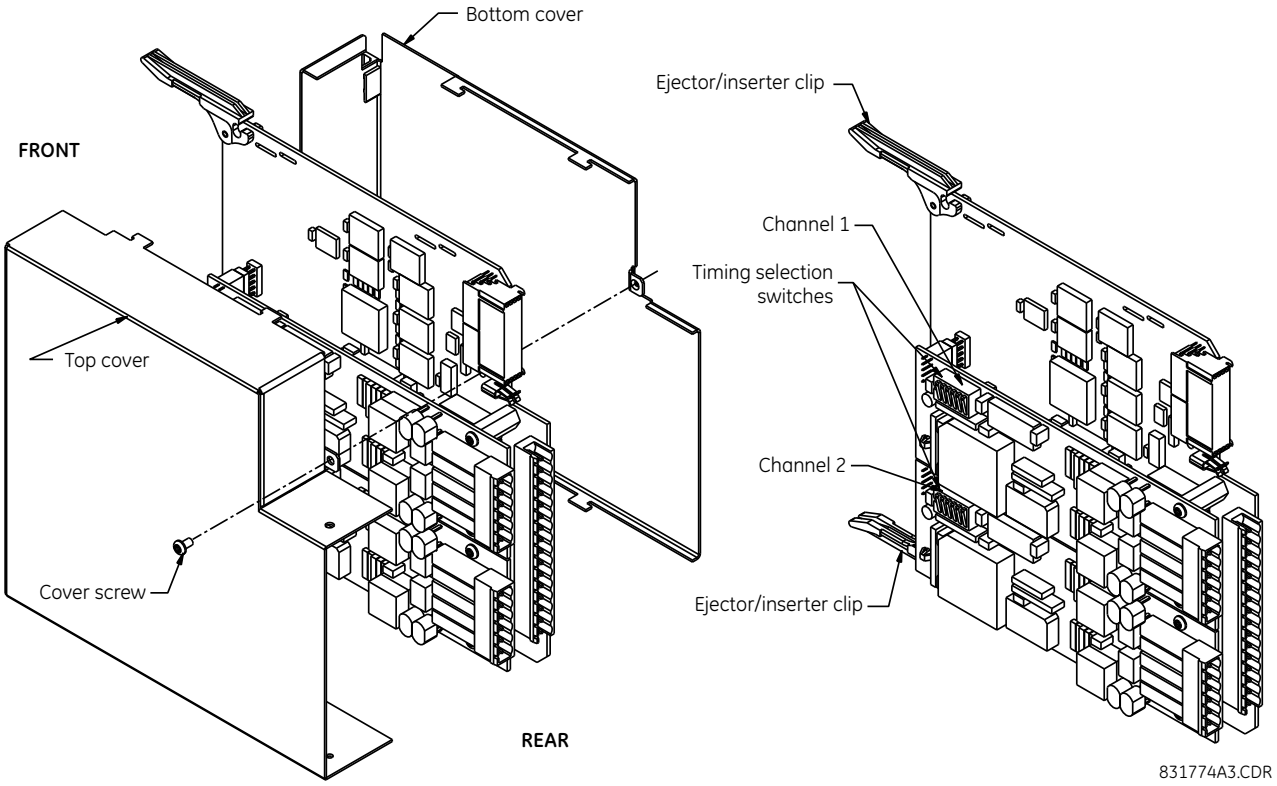



**Figure 3–48: C37.94SM TIMING SELECTION SWITCH SETTING**

Modules shipped since January 2012 have status LEDs that indicate the status of the DIP switches, as shown in the following figure.

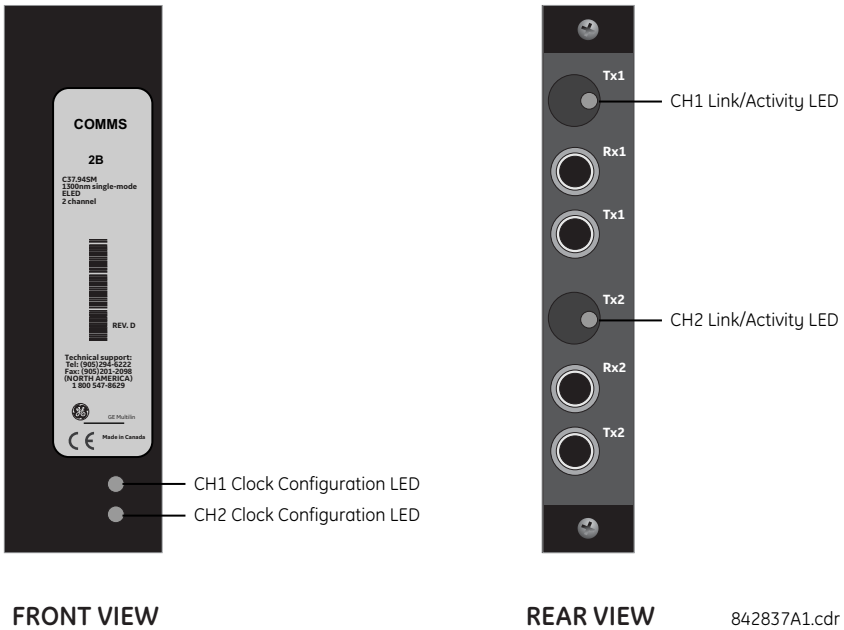



**Figure 3–49: STATUS LEDS**

The clock configuration LED status is as follows:

- Flashing green — loop timing mode while receiving a valid data packet

- Flashing yellow — internal mode while receiving a valid data packet
- Solid red — (switch to) internal timing mode while not receiving a valid data packet

The link/activity LED status is as follows:

- Flashing green — FPGA is receiving a valid data packet
- Solid yellow — FPGA is receiving a "yellow bit" and remains yellow for each "yellow bit"
- Solid red — FPGA is not receiving a valid packet or the packet received is invalid

### 4.1.1 INTRODUCTION

The EnerVista UR Setup software provides a graphical user interface (GUI) as one of two human interfaces to a UR device. The alternate human interface is implemented via the device's faceplate keypad and display (see the Faceplate Interface section in this chapter).

The EnerVista UR Setup software provides a single facility to configure, monitor, maintain, and troubleshoot the operation of relay functions, connected over local or wide-area networks. It can be used while disconnected (offline) or connected (online) to a UR device. In offline mode, settings files can be created for eventual downloading to the device. In online mode, communication with the device is real-time.

The EnerVista UR Setup software is provided with every L30 relay and runs on Microsoft Windows XP, 7, and Server 2008. This chapter provides a summary of the basic EnerVista UR Setup software interface features. The EnerVista UR Setup Help File provides details for getting started and using the EnerVista UR Setup software interface.

### 4.1.2 CREATING A SITE LIST

To start using the EnerVista UR Setup software, site and device definition are required. See the EnerVista UR Setup Help File or refer to the EnerVista UR Setup Software section in Chapter 1 for details.

### 4.1.3 ENERVISTA UR SETUP OVERVIEW



#### a) ENGAGING A DEVICE

The EnerVista UR Setup software can be used in online mode (relay connected) to directly communicate with the L30 relay. Communicating relays are organized and grouped by communication interfaces and into sites. Sites can contain any number of relays selected from the UR-series of relays.

#### b) USING SETTINGS FILES

The EnerVista UR Setup software interface supports three ways of handling changes to relay settings:

- In offline mode (relay disconnected) to create or edit relay settings files for later download to communicating relays
- While connected to a relay to modify relay settings, and then save the settings to the relay
- You can create/edit settings files and then write them to the relay while the interface is connected to the relay

Settings files are organized on the basis of file names assigned by the user. A settings file contains data pertaining to the following types of relay settings:

- Device definition
- Product setup
- System setup
- FlexLogic
- Grouped elements
- Control elements
- Inputs/outputs
- Remote resources
- Testing

Factory default values are supplied and can be restored after any changes.

The following communications settings are not transferred to the L30 with settings files:

Modbus Slave Address
Modbus TCP Port Number
RS485 COM2 Baud Rate
RS485 COM2 Parity
COM2 Minimum Response Time

COM2 Selection
RRTD Slave Address
RRTD Baud Rate
IP Address
IP Subnet Mask
IP Routing

When a settings file is loaded to a L30 that is in-service, the following sequence occurs:

1. The L30 takes itself out of service.
2. The L30 issues a **UNIT NOT PROGRAMMED** major self-test error.
3. The L30 closes the critical fail contact.

#### c) CREATING AND EDITING FLEXLOGIC

You create or edit a FlexLogic equation in order to customize the relay. You can subsequently view the automatically generated logic diagram.



#### d) VIEWING ACTUAL VALUES

You can view real-time relay data such as input/output status and measured parameters.

#### e) VIEWING TRIGGERED EVENTS

While the interface is in either online or offline mode, you can view and analyze data generated by triggered specified parameters, via one of the following:

- **Event recorder**

  The event recorder captures contextual data associated with the last 1024 events, listed in chronological order from most recent to oldest.

- **Oscillography**

  The oscillography waveform traces and digital states are used to provide a visual display of power system and relay operation data captured during specific triggered events.

#### f) FILE SUPPORT

- **Execution:** Any EnerVista UR Setup file that is opened launches the application or provides focus to the already opened application. If the file was a settings file (has a `URS` extension) that had been removed from the Settings List tree menu, it is added back to the Settings List tree menu.
- **Drag and Drop:** The Site List and Settings List control bar windows are each mutually a drag source and a drop target for device-order-code-compatible files or individual menu items. Also, the Settings List control bar window and any Windows Explorer directory folder are each mutually a file drag source and drop target.

  New files that are dropped into the Settings List window are added to the tree, which is automatically sorted alphabetically with respect to settings file names. Files or individual menu items that are dropped in the selected device menu in the Site List window are automatically sent to the online communicating device.

#### g) FIRMWARE UPGRADES

The firmware of a L30 device can be upgraded, locally or remotely, via the EnerVista UR Setup software. The corresponding instructions are provided by the EnerVista UR Setup Help file under the topic “Upgrading Firmware”.

If you are upgrading from version 7.0 or 7.1 to 7.2 or later, some CPU modules require a new boot version. Update this first in EnerVista under **Maintenance > Update Firmware**. Ensure that power to the unit is not lost during this update.

Before backing up settings and upgrading, set the **Settings > Product Setup > Security > Dual Permission Security Access > Remote Setting Authorized** and **Local Setting Authorized** settings to "ON." Otherwise, the upgrade is blocked and results in an "Unable to put relay in flash mode" message.

If using CyberSentry security, also ensure that the relay and firmware are not locked under the **Settings > Product Setup > Security > Supervisory** settings. A Supervisor role is required for these settings.

NOTE

Modbus addresses assigned to firmware modules, features, settings, and corresponding data items (that is, default values, minimum/maximum values, data type, and item size) can change slightly from version to version of firmware. The addresses are rearranged when new features are added or existing features are enhanced or modified. The **EEPROM DATA ERROR** message displayed after upgrading/downgrading the firmware is a resettable, self-test message intended to inform users that the Modbus addresses have changed with the upgraded firmware. This message does not signal any problems when appearing after firmware upgrades.

### 4.1.4 ENERVISTA UR SETUP MAIN WINDOW

The EnerVista UR Setup software main window supports the following primary display components:

1. Title bar that shows the pathname of the active data view
2. Main window menu bar
3. Main window tool bar
4. Site list control bar window
5. Settings list control bar window
6. Device data view windows, with common tool bar
7. Settings file data view windows, with common tool bar
8. Workspace area with data view tabs
9. Status bar
10. Quick action hot links

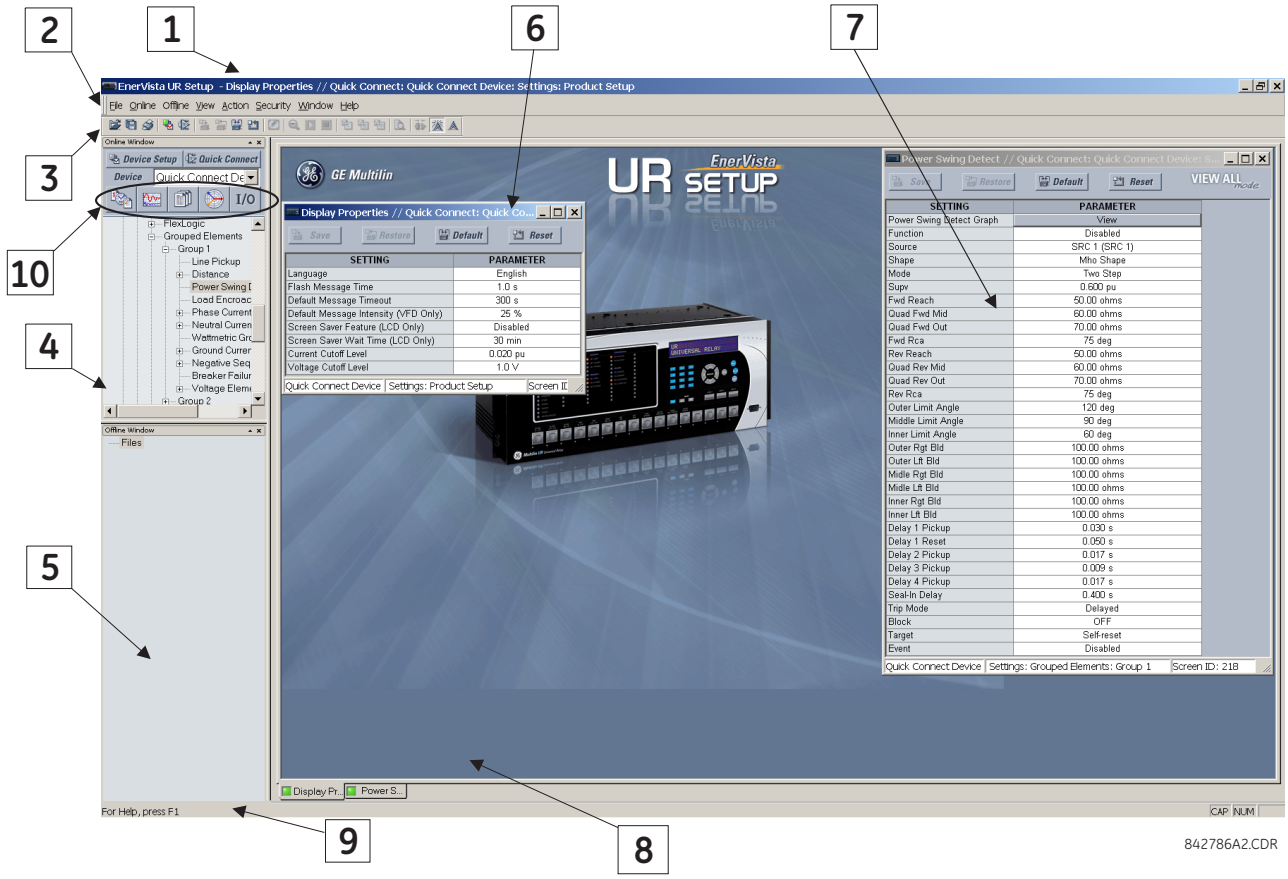



**Figure 4–1: ENERVISTA UR SETUP SOFTWARE MAIN WINDOW**

### 4.2.1 SETTINGS TEMPLATES

Setting file templates simplify the configuration and commissioning of multiple relays that protect similar assets. An example of this is a substation that has 10 similar feeders protected by 10 UR-series F60 relays.

In these situations, typically 90% or greater of the settings are identical between all devices. The templates feature allows engineers to configure and test these common settings, then lock them so that they are not available to users. For example, these locked down settings can be hidden from view for field engineers, allowing them to quickly identify and concentrate on the specific settings.

The remaining settings (typically 10% or less) can be specified as editable and be made available to field engineers installing the devices. These are settings such as protection element pickup values and CT and VT ratios.

The settings template mode allows the user to define which settings are visible in EnerVista UR Setup. Settings templates can be applied to both settings files (settings file templates) and online devices (online settings templates). The functionality is identical for both purposes.

Settings files conversion from previous firmware versions is supported.

#### a) ENABLING THE SETTINGS TEMPLATE



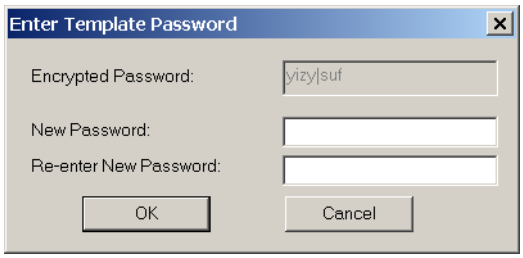
The settings file template feature is disabled by default. The following procedure describes how to enable the settings template for UR-series settings files.

1. Select a settings file from the offline window of the EnerVista UR Setup main screen.
2. Right-click the selected device or settings file and select the **Template Mode > Create Template** option.

The settings file template is now enabled and the file tree displayed in light blue. The settings file is now in template editing mode.

Alternatively, the settings template can also be applied to online settings. The following procedure describes this process.

1. Select an installed device from the online window of the EnerVista UR Setup main screen.
2. Right-click the selected device and select the **Template Mode > Create Template** option.




The software prompts for a template password. This password is required to use the template feature and must be at least four characters in length.

3. Enter and re-enter the new password, then click **OK** to continue.

The online settings template is now enabled. The device is now in template editing mode.

#### b) EDITING THE SETTINGS TEMPLATE

The settings template editing feature allows the user to specify which settings are available for viewing and modification in EnerVista UR Setup. By default, all settings except the FlexLogic equation editor settings are locked.

1. With the template already enabled, locate the device or settings file in the Online or Offline Window area in the software.
2. Right-click the device or file and select the **Template Mode > Edit Template** option to place the device in template editing mode. If prompted, enter the template password then click **OK**.
3. Open the relevant settings window that contains settings to be specified as viewable.

By default, all settings are specified as locked and displayed against a grey background. The icon on the upper right of the settings window also indicates that the EnerVista software is in **EDIT mode**. The following example shows the phase time overcurrent settings window in edit mode.

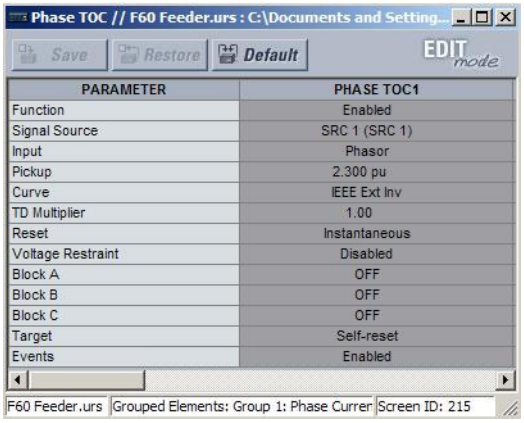



**Figure 4–2: SETTINGS TEMPLATE VIEW, ALL SETTINGS SPECIFIED AS LOCKED**

4. Specify the settings to make viewable by clicking them.

   The setting available to view is displayed against a yellow background as shown below.

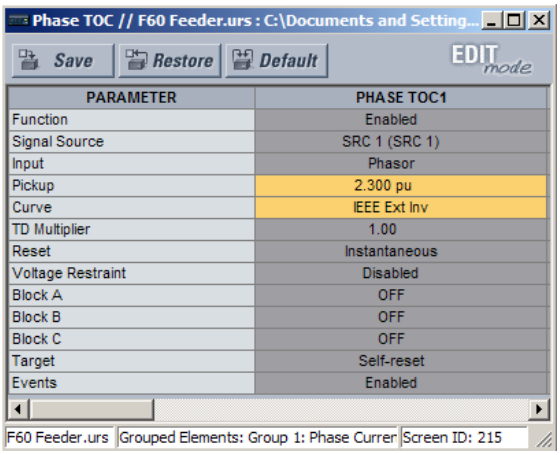



**Figure 4–3: SETTINGS TEMPLATE VIEW, TWO SETTINGS SPECIFIED AS EDITABLE**

5. Click on **Save** to save changes to the settings template.
6. Proceed through the settings tree to specify all viewable settings.

   The next time that the device/settings are accessed, only those specified as viewable/editable display in the menu hierarchy.

### c) ADDING PASSWORD PROTECTION TO A TEMPLATE

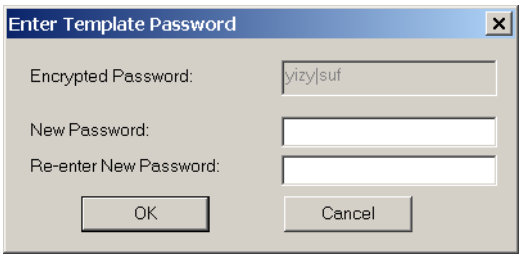
GE recommends that templates be saved with password protection to maximize security.

NOTE When templates are created for online settings, the password is added during the initial template creation step. It does not need to be added after the template is created.

To add password protection to a settings file template:

1. In the Offline Window area, right-click the device and select the T**emplate Mode > Password Protect Template** option.

The software prompts for a template password. This password must be at least four characters in length.




2. Enter and re-enter the new password, then click **OK** to continue.

The settings file template is now secured with password protection.

### d) VIEWING THE SETTINGS TEMPLATE

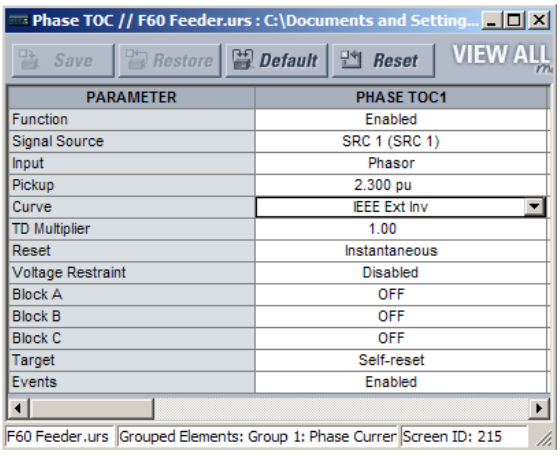
Once all necessary settings are specified for viewing, users are able to view the settings template on the online device or settings file. There are two ways to specify the settings view with the settings template feature:

- Display only those settings available for editing
- Display all settings, with settings not available for editing greyed-out

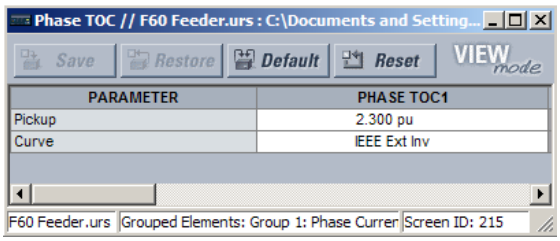
Use the following procedure to only display settings available for editing:

1. Right-click the device in the Online or Offline Window area and apply the template by selecting the **Template Mode > View In Template Mode** option.
2. Enter the template password then click **OK** to apply the template.

Once the template has been applied, users are limited to view and edit the settings specified by the template. The effect of applying the template to the phase time overcurrent settings is shown below.




Phase time overcurrent settings window without template applied.

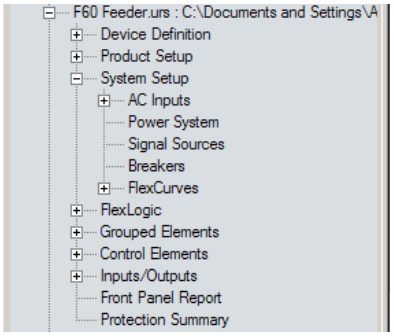



Phase time overcurrent window with template applied via the **Template Mode > View In Template Mode** command. The template specifies that only the Pickup and Curve settings be available.

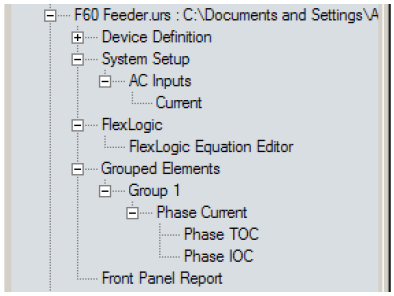
842858A1.CDR

**Figure 4–4: APPLYING TEMPLATES VIA THE VIEW IN TEMPLATE MODE COMMAND**

Viewing the settings in template mode also modifies the settings tree, showing only the settings categories that contain editable settings. The effect of applying the template to a typical settings tree view is shown below.




Typical settings tree view without template applied.




Typical settings tree view with template applied via the **Template Mode > View In Template Mode** command.

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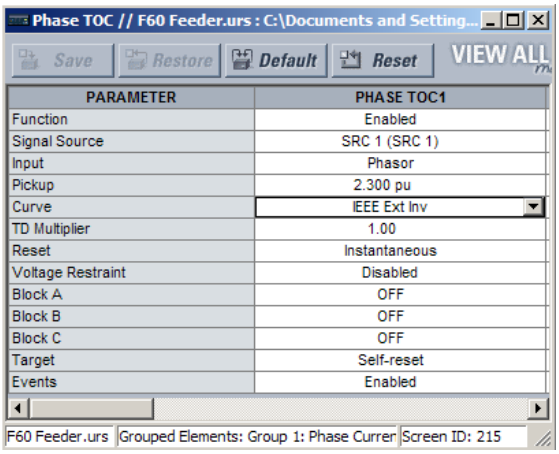
**Figure 4–5: APPLYING TEMPLATES VIA THE VIEW IN TEMPLATE MODE SETTINGS COMMAND**

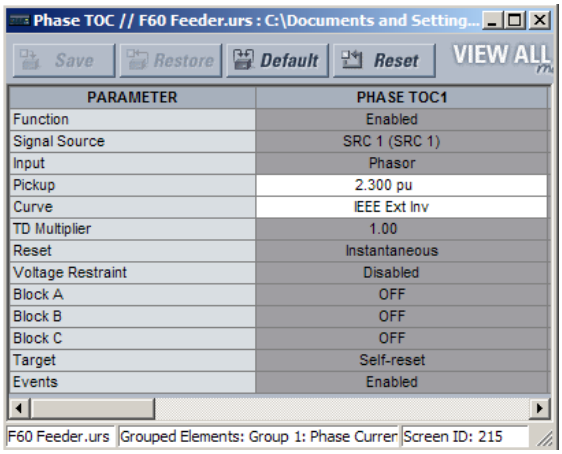
Use the following procedure to display settings available for editing and settings locked by the template.

1. Right-click the device in the Online or Offline Window area and apply the template by selecting the **Template Mode > View All Settings** option.
2. Enter the template password then click **OK** to apply the template.

Once the template has been applied, users are limited to edit the settings specified by the template, but all settings are shown. The effect of applying the template to the phase time overcurrent settings is shown below.




Phase time overcurrent settings window without template applied.




Phase time overcurrent window with template applied via the **Template Mode > View All Settings** command. The template specifies that only the Pickup and Curve settings be available.

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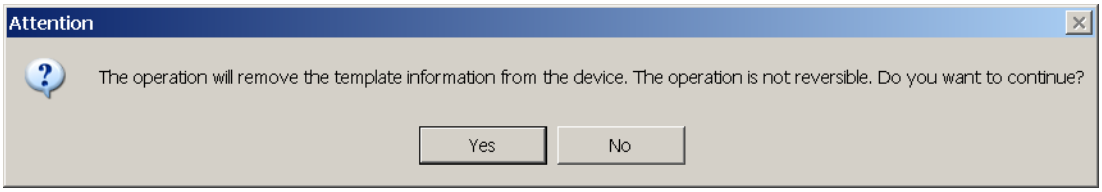
**Figure 4–6: APPLYING TEMPLATES VIA THE VIEW ALL SETTINGS COMMAND**

### e) REMOVING THE SETTINGS TEMPLATE

Once a settings template is removed, it cannot be reapplied and a new settings template needs to be defined before use.

1. Right-click the device in the Online or Offline Window area and select the **Template Mode > Remove Template** option.
2. Enter the template password and click **OK** to continue.

3. Verify one more time that you want to remove the template by clicking **Yes**.




The EnerVista software removes all template information and all settings are available.

### 4.2.2 SECURING AND LOCKING FLEXLOGIC EQUATIONS

The UR allows users to secure parts or all of a FlexLogic equation, preventing unauthorized viewing or modification of critical FlexLogic applications. This is accomplished using the settings template feature to lock individual entries within FlexLogic equations.

Secured FlexLogic equations remain secure when files are sent to and retrieved from any UR-series device.



#### a) LOCKING FLEXLOGIC EQUATION ENTRIES

To lock individual entries of a FlexLogic™ equation:

1. Right-click the settings file or online device and select the **Template Mode > Create Template** item to enable the settings template feature.
2. If prompted, enter the template password.
3. Select the **FlexLogic > FlexLogic Equation Editor** settings menu item.

   By default, all FlexLogic™ entries are specified as viewable and displayed against a yellow background. The icon on the upper right of the window also indicates that EnerVista UR Setup is in **EDIT mode**.
4. Specify the entries to lock by clicking on them.

   The locked entries display against a grey background as shown in the example.

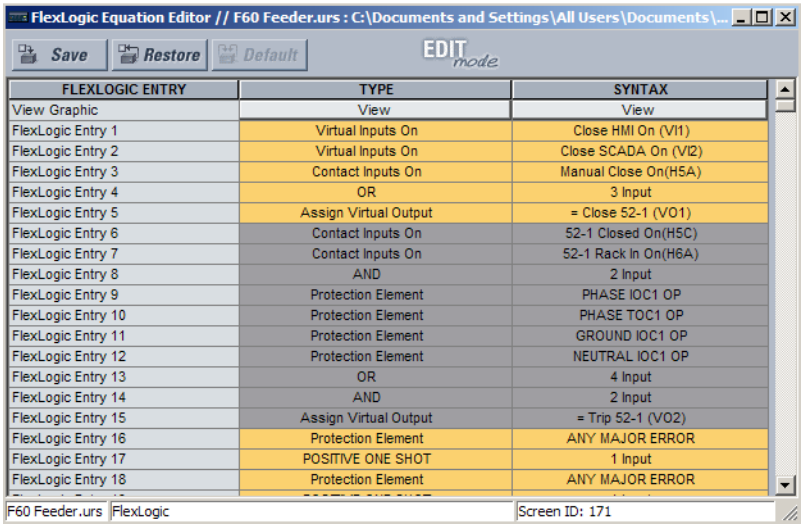
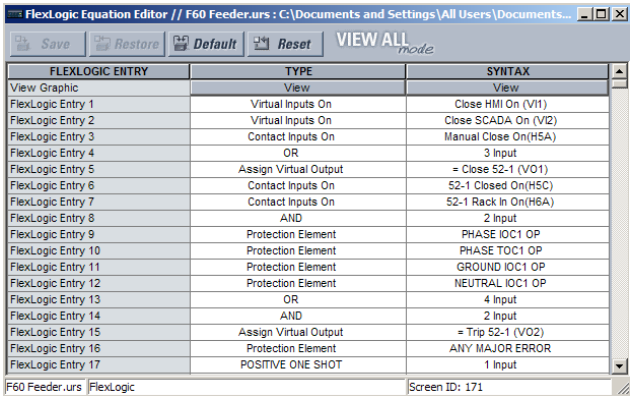


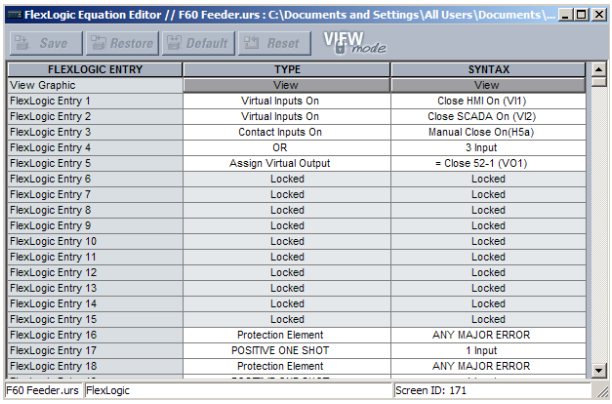

**Figure 4–7: LOCKING FLEXLOGIC ENTRIES IN EDIT MODE**

5. Click the **Save** button to save and apply changes to the settings template.
6. Select the **Template Mode > View In Template Mode** option to view the template.
7. Optionally apply a password to the template by right-clicking the device and selecting the **Template Mode > Password Protect Template** option.

Once the template has been applied, users are limited to view and edit the FlexLogic entries not locked by the template. The effect of applying the template to the FlexLogic entries in the above procedure is shown below.




Typical FlexLogic™ entries without template applied.




Typical FlexLogic™ entries locked with template via the **Template Mode > View In Template Mode** command.

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**Figure 4–8: LOCKING FLEXLOGIC ENTRIES THROUGH SETTING TEMPLATES**

The FlexLogic entries are also shown as locked in the graphical view (as shown below) and on the front panel display.

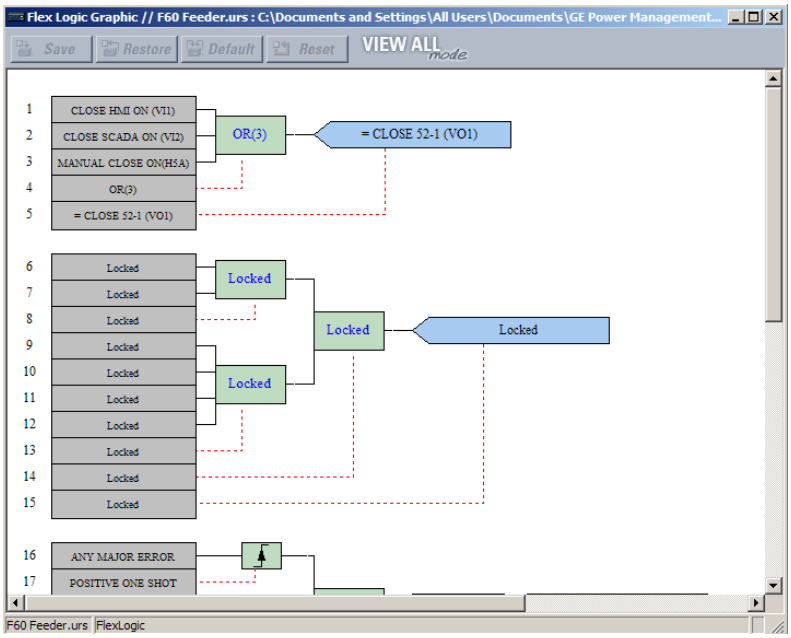


**Figure 4–9: SECURED FLEXLOGIC IN GRAPHICAL VIEW**

### b) LOCKING FLEXLOGIC EQUATIONS TO A SERIAL NUMBER

A settings file and associated FlexLogic equations also can be locked to a UR serial number. Once FlexLogic entries in a settings file have been secured, use the following procedure to lock the settings file to a serial number. A serial number is viewable under **Actual Values > Product Info > Model Information**, the inside front panel, and the rear of the device.

8. Right-click the setting file in the Offline Window area and select the **Edit Settings File Properties** option. The window opens.

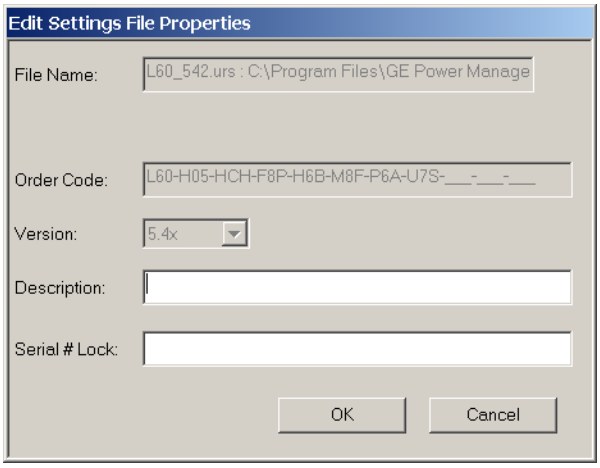


**Figure 4–10: TYPICAL SETTINGS FILE PROPERTIES WINDOW**

9. Enter the serial number of the L30 device to lock to the settings file in the **Serial # Lock** field.
10. Click the **OK** button to apply the change. The serial number is not validated.

The settings file and corresponding secure FlexLogic equations are now locked to the L30 device specified by the serial number.

### 4.2.3 SETTINGS FILE TRACEABILITY

A traceability feature for settings files allows the user to quickly determine if the settings in a L30 device have been changed since the time of installation from a settings file. When a settings file is transferred to a L30 device, the date, time, and serial number of the L30 are sent back to EnerVista UR Setup and added to the settings file on the local computer. This information can be compared with the L30 actual values at any later date to determine if security has been compromised.

The traceability information is only included in the settings file if a complete settings file is either transferred to the L30 device or obtained from the L30 device. Any partial settings transfers by way of drag and drop do not add the traceability information to the settings file.

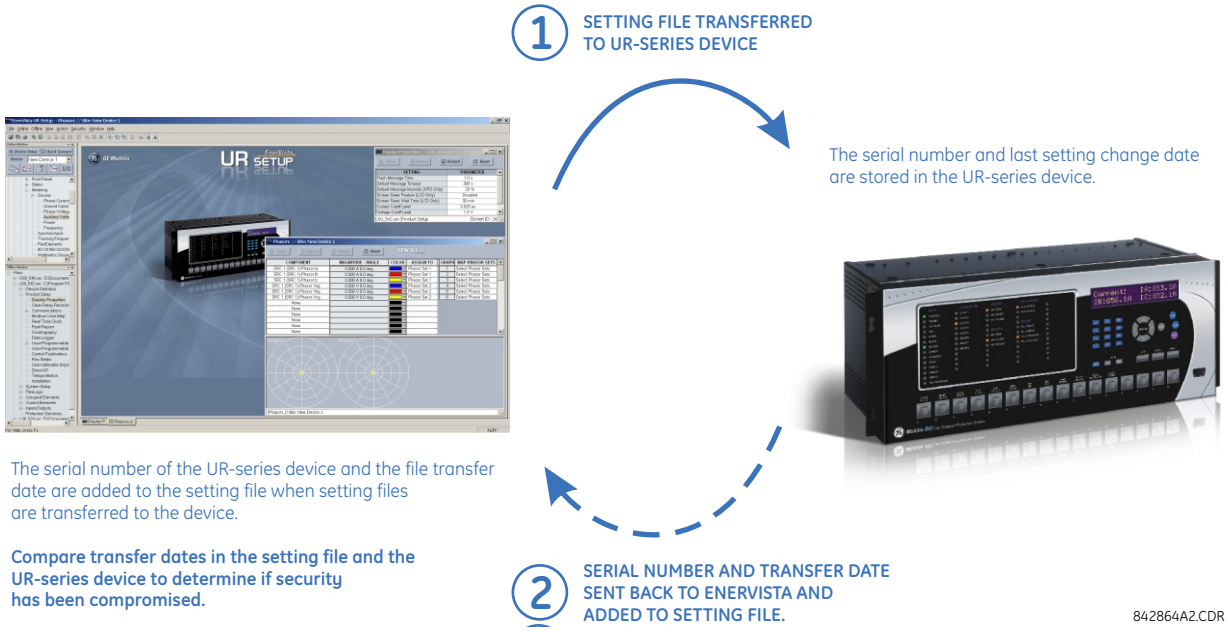


**Figure 4–11: SETTINGS FILE TRACEABILITY MECHANISM**

With respect to the above diagram, the traceability feature is used as follows.

1. The transfer date of a setting file written to a L30 is logged in the relay and can be viewed via EnerVista UR Setup or the front panel display. Likewise, the transfer date of a setting file saved to a local computer is logged in EnerVista UR Setup.
2. Comparing the dates stored in the relay and on the settings file at any time in the future indicates if any changes have been made to the relay configuration since the settings file was saved.

### a) SETTINGS FILE TRACEABILITY INFORMATION

The serial number and file transfer date are saved in the settings files when they are sent to a L30 device.

The L30 serial number and file transfer date are included in the settings file device definition within the EnerVista UR Setup offline window as shown in the example below.

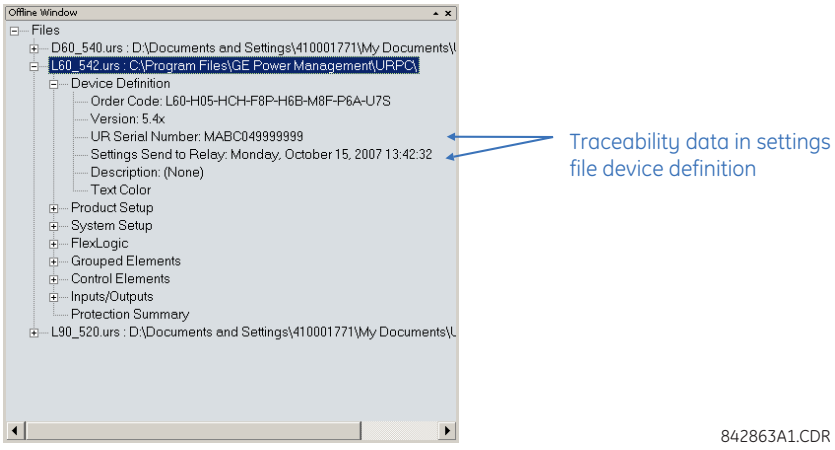


**Figure 4–12: DEVICE DEFINITION SHOWING TRACEABILITY DATA**

This information is also available in printed settings file reports as shown in the example below.

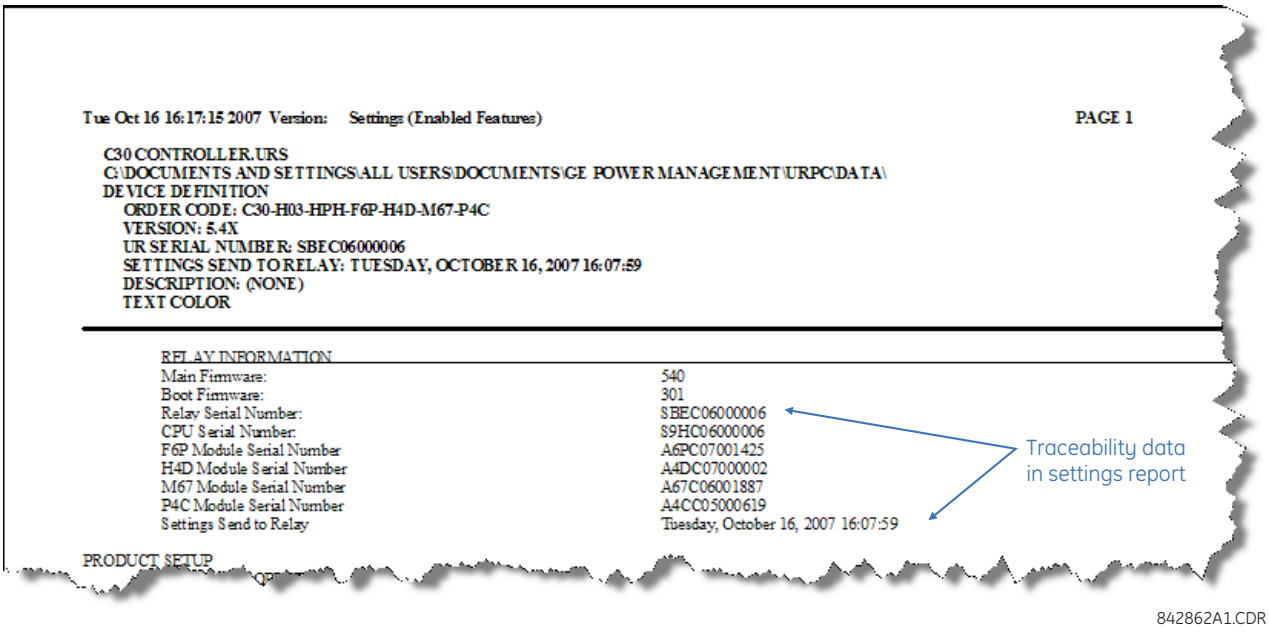


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**Figure 4–13: SETTINGS FILE REPORT SHOWING TRACEABILITY DATA**

### b) ONLINE DEVICE TRACEABILITY INFORMATION

The L30 serial number and file transfer date are available for an online device through the actual values. Select the **Actual Values > Product Info > Model Information** menu item within the EnerVista UR Setup online window as shown in the example below.

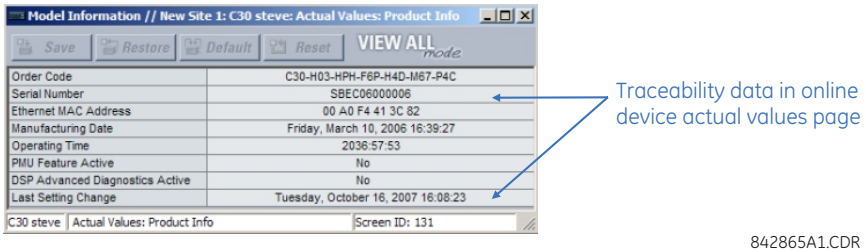


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**Figure 4–14: TRACEABILITY DATA IN ACTUAL VALUES WINDOW**

This information is also available from the front panel display through the following actual values:

**ACTUAL VALUES ⇨⇩ PRODUCT INFO ⇨ MODEL INFORMATION ⇨⇩ SERIAL NUMBER**
**ACTUAL VALUES ⇨⇩ PRODUCT INFO ⇨ MODEL INFORMATION ⇨⇩ LAST SETTING CHANGE**

### c) ADDITIONAL TRACEABILITY RULES

The following additional rules apply for the traceability feature

- If the user changes any settings within the settings file in the offline window, then the traceability information is removed from the settings file.
- If the user creates a new settings file, then no traceability information is included in the settings file.
- If the user converts an existing settings file to another revision, then any existing traceability information is removed from the settings file.
- If the user duplicates an existing settings file, then any traceability information is transferred to the duplicate settings file.

### 4.3.1 FACEPLATE

#### a) ENHANCED FACEPLATE

The front panel interface is one of two supported interfaces, the other interface being EnerVista UR Setup software. The front panel interface consists of LED panels, an RS232 port, keypad, LCD display, control pushbuttons, and optional user-programmable pushbuttons.

The faceplate is hinged to allow easy access to the removable modules.

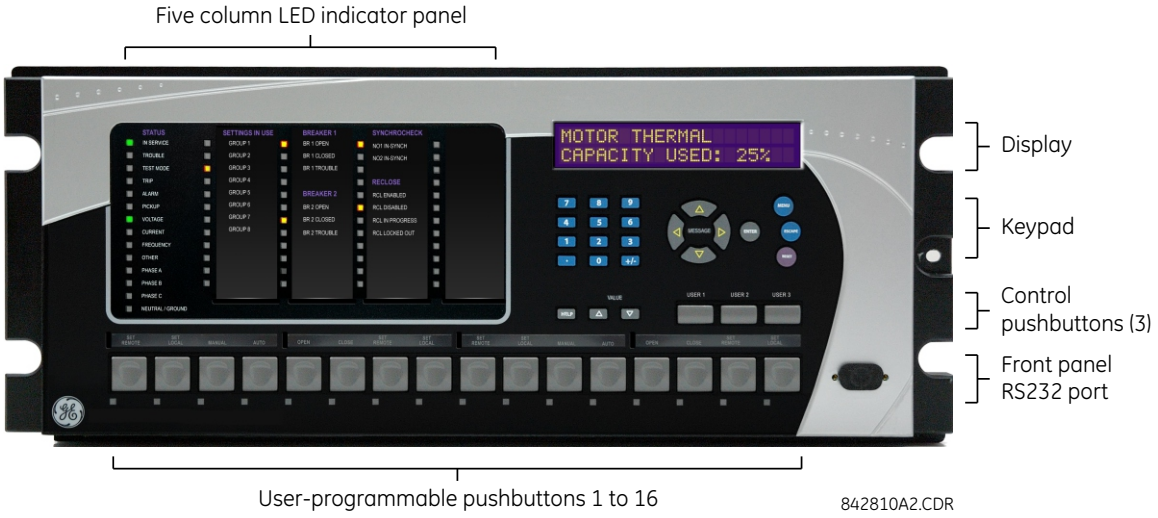


**Figure 4–15: UR-SERIES ENHANCED FACEPLATE**

#### b) BASIC FACEPLATE

There are two interfaces: the front panel and the EnerVista UR Setup software. The front panel interface consists of LED panels, an RS232 port, keypad, LCD display, control pushbuttons, and optional user-programmable pushbuttons.

The faceplate is hinged to allow easy access to the removable modules. There is also a removable dust cover that fits over the faceplate that must be removed in order to access the keypad panel. The following figure shows the horizontal arrangement of the faceplate panels.

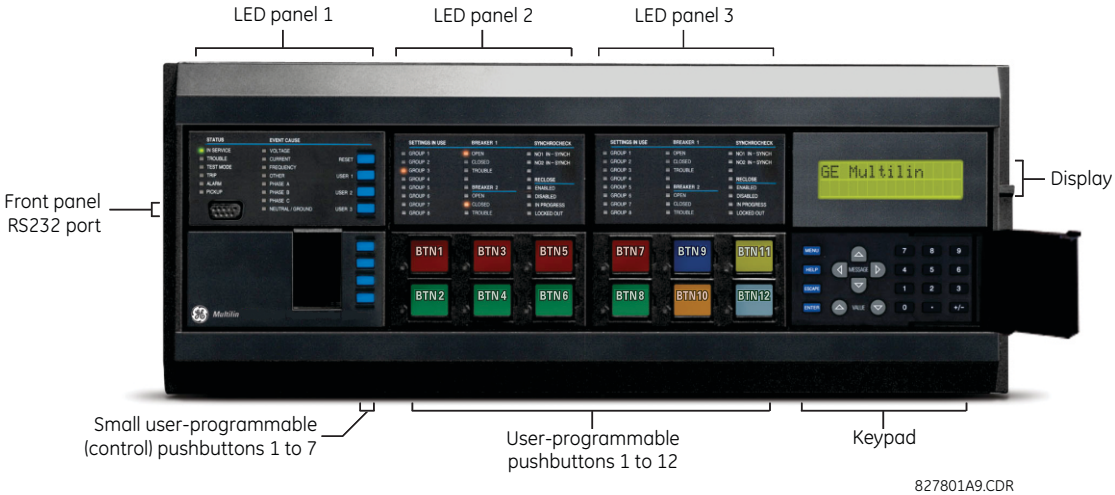


**Figure 4–16: UR-SERIES STANDARD HORIZONTAL FACEPLATE PANELS**

The following figure shows the vertical arrangement of the faceplate panels for relays ordered with the vertical option.

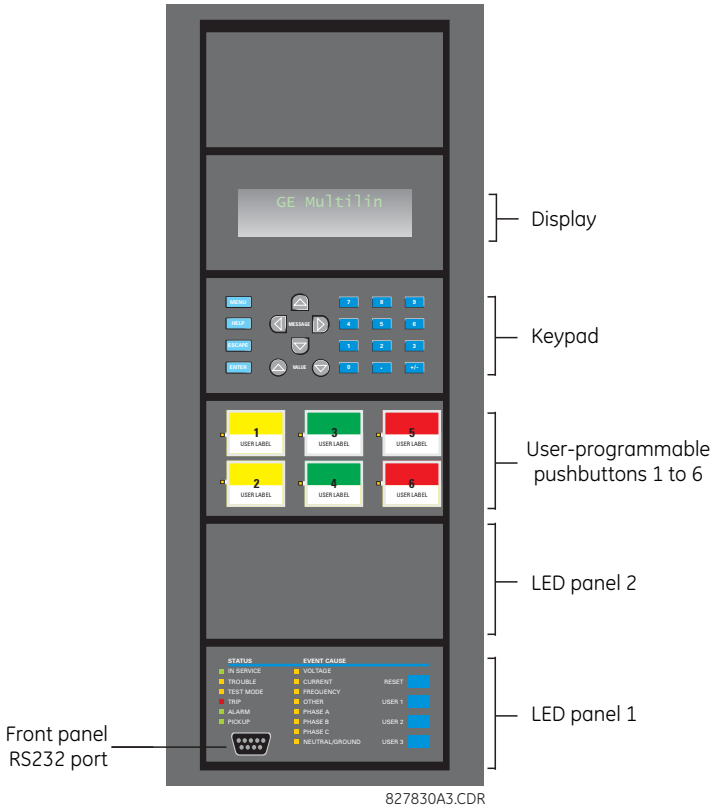


**Figure 4–17: UR-SERIES STANDARD VERTICAL FACEPLATE PANELS**

## 4.3.2 LED INDICATORS

### a) ENHANCED FACEPLATE

The enhanced front panel display provides five columns of LED indicators. The first column contains 14 status and event cause LEDs, and the next four columns contain the 48 user-programmable LEDs.

The RESET key is used to reset any latched LED indicator or target message, once the condition has been cleared (these latched conditions can also be reset via the **SETTINGS** ⇨⇩ **INPUT/OUTPUTS** ⇨⇩ **RESETTING** menu). The RS232 port is intended for connection to a computer.

The USER keys are used by the breaker control feature.

**Figure 4–18: TYPICAL LED INDICATOR PANEL FOR ENHANCED FACEPLATE**

The status indicators in the first column are described below.

- **IN SERVICE**: This LED indicates that control power is applied, all monitored inputs, outputs, and internal systems are OK, and that the device has been programmed.
- **TROUBLE**: This LED indicates that the relay has detected an internal problem.
- **TEST MODE**: This LED indicates that the relay is in test mode. For more information, see the Test Mode section in the Settings chapter.
- **TRIP**: This LED indicates that the FlexLogic operand serving as a trip switch has operated. This indicator always latches; as such, a reset command must be initiated to allow the latch to be reset.
- **ALARM**: This LED indicates that the FlexLogic operand serving as an alarm switch has operated. This indicator is never latched.
- **PICKUP**: This LED indicates that an element is picked up. This indicator is never latched.

The event cause indicators in the first column are described below.

Events cause LEDs are turned on or off by protection elements that have their respective target setting selected as either “Enabled” or “Latched”. If a protection element target setting is “Enabled”, then the corresponding event cause LEDs remain on as long as operate operand associated with the element remains asserted. If a protection element target setting is “Latched”, then the corresponding event cause LEDs turn on when the operate operand associated with the element is asserted and remain on until the RESET button on the front panel is pressed after the operand is reset.

All elements that are able to discriminate faulted phases can independently turn off or on the phase A, B, or C LEDs. This includes phase instantaneous overcurrent, phase undervoltage, etc. This means that the phase A, B, and C operate operands for individual protection elements are ORed to turn on or off the phase A, B, or C LEDs.

- **VOLTAGE**: This LED indicates voltage was involved.
- **CURRENT**: This LED indicates current was involved.
- **FREQUENCY**: This LED indicates frequency was involved.
- **OTHER**: This LED indicates a composite function that is not solely current, voltage, or frequency based (distance or power for example) or a control function (digital element or trip bus for example).
- **PHASE A**: This LED indicates phase A was involved.
- **PHASE B**: This LED indicates phase B was involved.
- **PHASE C**: This LED indicates phase C was involved.
- **NEUTRAL/GROUND**: This LED indicates that neutral or ground was involved.

The user-programmable LEDs consist of 48 amber LED indicators in four columns. The operation of these LEDs is user-defined. Support for applying a customized label beside every LED is provided. Default labels are shipped in the label package of every L30, together with custom templates. The default labels can be replaced by user-printed labels.

User customization of LED operation is of maximum benefit in installations where languages other than English are used to communicate with operators. Refer to the User-Programmable LEDs section in chapter 5 for the settings used to program the operation of the LEDs on these panels.

### b) BASIC FACEPLATE

The basic faceplate consists of three panels with LED indicators, keys, and a communications port. The RESET key is used to reset any latched LED indicator or target message, once the condition has been cleared (these latched conditions can also be reset via the **SETTINGS** ⇨⇩ **INPUT/OUTPUTS** ⇨⇩ **RESETTING** menu). The RS232 port is for connection to a computer.

The **USER** keys are used by the breaker control feature.

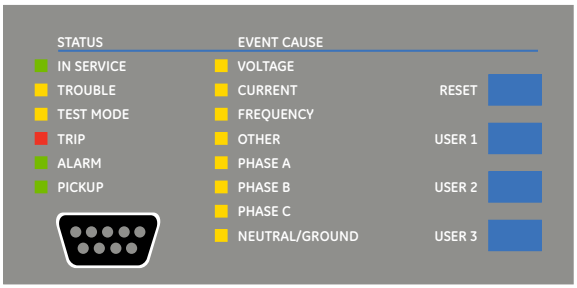


**Figure 4–19: LED PANEL 1**

**STATUS INDICATORS:**

- **IN SERVICE**: Indicates that control power is applied; all monitored inputs/outputs and internal systems are OK; the relay has been programmed.
- **TROUBLE**: Indicates that the relay has detected an internal problem.
- **TEST MODE**: Indicates that the relay is in test mode. For more information, see the Test Mode section in the Settings chapter.
- **TRIP**: Indicates that the selected FlexLogic operand serving as a Trip switch has operated. This indicator always latches; the reset command must be initiated to allow the latch to be reset.
- **ALARM**: Indicates that the selected FlexLogic operand serving as an Alarm switch has operated. This indicator is never latched.
- **PICKUP**: Indicates that an element is picked up. This indicator is never latched.

**EVENT CAUSE INDICATORS:**

Events cause LEDs are turned on or off by protection elements that have their respective target setting selected as either “Enabled” or “Latched”. If a protection element target setting is “Enabled”, then the corresponding event cause LEDs remain on as long as operate operand associated with the element remains asserted. If a protection element target setting is “Latched”, then the corresponding event cause LEDs turn on when the operate operand associated with the element is asserted and remain on until the RESET button on the front panel is pressed after the operand is reset.

All elements that are able to discriminate faulted phases can independently turn off or on the phase A, B, or C LEDs. This includes phase instantaneous overcurrent, phase undervoltage, etc. This means that the phase A, B, and C operate operands for individual protection elements are ORed to turn on or off the phase A, B, or C LEDs.

- **VOLTAGE**: Indicates voltage was involved.
- **CURRENT**: Indicates current was involved.
- **FREQUENCY**: Indicates frequency was involved.
- **OTHER**: Indicates a composite function that is not solely current, voltage, or frequency based (distance or power for example) or a control function (digital element or trip bus for example).
- **PHASE A**: Indicates phase A was involved.
- **PHASE B**: Indicates phase B was involved.
- **PHASE C**: Indicates phase C was involved.
- **NEUTRAL/GROUND**: Indicates that neutral or ground was involved.

**USER-PROGRAMMABLE INDICATORS:**

The second and third provide 48 amber LED indicators whose operation is controlled by the user. Support for applying a customized label beside every LED is provided.

User customization of LED operation is of maximum benefit in installations where languages other than English are used to communicate with operators. Refer to the User-Programmable LEDs section in chapter 5 for the settings used to program the operation of the LEDs on these panels.

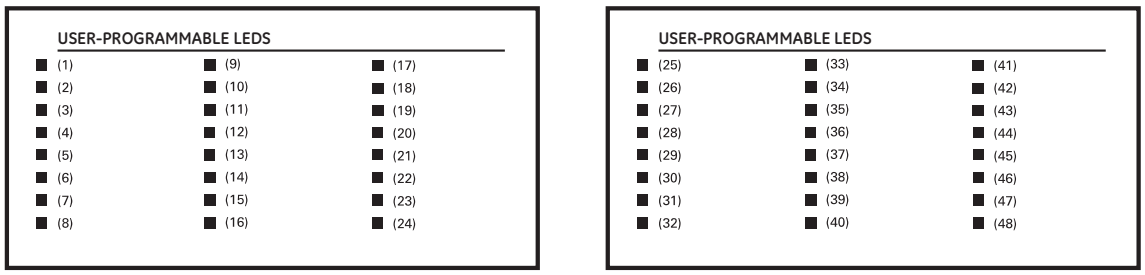


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**Figure 4–20: LED PANELS 2 AND 3 (INDEX TEMPLATE)**

**DEFAULT LABELS FOR LED PANEL 2:**

The default labels are intended to represent:

- **GROUP 1...6**: The illuminated GROUP is the active settings group.
- **BREAKER 1(2) OPEN**: The breaker is open.
- **BREAKER 1(2) CLOSED**: The breaker is closed.
- **BREAKER 1(2) TROUBLE**: A problem related to the breaker has been detected.
- **SYNCHROCHECK NO1(4) IN-SYNCH**: Voltages have satisfied the synchrocheck element.
- **RECLOSE ENABLED**: The recloser is operational.
- **RECLOSE DISABLED**: The recloser is not operational.
- **RECLOSE IN PROGRESS**: A reclose operation is in progress.
- **RECLOSE LOCKED OUT**: The recloser is not operational and requires a reset.

The relay is shipped with the default label for the LED panel 2. The LEDs, however, are not pre-programmed. To match the pre-printed label, the LED settings must be entered as shown in the User-Programmable LEDs section of chapter 5. The LEDs are fully user-programmable. The default labels can be replaced by user-printed labels for both panels as explained in the following section.

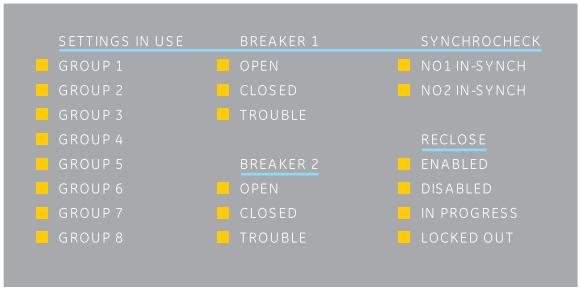


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**Figure 4–21: LED PANEL 2 (DEFAULT LABELS)**

### 4.3.3 CUSTOM LABELING OF LEDS

#### a) ENHANCED FACEPLATE

The following procedure requires these pre-requisites:

- EnerVista UR Setup software is installed and operational
- The L30 settings have been saved to a settings file
- The L30 front panel label cutout sheet (GE Multilin part number 1006-0047) has been downloaded from http://www.gegridsolutions.com/products/support/ur/URLEDenhanced.doc and printed
- Small-bladed knife

To create custom LED labels for the enhanced front panel display:

1. Start the EnerVista UR Setup software.
2. Select the **Front Panel Report** item at the bottom of the menu tree for the settings file. The front panel report window displays.

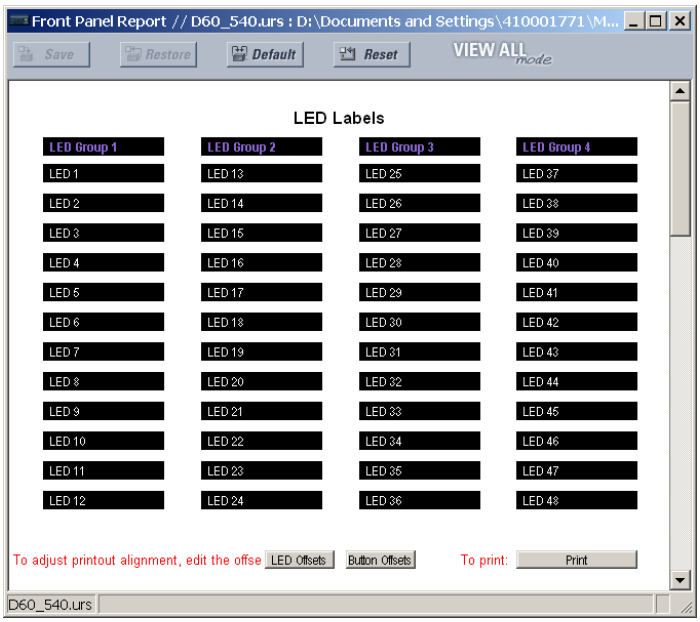



**Figure 4–22: FRONT PANEL REPORT WINDOW**

3. Enter the text to appear next to each LED and above each user-programmable pushbuttons in the fields provided.
4. Feed the L30 front panel label cutout sheet into a printer and press the **Print** button in the front panel report window.
5. When printing is complete, fold the sheet along the perforated lines and punch out the labels.
6. Remove the L30 label insert tool from the package and bend the tabs as described in the following procedures. These tabs are used for removal of the default and custom LED labels.

NOTE

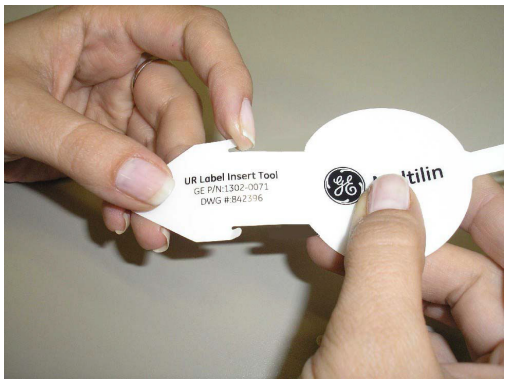
It is important that the tool be used EXACTLY as shown below, with the printed side containing the GE part number facing the user.

The label package shipped with every L30 contains the three default labels shown below, the custom label template sheet, and the label removal tool.

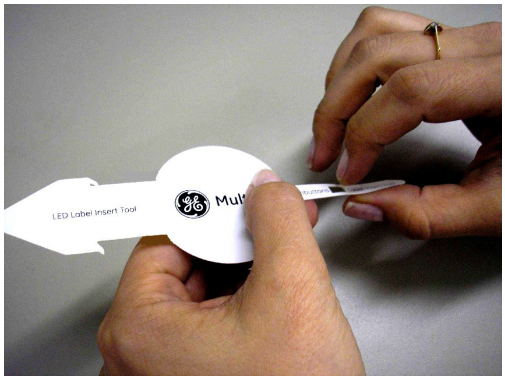
If the default labels are suitable for your application, insert them in the appropriate slots and program the LEDs to match them. If you require custom labels, follow the procedures below to remove the original labels and insert the new ones.

The following procedure describes how to setup and use the label removal tool.

1. Bend the tabs at the left end of the tool upwards as shown below.



2. Bend the tab at the center of the tool tail as shown below.

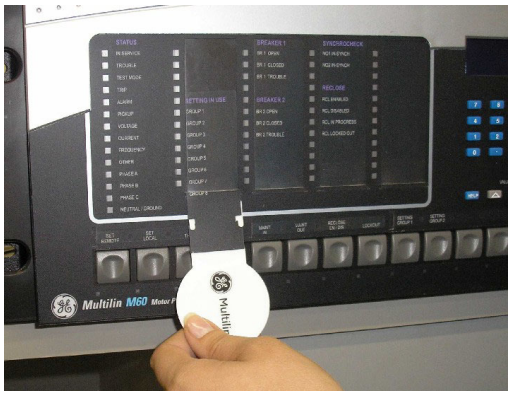



The following procedure describes how to remove the LED labels from the L30 enhanced front panel and insert the custom labels.

1. Use the knife to lift the LED label and slide the label tool underneath. Make sure the bent tabs are pointing away from the relay.

2. Slide the label tool under the LED label until the tabs snap out as shown below. This attaches the label tool to the LED label.

3. Remove the tool and attached LED label as shown below.



4. Slide the new LED label inside the pocket until the text is properly aligned with the LEDs, as shown below.

The following procedure describes how to remove the user-programmable pushbutton labels from the L30 enhanced front panel and insert the custom labels.

1. Use the knife to lift the pushbutton label and slide the tail of the label tool underneath, as shown below. Make sure the bent tab is pointing away from the relay.

2. Slide the label tool under the user-programmable pushbutton label until the tabs snap out as shown below. This attaches the label tool to the user-programmable pushbutton label.

3. Remove the tool and attached user-programmable pushbutton label as shown below.

4. Slide the new user-programmable pushbutton label inside the pocket until the text is properly aligned with the buttons, as shown below.

### 4.3.4 DISPLAY

All messages are displayed on a backlit liquid crystal display (LCD) to make them visible under poor lighting conditions. While the keypad and display are not actively being used, the display defaults to user-defined messages. Any high-priority event-driven message automatically overrides the default message and appears on the display.

Settings files conversion from previous firmware versions is supported.

### 4.3.5 KEYPAD

Display messages are organized into pages under the following headings: actual values, settings, commands, and targets. The MENU key navigates through these pages. Each heading page is divided further into logical subgroups.

The MESSAGE keys navigate through the subgroups. The VALUE keys increment or decrement numerical setting values when in programming mode. These keys also scroll through alphanumeric values in the text edit mode. Alternatively, values can be entered with the numeric keypad.

The decimal key initiates and advances to the next character in text edit mode or enters a decimal point.

The HELP key can be pressed at any time for context-sensitive help messages.

The ENTER key stores altered setting values.

When entering an IP address on the front panel, key in the first sequence of the number, then press the • key for the decimal place. For example, for 127.0.0.1, press 127, then •, then 0, then •, then 0, then •, then 1. To save the address, press the ENTER key.

### 4.3.6 BREAKER CONTROL

#### a) INTRODUCTION

The L30 can interface with associated circuit breakers. In many cases the application monitors the state of the breaker, that can be presented on faceplate LEDs, along with a breaker trouble indication. Breaker operations can be manually initiated from faceplate keypad or automatically initiated from a FlexLogic operand. A setting is provided to assign names to each breaker; this user-assigned name is used for the display of related flash messages. These features are provided for two breakers; the user can use only those portions of the design relevant to a single breaker, which must be breaker 1.

For the following discussion it is assumed the **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ BREAKERS ⇨ BREAKER 1(2) ⇨ BREAKER FUNCTION** setting is "Enabled" for each breaker.

### b) CONTROL MODE SELECTION AND MONITORING

Installations can require that a breaker is operated in the three-pole only mode (3-pole), or in the one and three-pole (1-pole) mode, selected by setting. If the mode is selected as three-pole, a single input tracks the breaker open or closed position. If the mode is selected as one-pole, all three breaker pole states must be input to the relay. These inputs must be in agreement to indicate the position of the breaker.

For the following discussion it is assumed the **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ BREAKERS ⇨ BREAKER 1(2) ⇨⇩ BREAKER 1(2) PUSH BUTTON CONTROL** setting is "Enabled" for each breaker.

### c) FACEPLATE (USER KEY) CONTROL

After the 30 minute interval during which command functions are permitted after a correct command password, the user cannot open or close a breaker via the keypad. The following discussions begin from the not-permitted state.

### d) CONTROL OF TWO BREAKERS

For the following example setup, the `(Name)` field represents the user-programmed variable name.

For this application (setup shown below), the relay is connected and programmed for both breaker 1 and breaker 2. The USER 1 key performs the selection of which breaker is to be operated by the USER 2 and USER 3 keys. The USER 2 key is used to manually close the breaker and the USER 3 key is used to manually open the breaker.



| | |
|---|---|
| `ENTER COMMAND PASSWORD` | This message appears when the USER 1, USER 2, or USER 3 key is pressed and a **COMMAND PASSWORD** is required; i.e. if **COMMAND PASSWORD** is enabled and no commands have been issued within the last 30 minutes. |
| `Press USER 1 To Select Breaker` | This message appears if the correct password is entered or if none is required. This message displays for 30 seconds or until the USER 1 key is pressed again. |
| `BKR1-(Name) SELECTED USER 2=CLS/USER 3=OP` | This message is displayed after the USER 1 key is pressed for the second time. Three possible actions can be performed from this state within 30 seconds as per items **(1)**, **(2)** and **(3)** below: |
| **(1)** | |
| `USER 2 OFF/ON To Close BKR1-(Name)` | If the USER 2 key is pressed, this message appears for 20 seconds. If the USER 2 key is pressed again within that time, a signal is created that can be programmed to operate an output relay to close breaker 1. |
| **(2)** | |
| `USER 3 OFF/ON To Open BKR1-(Name)` | If the USER 3 key is pressed, this message appears for 20 seconds. If the USER 3 key is pressed again within that time, a signal is created that can be programmed to operate an output relay to open breaker 1. |
| **(3)** | |
| `BKR2-(Name) SELECTED USER 2=CLS/USER 3=OP` | If the USER 1 key is pressed at this step, this message appears showing that a different breaker is selected. Three possible actions can be performed from this state as per **(1)**, **(2)** and **(3)**. Repeatedly pressing the USER 1 key alternates between available breakers. Pressing keys other than USER 1, 2, or 3 at any time aborts the breaker control function. |

### e) CONTROL OF ONE BREAKER

For this application the relay is connected and programmed for breaker 1 only. Operation for this application is identical to that described above for two breakers.

## 4.3.7 MENUS

### a) NAVIGATION

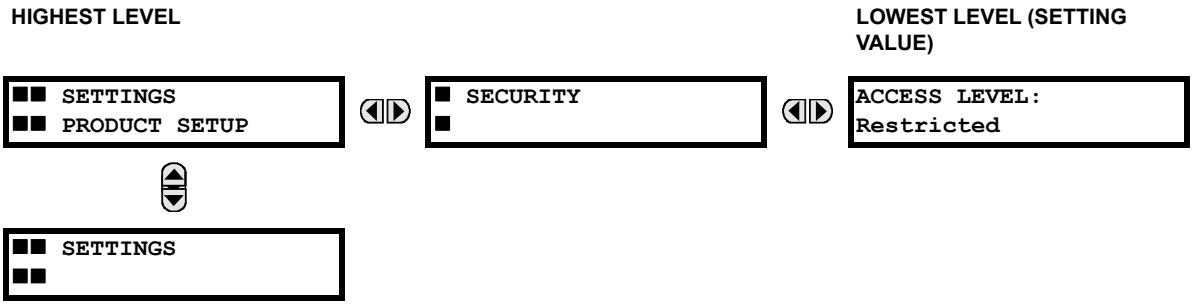
Press the MENU key to select a header display page (top-level menu). The header title appears momentarily followed by a header display page menu item. Each press of the MENU key advances through the following main heading pages:

- Actual values
- Settings

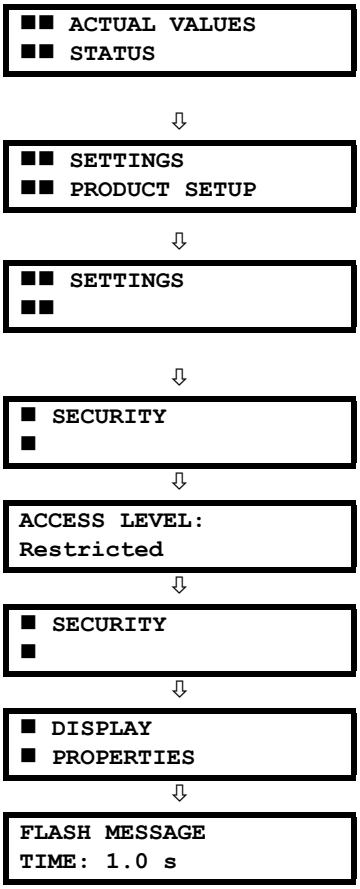
- Commands
- Targets
- User displays (when enabled)

### b) HIERARCHY

The setting and actual value messages are arranged hierarchically. The header display pages are indicated by double scroll bar characters (■■), while sub-header pages are indicated by single scroll bar characters (■). The header display pages represent the highest level of the hierarchy and the sub-header display pages fall below this level. The MESSAGE UP and DOWN keys move within a group of headers, sub-headers, setting values, or actual values. Continually pressing the MESSAGE RIGHT key from a header display displays specific information for the header category. Conversely, continually pressing the MESSAGE LEFT key from a setting value or actual value display returns to the header display.




### c) EXAMPLE MENU NAVIGATION




Press the MENU key until the header for the first Actual Values page appears. This page contains system and relay status information. Repeatedly press the MESSAGE keys to display the other actual value headers.

Press the MENU key until the header for the first page of Settings appears. This page contains settings to configure the relay.

Press the MESSAGE DOWN key to move to the next Settings page. This page contains settings for . Repeatedly press the MESSAGE UP and DOWN keys to display the other setting headers and then back to the first Settings page header.

From the Settings page one header (Product Setup), press the MESSAGE RIGHT key once to display the first sub-header (Security).

Press the MESSAGE RIGHT key once more and this will display the first setting for Security. Pressing the MESSAGE DOWN key repeatedly will display the remaining setting messages for this sub-header.

Press the MESSAGE LEFT key once to move back to the first sub-header message.

Pressing the MESSAGE DOWN key displays the second setting sub-header associated with the Product Setup header.

Press the MESSAGE RIGHT key once more to display the first setting for Display Properties.

### a) ENTERING NUMERICAL DATA

Each numerical setting has its own minimum, maximum, and increment value associated with it. These parameters define what values are acceptable for a setting.

```
FLASH MESSAGE
TIME:  1.0 s
```

For example, select the **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **DISPLAY PROPERTIES** ⇨ **FLASH MESSAGE TIME** setting.

⇩

```
MINIMUM:   0.5
MAXIMUM:  10.0
```

Press the HELP key to view the minimum and maximum values. Press the HELP key again to view the next context sensitive help message.

Two methods of editing and storing a numerical setting value are available.

- **0 to 9 and decimal point**: The relay numeric keypad works the same as that of any electronic calculator. A number is entered one digit at a time. The leftmost digit is entered first and the rightmost digit is entered last. Pressing the MESSAGE LEFT key or pressing the ESCAPE key, returns the original value to the display.
- **VALUE keys**: The VALUE UP key increments the displayed value by the step value, up to the maximum value allowed. While at the maximum value, pressing the VALUE UP key again allows the setting selection to continue upward from the minimum value. The VALUE DOWN key decrements the displayed value by the step value, down to the minimum value. While at the minimum value, pressing the VALUE DOWN key again allows the setting selection to continue downward from the maximum value.



```
FLASH MESSAGE
TIME:  2.5 s
```

As an example, set the flash message time setting to 2.5 seconds. Press the appropriate numeric keys in the sequence “2 . 5". The display message changes as the digits are being entered.

⇩

```
NEW SETTING
HAS BEEN STORED
```

Until ENTER is pressed, editing changes are not registered by the relay. Therefore, press ENTER to store the new value in memory. This flash message momentarily appears as confirmation of the storing process. Numerical values which contain decimal places are rounded-off if more decimal place digits are entered than specified by the step value.

### b) ENTERING ENUMERATION DATA

Enumeration settings have data values which are part of a set, whose members are explicitly defined by a name. A set is comprised of two or more members.

```
ACCESS LEVEL:
Restricted
```

For example, the selections available for **ACCESS LEVEL** are "Restricted", "Command", "Setting", and "Factory Service".

Enumeration type values are changed using the VALUE keys. The VALUE UP key displays the next selection while the VALUE DOWN key displays the previous selection.

```
ACCESS LEVEL:
Setting
```

If the **ACCESS LEVEL** needs to be "Setting", press the VALUE keys until the proper selection is displayed. Press HELP at any time for the context sensitive help messages.

⇩

```
NEW SETTING
HAS BEEN STORED
```

Changes are not registered by the relay until the ENTER key is pressed. Pressing ENTER stores the new value in memory. This flash message momentarily appears as confirmation of the storing process.

### c) ENTERING ALPHANUMERIC TEXT

Text settings have data values which are fixed in length, but user-defined in character. They can be upper case letters, lower case letters, numerals, and a selection of special characters.

There are several places where text messages can be programmed to allow the relay to be customized for specific applications. One example is the Message Scratchpad. Use the following procedure to enter alphanumeric text messages.

For example: to enter the text, “Breaker #1”.

1. Press the decimal point to enter text edit mode.
2. Press the VALUE keys until the character 'B' appears; press the decimal key to advance the cursor to the next position.
3. Repeat step 2 for the remaining characters: r,e,a,k,e,r, ,#,1.
4. Press ENTER to store the text.
5. If you have any problem, press HELP to view context sensitive help. Flash messages appear sequentially for several seconds each. For the case of a text setting message, pressing HELP displays how to edit and store new values.

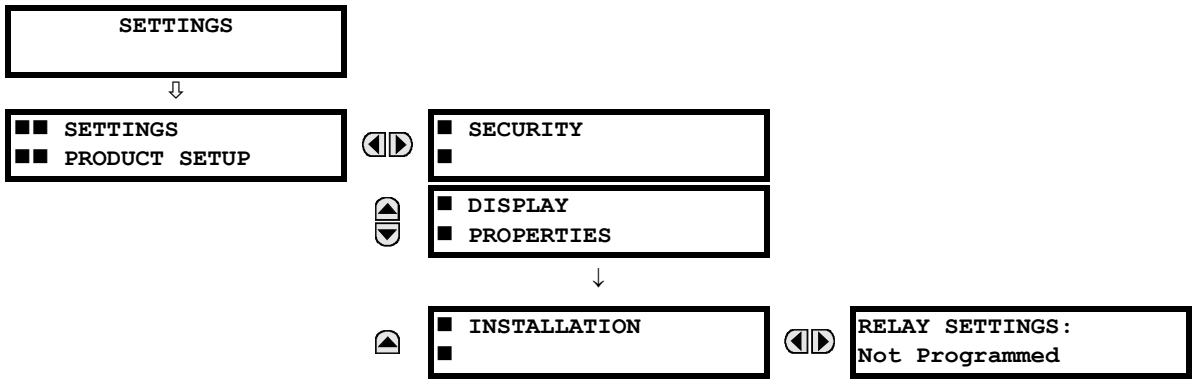
### d) ACTIVATING THE RELAY

| |
|---|
| RELAY SETTINGS:<br>Not Programmed |

When the relay is powered up, the Trouble LED is on, the In Service LED off, and this message displayed, indicating the relay is in the "Not Programmed" state and is safeguarding (output relays blocked) against the installation of a relay whose settings have not been entered. This message remains until the relay is explicitly put in the "Programmed" state.

To change the **RELAY SETTINGS**: "Not Programmed" mode to "Programmed", proceed as follows:

1. Press the MENU key until the **SETTINGS** header flashes momentarily and the **PRODUCT SETUP** message appears on the display.
2. Press the MESSAGE RIGHT key until the **SECURITY** message appears on the display.
3. Press the MESSAGE DOWN key until the **INSTALLATION** message appears on the display.
4. Press the MESSAGE RIGHT key until the **RELAY SETTINGS: Not Programmed** message is displayed.




5. After the **RELAY SETTINGS: Not Programmed** message appears on the display, press the VALUE keys change the selection to "Programmed".
6. Press the ENTER key.

| | | |
|---|---|---|
| RELAY SETTINGS:<br>Not Programmed | RELAY SETTINGS:<br>Programmed | NEW SETTING<br>HAS BEEN STORED |

7. When the "NEW SETTING HAS BEEN STORED" message appears, the relay is in "Programmed" state and the In Service LED turns on.

### e) ENTERING INITIAL PASSWORDS

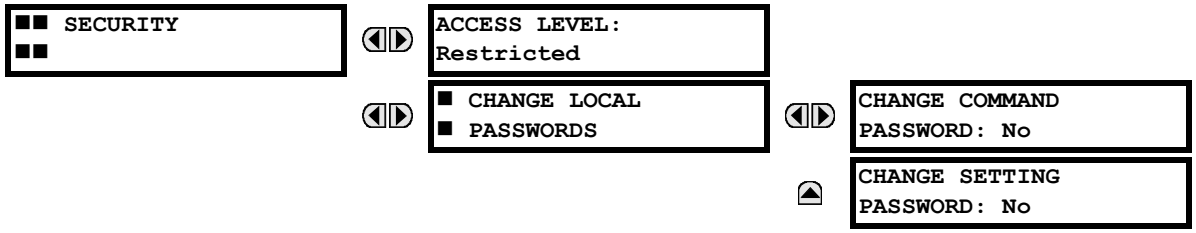
The information in this section refers to password security. For information on how to set or change CyberSentry passwords, see the Settings > Product Setup > Security > CyberSentry section in the next chapter.

The L30 supports password entry from a local or remote connection.

Local access is defined as any access to settings or commands via the faceplate interface. This includes both keypad entry and the faceplate RS232 connection. Remote access is defined as any access to settings or commands via any rear communications port. This includes both Ethernet and RS485 connections. Any changes to the local or remote passwords enables this functionality.

To enter the initial setting (or command) password, proceed as follows:

1. Press the MENU key until the **SETTINGS** header flashes momentarily and the **PRODUCT SETUP** message appears on the display.
2. Press the MESSAGE RIGHT key until the **ACCESS LEVEL** message appears on the display.
3. Press the MESSAGE DOWN key until the **CHANGE LOCAL PASSWORDS** message appears on the display.
4. Press the MESSAGE RIGHT key until the **CHANGE SETTING PASSWORD** or **CHANGE COMMAND PASSWORD** message appears on the display.




5. After the **CHANGE...PASSWORD** message appears on the display, press the VALUE UP or DOWN key to change the selection to "Yes".
6. Press the ENTER key and the display prompts you to **ENTER NEW PASSWORD**.
7. Type in a password and press the ENTER key.
8. When the **VERIFY NEW PASSWORD** is displayed, re-type in the same password and press ENTER.

9. When the **NEW PASSWORD HAS BEEN STORED** message appears, your new Setting (or Command) Password will be active.

### f) CHANGING EXISTING PASSWORD

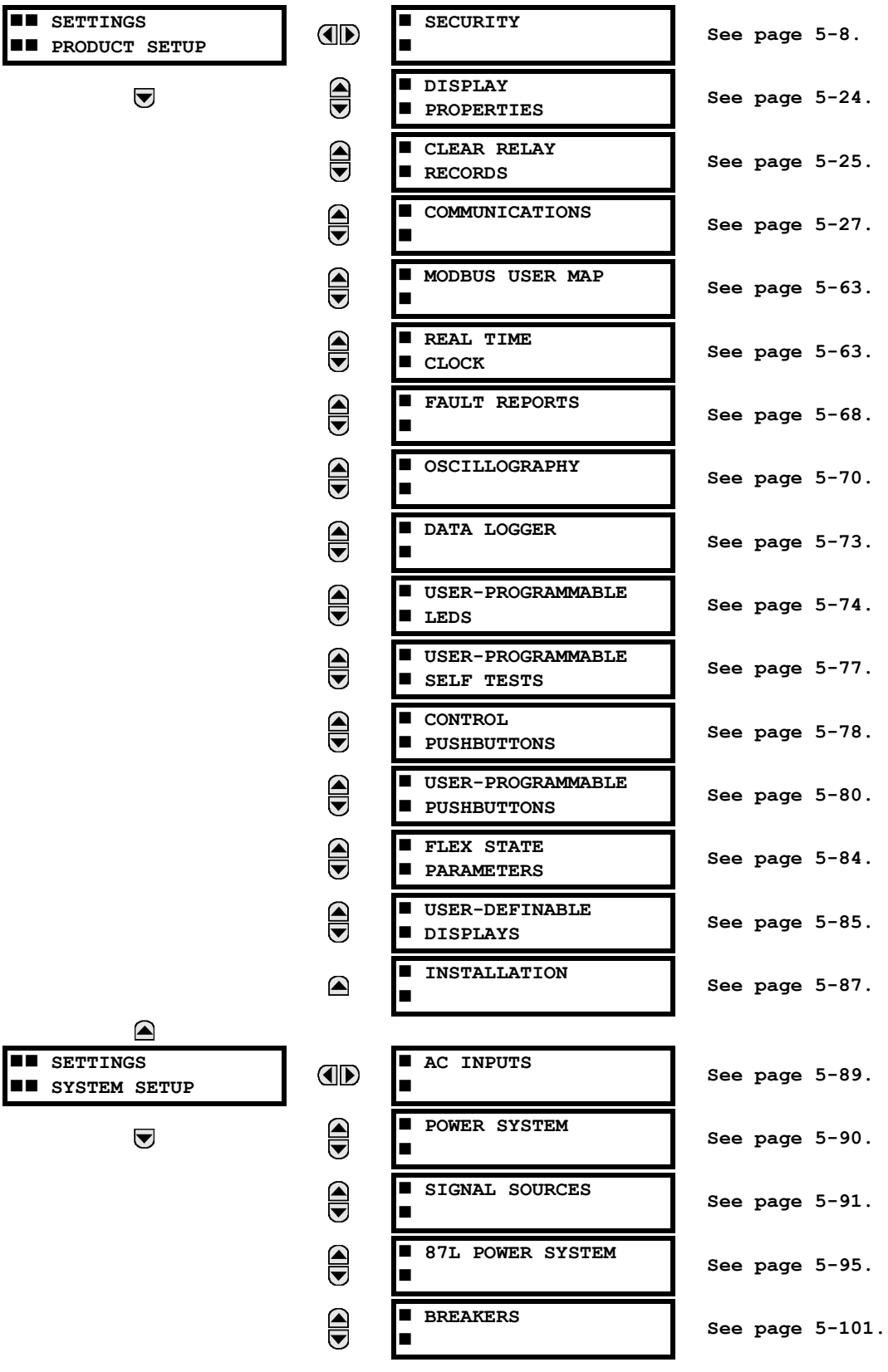
To change an existing password, follow the instructions in the previous section with the following exception. A message prompts you to type in the existing password (for each security level) before a new password can be entered.

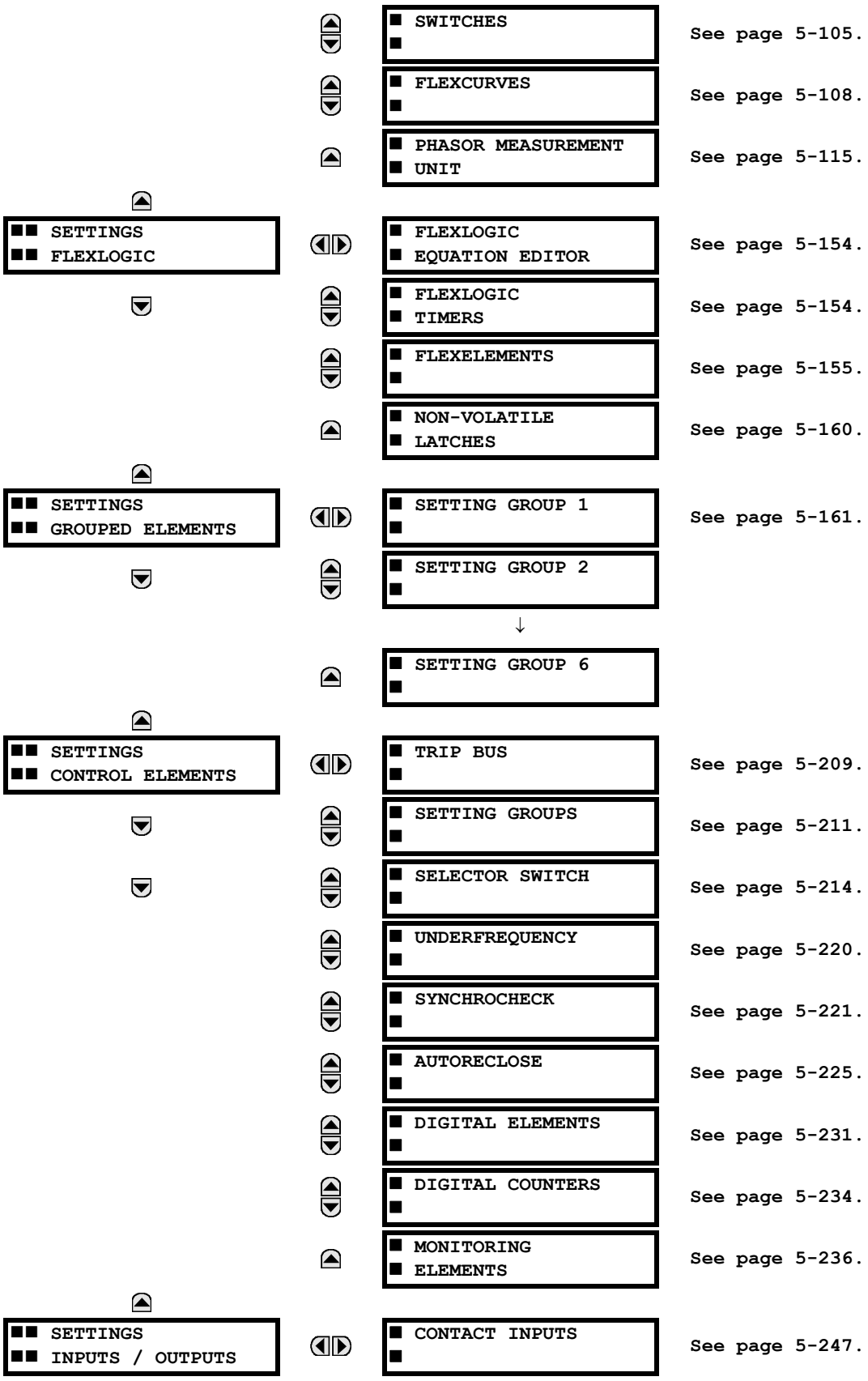
### g) INVALID PASSWORD ENTRY

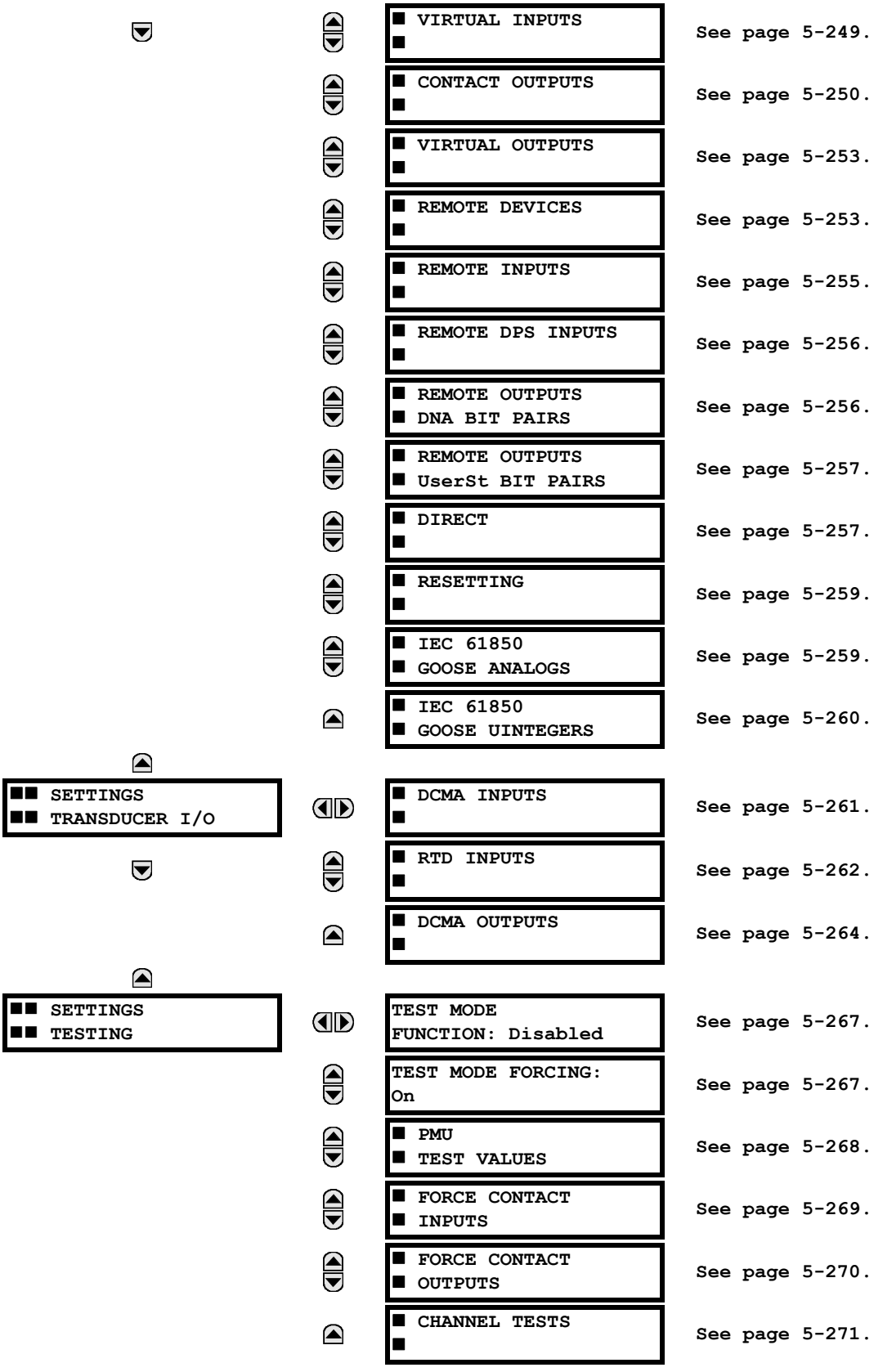
By default, when an incorrect Command or Setting password has been entered via the faceplate interface three times within three minutes, the LOCAL ACCESS DENIED FlexLogic operand is set to "On" and the L30 does not allow settings or command level access via the faceplate interface for the next five minutes.

By default, when an incorrect Command or Setting password has been entered via any external communications interface three times within three minutes, the REMOTE ACCESS DENIED FlexLogic operand is set to "On" and the L30 does not allow settings or command access via the any external communications interface for five minutes. The REMOTE ACCESS DENIED FlexLogic operand is set to "Off" after five minutes for a Command password or 30 minutes for a Settings password.

These default settings can be changed in EnerVista under **Settings > Product Setup > Security**.


SETTINGS
PRODUCT SETUP
SECURITY
See page 5-8.
DISPLAY PROPERTIES
See page 5-24.
CLEAR RELAY RECORDS
See page 5-25.
COMMUNICATIONS
See page 5-27.
MODBUS USER MAP
See page 5-63.
REAL TIME CLOCK
See page 5-63.
FAULT REPORTS
See page 5-68.
OSCILLOGRAPHY
See page 5-70.
DATA LOGGER
See page 5-73.
USER-PROGRAMMABLE LEDS
See page 5-74.
USER-PROGRAMMABLE SELF TESTS
See page 5-77.
CONTROL PUSHBUTTONS
See page 5-78.
USER-PROGRAMMABLE PUSHBUTTONS
See page 5-80.
FLEX STATE PARAMETERS
See page 5-84.
USER-DEFINABLE DISPLAYS
See page 5-85.
INSTALLATION
See page 5-87.
SETTINGS
SYSTEM SETUP
AC INPUTS
See page 5-89.
POWER SYSTEM
See page 5-90.
SIGNAL SOURCES
See page 5-91.
87L POWER SYSTEM
See page 5-95.
BREAKERS
See page 5-101.


SETTINGS
FLEXLOGIC
SETTINGS
GROUPED ELEMENTS
SETTINGS
CONTROL ELEMENTS
SETTINGS
INPUTS / OUTPUTS
SWITCHES
See page 5-105.
FLEXCURVES
See page 5-108.
PHASOR MEASUREMENT UNIT
See page 5-115.
FLEXLOGIC EQUATION EDITOR
See page 5-154.
FLEXLOGIC TIMERS
See page 5-154.
FLEXELEMENTS
See page 5-155.
NON-VOLATILE LATCHES
See page 5-160.
SETTING GROUP 1
See page 5-161.
SETTING GROUP 2
SETTING GROUP 6
TRIP BUS
See page 5-209.
SETTING GROUPS
See page 5-211.
SELECTOR SWITCH
See page 5-214.
UNDERFREQUENCY
See page 5-220.
SYNCHROCHECK
See page 5-221.
AUTORECLOSE
See page 5-225.
DIGITAL ELEMENTS
See page 5-231.
DIGITAL COUNTERS
See page 5-234.
MONITORING ELEMENTS
See page 5-236.
CONTACT INPUTS
See page 5-247.


VIRTUAL INPUTS
See page 5-249.
CONTACT OUTPUTS
See page 5-250.
VIRTUAL OUTPUTS
See page 5-253.
REMOTE DEVICES
See page 5-253.
REMOTE INPUTS
See page 5-255.
REMOTE DPS INPUTS
See page 5-256.
REMOTE OUTPUTS
DNA BIT PAIRS
See page 5-256.
REMOTE OUTPUTS
UserSt BIT PAIRS
See page 5-257.
DIRECT
See page 5-257.
RESETTING
See page 5-259.
IEC 61850
GOOSE ANALOGS
See page 5-259.
IEC 61850
GOOSE UINTEGERS
See page 5-260.
SETTINGS
TRANSDUCER I/O
DCMA INPUTS
See page 5-261.
RTD INPUTS
See page 5-262.
DCMA OUTPUTS
See page 5-264.
SETTINGS
TESTING
TEST MODE
FUNCTION: Disabled
See page 5-267.
TEST MODE FORCING:
On
See page 5-267.
PMU
TEST VALUES
See page 5-268.
FORCE CONTACT
INPUTS
See page 5-269.
FORCE CONTACT
OUTPUTS
See page 5-270.
CHANNEL TESTS
See page 5-271.

### 5.1.2 INTRODUCTION TO ELEMENTS

In the design of UR relays, the term *element* is used to describe a feature that is based around a comparator. The comparator is provided with an input (or set of inputs) that is tested against a programmed setting (or group of settings) to determine if the input is within the defined range that will set the output to logic 1, also referred to as *setting the flag*. A single comparator may make multiple tests and provide multiple outputs; for example, the time overcurrent comparator sets a pickup flag when the current input is above the setting and sets an operate flag when the input current has been at a level above the pickup setting for the time specified by the time-current curve settings. All comparators use analog actual values as the input.

NOTE

An exception to this rule is digital elements, which use logic states as inputs.

Elements are arranged into two classes, *grouped* and *control*. Each element classed as a grouped element is provided with six alternate sets of settings, in setting groups numbered 1 through 6. The performance of a grouped element is defined by the setting group that is active at a given time. The performance of a control element is independent of the selected active setting group.

The main characteristics of an element are shown on the element logic diagram. This includes the inputs, settings, fixed logic, and the output operands generated (abbreviations used on scheme logic diagrams are defined in Appendix F).

Some settings are specified in per-unit (pu) calculated quantities:

**pu quantity** = (actual quantity) / (base quantity)

Where the current source is from a single CT, the *base quantity* is the nominal secondary or primary current of the CT. Use the secondary current base to convert per-unit current settings to/from a secondary current value, and use the primary current base to convert to/from a primary current value.

Where the current source is the sum of two or more CTs with different nominal primary current, the primary base quantity is the largest nominal primary current. For example, if CT1 = 300 / 5 A and CT2 = 100 / 1 A, then in order to sum these, CT2 is scaled to the CT1 ratio. In this case, the base quantity is 300 A primary, 5 A secondary for CT1, and 300/(100/1) = 3 A secondary for CT2.

For voltage elements the primary base quantity is the nominal phase-to-phase primary voltage of the protected system provided that the VT ratio setting is set to the nominal ratio of the VTs and the secondary voltage setting is set to the phase-to-phase voltage seen by the relay when the voltage of the protected system in nominal. The UR uses the convention that nominal voltages in a three-phase system are phase-to-phase voltages.

For example, on a system with a 13.8 kV nominal primary voltage, the base quantity is 13800 V. With 14400:120 V delta-connected VTs, the secondary base quantity and secondary voltage setting is:

$$\frac{13800}{14400} \times 120 = 115 \text{ V} \quad \textbf{(EQ 5.1)}$$

For wye-connected VTs, the primary and secondary bases quanitities are as before, but the secondary voltage (here a phase-to-phase ground value) is:

$$\frac{13800}{14400} \times \frac{120}{\sqrt{3}} = 66.4 \text{ V} \quad \textbf{(EQ 5.2)}$$

Many settings are common to most elements and are discussed below:

- **FUNCTION setting:** This setting programs the element to be operational when selected as “Enabled”. The factory default is “Disabled”. Once programmed to “Enabled”, any element associated with the function becomes active and all options become available.
- **NAME setting:** This setting is used to uniquely identify the element.
- **SOURCE setting:** This setting is used to select the AC source to be monitored. See the Introduction to AC Sources section later.
- **PICKUP setting:** For simple elements, this setting is used to program the level of the measured parameter above or below which the pickup state is established. In more complex elements, a set of settings may be provided to define the range of the measured parameters which will cause the element to pickup.

- **PICKUP DELAY setting:** This setting sets a time-delay-on-pickup, or on-delay, for the duration between the pickup and operate output states.
- **RESET DELAY setting:** This setting is used to set a time-delay-on-dropout, or off-delay, for the duration between the Operate output state and the return to logic 0 after the input transits outside the defined pickup range.
- **BLOCK setting:** The default output operand state of all comparators is a logic 0 or "flag not set". The comparator remains in this default state until a logic 1 is asserted at the RUN input, allowing the test to be performed. If the RUN input changes to logic 0 at any time, the comparator returns to the default state. The RUN input is used to supervise the comparator. The BLOCK input is used as one of the inputs to RUN control.
- **TARGET setting:** This setting is used to define the operation of an element target message. When set to **"**Disabled**"**, no target message or illumination of a faceplate LED indicator is issued upon operation of the element. When set to "Self-Reset", the target message and LED indication follow the operate state of the element, and self-resets once the operate element condition clears. When set to "Latched", the target message and LED indication will remain visible after the element output returns to logic 0 until a RESET command is received by the relay.
- **EVENTS setting:** This setting is used to control whether the pickup, dropout or operate states are recorded by the event recorder. When set to "Disabled", element pickup, dropout or operate are not recorded as events. When set to "Enabled", events are created for:

  (Element) PKP (pickup)
  (Element) DPO (dropout)
  (Element) OP (operate)

  The DPO event is created when the measure and decide comparator output transits from the pickup state (logic 1) to the dropout state (logic 0). This could happen when the element is in the operate state if the reset delay time is not 0.

  Not every operand of a given element in a UR relay generates events, only the major output operands. Elements, asserting output per phase, log operating phase output only, without asserting the common three-phase operand event.



### 5.1.3 INTRODUCTION TO AC SOURCES

#### a) BACKGROUND

The L30 may be used on systems with breaker-and-a-half or ring bus configurations.

In these applications, each of the two three-phase sets of individual phase currents (one associated with each breaker) can be used as an input to a breaker failure element. The sum of both breaker phase currents and 3I_0 residual currents may be required for the circuit relaying and metering functions. Two separate synchrocheck elements can be programmed to check synchronization between two different buses VT and the line VT. These requirements can be satisfied with a single L30, equipped with sufficient CT and VT input channels, by selecting proper parameter to measure. A mechanism is provided to specify the AC parameter (or group of parameters) used as the input to protection/control comparators and some metering elements. Selection of the measured parameters is partially performed by the design of a measuring element or protection/control comparator by identifying the measured parameter type (fundamental frequency phasor, harmonic phasor, symmetrical component, total waveform RMS magnitude, phase-phase or phase-ground voltage, etc.). The user completes the process by selecting the instrument transformer input channels to use and some parameters calculated from these channels. The input parameters available include the summation of currents from multiple input channels. For the summed currents of phase, 3I_0, and ground current, current from CTs with different ratios are adjusted to a single ratio before summation. A mechanism called a *source* configures the routing of CT and VT input channels to measurement subsystems.

Sources, in the context of L30 series relays, refer to the logical grouping of current and voltage signals such that one source contains all the signals required to measure the load or fault in a particular power apparatus. A given source may contain all or some of the following signals: three-phase currents, single-phase ground current, three-phase voltages and an auxiliary voltages from a single-phase VT for checking for synchronism.

To illustrate the concept of Sources, as applied to current inputs only, consider the breaker-and-a-half scheme below. Some protection elements, like breaker failure, require individual CT current as an input. Other elements, like distance, require the sum of both current as an input. The line differential function requires the CT currents to be processed individually to cope with a possible CT saturation of one CT during an external fault on the upper bus. The current into protected line is the phasor sum (or difference) of the currents in CT1 and CT2, depending on the current distribution on the upper bus.

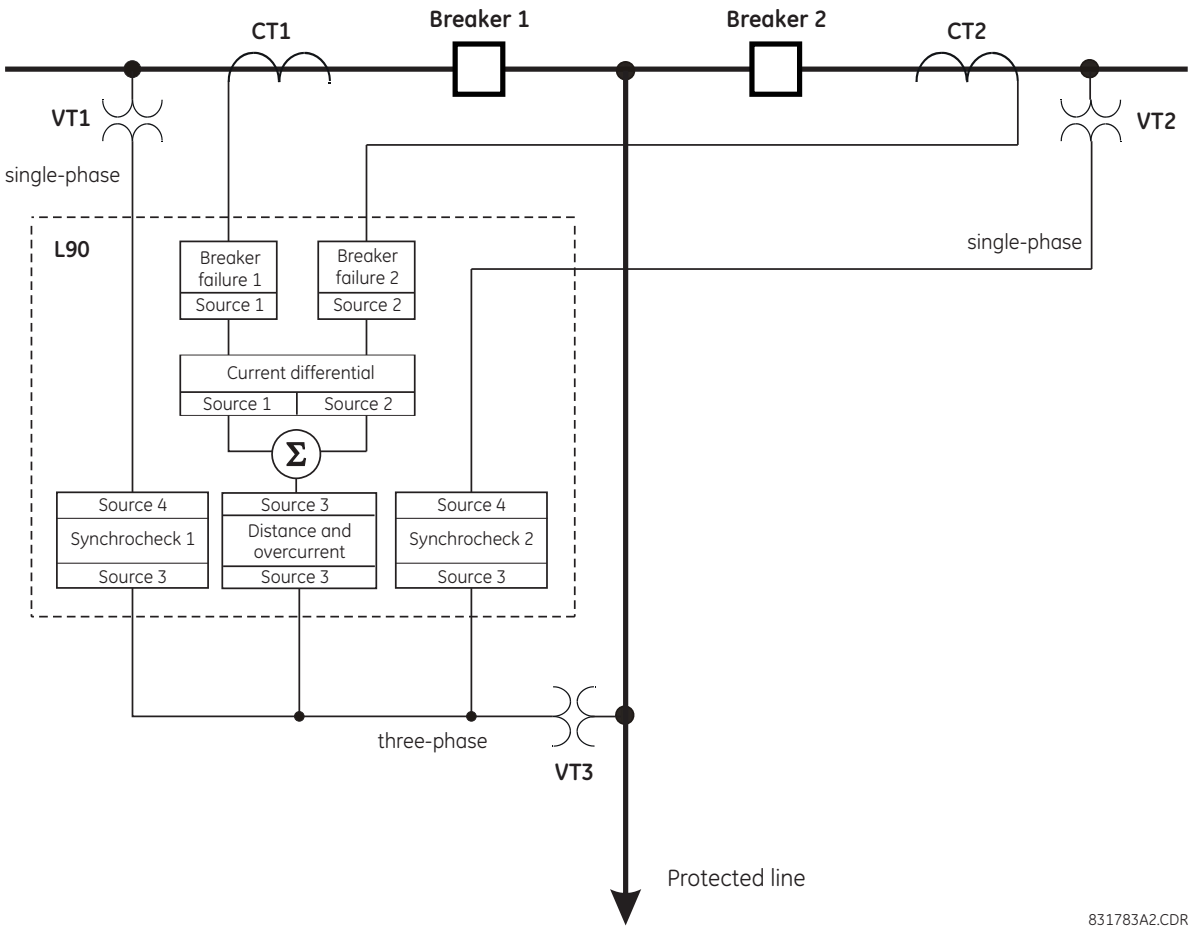



**Figure 5–1: BREAKER-AND-A-HALF SCHEME**

In conventional analog or electronic relays, the sum of the currents is obtained from an appropriate external connection of all CTs through which any portion of the current for the element being protected could flow. Auxiliary CTs are required to perform ratio matching if the ratios of the primary CTs to be summed are not identical. In the L30 relay, provisions have been included for all the current signals to be brought to the device where grouping, CT ratio correction, and summation are applied internally via configuration settings. Up to four currents can be brought into L30 relay; current summation and CT ratio matching is performed internally. A major advantage of internal summation is that individual currents are available to the protection device (for example, as additional information to apply a restraint current properly, or to allow the provision of additional features that operate on the individual currents, such as breaker failure). Given the flexibility of this approach, it becomes necessary to add configuration settings to the platform to allow the user to select which sets of CT inputs will be added to form the net current into the protected device. The internal grouping of current and voltage signals forms an internal source. This source can be assigned a specific name and becomes available to protection and metering elements in the relay. Individual names can be given to each source to identify them for later use. For example, in the scheme shown above, three different sources are be configured as inputs for separate elements:

- Source 1: CT1 current, for the breaker failure 1 element and first current source for the line differential element.
- Source 2: CT2 current, for breaker failure 2 element and second current source for the line differential element.
- Source 3: the sum of the CT1 and CT2 currents for the distance function.

In addition, two separate synchrocheck elements can be programmed to check synchronization between line voltage and two different bus voltages (SRC3–SRC1 and SRC3–SRC2).

### b) CT/VT MODULE CONFIGURATION

CT and VT input channels are contained in CT/VT modules. The type of input channel can be phase/neutral/other voltage, phase/ground current, or sensitive ground current. The CT/VT modules calculate total waveform RMS levels, fundamental frequency phasors, symmetrical components and harmonics for voltage or current, as allowed by the hardware in each channel. These modules may calculate other parameters as directed by the CPU module.

A CT/VT module contains up to eight input channels, numbered 1 through 8. The channel numbering corresponds to the module terminal numbering 1 through 8 and is arranged as follows: Channels 1, 2, 3, and 4 are always provided as a group, hereafter called a “bank,” and all four are either current or voltage, as are channels 5, 6, 7, and 8. Channels 1, 2, 3 and 5, 6, 7 are arranged as phase A, B and C respectively. Channels 4 and 8 are either another current or voltage.

Banks are ordered sequentially from the block of lower-numbered channels to the block of higher-numbered channels, and from the CT/VT module with the lowest slot position letter to the module with the highest slot position letter, as follows:

The UR platform allows for a maximum of six sets of three-phase voltages and six sets of three-phase currents. The result of these restrictions leads to the maximum number of CT/VT modules in a chassis to three. The maximum number of sources is six. A summary of CT/VT module configurations is shown below.

| ITEM | MAXIMUM NUMBER |
|---|---|
| CT/VT Module | 1 |
| CT Bank (3 phase channels, 1 ground channel) | 2 |
| VT Bank (3 phase channels, 1 auxiliary channel) | 1 |

### c) CT/VT INPUT CHANNEL CONFIGURATION

Upon relay startup, configuration settings for every bank of current or voltage input channels in the relay are automatically generated from the order code. Within each bank, a channel identification label is automatically assigned to each bank of channels in a given product. The *bank* naming convention is based on the physical location of the channels, required by the user to know how to connect the relay to external circuits. Bank identification consists of the letter designation of the slot in which the CT/VT module is mounted as the first character, followed by numbers indicating the channel, either 1 or 5. See the HardFiber instruction manual for designations of HardFiber voltage and current banks.

For three-phase channel sets, the number of the lowest numbered channel identifies the set. For example, F1 represents the three-phase channel set of F1/F2/F3, where F is the slot letter and 1 is the first channel of the set of three channels.

Upon startup, the CPU configures the settings required to characterize the current and voltage inputs, and will display them in the appropriate section in the sequence of the banks (as described above) as follows for a maximum configuration: F1, F5, L1, L5, S1, and S5.

### a) SECURITY OVERVIEW

The following security features are available:

- Password security — Basic security present in the default offering of the product
- EnerVista security — Role-based access to various EnerVista software screens and configuration elements. The feature is available in the default offering of the product and only in the EnerVista software.
- CyberSentry security — Advanced security options available as a software option. When purchased, the options are automatically enabled, and the default Password security and EnerVista security are disabled.

Changing the password, or any other setting, does not take the relay out of service. The relay is taken out of service when a settings file is written to it.

#### LOST PASSWORD

If all passwords are lost, reset the unit to default values. Follow the instructions outlined later for **COMMANDS ⇨⇩ RELAY MAINTENANCE ⇨ SERVICE COMMAND**. Note that the relay is reset to default values, not just the passwords.

Then for CyberSentry, change the default password of ChangeMe1# as outlined in the Set Up CyberSentry and Change Default Password section at the end of the Installation chapter.

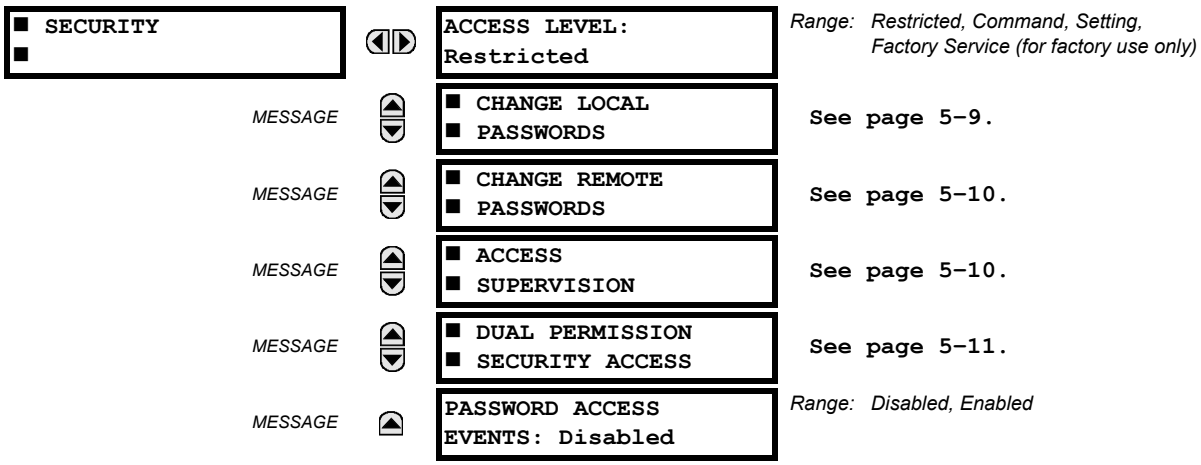
#### PASSWORD REQUIREMENTS

A user account requires an alpha-numeric password that meets the following requirements:

- Password is case-sensitive
- Password cannot contain the user account name or parts of the user account that exceed two consecutive characters
- Password must be 6 to 20 characters in length
- Password must contain characters from three of the following four categories:
  - English uppercase characters (A through Z)
  - English lowercase characters (a through z)
  - Base 10 digits (0 through 9)
  - Non-alphabetic characters (for example, ~, !, @, #, $,%, &)

### b) PASSWORD SECURITY

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY**




The L30 supports password entry from a local or remote connection.

Local access is defined as any access to settings or commands via the faceplate interface. This includes both keypad entry and the through the faceplate RS232 port. Remote access is defined as any access to settings or commands via any rear communications port. This includes both Ethernet and RS485 connections. Any changes to the local or remote passwords enables this functionality.

When entering a settings or command password via EnerVista or any serial interface, the user must enter the corresponding connection password. If the connection is to the back of the L30, the remote password must be used. If the connection is to the RS232 port of the faceplate, the local password must be used.

NOTE

For a relay without a CyberSentry software option, any user can activate the **RESET** button without password entry.

For the **ACCESS LEVEL**, the "Restricted" option means both settings and commands can be accessed, but there is no access to factory configuration. The "Factory Service" level is not available and intended for factory use only. In addition, there are two user security access levels, setting and command, for which you set a password for each. Use of a password for each level controls whether users can enter commands or change settings. Another option is to specify setting and/or command access for individual user accounts.

The **PASSWORD ACCESS EVENTS** settings allows recording of password access events in the event recorder.

The local setting and command sessions are initiated by the user through the front panel display and are disabled either by the user or by timeout (via the setting and command level access timeout settings). The remote setting and command sessions are initiated by the user through the EnerVista UR Setup software and are disabled either by the user or by timeout.

The state of the session (local or remote, setting or command) determines the state of the following FlexLogic operands.

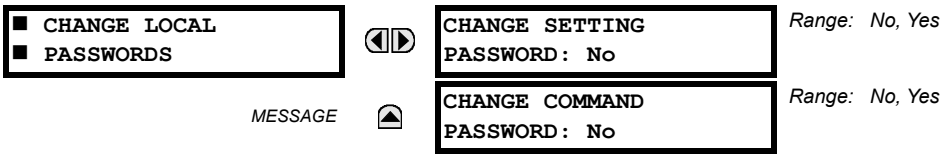
- ACCESS LOC SETG OFF: Asserted when local setting access is disabled
- ACCESS LOC SETG ON: Asserted when local setting access is enabled
- ACCESS LOC CMND OFF: Asserted when local command access is disabled
- ACCESS LOC CMND ON: Asserted when local command access is enabled
- ACCESS REM SETG OFF: Asserted when remote setting access is disabled
- ACCESS REM SETG ON: Asserted when remote setting access is enabled
- ACCESS REM CMND OFF: Asserted when remote command access is disabled
- ACCESS REM CMND ON: Asserted when remote command access is enabled

NOTE

A command or setting write operation is required to update the state of the remote and local security operands listed.

### LOCAL PASSWORDS

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ CHANGE LOCAL PASSWORDS**




Proper password codes are required to enable each access level. When a **CHANGE COMMAND PASSWORD** or **CHANGE SETTING PASSWORD** setting is programmed to “Yes” via the front panel interface, the following message sequence is invoked:

1. ENTER NEW PASSWORD: _____.
2. VERIFY NEW PASSWORD: _____.
3. NEW PASSWORD HAS BEEN STORED.

To gain write access to a “Restricted” setting, program the **ACCESS LEVEL** setting in the main security menu to “Setting” and then change the setting, or attempt to change the setting and follow the prompt to enter the programmed password. If the password is correctly entered, access is allowed. Access automatically reverts to the “Restricted” level according to the access level timeout setting values.

NOTE

If the setting and command passwords are identical, then this one password allows access to both commands and settings.

If a remote connection is established, local passcodes are not visible.

### REMOTE PASSWORDS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ CHANGE REMOTE PASSWORDS

```
■ CHANGE REMOTE
■ PASSWORDS
```

```
CHANGE SETTING
PASSWORD: No
```

*Range: No, Yes*

*MESSAGE*

```
CHANGE COMMAND
PASSWORD: No
```

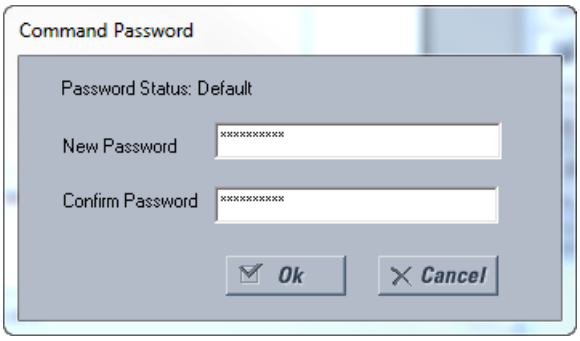
*Range: No, Yes*

This menu displays when the **ACCESS LEVEL** setting is other than Restricted or Command.

Proper passwords are required to enable each command or setting level access.

To set the command or setting password:

1. In the EnerVista software, navigate to **Settings > Product Setup > Security** menu item to open the remote password settings window.
2. Click the command or setting password **Change** button.
3. Enter the new password in the **New Password** field. Requirements are outlined in the Password Requirements section at the beginning of the chapter. When an original password has already been used, enter it in the **Enter Password** field and click the **Send Password to Device** button.
4. Re-enter the password in the **Confirm Password** field.
5. Click the **OK** button. The password is checked to ensure that is meets requirements.




NOTE

If you establish a local connection to the relay (serial), you cannot view remote passcodes.

### ACCESS SUPERVERSION

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ ACCESS SUPERVISION

```
■ ACCESS
■ SUPERVISION
```

```
■ ACCESS LEVEL
■ TIMEOUTS
```

*MESSAGE*

```
INVALID ATTEMPTS
BEFORE LOCKOUT: 3
```

*Range: 2 to 5 in steps of 1*

*MESSAGE*

```
PASSWORD LOCKOUT
DURATION: 5 min
```

*Range: 5 to 60 minutes in steps of 1*

This menu displays when the **ACCESS LEVEL** setting is other than Restricted or Command.

The following access supervision settings are available.

- **INVALID ATTEMPTS BEFORE LOCKOUT**: This setting specifies the number of times an incorrect password can be entered within a three-minute time span before lockout occurs. When lockout occurs, the LOCAL ACCESS DENIED or

REMOTE ACCESS DENIED FlexLogic operands are set to "On". These operands are returned to the "Off" state upon expiration of the lockout.

- **PASSWORD LOCKOUT DURATION**: This setting specifies the time that the L30 will lockout password access after the number of invalid password entries specified by the **INVALID ATTEMPTS BEFORE LOCKOUT** setting has occurred.

The L30 provides a means to raise an alarm upon failed password entry. Should password verification fail while accessing a password-protected level of the relay (either settings or commands), the UNAUTHORIZED ACCESS FlexLogic operand is asserted. The operand can be programmed to raise an alarm via contact outputs or communications. This feature can be used to protect against both unauthorized and accidental access attempts.

The UNAUTHORIZED ACCESS operand is reset with the **COMMANDS ⇨⇩ CLEAR RECORDS ⇨⇩ RESET UNAUTHORIZED ALARMS** command. Therefore, to apply this feature with security, the command level should be password-protected. The operand does not generate events or targets.

The access level timeout settings are shown below.

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ ACCESS SUPERVISION ⇨ ACCESS LEVEL TIMEOUTS**

```
■ ACCESS LEVEL
■ TIMEOUTS
```

```
COMMAND LEVEL ACCESS
TIMEOUT: 5 min
```

*Range: 5 to 480 minutes in steps of 1*

*MESSAGE*

```
SETTING LEVEL ACCESS
TIMEOUT: 30 min
```

*Range: 5 to 480 minutes in steps of 1*

These settings allow the user to specify the length of inactivity required before returning to the restricted access level. Note that the access level will set as restricted if control power is cycled.

- **COMMAND LEVEL ACCESS TIMEOUT**: This setting specifies the length of inactivity (no local or remote access) required to return to restricted access from the command password level.
- **SETTING LEVEL ACCESS TIMEOUT**: This setting specifies the length of inactivity (no local or remote access) required to return to restricted access from the settings password level.



### DUAL PERMISSION SECURITY ACCESS

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ DUAL PERMISSION SECURITY ACCESS**

```
■ DUAL PERMISSION
■ SECURITY ACCESS
```

```
LOCAL SETTING AUTH:
On
```

*Range: selected FlexLogic operands (see below)*

*MESSAGE*

```
REMOTE SETTING AUTH:
On
```

*Range: FlexLogic operand*

*MESSAGE*

```
ACCESS AUTH
TIMEOUT: 30 min
```

*Range: 5 to 480 minutes in steps of 1*

This menu displays when the **ACCESS LEVEL** setting is other than Restricted or Command.

The dual permission security access feature provides a mechanism for customers to prevent unauthorized or unintended upload of settings to a relay through the local or remote interfaces interface.

The following settings are available through the local (front panel) interface only.

- **LOCAL SETTING AUTH**: This setting is used for local (front panel or RS232 interface) setting access supervision. Valid values for the FlexLogic operands are either "On" (default) or any physical "Contact Input ~~ On" value.

  If this setting is "On", then local setting access functions as normal; that is, a local setting password is required. If this setting is any contact input on FlexLogic operand, then the operand must be asserted (set as on) prior to providing the local setting password to gain setting access.

  If setting access is *not* authorized for local operation (front panel or RS232 interface) and the user attempts to obtain setting access, then the **UNAUTHORIZED ACCESS** message is displayed on the front panel.

  If this setting is "Off," firmware upgrades are blocked. If this setting is "On," firmware upgrades are allowed.

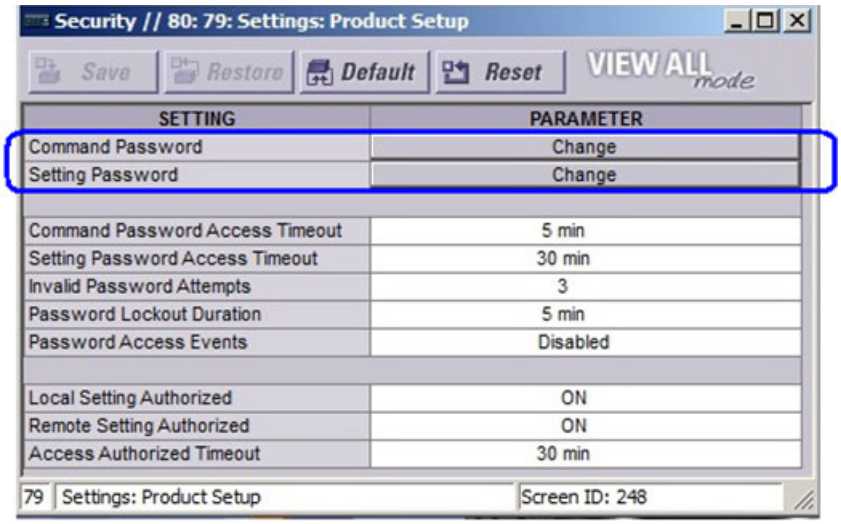
- **REMOTE SETTING AUTH**: This setting is used for remote (Ethernet or RS485 interfaces) setting access supervision.

If this setting is “On” (the default setting), then remote setting access functions as normal; that is, a remote password is required). If this setting is “Off”, then remote setting access is blocked even if the correct remote setting password is provided. If this setting is any other FlexLogic operand, then the operand must be asserted (set as on) prior to providing the remote setting password to gain setting access.

If this setting is "Off," firmware upgrades are blocked. If this setting is "On," firmware upgrades are allowed.

- **ACCESS AUTH TIMEOUT**: This setting represents the timeout delay for local setting access. This setting is applicable when the **LOCAL SETTING AUTH** setting is programmed to any operand except “On”. The state of the FlexLogic operand is continuously monitored for an off-to-on transition. When this occurs, local access is permitted and the timer programmed with the **ACCESS AUTH TIMEOUT** setting value is started. When this timer expires, local setting access is immediately denied. If access is permitted and an off-to-on transition of the FlexLogic operand is detected, the timeout is restarted. The status of this timer is updated every five seconds.

The following settings are available through the remote (EnerVista UR Setup) interface only. Select the **Settings > Product Setup > Security** menu item to display the security settings window.




The **Remote Settings Authorized** setting is used for remote (Ethernet or RS485 interfaces) setting access supervision. If this setting is “On” (the default setting), then remote setting access functions as normal; that is, a remote password is required. If this setting is “Off”, then remote setting access is blocked even if the correct remote setting password is provided. If this setting is any other FlexLogic operand, then the operand must be asserted (set as on) prior to providing the remote setting password to gain setting access.

The **Access Authorized Timeout** setting represents the timeout delay remote setting access. This setting is applicable when the **Remote Settings Authorized** setting is programmed to any operand except “On” or “Off”. The state of the FlexLogic operand is continuously monitored for an off-to-on transition. When this occurs, remote setting access is permitted and the timer programmed with the **Access Authorized Timeout** setting value is started. When this timer expires, remote setting access is immediately denied. If access is permitted and an off-to-on transition of the FlexLogic operand is detected, the timeout is restarted. The status of this timer is updated every five seconds.

### c) ENERVISTA SECURITY

#### ENABLING THE SECURITY MANAGEMENT SYSTEM

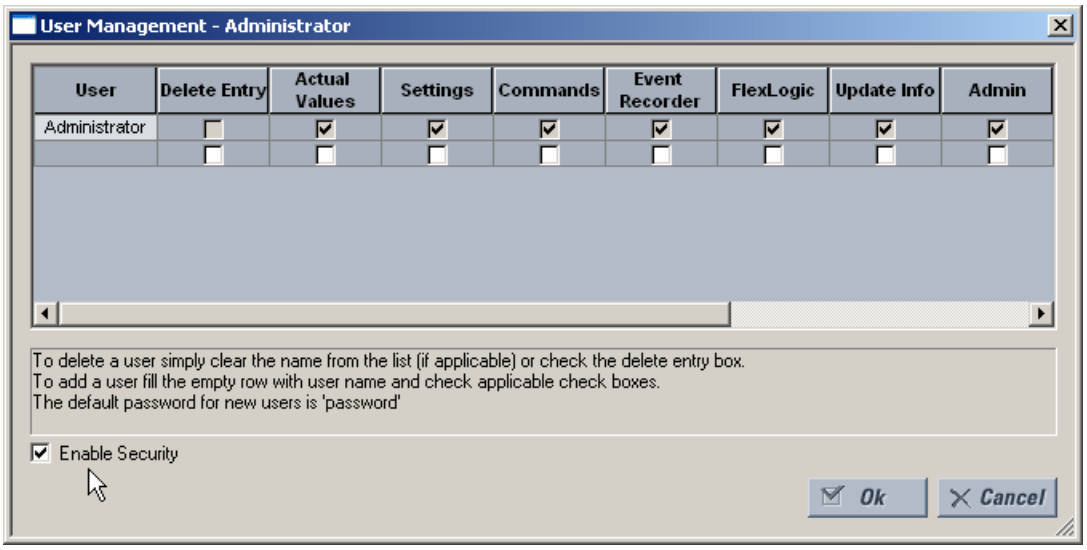
Access to files is controlled by the operating system and EnerVista software as follows:

- Access privileges to files are defined by the Windows operating system. A standard user does not have access to a file created by an administrator or another user.
- When the EnerVista UR Setup software security system is disabled (passwords are not required), all users have administrator access

The EnerVista security system allows an administrator to manage access privileges of multiple users of EnerVista. It is disabled by default to allow access to the device immediately after installation. When security is disabled, all users have administrator access. GE recommends enabling the EnerVista security before placing the device in service.

To enable the security system and require password use:

1. Select the **Security > User Management** menu item to open the user management window.




2. Check the **Enable Security** box in the lower-left corner to enable the security management system.

NOTE

If you force password entry using this feature, ensure that you know the Administrator password. If you do not know the password and are locked out of the software, reset the device to factory defaults as outlined later for **COMMANDS ⇨⇩ RELAY MAINTENANCE ⇨ SERVICE COMMAND**. When using CyberSentry, the default password is "ChangeMe1#".

Security is now enabled for the EnerVista UR Setup software. Upon starting the software, users are now required to enter a username and password.

### ADDING A NEW USER

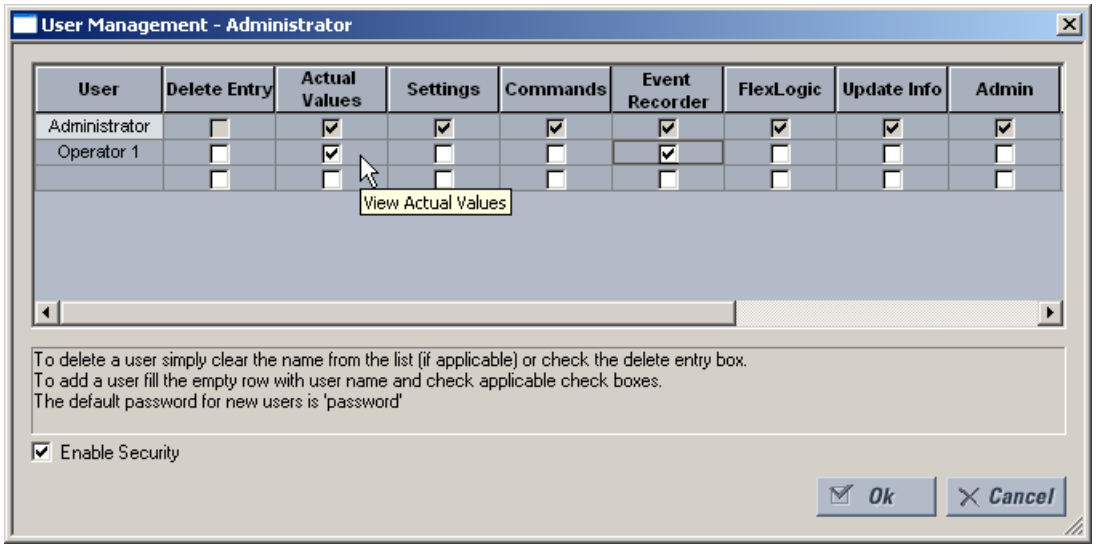
The following pre-requisites are required to add user accounts to the EnerVista security management system:

- The user adding the account must have administrator rights
- The EnerVista security management system must be enabled (previous section)

To add user accounts:

1. Select the **Security > User Management** menu item to open the user management window.
2. Enter a username in the **User** field. The username must be 4 to 20 characters in length.

3. Select the user access rights by enabling the check box of one or more of the fields.




The table outlines access rights.

**Table 5–1: ACCESS RIGHTS SUMMARY**

| FIELD | DESCRIPTION |
|---|---|
| Delete Entry | Deletes the user account when exiting the user management window |
| Actual Values | Allows the user to read actual values |
| Settings | Allows the user to read setting values |
| Commands | Allows the user to execute commands |
| Event Recorder | Allows the user to use the digital fault recorder |
| FlexLogic | Allows the user to read FlexLogic values |
| Update Info | Allows the user to write to any function to which they have read privileges. When any of the Settings, Event Recorder, and FlexLogic check boxes are enabled by themselves, the user is granted read access. When any of them are enabled in conjunction with the Update Info box, they are granted read and write access. The user is not granted write access to functions that are not checked, even if the Update Info field is checked. |
| Admin | The user is an EnerVista UR Setup administrator, therefore receiving all of the administrative rights. Exercise caution when granting administrator rights. |

4. Click **OK** to add the user account to the security management system.

### MODIFYING USER PRIVILEGES

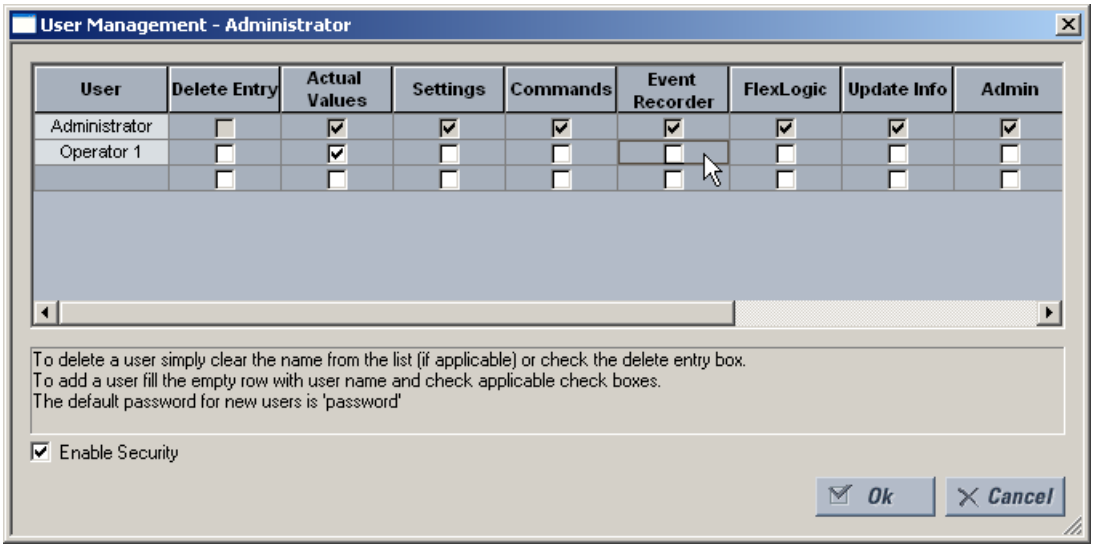
The following pre-requisites are required to modify user privileges in the EnerVista security management system:

- The user modifying the privileges must have administrator rights
- The EnerVista security management system must be enabled

To modify user privileges:

1. Select the **Security > User Management** menu item to open the user management window.
2. Locate the username in the **User** field.

3. Modify the user access rights by enabling or disabling one or more of the check boxes.




The table outlines access rights.

**Table 5–2: ACCESS RIGHTS SUMMARY**

| FIELD | DESCRIPTION |
|---|---|
| Delete Entry | Deletes the user account when exiting the user management window |
| Actual Values | Allows the user to read actual values |
| Settings | Allows the user to read setting values |
| Commands | Allows the user to execute commands |
| Event Recorder | Allows the user to use the digital fault recorder |
| FlexLogic | Allows the user to read FlexLogic values |
| Update Info | Allows the user to write to any function to which they have read privileges. When any of the Settings, Event Recorder, and FlexLogic check boxes are enabled by themselves, the user is granted read access. When any of them are enabled in conjunction with the Update Info box, they are granted read and write access. The user is not granted write access to functions that are not checked, even if the Update Info field is checked. |
| Admin | The user is an EnerVista UR Setup administrator, therefore receiving all of the administrative rights. Exercise caution when granting administrator rights. |

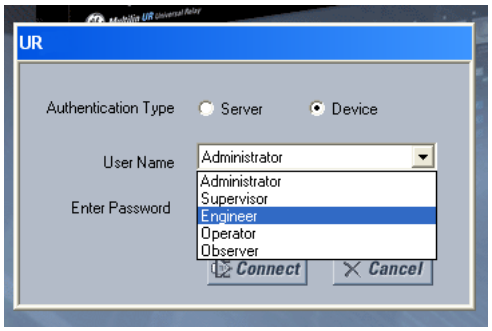
4. Click **OK** to save the changes.

### d) CYBERSENTRY SECURITY

The EnerVista software provides the means to configure and authenticate UR using either server or device or authentication. Access to various functionality depends on user role.

The login screen of EnerVista has two options for access to the UR, server and device authentication.

**Figure 5–2: LOGIN SCREEN FOR CYBERSENTRY**



When the "Server" Authentication Type option is selected, the UR uses the RADIUS server and not its local authentication database to authenticate the user.

When the "Device" button is selected, the UR uses its local authentication database and not the RADIUS server to authenticate the user. In this case, it uses built-in roles (Administrator, Engineer, Supervisor, Operator, Observer, or Administrator and Supervisor when Device Authentication is disabled) as login accounts and the associated passwords are stored on the UR device. In this case, access is not user-attributable. In cases where user-attributable access is required, especially for auditable processes for compliance reasons, use server authentication (RADIUS) only.

No password or security information is displayed in plain text by the EnerVista software or UR device, nor are they ever transmitted without cryptographic protection.

NOTE

Only (TCP/UDP) ports and services that are needed for device configuration and for customer enabled features are open. All the other ports are closed. For example, Modbus is on by default, so its TCP port number, 502, is open. But if Modbus is disabled, port 502 is closed. This function has been tested and no unused ports have been found open.

When CyberSentry is enabled, Modbus communications over Ethernet is encrypted, which is not always tolerated by SCADA systems. The UR has a bypass access feature for such situations, which allows unencrypted Modbus over Ethernet. The **BYPASS ACCESS** setting is available on the **SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ SUPERVISORY** screen. Note that other protocols (DNP, 101, 103, 104, EGD) are not encrypted, and they are good communications options for SCADA systems when CyberSentry is enabled.

When using the rear RS485 port and CyberSentry, registers can be read with a maximum buffer of 64 bytes. Settings may or may not be written, so use another port or configure the **SERIAL INACTIVITY TIMEOUT** setting to a high value, such as eight minutes, to give the relay enough time to finish the task.

### CYBERSENTRY SETTINGS THROUGH ENERVISTA



CyberSentry security settings are configured under **Device > Settings > Product Setup > Security**.

For the **Device > Settings > Product Setup > Supervisory** option, the panel looks like the following.

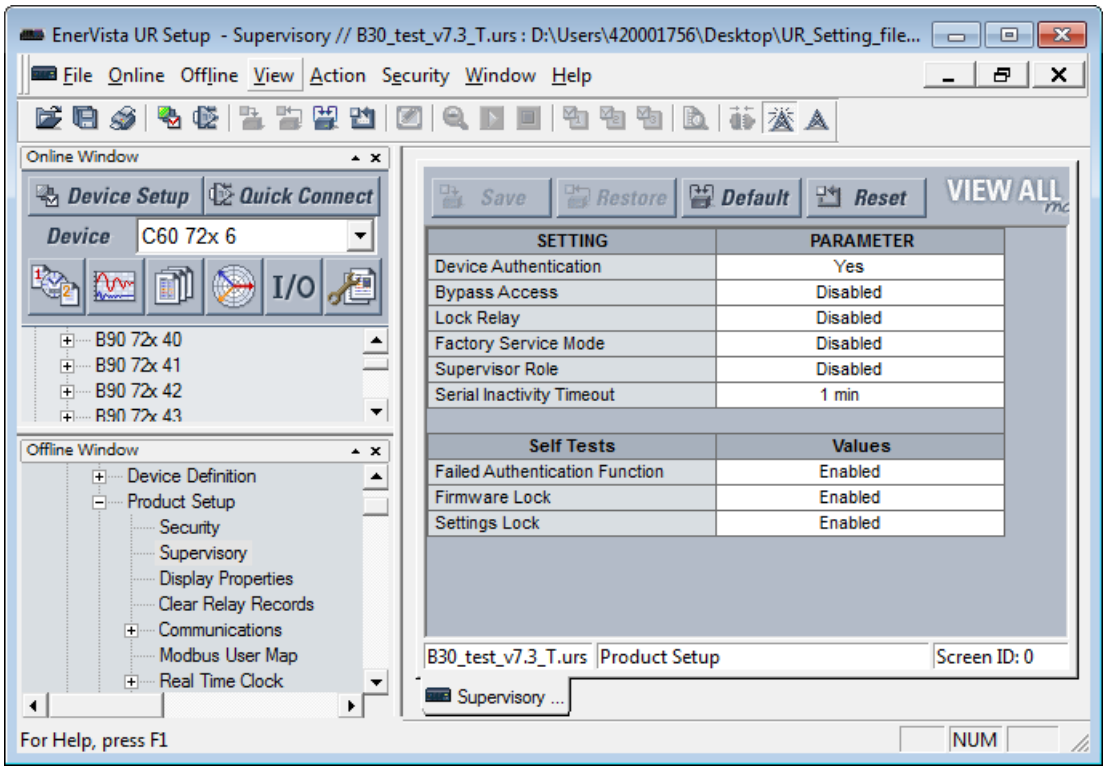



**Figure 5–3: SUPERVISORY PANEL**

For the Security panel, the following settings are available.

### RADIUS Server Settings

| SETTING NAME | DESCRIPTION | MIN | MAX | DEFAULT | UNITS | MINIMUM PERMISSION |
|---|---|---|---|---|---|---|
| Primary RADIUS IP Address | IP address of the main RADIUS server. Default value indicates no Primary RADIUS server is configured, and hence RADIUS is disabled. Restart the relay for any change to take effect. | 0.0.0.0 | 223.255.255.254 | 0.0.0.0 | - | Administrator |
| Primary Authentication Port | RADIUS authentication port | 1 | 65535 | 1812 | - | Administrator |
| Primary Accounting Port | RADIUS accounting port | 1 | 65535 | 1813 | - | Administrator |
| Vendor ID | An identifier that specifies RADIUS vendor-specific attributes used with the protocol | | | Value that represents General Electric | | Administrator |
| RADIUS Authentication (Shared) Secret | Shared secret used in authentication. It displays as asterisks. This setting must meet the CyberSentry password requirements. | See the *Password Requirements* section | See the following password section for requirements | N/A | - | Administrator |
| RADIUS Authentication Method | Authentication method used by RADIUS server. Currently fixed to EAP-TTLS. | EAP-TTLS | EAP-TTLS | EAP-TTLS | - | Administrator |
| Confirm RADIUS Authentication (Shared) Secret | Confirmation of the shared secret. The entry displays as asterisks. | See the *Password Requirements* section | 245 characters | N/A | - | Administrator |

### General Security Settings

| SETTING NAME | DESCRIPTION | MIN | MAX | DEFAULT | UNITS | MINIMUM PERMISSION |
|---|---|---|---|---|---|---|
| Session Lockout | Number of failed authentications before the device blocks subsequent authentication attempts for the lockout period | 0 (lockout disabled) | 99 | 3 | - | Administrator |
| Session Lockout Period | The period in minutes that a user is prevented from logging in after being locked out | 0 (no period) | 9999 | 3 | min | Administrator |
| Syslog Server IP Address | The IP address of the target Syslog server to which all security events are transmitted | 0.0.0.0 | 223.255.255.254 | 0.0.0.0 | - | Administrator |
| Syslog Server Port Number | The UDP port number of the target syslog server to which all security events are transmitted | 1 | 65535 | 514 | - | Administrator |
| Device Authentication | When enabled, local device authentication with roles is allowed. When disabled, the UR only authenticates to the AAA server (RADIUS). **NOTE:** Administrator and Supervisor (if still enabled) remain active even after device authentication is disabled. The only permission for local Administrator is to re-enable device authentication when device authentication is disabled. To re-enable device authentication, the Supervisor unlocks the device for setting changes, and then the Administrator can re-enable device authentication. | Disabled | Enabled | Enabled | - | Administrator |
| Firmware Locked | Indicates if the device receives firmware upgrades. If Yes and the firmware upgrade attempt is made, the device denies the upgrade and displays an error message that the lock is set. On each firmware upgrade, this setting goes back to the default. | No | Yes | Yes | - | Administrator |
| Factory Service Mode | When enabled (checkbox selected), the device can go into factory service mode. To enable, Supervisor authentication is necessary. | Disabled | Enabled | Disabled | - | Supervisor (Administrator when Supervisor is disabled) |
| Restore to Defaults | Sets the device to factory defaults | No | Yes | No | - | Administrator |

| SETTING NAME | DESCRIPTION | MIN | MAX | DEFAULT | UNITS | MINIMUM PERMISSION |
|---|---|---|---|---|---|---|
| Supervisor role | When enabled (checkbox selected), the Supervisor role is active. To enable, Administrator authentication is necessary. When disabled, the Supervisor role is inactive. To disable, Supervisor authentication is necessary. | Disabled | Enabled | Enabled | - | Administrator to enable and Supervisor to disable |
| RADIUS user names | Ensure that RADIUS user names are not the same as local/device role names | See RADIUS server documents | See RADIUS server documents | | - | Administrator |
| Password | Local/device roles except for Observer are password-protected. All RADIUS users are password-protected. | See the *Password Requirements* section | See the following password section for requirements | Change Me1# | Text | The specified role and Administrator, except for Supervisor, where it is only itself |

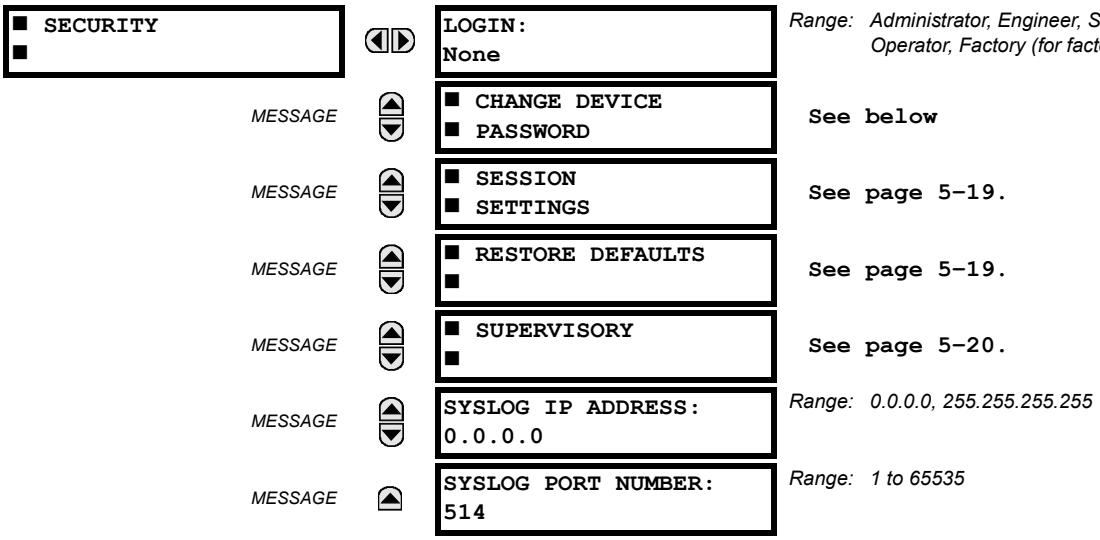
**Security Alarm Settings**

| SETTING NAME | DESCRIPTION / DETAILS | MIN | MAX | DEFAULT | UNITS | MINIMUM PERMISSIONS |
|---|---|---|---|---|---|---|
| Failed Authentications | A threshold number indicating when an alarm is set off to indicate too many failed authentication attempts | 0 (disabled) | 99 | 3 | - | Administrator |
| Firmware lock | A Boolean value indicating if the device can receive a firmware upgrade. If Yes and a firmware upgrade attempt is made, the device alarm activates. If No the device alarm does not activate. On each firmware upgrade this setting goes back to the default. | No | Yes | Yes | - | Administrator |
| Settings lock | A Boolean value indicating if the device can accept any settings changes. If Yes and a settings change attempt is made, the device alarm activates. If No, the device alarm does not activate. | No | Yes | Yes | - | Supervisor (Administrator if Supervisor has been disabled) |



## CYBERSENTRY SETTINGS THROUGH THE FRONT PANEL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY




**LOGIN**: This setting is applicable for *Device Authentication* only. This setting allows a user to login with a specific role, see descriptions below. For the Supervisor role, the “Supervisor Role” setting should be enabled.

Whenever a new role is logged in, the user is prompted with a display to enter a password. Passwords must obey the requirements specified at the beginning of the chapter in the Password Requirements section.The UR device supports five roles. All roles have their corresponding passwords. The Observer is the only role that does not require a password. There are no time-outs for the Administrator, Engineer, Operator, and Supervisor when logged in using the front panel; log out manually or use the **Command > Security** commands in the software.

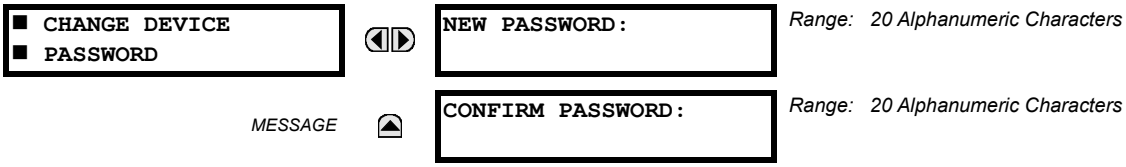
The roles are defined as follows:

- Administrator: Complete read and write access to all settings and commands. This role does not allow concurrent access. This role has an operand to indicate when it is logged on.
- Engineer: Complete read and write access to all settings and commands with the exception of configuring Security settings and Firmware upgrades. This role does not allow concurrent access.
- Operator: The Operator has read/write access to all settings under the command menu/section. This role does not exist offline.
- Supervisor: This is only an approving role. This role's authentication commits setting changes submitted by Administrator or Engineer. The Supervisor role authenticates to unlock the UR relay for setting changes and not approve changes after the fact. Only Supervisor can set the Settings and Firmware Lock in the Security Settings. This role also has the ability to forcefully logoff any other role and clear the security event log. This role can also be disabled, but only through a Supervisor authentication. When this role is disabled its permissions are assigned to the Administrator role.
- Observer: This role has read only access to all UR settings. This role allows concurrent access but it has no download access to any files on the device. Observer is the default role if no authentication has been done to the device. This role displays as "None" on the front panel.

NOTE The Factory service role is not available and is intended for factory use only.

### Device Password

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ CHANGE DEVICE PASSWORD




The menu displays on the front panel and EnerVista on a successful login of Administrator role.

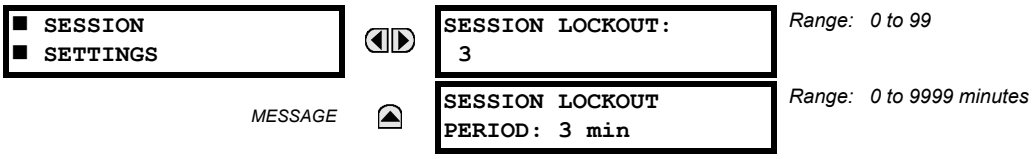
Passwords are stored in text format. No encryption is applied.

NOTE **Notes:**

- In Device Authentication mode, the Observer role does not have a password associated with it. In Server Authentication mode the Observer role requires a password.
- The default password is "ChangeMe1#".
- Once the passwords are set, the Administrator with Supervisor approval can change the role associated password.
- In CyberSentry, password encryption is not supported.

### Session Settings

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ SESSION SETTINGS




The following session settings are available.

- **SESSION LOCKOUT**: This setting specifies the number of failed authentications (the default is three and the maximum is 99) before the device blocks subsequent authentication attempts for the lockout period. A value of zero means lockout is disabled.
- **SESSION LOCKOUT PERIOD**: This setting specifies the period of time in minutes of a lockout period (the default is three and the maximum is 9999). A value of 0 means that there is no lockout period.

### Restore Defaults

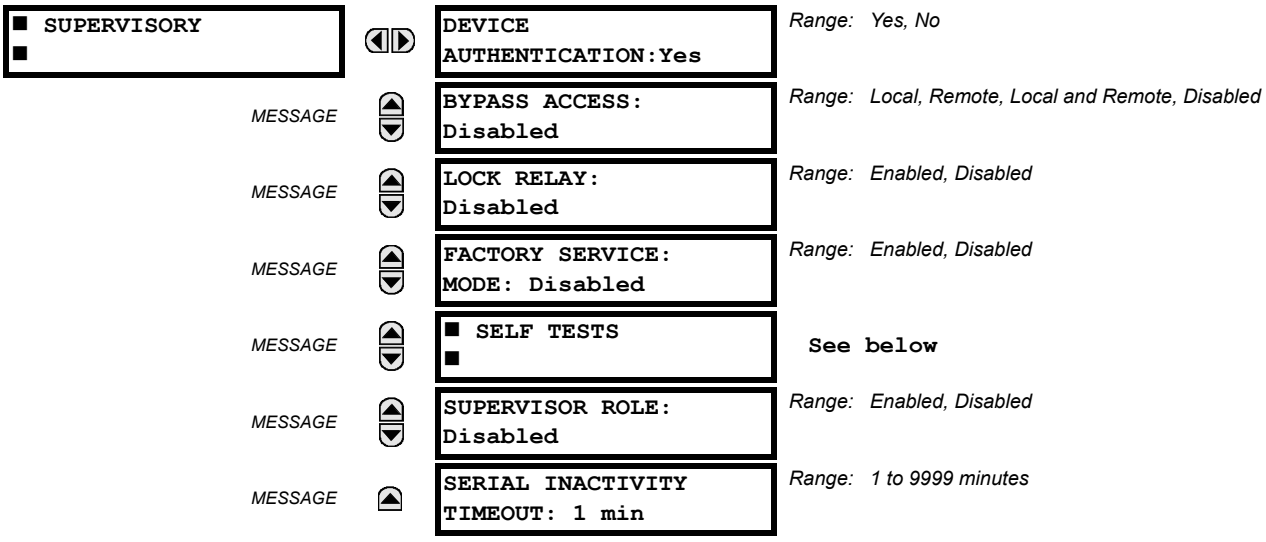
PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ RESTORE DEFAULTS

*Range: Yes, No*

- **LOAD FACTORY DEFAULTS**: This setting is used to reset all the settings, communication and security passwords. An Administrator role is used to change this setting and a Supervisor role (if not disabled) approves it.

**Supervisory**

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩SUPERVISORY




*Range: Yes, No*

*Range: Local, Remote, Local and Remote, Disabled*

*Range: Enabled, Disabled*

*Range: Enabled, Disabled*

**See below**

*Range: Enabled, Disabled*

*Range: 1 to 9999 minutes*

The Supervisory menu settings are available for Supervisor role only or if the Supervisor role is disabled then for the Administrator role only.

**DEVICE AUTHENTICATION:** This setting is enabled by default, meaning "Yes" is selected. When enabled, Device Authentication with roles is enabled. When this setting is disabled, the UR only authenticates to the AAA server (Radius). However, the Administrator and Supervisor (when enabled) remain active even after device authentication is disabled and their only permission is to re-enable device authentication. To re-enable device authentication, the Supervisor unlocks the device for setting changes, then the Administrator re-enables device authentication.

**BYPASS ACCESS:** The bypass security feature provides an easier access, with no authentication and encryption for those special situations when this is considered safe. Only the Supervisor, or the Administrator when the Supervisor role is disabled, can enable this feature.

| MODE | FRONT PANEL OR SERIAL (RS232, RS485) | ETHERNET |
|---|---|---|
| Normal mode | Authentication — Role Based Access Control (RBAC) and passwords in clear | Authentication — RBAC and passwords encrypted SSH tunneling |
| Bypass access mode | No passwords for allowed RBAC levels | No passwords for allowed RBAC levels<br>No SSH tunneling |

The bypass options are as follows:

- Local — Bypasses authentication for push buttons, keypad, and RS232
- Remote — Bypasses authentication for RS485 and Ethernet
- Local and Remote — Bypasses authentication for push buttons, keypad, RS232, RS485, and Ethernet

When CyberSentry is enabled, Modbus communications over Ethernet is encrypted, which is not always tolerated by SCADA systems. The UR has the Bypass Access feature for such situations, which allows unencrypted Modbus over Ethernet. Setting it to "Remote" ensures no authentication is required over Ethernet and Modbus communication is unencrypted. Only a Supervisor or Administrator (if Supervisor role is disabled) can enable this feature. Note that other protocols (DNP, 101, 103, 104, EGD) are not encrypted, and they are good communications options for SCADA systems when CyberSentry is enabled.

**LOCK RELAY:** This setting uses a Boolean value (Enable/Disable) to indicate if the device accepts setting changes and whether the device can receive a firmware upgrade. This setting can be changed only by the Supervisor role, if it is enabled or by the Administrator if the Supervisor role is disabled. The Supervisor role enables this setting for the relay to start accepting setting changes or command changes or firmware upgrade. After all the setting changes are applied or commands executed, the Supervisor disables to lock setting changes.

**Example:** If this setting is "Yes" and an attempt is made to change settings or upgrade the firmware, the UR device denies the setting changes and denies upgrading the firmware. If this setting is "No", the UR device accepts setting changes and firmware upgrade.

This role is disabled by default.

**FACTORY SERVICE MODE:** When enabled (meaning "Yes" is selected) the device can go into factory service mode. For this setting to become enabled a Supervisor authentication is necessary. The default value is Disabled.

**SUPERVISOR ROLE:** When enabled (meaning "Yes" is selected) the Supervisor role is active. When "No" is selected this role is disabled. To disabled this setting a Supervisor authentication is necessary. If disabled, the Supervisor role is not allowed to log on. In this case the Administrator can change the settings under the Supervisory menu.

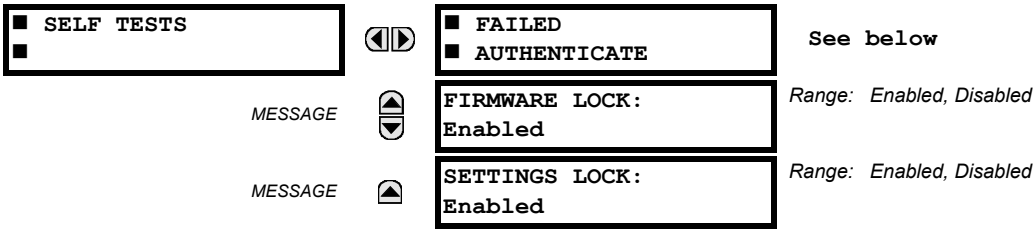
If enabled, Supervisor authentication is required to change the settings in the Supervisory menu. If the Supervisor disables his role after authentication, the Supervisor session remains valid until he switches to another role using MMI or until he ends the current Supervisor session if using communications.

This role is disabled by default.

**SERIAL INACTIVITY TIMEOUT:** The role logged via a serial port is auto logged off after the Serial Inactivity timer times out. A separate timer is maintained for RS232 and RS485 connections. Set this value to a high number, such as eight minutes, when using the rear RS485 terminals for settings write.

### a) SELF TESTS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩SUPERVISORY ⇨SELF TESTS

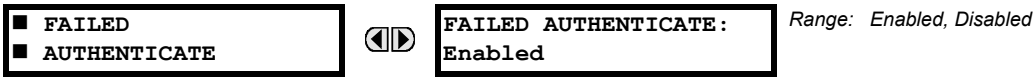



**FAILED AUTHENTICATE:** When Enabled, the number of failed authentications is compared with the Session Lockout threshold. When the Session Lockout threshold is exceeded, a minor alarm indication comes up. Operand is AUTHENTICATION FAIL.

**FIRMWARE LOCK:** When Enabled, any firmware upgrade attempt brings up a minor self-test alarm. Operand is UNAUTH FW ATTEMPT.

**SETTINGS LOCK:** When Enabled, an unauthorized write attempt to a setting for a given role activates a minor self test alarm. Operand is UNAUTH SETTING WRITE.

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩SUPERVISORY ⇨SELF TESTS ⇨FAILED AUTHENTICATE




#### CYBERSENTRY SETUP

When first using CyberSentry security, use the following procedure for set up.

1. Log in to the relay as Administrator by using the Value keys on the front panel to enter the default password "ChangeMe1#". Note that the "Lock relay" setting needs to be disabled in the **Security > Supervisory** menu. When this setting is disabled, configuration and firmware upgrade are possible. By default, this setting is disabled.
2. Enable the Supervisor role if you have a need for it.
3. Make any required changes in configuration, such as setting a valid IP address for communication over Ethernet.
4. Log out of the Administrator account by choosing None.

Next, device or server authentication can be chosen on the login screen, but the choice is available only in EnerVista. Use device authentication to log in using the five pre-configured roles (Administrator, Supervisor, Engineer, Operator, Observer). When using a serial connection, only device authentication is supported. When server authentication is required, characteristics for communication with a RADIUS server must be configured. This is possible only in the EnerVista software. The RADIUS server itself also must be configured. The appendix called RADIUS Server gives an example of how to setup a simple RADIUS server. Once both the RADIUS server and the parameters for connecting UR to the server have been configured, you can choose server authentication on the login screen of EnerVista.

**NOTICE** The use of CyberSentry for devices communicating through an Ethernet-to-RS485 gateway is not supported. Because these gateways do not support the secure protocols necessary to communicate with such devices, the connection cannot be established. Use the device as a non-CyberSentry device.

**NOTICE** Users logged in through the front panel are not timed out and cannot be forcefully logged out by a supervisor. Roles logged in through the front panel that do no allow multiple instances (Administrator, Supervisor, Engineer, Operator) must switch to None (equivalent to a logout) when they are done in order to log out.

**NOTICE** For all user roles except Observer, only one instance can be logged in at one time, for both login by front panel and software.

To configure server authentication:

1. In the EnerVista software, choose device authentication and log in as Administrator.
2. Configure the following RADIUS server parameters: IP address, authentication port, shared secret, and vendor ID.
3. On the RADIUS server, configure the user accounts. Do not use the five pre-defined roles as user names (Administrator, Supervisor, Engineer, Operator, Observer) in the RADIUS server. If you do, the UR relay automatically provides the authentication from the device.
4. In the EnerVista software, choose server authentication and log in using the user name and password configured on the RADIUS server for server authentication login.
5. After making any required changes, log out.

**NOTICE** When changing settings offline, ensure that only settings permitted by the role that performs the settings download are changed because only those changes are applied.

Pushbuttons (both user-control buttons and user-programmable buttons) located on the front panel can be pressed by an Administrator or Engineer role. This also applies to the reset button, which resets targets, where targets are errors displayed on the front panel or the Targets panel of the EnerVista software. The reset button has special behavior in that it allows these two roles to press it even when they are logged in through the RS232 port and not through the front panel.

To reset the security event log and self-test operands:

1. Log in as Supervisor (if the role is enabled) or Administrator (if the Supervisor role is disabled) and execute a clear security command under **Commands > Security > Clear Security**.

### b) SYSLOG FORMAT

System logs are produced with the CyberSentry option. The format is as follows.

| | Security log | Event Number | Date & Timestamp | Username | IP address | Role | Activity Value |
|---|---|---|---|---|---|---|---|

**Event Number** — Event identification number (index)

**Date & Timestamp** — UTC date and time

**Username** — 255 chars maximum, but in the security log it is truncated to 20 characters

**IP address** — Device IP address

**Role** — 16 bit unsigned, of type format F617

| ENUMERATION | ROLE |
|---|---|
| 0 | None |
| 1 | Administrator |
| 2 | Supervisor |
| 3 | Engineer |
| 4 | Operator |
| 5 | Factory |

**Activity Value** — 16 bit unsigned

| ENUMERATION | DESCRIPTION |
|---|---|
| 1 | Authentication Failed |
| 2 | User Lockout |
| 3 | FW Upgrade |
| 4 | FW Lock |
| 5 | Settings Lock |
| 6 | Settings Change. Because this can fill the entire event log, it is supported by the already existing Settings_Change.log file. This event is not required. |
| 7 | Clear Oscillography command |
| 8 | Clear Data Logger command (not applicable to all UR products) |
| 9 | Clear Demand Records command (not applicable to all UR products) |
| 10 | Clear Energy command (not applicable to all UR products) |
| 11 | Clear Unauthorized Access command |
| 12 | Clear Teleprotection Counters command (not applicable to all UR products) |
| 13 | Clear All Relay Records command |
| 14 | Role Log in |
| 15 | Role Log off |

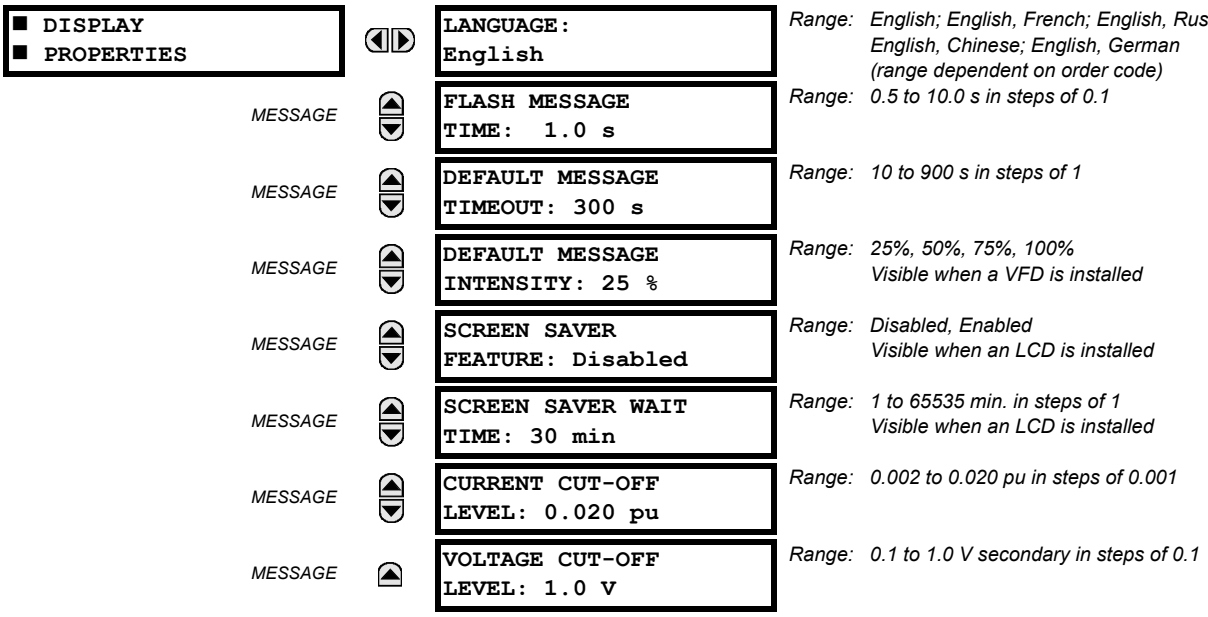
The following events are recorded in the syslog.

**Table 5–3: SYSTEM EVENTS RECORDED**

| EVENT | SEVERITY | DESCRIPTION |
|---|---|---|
| FAILED_AUTH, ORIGIN, TIMESTAMP | Warning (4) | A failed authentication with origin information (username and IP:MAC address), a time stamp in UTC time when it occurred |
| AUTH_LOCKOUT, ORIGIN, TIMESTAMP | Error (3) | An authentication lockout has occurred because of too many failed authentication attempts |
| FIRMWARE_UPGD, ORIGIN, TIMESTAMP | Warning (4) | Indicates that a change of firmware has occurred |
| FIRMWARE_LOCK, ORIGIN, TIMESTAMP | Critical (1) | An attempt was made to change firmware while the firmware lock was enabled |
| SETTING_CHG, ORIGIN, TIMESTAMP | Notice (5) | Indicates setting change(s) |
| SETTING_LOCK, ORIGIN, TIMESTAMP | Critical (1) | An attempt was made to change settings while the settings lock was enabled |
| LOGIN, ORIGIN, TIMESTAMP | Warning (4) | Indicates when a certain role logged in |
| LOGOUT, ORIGIN, TIMESTAMP | Notice (5) | Indicates when a certain role logged out or timed out |
| CLEAR_OSCILLOGRAPHY | Notice (5) | Clear oscillography command was issued |
| CLEAR_DATA_LOGGER | Notice (5) | Clear data logger command was issued |
| CLEAR_DEMAND_RECS | Notice (5) | Clear demand records command was issued |
| CLEAR_ENERGY | Notice (5) | Clear energy command was issued |
| RESET_UNAUTH_ACCESS | Warning (4) | Reset Unauthorized access command was issued |
| CLEAR_TELEPROTECTION_CNT | Notice (5) | Clear teleprotection counters command was issued |
| CLEAR_ALL_RECS | Warning (4) | Clear all records command was issued |

### 5.2.2 DISPLAY PROPERTIES

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES




5

Some relay messaging characteristics can be modified to suit different situations using the display properties settings.

- **LANGUAGE**: This setting selects the language used to display settings, actual values, and targets. The setting displays when a language other than English was purchased, and the range depends on the order code of the relay. Restart the relay after changing this setting.
- **FLASH MESSAGE TIME**: Flash messages are status, warning, error, or information messages displayed for several seconds in response to certain key presses during setting programming. These messages override any normal messages. The duration of a flash message on the display can be changed to accommodate different reading rates.
- **DEFAULT MESSAGE TIMEOUT**: If the keypad is inactive for a period of time, the relay automatically reverts to a default message. The inactivity time is modified via this setting to ensure messages remain on the screen long enough during programming or reading of actual values.
- **DEFAULT MESSAGE INTENSITY**: To extend phosphor life in the vacuum fluorescent display, the brightness can be attenuated during default message display. During keypad interrogation, the display always operates at full brightness.
- **SCREEN SAVER FEATURE** and **SCREEN SAVER WAIT TIME**: These settings are only visible if the L30 has a liquid crystal display (LCD) and control its backlighting. When the **SCREEN SAVER FEATURE** is "Enabled", the LCD backlighting is turned off after the **DEFAULT MESSAGE TIMEOUT** followed by the **SCREEN SAVER WAIT TIME**, providing that no keys have been pressed and no target messages are active. When a keypress occurs or a target becomes active, the LCD backlighting is turned on.
- **CURRENT CUT-OFF LEVEL**: This setting modifies the current cut-off threshold. Very low currents (1 to 2% of the rated value) are very susceptible to noise. Some customers prefer very low currents to display as zero, while others prefer the current be displayed even when the value reflects noise rather than the actual signal. The L30 applies a cut-off value to the magnitudes and angles of the measured currents. If the magnitude is below the cut-off level, it is substituted with zero. This applies to phase and ground current phasors as well as true RMS values and symmetrical components. The cut-off operation applies to quantities used for metering, protection, and control, as well as those used by communications protocols. Note that the cut-off level for the sensitive ground input is 10 times lower that the **CURRENT CUT-OFF LEVEL** setting value. Raw current samples available via oscillography are not subject to cut-off.

  This setting does not affect the 87L metering cutoff, which is constantly at 0.02 pu.
- **VOLTAGE CUT-OFF LEVEL**: This setting modifies the voltage cut-off threshold. Very low secondary voltage measurements (at the fractional volt level) can be affected by noise. Some customers prefer these low voltages to be displayed as zero, while others prefer the voltage to be displayed even when the value reflects noise rather than the actual signal. The L30 applies a cut-off value to the magnitudes and angles of the measured voltages. If the magnitude is below

the cut-off level, it is substituted with zero. This operation applies to phase and auxiliary voltages, and symmetrical components. The cut-off operation applies to quantities used for metering, protection, and control, as well as those used by communications protocols. Raw samples of the voltages available via oscillography are not subject cut-off.

The **CURRENT CUT-OFF LEVEL** and the **VOLTAGE CUT-OFF LEVEL** are used to determine the metered power cut-off levels. The power cut-off level is calculated as shown below. For Delta connections:

$$\text{3-phase power cut-off} = \frac{\sqrt{3} \times \textbf{CURRENT CUT-OFF LEVEL} \times \textbf{VOLTAGE CUT-OFF LEVEL} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}} \quad \textbf{(EQ 5.3)}$$

For Wye connections:

$$\text{3-phase power cut-off} = \frac{3 \times \textbf{CURRENT CUT-OFF LEVEL} \times \textbf{VOLTAGE CUT-OFF LEVEL} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}} \quad \textbf{(EQ 5.4)}$$

$$\text{per-phase power cut-off} = \frac{\textbf{CURRENT CUT-OFF LEVEL} \times \textbf{VOLTAGE CUT-OFF LEVEL} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}} \quad \textbf{(EQ 5.5)}$$

where VT primary = VT secondary × VT ratio and CT primary = CT secondary × CT ratio.

For example, given the following settings:

**CURRENT CUT-OFF LEVEL**: "0.02 pu"
**VOLTAGE CUT-OFF LEVEL**: "1.0 V"
**PHASE CT PRIMARY**: "100 A"
**PHASE VT SECONDARY**: "66.4 V"
**PHASE VT RATIO**: "208.00 : 1"
**PHASE VT CONNECTION**: "Delta".

We have:

CT primary = "100 A", and
VT primary = **PHASE VT SECONDARY** x **PHASE VT RATIO** = 66.4 V x 208 = 13811.2 V

The power cut-off is therefore:

power cut-off = (**CURRENT CUT-OFF LEVEL** × **VOLTAGE CUT-OFF LEVEL** × CT primary × VT primary)/VT secondary
= ( $\sqrt{3}$ × 0.02 pu × 1.0 V × 100 A × 13811.2 V) / 66.4 V
= 720.5 watts

Any calculated power value below this cut-off will not be displayed. As well, the three-phase energy data will not accumulate if the total power from all three phases does not exceed the power cut-off.

NOTE

Lower the **VOLTAGE CUT-OFF LEVEL** and **CURRENT CUT-OFF LEVEL** with care as the relay accepts lower signals as valid measurements. Unless dictated otherwise by a specific application, the default settings of "0.02 pu" for **CURRENT CUT-OFF LEVEL** and "1.0 V" for **VOLTAGE CUT-OFF LEVEL** are recommended.

### 5.2.3 CLEAR RELAY RECORDS

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ CLEAR RELAY RECORDS**

```
■ CLEAR RELAY
■ RECORDS
```

```
CLEAR FAULT REPORTS:
Off
```
*Range: FlexLogic operand*

*MESSAGE*

```
CLEAR EVENT RECORDS:
Off
```
*Range: FlexLogic operand*

*MESSAGE*

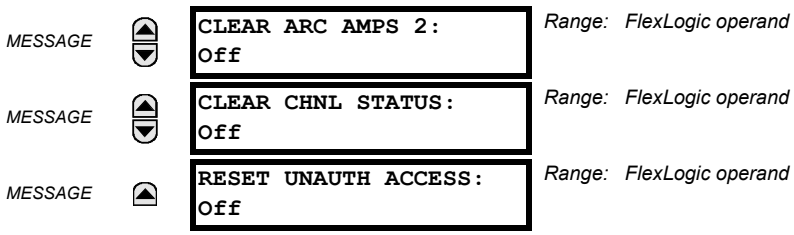
```
CLEAR OSCILLOGRAPHY:
Off
```
*Range: FlexLogic operand*

*MESSAGE*

```
CLEAR DATA LOGGER:
Off
```
*Range: FlexLogic operand*

*MESSAGE*

```
CLEAR ARC AMPS 1:
Off
```
*Range: FlexLogic operand*




Selected records can be cleared from user-programmable conditions with FlexLogic operands. Assigning user-programmable pushbuttons to clear specific records are typical applications for these commands. Since the L30 responds to rising edges of the configured FlexLogic operands, they must be asserted for at least 50 ms to take effect.

Clearing records with user-programmable operands is not protected by the command password. However, user-programmable pushbuttons are protected by the command password. Thus, if they are used to clear records, the user-programmable pushbuttons can provide extra security if required.

For example, to assign user-programmable pushbutton 1 to clear demand records, the following settings should be applied.

1. Assign the clear demand function to pushbutton 1 by making the following change in the **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **CLEAR RELAY RECORDS** menu:

   **CLEAR DEMAND:** "PUSHBUTTON 1 ON"

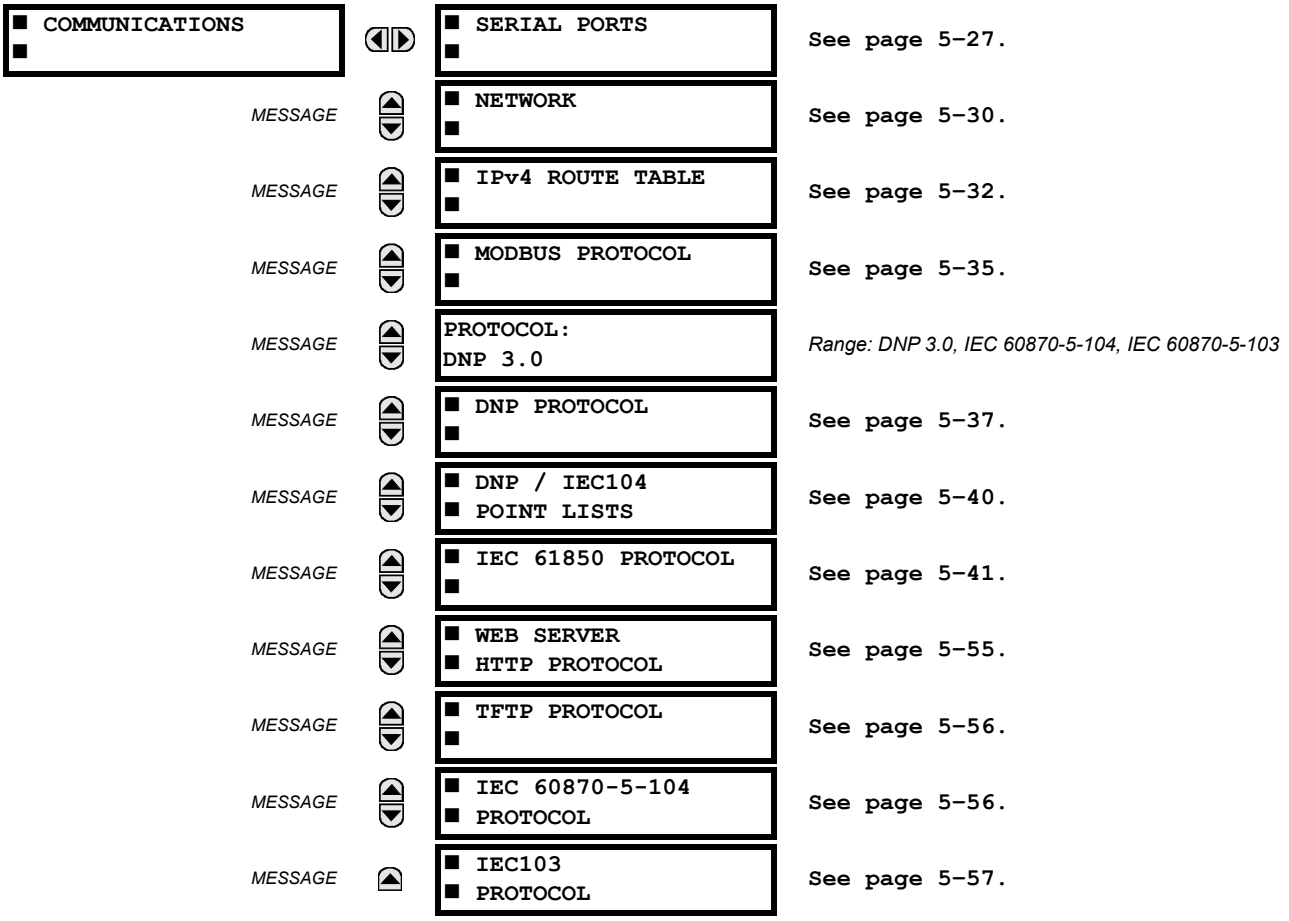
2. Set the properties for user-programmable pushbutton 1 by making the following changes in the **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **USER-PROGRAMMABLE PUSHBUTTONS** ⇨ **USER PUSHBUTTON 1** menu:

   **PUSHBUTTON 1 FUNCTION:** "Self-reset"
   **PUSHBTN 1 DROP-OUT TIME:** "0.20 s"

5

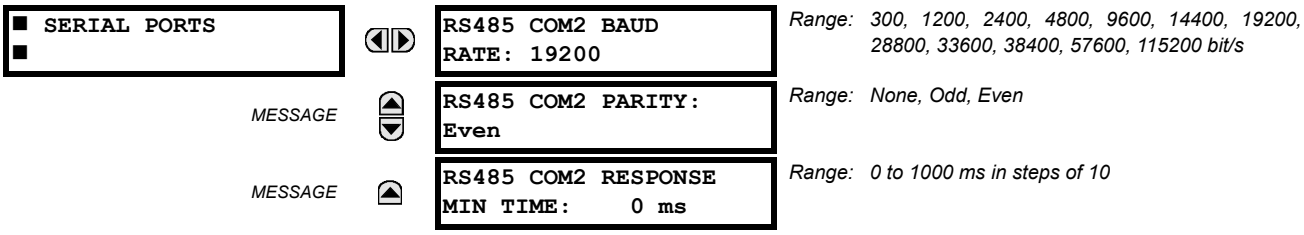
### a) MAIN MENU

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS




### b) SERIAL PORTS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨ SERIAL PORTS




**RS485 COM2 BAUD RATE** and **PARITY**: The L30 is equipped with two independent serial communication ports. The faceplate RS232 port is intended for local use and is fixed at 19200 bit/s baud and even parity. The rear COM2 port is RS485 and has settings for baud rate and parity. It is important that these parameters agree with the settings used on the computer or other equipment that is connected to these ports. Any of these ports can be connected to a computer running EnerVista UR Setup. This software can download and upload setting files, view measured parameters, and upgrade the relay firmware. A maximum of 32 relays can be daisy-chained and connected to a DCS, PLC, or computer using the RS485 ports. If IEC 60870-103 is chosen as the protocol, valid baud rates are 9600 and 19200 bit/s, and valid parity is Even.

**RS485 COM2 RESPONSE MIN TIME**: This setting specifies the minimum time before the rear RS485 port transmits after receiving data from a host. This feature allows operation with hosts that hold the RS485 transmitter active for some time after each transmission.

### c) ETHERNET NETWORK TOPOLOGY

The L30 has three Ethernet ports. Each Ethernet port must belong to a different network or subnetwork. Configure the IP address and subnet to ensure that each port meets this requirement. Two subnets are different when the bitwise AND operation performed between their respective IP address and mask produces a different result. Communication becomes unpredictable when more than one port is configured to the same subnet.

**Example 1**

IP1/Mask1: 10.1.1.2/255.255.255.0 (where LAN 1 is 10.1.1.x/255.255.255.0)

IP2/Mask2: 10.2.1.2/255.255.255.0 (where LAN2 is 10.2.1.x/255.255.255.0)

IP3/Mask3: 10.3.1.2/255.255.255.0 (where LAN3 is 10.3.1.x/255.255.255.0)

**Example 2**

IP1/Mask1: 10.1.1.2/255.0.0.0 (where LAN1 is 10.x.x.x/255.0.0.0)

IP2/Mask2: 11.1.1.2/255.0.0.0 (where LAN2 is 11.x.x.x/255.0.0.0)

IP3/Mask3: 12.1.1.2/255.0.0.0 (where LAN3 is 12.x.x.x/255.0.0.0)

**Example 3 — Incorrect**

IP1/Mask1: 10.1.1.2/255.0.0.0

IP2/Mask2: 10.2.1.2/255.0.0.0

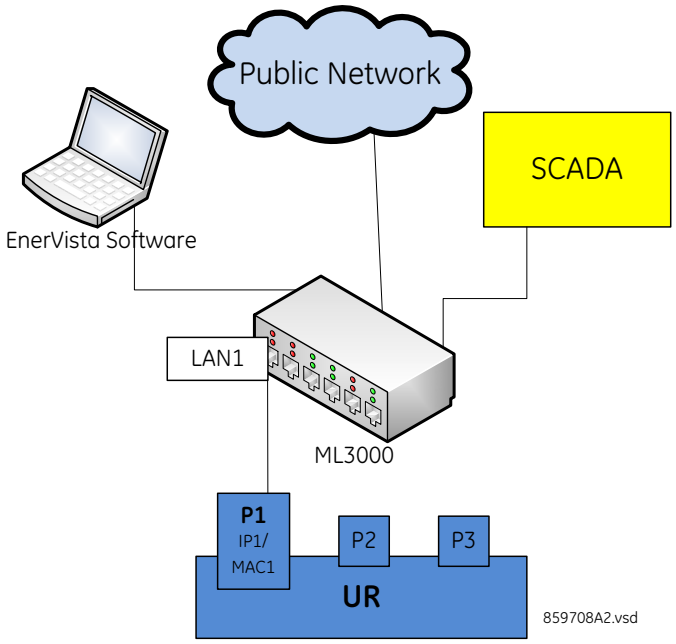
IP3/Mask3: 10.3.1.2/255.0.0.0

This example is incorrect because the mask of 255.0.0.0 used for the three IP addresses makes them belong to the same network of 10.x.x.x.

**Single LAN, No Redundancy**

The topology shown in the following figure allows communications to SCADA, local configuration/monitoring through EnerVista, and access to the public network shared on the same LAN. No redundancy is provided.

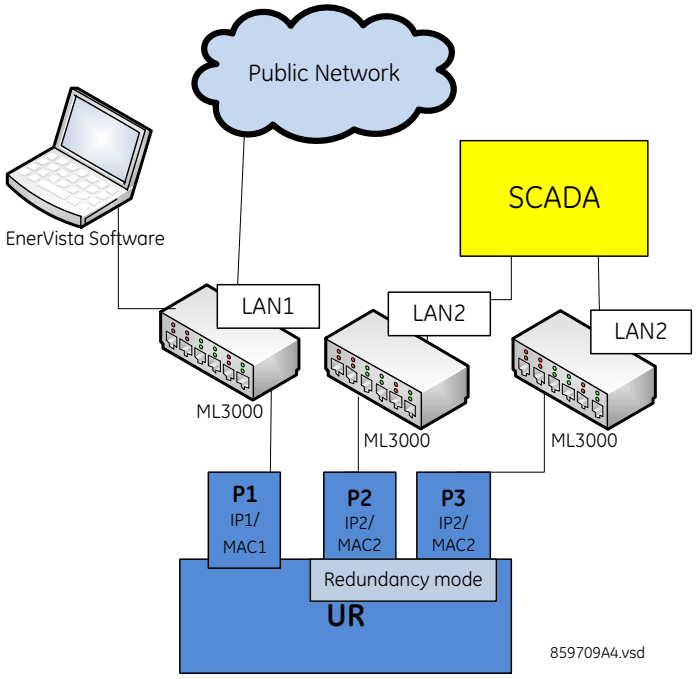
**Figure 5–4: NETWORK CONFIGURATION FOR SINGLE LAN**



### Multiple LANS, with Redundancy

The topology in the following figure provides local configuration/monitoring through EnerVista software and access to the public network shared on LAN1, to which port 1 (P1) is connected. There is no redundancy provided on LAN1. Communications to SCADA is provided through LAN2. P2 and P3 are connected to LAN2, where P2 is the primary channel and P3 is the redundant channel. In this configuration, P3 uses the IP and MAC address of P2.

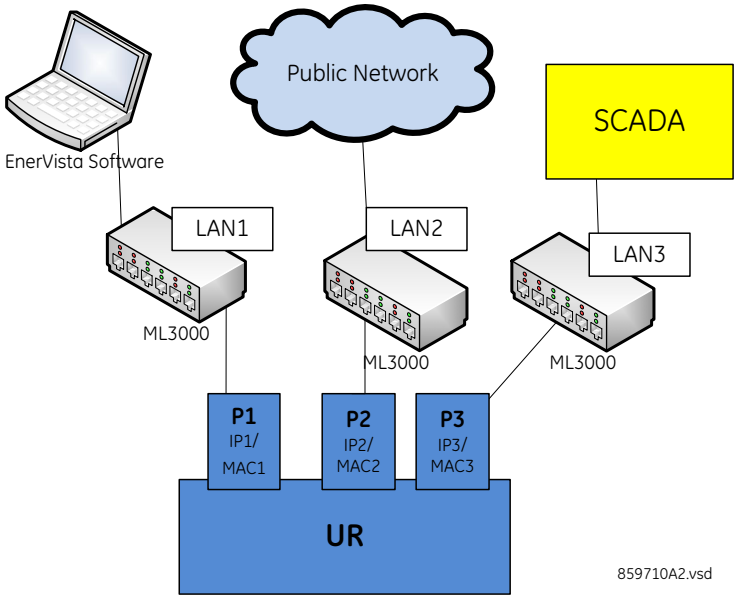
**Figure 5–5: MULTIPLE LANS, WITH REDUNDANCY**




### Multiple LANS, No Redundancy

The following topology provides local configuration/monitoring through EnerVista software on LAN1, to which port 1 (P1) is connected, access to the public network on LAN2, to which port 2 (P2) is connected and communications with SCADA on LAN3, to which port 3 (P3) is connected. There is no redundancy.

**Figure 5–6: MULTIPLE LANS, NO REDUNDANCY**



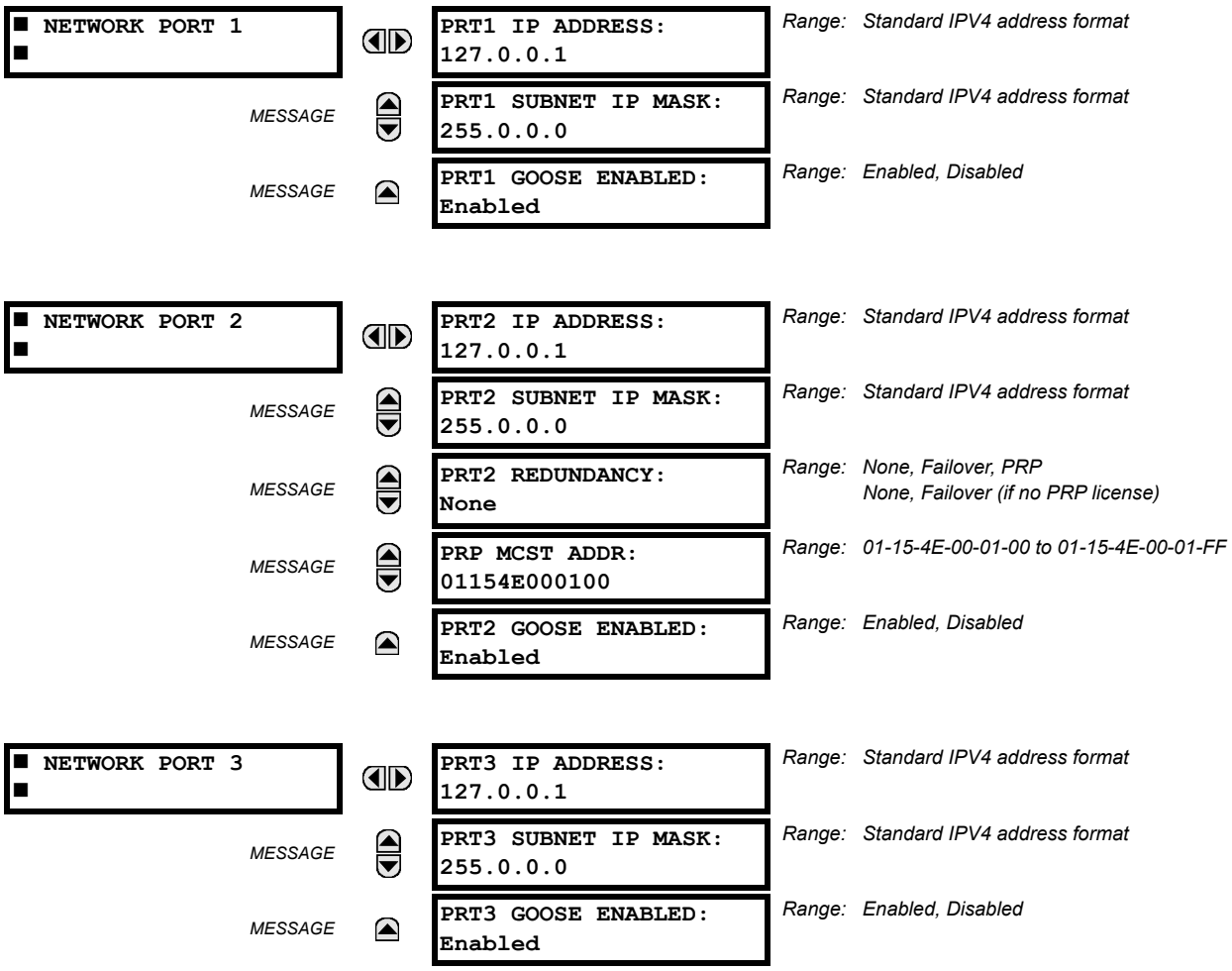
### d) NETWORK

As outlined in the previous section, when using more than one Ethernet port, configure each to belong to a different network or subnet using the IP addresses and mask. Configure the network IP and subnet settings before configuring the routing settings.

Follow the IP and subnet mask rules outlined in the Configuring the L30 for Software Access section of the first chapter.

To obtain a list of all port numbers used, for example for audit purposes, contact GE technical support with substantiating information, such as the serial number and order code of your device.

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ NETWORK ⇨ NETWORK PORT 1(3)**




The IP addresses are used with the DNP, Modbus/TCP, IEC 61580, IEC 60870-5-104, TFTP, HTTP, and PRP protocols. PRP is explained in its own section later.

**PRT1 (2 OR 3) IP ADDRESS**: This setting sets the ports IPv4 address in standard IPV4 format. This setting is valid on port 3 if port 2 **REDUNDANCY** is set to None.

**PRT1 (2 OR 3) SUBNET MASK**: This setting sets the ports IPv4 subnet mask in standard IPV4 format. This setting is valid on port 3 if port 2 **REDUNDANCY** is set to None.

**PRT1 (2 OR 3) GOOSE ENABLED**: This setting enables/disables Goose on the respective port. By default Goose is enabled.

**PRT2 REDUNDANCY** determines if ports 2 and 3 operate in redundant or independent mode. If the software options in the order code include PRP, the available options are None, Failover, and PRP. If the software options in the order code do not include PRP, the available options are None and Failover. In non-redundant mode (**REDUNDANCY** set to None), ports 2 and 3 operate independently with their own MAC, IP, and mask addresses. If **REDUNDANCY** is set to Failover, the operation of ports 2 and 3 is as follows:

- Ports 2 and 3 use the port 2 MAC address, IP address, and mask

- The configuration fields for IP address and mask on port 3 are hidden
- Port 3 is in standby mode and does not actively communicate on the Ethernet network but monitors its link to the Multilink switch. If port 2 detects a problem with the link, communications is switched to Port 3. Port 3 is, in effect, acting as a redundant or backup link to the network for port 2. Once port 2 detects that the link between itself and the switch is good and that communication is healthy for five minutes, then switching back to port 2 is performed. The delay in switching back ensures that rebooted switching devices connected to the L30, which signal their ports as active prior to being completely functional, have time to completely initialize themselves and become active. Once port 2 is active again, port 3 returns to standby mode.

If **REDUNDANCY** is set to PRP, the operation of ports 2 and 3 is as follows:

- Ports 2 and 3 use the port 2 MAC address, IP address, and mask
- The configuration fields for IP address and mask on port 3 are overwritten with those from port 2. This is visible on the front panel but not displayed in the EnerVista software.
- Port 2 **MCST ADDRESS** field is visible
- The port 2 PTP function still uses only port 2 and the port 3 PTP function still uses only port 3. The relay still synchronizes to whichever port has the best master. When ports 2 and 3 see the same master, as is typically the case for PRP networks, the port with the better connectivity is used.

NOTE

The two ports must be connected to completely independent LANS with no single point of failure, such as common power supplies that feed switches on both LANS.

When **REDUNDANCY** is set to PRP or failover and the network path with resolved default gateway is broken, then the ARP table needs approximately five seconds to rebuild. The layer 2 protocols (GOOSE and PTP) are not affected. However, the TCP/IP or UDP protocols (MMS connections, DNP3.0, and so on) can require reconnection if their active connection does not ride through re-transmission frames.

For this setting change to take effect, restart the unit.

**PRT2 PRP MCST ADDR**: This setting allows the user to change the multicast address used by the PRP supervision frames. This setting is available if **REDUNDANCY** is set to PRP. All devices in the same PRP network need to have the same multicast address. Choose an address that does not conflict with another multicast protocol.

### e) FAR-END FAULT INDICATION (FEFI)

Since 100BASE-FX does not support Auto-Negotiation, a Far-End Fault Indication (FEFI) feature is included in UR 7 that allows for detection of link failures.

The purpose of the Far-End Fault feature is to allow the stations on both ends of a pair of fibers to be informed when there is a problem with one of the fibers. Without the Far-End Fault feature, it is impossible for a fiber interface to detect a problem that affects only its transmit fiber.

When the Far-End Fault feature is supported, a loss of receive signal (link) causes the transmitter to generate a Far-End Fault pattern in order to inform the device at the far end of the fiber pair that a fault has occurred.

When the local receiver again detects a signal, the local transmitter automatically returns to normal operation.

If a Far-End Fault pattern is received by a fiber interface that supports the Far-End Fault feature and it is enabled, it reacts by dropping the link as if there were no signal at all.

If the receiving interface does not support the Far-End Fault feature or has it disabled, an incoming Far-End Fault pattern is ignored.

It is strongly recommended to have switches used at substation automation support the Far-End Fault feature, especially when UR 7 redundancy Failover is selected for redundancy purpose.

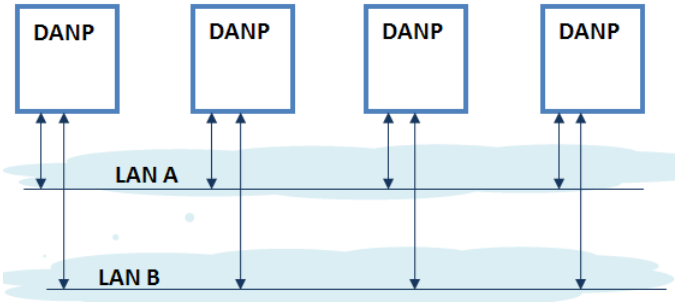
### f) PARALLEL REDUNDANCY PROTOCOL (PRP)

The Parallel Redundancy Protocol (PRP) defines a redundancy protocol for high availability in substation automation networks. It applies to networks based on Ethernet technology (ISO/IEC 8802-3) and is based on the second edition (July 2012) of the IEC 62439-3, clause 4.

PRP is designed to provide seamless recovery in case of a single failure in the network, by using a combination of LAN duplication and frame duplication technique. Identical frames are sent on two completely independent networks that connect source and destination. Under normal circumstances both frames reach the destination and one of them is sent up the

OSI stack to the destination application, while the second one is discarded. If an error occurs in one of the networks and traffic is prevented from flowing on that path, connectivity is still provided through the other network to ensure continuous communication. Take care when designing the two LANs, so that no single point of failure (such as a common power supply) is encountered, as such scenarios can bring down both LANs simultaneously.

**Figure 5–7: EXAMPLE OF PARALLEL REDUNDANT NETWORK**




PRP uses specialized nodes called doubly attached nodes (DANPs) for handling the duplicated frames. DANPs devices have an additional module, called Link Redundancy Entity (LRE). LRE is responsible for duplicating frames and adding the specific PRP trailer when sending the frames out on the LAN, as well as making decisions on received frames as to which one is sent up the OSI stack to the application layer and which one is discarded. LRE is responsible for making PRP transparent to the higher layers of the stack. There is a second type of specialized device used in PRP networks, called RedBox, with the role of connecting Single Attached Nodes (SANs) to a redundant network.

UR relays implement only the DANP functionality. The RedBox functionality is not implemented.

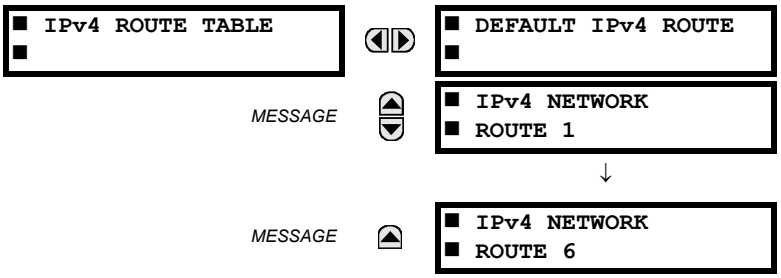
The original standard IEC 62439-3 (2010) was amended to align PRP with the High-availability Seamless Redundancy (HSR) protocol. To achieve this, the original PRP was modified at the cost of losing compatibility with the PRP 2010 version. The revised standard IEC 62439-3 (2012) is commonly referred to as PRP-1, while the original standard is PRP-0. The UR relays support only PRP-1.

The relay implements PRP on two of its Ethernet ports, specifically Port 2 and 3 of the CPU module. Use the previous section (network port configuration) to configure PRP.

PRP is purchased as a separate option. If purchased (valid order code), PRP can be enabled in configuration through a setting available on the network configuration menu, REDUNDANCY, which already has the capability of enabling failover redundancy. The options on this setting must be changed to accommodate two types of redundancy: failover and PRP. When REDUNDANCY is set to either failover or PRP, the ports dedicated for PRP (Port 2 and 3) operate in redundant mode. In this mode, Port 3 uses the Mac, IP address, and mask of Port 2.

### g) ROUTING

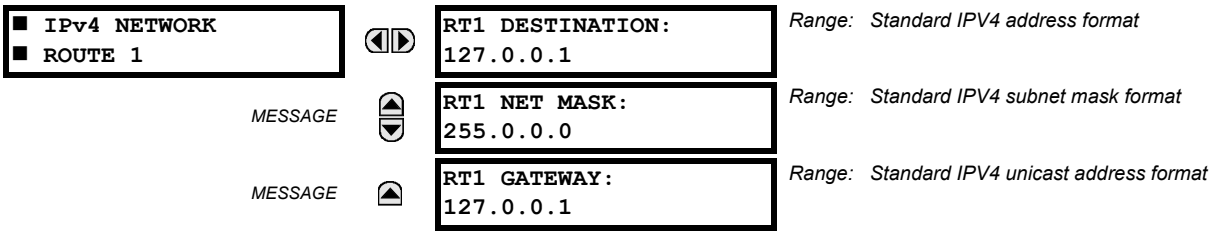
**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IPv4 ROUTE TABLE**




A default route and a maximum number of six static routes can be configured.

The default route is used as the last choice when no other route towards a given destination is found.

*Range: Standard IPV4 unicast address format*




Configure the network IP and subnet settings before configuring the routing settings.

**ADDING AND DELETING STATIC ROUTES**

Host routes are not supported at present.

The routing table configuration is available on the serial port and front panel. This is a deliberate decision, to avoid loss of connectivity when remotely configuring the UR.

By default the value of the destination field is 127.0.0.1 for all static routes (1 to 6). This is equivalent to saying that the static routes are not configured. When the destination address is 127.0.0.1, the mask and gateway must be also kept on default values.

By default, the value of the route gateway address is 127.0.0.1. This means the default route is not configured.

To add a route:

1. Use any of the static network route entries numbered 1 to 6 to configure a static network route. Once a route destination is configured for any of the entries 1 to 6, that entry becomes a static route and it must meet all the rules listed in the next section, General Conditions to be Satisfied by Static Routes.
2. To configure the default route, enter a default gateway address. Once a default gateway address is configured, it must be validated against condition 2 of the General Conditions to be Satisfied by Static Routes.

To delete a route:

1. Replace the route destination with the default loopback address (127.0.0.1). When deleting a route, the mask and gateway must be also brought back to default values.
2. Delete the default route by replacing the default gateway with the default value 127.0.0.1.

**GENERAL CONDITIONS TO BE SATISFIED BY STATIC ROUTES**

The following rules are validated internally:

- The route mask has IP mask format. In binary this needs to be a set of contiguous bits of 1 from left to right, followed by one or more contiguous bits of 0.
- The route destination and mask must match. This can be verified by checking that
  RtDestination and RtMask = RtDestination
  Example of good configuration: RtDestination = 10.1.1.0; Rt Mask = 255.255.255.0
  Example of bad configuration: RtDestination = 10.1.1.1; Rt Mask = 255.255.255.0

The following rules must be observed when you configure static routes:

- The route destination must not be a connected network
- The route gateway must be on a connected network. This rule applies to the gateway address of the default route as well. This can be verified by checking that:
  (RtGwy & Prt1Mask) == (Prt1IP & Prt1Mask) || (RtGwy & Prt2Mask) == (Prt2IP & Prt2Mask) || (RtGwy & Prt3Mask) == (Prt3IP & Prt3Mask)

  where

  & is the bitwise-AND operator

  == is the equality operator

  || is the logical OR operator

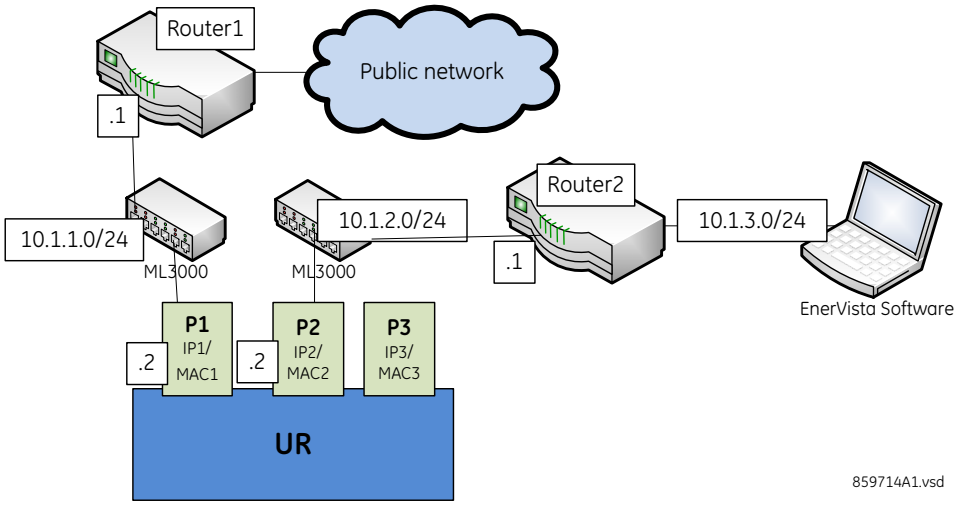
### ROUTING BEHAVIOR COMPARED TO PREVIOUS RELEASES

Prior to release 7.10, the UR did not have an explicit manner of configuring routes. The only available route was the default route configured as part of the network settings (port gateway IP address). This limited the ability to route to specific destinations, particularly if these destinations were reachable through a different interface than the one on which the default gateway was.

Starting with UR 7.10, up to six static network routes can be configured in addition to a default route. The default route configuration was also moved from the network settings into the routing section.

The figure shows an example of topology that benefits from the addition of static routes.

**Figure 5–8: USING STATIC ROUTES**




In the figure, the UR connects through the following two Ethernet ports:

- Port 1 (IP address 10.1.1.2) connects the UR to LAN 10.1.1.0/24 and to the Internet through Router1. Router 1 has an interface on 10.1.1.0/24 and the IP address of this interface is 10.1.1.1.
- Port 2 (IP address 10.1.2.2) connects the UR to LAN 10.1.2.0/24 and to the EnerVista software through Router 2. Router 2 has an interface on 10.1.2.0/24 and the IP address of this interface is 10.1.2.1.

The configuration before release 7.10 was as follows:

- PRT1 IP ADDRESS = 10.1.1.2
  PRT1 SUBNET IP MASK = 255.255.255.0
  PRT1 GWY IP ADDRESS = 10.1.1.1
  PRT2 IP ADDRESS = 10.1.2.2
  PRT2 SUBNET IP MASK = 255.255.255.0

The behavior before release 7.10 was as follows. When sending packets to EnerVista, the UR noticed that the destination was not on a connected network and it tried to find a route to destination. Since the default route was the only route it knew, it used it. Yet EnerVista was on a private network, which was not reachable through Router 1. Hence a destination unreachable message was received from the router.

The configuration starting release 7.10 is as follows:

- PRT1 IP ADDRESS = 10.1.1.2
  PRT1 SUBNET IP MASK = 255.255.255.0
  PRT2 IP ADDRESS = 10.1.2.2
  PRT2 SUBNET IP MASK = 255.255.255.0
  IPV4 DEFAULT ROUTE: GATEWAY ADDRESS = 10.1.1.1
  STATIC NETWORK ROUTE 1: RT1 DESTINATION = 10.1.3.0/24; RT1 NET MASK = 255.255.255.0; and RT1 GATEWAY = 10.1.2.1

The behavior since release 7.10 is as follows. There is one added static network route to the destination 10.1.3.0/24, where a computer running EnerVista is located. This static route uses a different gateway (10.1.2.1) than the default route. This gateway is the address of Router 2, which has knowledge about 10.1.3.0 and is able to route packets coming from UR and destined to EnerVista.

**SHOW ROUTES AND ARP TABLES**

This feature is available on the Web interface, where the main menu contains an additional Communications menu and two submenus:

- Routing Table
- ARP Table

The tables outline the information displayed when the two submenus are selected.

**Table 5–4: ROUTING TABLE INFORMATION**

| FIELD | DESCRIPTION |
|---|---|
| Destination | The IP address of the remote network to which this route points |
| Mask | The network mask for the destination |
| Gateway | The IP address of the next router to the remote network |
| Interface | Interface through which the specified network can be reached |

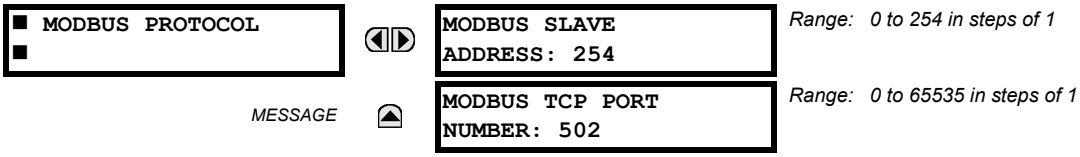
**Table 5–5: IP ARP INFORMATION**

| FIELD | DESCRIPTION |
|---|---|
| IP Address | The network address that corresponds to Hardware Address |
| Age (min) | Age, in minutes, of the cache entry. A hyphen (-) means the address is local. |
| Hardware Address | LAN hardware address, a MAC address that corresponds to network address |
| Type | Dynamic or Static |
| Interface | Interface to which this address mapping has been assigned |



### h) MODBUS PROTOCOL

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ MODBUS PROTOCOL**




The serial communication ports utilize the Modbus protocol, unless the port is configured for DNP or IEC 60870-5-103 operation. This allows the EnerVista UR Setup software to be used on the port. The UR operates as a Modbus slave device only.

When using Modbus protocol on the RS232 port, the L30 responds regardless of the **MODBUS SLAVE ADDRESS** programmed. For the RS485 port, each device on the serial bus must have a unique slave address from 1 to 254. Address 0 and addresses from 248 and up are reserved by the Modbus protocol specification, and so their use here is not recommended. Address 0 is the broadcast address that all Modbus slave devices listen to. When **MODBUS SLAVE ADDRESS** is set to 0, the UR accepts broadcast messages, but in compliance with protocol specifications for broadcast messages, never replies. Addresses do not have to be sequential, but no two devices can have the same address or conflicts resulting in errors occur. Generally, each device added to the link should use the next higher address starting at 1. When using Modbus TCP/IP, the client must use the programmed **MODBUS SLAVE ADDRESS** value in the Unit Identifier field. See Appendix B for more information on the Modbus protocol.

Modbus over TCP/IP can also be used on any of the Ethernet ports. The listening TCP port 502 is reserved for Modbus communications, and only in exceptional cases when **MODBUS TCP PORT NUMBER** is set to any other port. The **MODBUS TCP PORT NUMBER** setting sets the TCP port used by Modbus on Ethernet. A **MODBUS TCP PORT NUMBER** of 0 disables Modbus over TCP/IP, meaning closes the Modbus TCP port. When it is set to 0, use the front panel or serial port to communicate with the relay.

NOTE

When a 0 value is involved in a change, the changes to the **MODBUS TCP PORT NUMBER** setting take effect when the L30 is restarted.

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

### i) PROTOCOL

The Protocol menu setting allows selection of one of the following protocols: DNP 3.0, IEC60870-104, or IEC60870-103. For any change to take effect, restart the unit.

The table shows which of DNP 3.0, IEC 60870-5-104, IEC 60870-5-103, and IEC 61850 protocols are operational on the RS232, RS485, and Ethernet ports. It shows all possible combinations of the **PROTOCOL** and **DNP CHANNEL 1(2) PORT** settings.

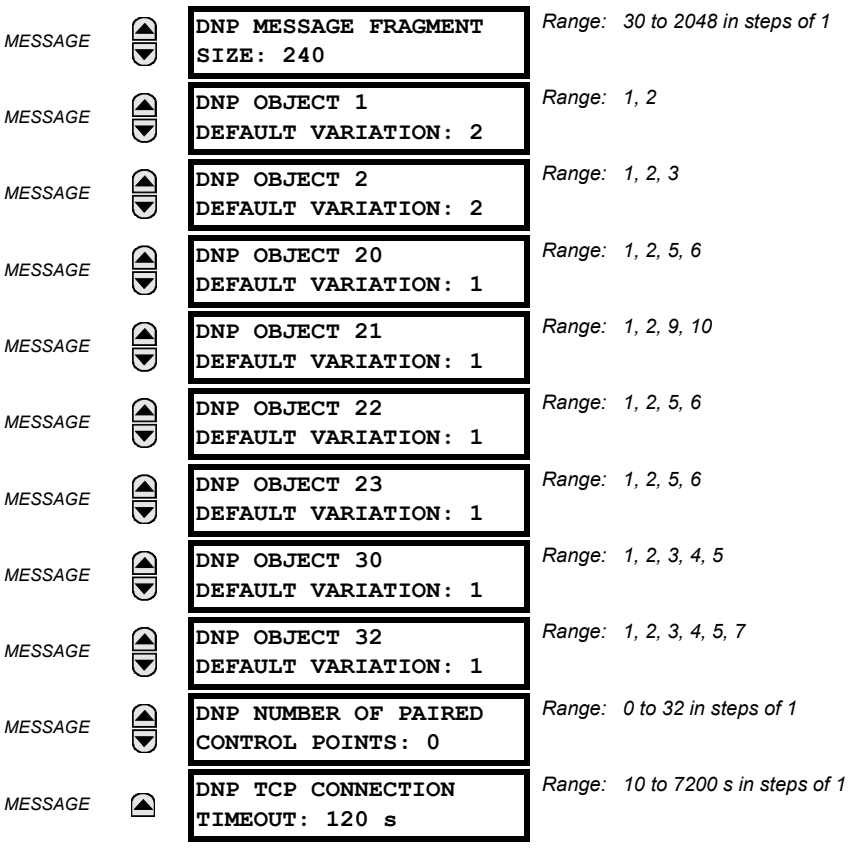
**Table 5–6: PORT AND PROTOCOL COMBINATIONS**

| PROTOCOL SETTING | DNP CHANNEL 1(2) PORT SETTINGS | RS232 | RS485 | ETHERNET |
|---|---|---|---|---|
| DNP | Channel 1: Eth TCP<br>Channel 2: Eth TCP | Modbus | Modbus | DNP, Modbus, IEC 61850 |
| | Channel 1: Eth TCP<br>Channel 2: none | Modbus | Modbus | DNP, Modbus, IEC 61850 |
| | Channel 1: none<br>Channel 2: Eth TCP | Modbus | Modbus | DNP, Modbus, IEC 61850 |
| | Channel 1: Eth UDP<br>Channel 2: none | Modbus | Modbus | DNP, Modbus, IEC 61850 |
| | Channel 1: Eth TCP<br>Channel 2: RS485 | Modbus | DNP | DNP, Modbus, IEC 61850 |
| | Channel 1: Eth TCP<br>Channel 2: RS232 | DNP | Modbus | DNP, Modbus, IEC 61850 |
| | Channel 1: Eth UDP<br>Channel 2: RS485 | Modbus | DNP | DNP, Modbus, IEC 61850 |
| | Channel 1: Eth UDP<br>Channel 2: RS232 | DNP | Modbus | DNP, Modbus, IEC 61850 |
| | Channel 1: RS485<br>Channel 2: Eth TCP | Modbus | DNP | DNP, Modbus, IEC 61850 |
| | Channel 1: RS232<br>Channel 2: Eth TCP | DNP | Modbus | DNP, Modbus, IEC 61850 |
| | Channel 1: RS485<br>Channel 2: RS232 | DNP | DNP | Modbus, IEC 61850 |
| | Channel 1: RS232<br>Channel 2: RS485 | DNP | DNP | Modbus, IEC 61850 |
| | Channel 1: RS485<br>Channel 2: none | Modbus | DNP | Modbus, IEC 61850 |
| IEC 104 | | Modbus | Modbus | IEC 104, Modbus, IEC 61850 |
| IEC 103 | | Modbus | IEC 103 | Modbus, IEC 61850 |

## j) DNP PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP PROTOCOL

| | | | |
|---|---|---|---|
| ■ DNP PROTOCOL ■ | | ■ DNP CHANNELS ■ | Range: see sub-menu below |
| | MESSAGE | DNP ADDRESS: 1 | Range: 0 to 65519 in steps of 1 |
| | MESSAGE | ■ DNP NETWORK ■ CLIENT ADDRESSES | Range: see sub-menu below |
| | MESSAGE | DNP TCP/UDP PORT NUMBER: 20000 | Range: 0 to 65535 in steps of 1 |
| | MESSAGE | DNP UNSOL RESPONSE FUNCTION: Disabled | Range: Enabled, Disabled |
| | MESSAGE | DNP UNSOL RESPONSE TIMEOUT: 5 s | Range: 0 to 60 s in steps of 1 |
| | MESSAGE | DNP UNSOL RESPONSE MAX RETRIES: 10 | Range: 1 to 255 in steps of 1 |
| | MESSAGE | DNP UNSOL RESPONSE DEST ADDRESS: 1 | Range: 0 to 65519 in steps of 1 |
| | MESSAGE | DNP CURRENT SCALE FACTOR: 1 | Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000 |
| | MESSAGE | DNP VOLTAGE SCALE FACTOR: 1 | Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000 |
| | MESSAGE | DNP POWER SCALE FACTOR: 1 | Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000 |
| | MESSAGE | DNP ENERGY SCALE FACTOR: 1 | Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000 |
| | MESSAGE | DNP PF SCALE FACTOR: 1 | Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000 |
| | MESSAGE | DNP OTHER SCALE FACTOR: 1 | Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000 |
| | MESSAGE | DNP CURRENT DEFAULT DEADBAND: 30000 | Range: 0 to 100000000 in steps of 1 |
| | MESSAGE | DNP VOLTAGE DEFAULT DEADBAND: 30000 | Range: 0 to 100000000 in steps of 1 |
| | MESSAGE | DNP POWER DEFAULT DEADBAND: 30000 | Range: 0 to 100000000 in steps of 1 |
| | MESSAGE | DNP ENERGY DEFAULT DEADBAND: 30000 | Range: 0 to 100000000 in steps of 1 |
| | MESSAGE | DNP PF DEFAULT DEADBAND: 30000 | Range: 0 to 100000000 in steps of 1 |
| | MESSAGE | DNP OTHER DEFAULT DEADBAND: 30000 | Range: 0 to 100000000 in steps of 1 |
| | MESSAGE | DNP TIME SYNC IIN PERIOD: 1440 min | Range: 1 to 10080 min. in steps of 1 |

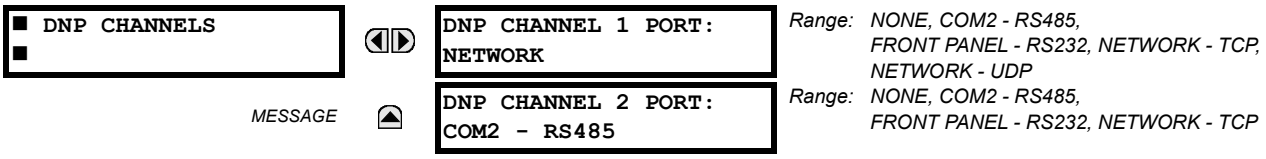



The L30 supports the Distributed Network Protocol (DNP) version 3.0. DNP is enabled when the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨ PROTOCOL** setting is set to DNP 3.0. The L30 can be used as a DNP slave device connected to multiple DNP masters (usually an RTU or a SCADA master station). Since the L30 maintains two sets of DNP data change buffers and connection information, two DNP masters can actively communicate with the L30 at one time.

NOTE For any change to DNP settings, restart the relay.

The DNP Channels sub-menu is shown below.

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP PROTOCOL ⇨ DNP CHANNELS**



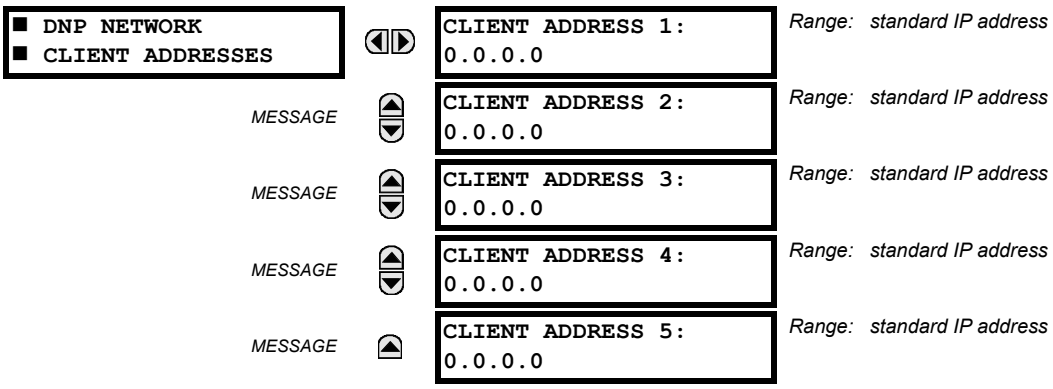

The **DNP CHANNEL 1 PORT** and **DNP CHANNEL 2 PORT** settings select the communications port assigned to the DNP protocol for each channel. Once DNP is assigned to a serial port, DNP is the only protocol running on that port; Modbus or IEC 60870-5-103 are disabled. If DNP is assigned to RS485, the protocol must be set to DNP on the serial port configuration as well, for the change to take effect. When the **DNP CHANNEL 1(2) PORT** setting is set to "Network - TCP," the channel 1(2) DNP protocol can be used over TCP/IP on the Ethernet ports. When the **DNP CHANNEL 1 PORT** setting is set to "Network - UDP," the channel 1 DNP protocol can be used over UDP/IP on the Ethernet ports. See the DNP appendix for information on the DNP protocol.

NOTE Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

The **DNP ADDRESS** setting is the DNP slave address. This number identifies the L30 on a DNP communications link. Each DNP slave should be assigned a unique address.

The L30 can specify a maximum of five clients for its DNP connections. These are IP addresses for the controllers to which the L30 can connect. The settings in this sub-menu are shown below.

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP PROTOCOL ⇨ DNP NETWORK CLIENT ADDRESSES**




The **DNP TCP/UDP PORT NUMBER** is for normal DNP operation. To close the port, set the port number to 0.

The **DNP UNSOL RESPONSE FUNCTION** should be "Disabled" for RS485 applications since there is no collision avoidance mechanism. The **DNP UNSOL RESPONSE TIMEOUT** sets the time the L30 waits for a DNP master to confirm an unsolicited response. The **DNP UNSOL RESPONSE MAX RETRIES** setting determines the number of times the L30 retransmits an unsolicited response without receiving confirmation from the master; a value of "255" allows infinite re-tries. The **DNP UNSOL RESPONSE DEST ADDRESS** is the DNP address to which all unsolicited responses are sent. The IP address to which solicited responses are sent is determined by the L30 from the current TCP connection or the most recent UDP message.

The DNP scale factor settings are numbers used to scale analog input point values. These settings group the L30 analog input data into the following types: current, voltage, power, energy, power factor, and other. Each setting represents the scale factor for all analog input points of that type. For example, if the **DNP VOLTAGE SCALE FACTOR** setting is set to "1000", all DNP analog input points that are voltages will be returned with values 1000 times smaller (for example, a value of 72000 V on the L30 will be returned as 72). These settings are useful when analog input values must be adjusted to fit within certain ranges in DNP masters. Note that a scale factor of 0.1 is equivalent to a multiplier of 10 (that is, the value will be 10 times larger).

The **DNP DEFAULT DEADBAND** settings determine when to trigger unsolicited responses containing analog input data. These settings group the L30 analog input data into the following types: current, voltage, power, energy, power factor, and other. Each setting represents the default deadband value for all analog input points of that type. For example, to trigger unsolicited responses from the L30 when any current values change by 15 A, the **DNP CURRENT DEFAULT DEADBAND** setting should be set to "15". Note that these settings are the deadband default values. DNP object 34 points can be used to change deadband values, from the default, for each individual DNP analog input point.

NOTE

The L30 relay does not support energy metering. As such, the **DNP ENERGY SCALE FACTOR** and **DNP ENERGY DEFAULT DEADBAND** settings are not applicable.

The **DNP TIME SYNC IIN PERIOD** setting determines how often the Need Time Internal Indication (IIN) bit is set by the L30. Changing this time allows the DNP master to send time synchronization commands more or less often, as required.

The **DNP MESSAGE FRAGMENT SIZE** setting determines the size, in bytes, at which message fragmentation occurs. Large fragment sizes allow for more efficient throughput; smaller fragment sizes cause more application layer confirmations to be necessary which can provide for more robust data transfer over noisy communication channels.

NOTE

Check the "DNP Points Lists" L30 web page to view the analog inputs and/or binary inputs points lists. This page can be viewed with a web browser by entering the IP address of the UR Ethernet port employed to access the L30 "Main Menu", then by selecting the "Device Information Menu" > "DNP Points Lists" menu item.

The **DNP OBJECT 1 DEFAULT VARIATION** to **DNP OBJECT 32 DEFAULT VARIATION** settings allow the user to select the DNP default variation number for object types 1, 2, 20, 21, 22, 23, 30, and 32. The default variation refers to the variation response when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. See the DNP Implementation section in the DNP appendix.

The DNP binary outputs typically map one-to-one to IED data points. That is, each DNP binary output controls a single physical or virtual control point in an IED. In the L30 relay, DNP binary outputs are mapped to virtual inputs. However, some legacy DNP implementations use a mapping of one DNP binary output to two physical or virtual control points to support the concept of trip/close (for circuit breakers) or raise/lower (for tap changers) using a single control point. That is, the DNP master can operate a single point for both trip and close, or raise and lower, operations. The L30 can be configured to support paired control points, with each paired control point operating two virtual inputs. The **DNP NUMBER OF PAIRED CONTROL POINTS** setting allows configuration of from 0 to 32 binary output paired controls. Points not configured as paired operate on a one-to-one basis.

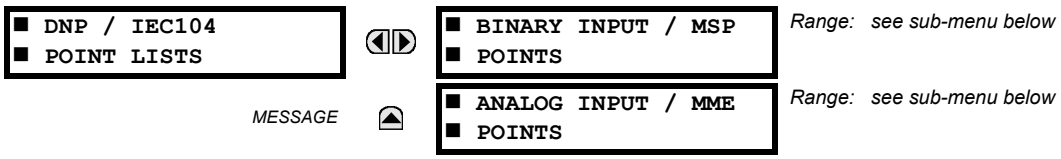
The **DNP TCP CONNECTION TIMEOUT** setting specifies a time delay for the detection of dead network TCP connections. If there is no data traffic on a DNP TCP connection for greater than the time specified by this setting, the connection will be aborted by the L30. This frees up the connection to be re-used by a client.

NOTE

For any change to DNP settings, restart the relay.

### k) DNP / IEC 60870-5-104 POINT LISTS

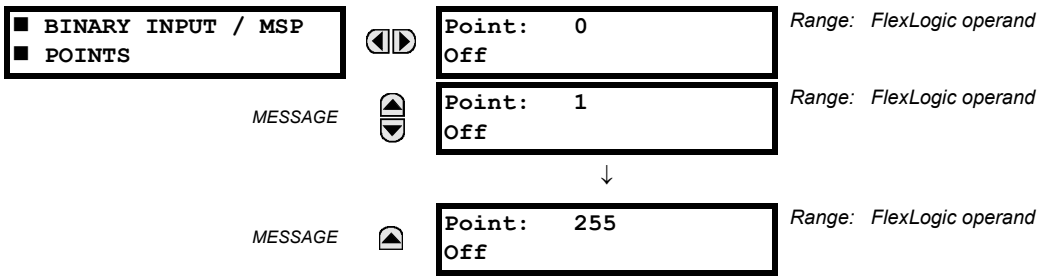
**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP / IEC104 POINT LISTS**




Up to 256 binary and up to 256 analog input points for the DNP protocol, or the MSP and MME points for IEC 60870-5-104 protocol, can be configured. The value for each point is user-programmable and can be configured by assigning FlexLogic operands for binary inputs / MSP points or FlexAnalog parameters for analog inputs / MME points.

The menu for the binary input points (DNP) or MSP points (IEC 60870-5-104) is shown below.

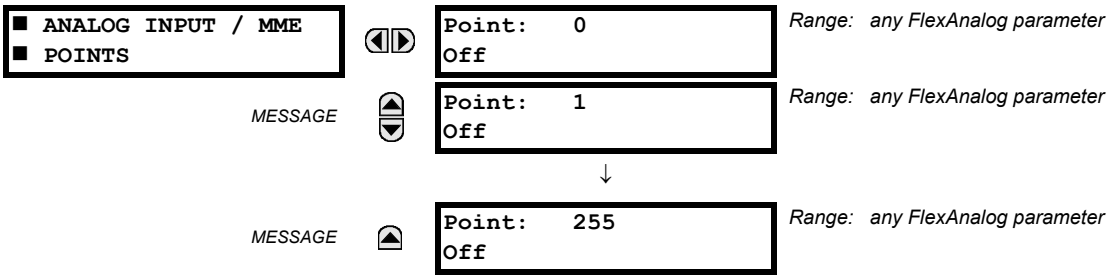
**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP / IEC104 POINT LISTS ⇨ BINARY INPUT / MSP POINTS**




Up to 256 binary input points can be configured for the DNP or IEC 60870-5-104 protocols. The points are configured by assigning an appropriate FlexLogic operand. See the Introduction to FlexLogic section in this chapter for the full range of assignable operands.

The menu for the analog input points (DNP) or MME points (IEC 60870-5-104) is shown below.

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP / IEC104 POINT LISTS ⇨⇩ ANALOG INPUT / MME POINTS




Up to 256 analog input points can be configured for the DNP or IEC 60870-5-104 protocols. The analog point list is configured by assigning an appropriate FlexAnalog parameter to each point. Refer to Appendix A: FlexAnalog Parameters for the full range of assignable parameters.

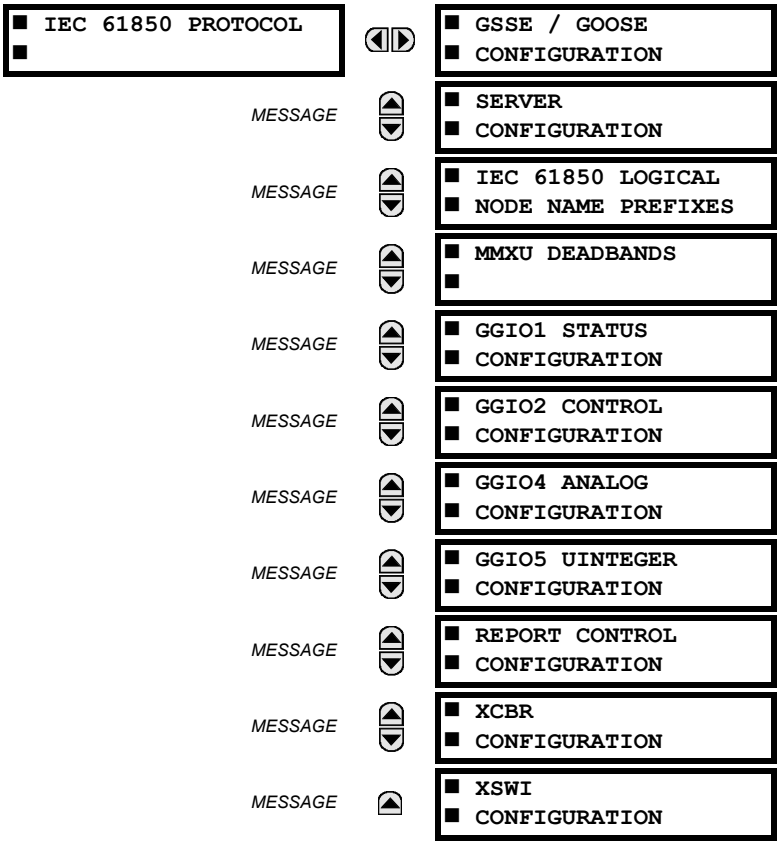
NOTE

The DNP / IEC 60870-5-104 point lists always begin with point 0 and end at the first "Off" value. Since DNP / IEC 60870-5-104 point lists must be in one continuous block, any points assigned after the first "Off" point are ignored.

Changes to the DNP / IEC 60870-5-104 point lists take effect when the L30 is restarted.

### l) IEC 61850 PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL




SOFTWARE OPTION

The L30 Line Current Differential System is provided with optional IEC 61850 communications capability. This feature is specified as a software option at the time of ordering. See the Order Codes section in chapter 2 for details.

NOTE

IEC 61850 messaging can form part of protection schemes. Consider 61850 settings with the same criticality as protection element settings. To ensure reliable performance of protection schemes utilizing 61850 messaging, it can be desirable to route 61850 traffic on a separate port from SCADA communications, or to use redundant, independent ports, and a high speed network recovery method, such as PRP.

The L30 supports the Manufacturing Message Specification (MMS) protocol as specified by IEC 61850. MMS is supported over two protocol stacks: TCP/IP over Ethernet. The L30 operates as an IEC 61850 server. The Remote Inputs and Outputs section in this chapter describe the peer-to-peer GSSE/GOOSE message scheme.

The EnerVista software includes an interface that is compatible with firmware versions 5.0 to 7.2 to configure subscribers. Use the Simplified GOOSE Configurator in the Offline Window area.

The GSSE/GOOSE configuration main menu is divided into two areas: transmission and reception.

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION**

| | | |
|---|---|---|
| ■ GSSE / GOOSE<br>■ CONFIGURATION | ◀▶ | ■ TRANSMISSION<br>■ |
| | *MESSAGE* ▲ | ■ RECEPTION<br>■ |

The main transmission menu is shown below:

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨ TRANSMISSION**

| | | |
|---|---|---|
| ■ TRANSMISSION<br>■ | ◀▶ | ■ GENERAL<br>■ |
| | *MESSAGE* ▲▼ | ■ GSSE<br>■ |
| | *MESSAGE* ▲▼ | ■ FIXED GOOSE<br>■ |
| | *MESSAGE* ▲ | ■ CONFIGURABLE GOOSE<br>■ |

The general transmission settings are shown below:

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨ TRANSMISSION ⇨ GENERAL**

| | | | |
|---|---|---|---|
| ■ GENERAL<br>■ | ◀▶ | DEFAULT GSSE/GOOSE<br>UPDATE TIME: 60 s | *Range: 1 to 60 s in steps of 1* |

The **DEFAULT GSSE/GOOSE UPDATE TIME** sets the time between GSSE or GOOSE messages when there are no remote output state changes to be sent. When remote output data changes, GSSE or GOOSE messages are sent immediately. This setting controls the steady-state *heartbeat* time interval.

The **DEFAULT GSSE/GOOSE UPDATE TIME** setting is applicable to GSSE, fixed L30 GOOSE, and configurable GOOSE.

The GSSE settings are shown below:

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨ TRANSMISSION ⇨⇩ GSEE**

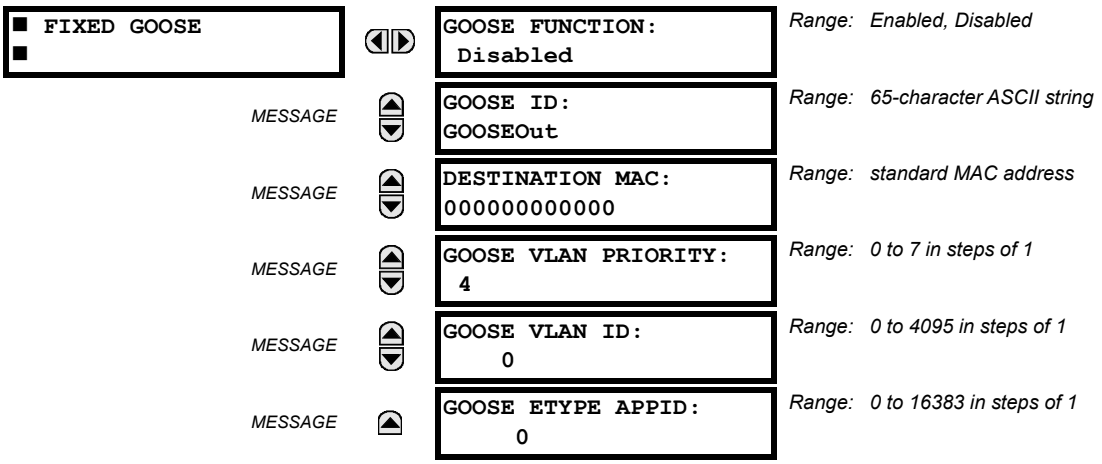
| | | | |
|---|---|---|---|
| ■ GSSE<br>■ | ◀▶ | GSSE FUNCTION:<br>Enabled | *Range: Enabled, Disabled* |
| | *MESSAGE* ▲▼ | GSSE ID:<br>GSSEOut | *Range: 65-character ASCII string* |
| | *MESSAGE* ▲ | DESTINATION MAC:<br>000000000000 | *Range: standard MAC address* |

These settings are applicable to GSSE only. If the fixed GOOSE function is enabled, GSSE messages are not transmitted.

The **GSSE ID** setting represents the IEC 61850 GSSE application ID name string sent as part of each GSSE message. This string identifies the GSSE message to the receiving device. In L30 releases previous to 5.0x, this name string was represented by the **RELAY NAME** setting.

The fixed GOOSE settings are shown below:

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨ TRANSMISSION ⇨⇩ FIXED GOOSE**




These settings are applicable to fixed (DNA/UserSt) GOOSE only.

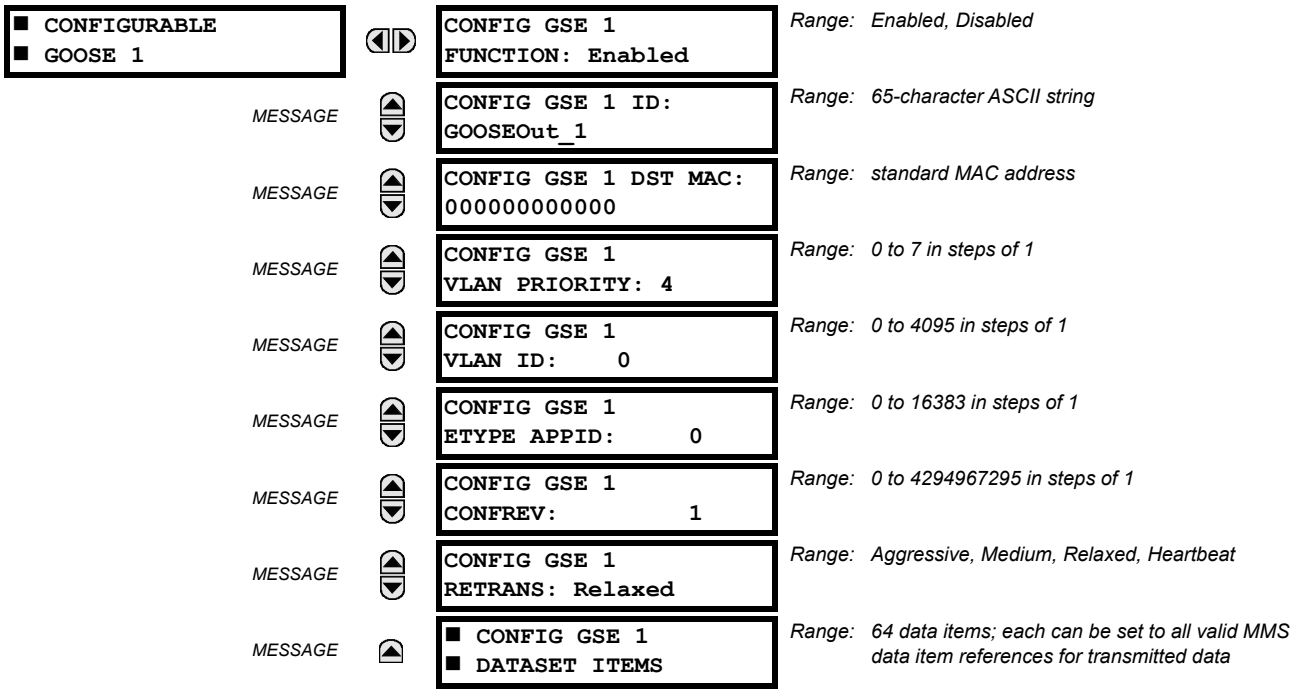
The **GOOSE ID** setting represents the IEC 61850 GOOSE application ID (GoID) name string sent as part of each GOOSE message. This string identifies the GOOSE message to the receiving device. In revisions previous to 5.0x, this name string was represented by the **RELAY NAME** setting.

The **DESTINATION MAC** setting allows the destination Ethernet MAC address to be set. This address must be a multicast address; the least significant bit of the first byte must be set. In L30 releases previous to 5.0x, the destination Ethernet MAC address was determined automatically by taking the sending MAC address (that is, the unique, local MAC address of the L30) and setting the multicast bit.

The **GOOSE VLAN PRIORITY** setting indicates the Ethernet priority of GOOSE messages. This allows GOOSE messages to have higher priority than other Ethernet data. The **GOOSE ETYPE APPID** setting allows the selection of a specific application ID for each GOOSE sending device. This value can be left at its default if the feature is not required. Both the **GOOSE VLAN PRIORITY** and **GOOSE ETYPE APPID** settings are required by IEC 61850.

The configurable GOOSE settings are shown below.

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨ TRANSMISSION ⇨⇩ CONFIGURABLE GOOSE ⇨ CONFIGURABLE GOOSE 1(8)**




The configurable GOOSE settings allow the L30 to be configured to transmit a number of different datasets within IEC 61850 GOOSE messages. Up to eight different configurable datasets can be configured and transmitted. This is useful for intercommunication between L30 IEDs and devices from other manufacturers that support IEC 61850.

The configurable GOOSE feature allows for the configuration of the datasets to be transmitted or received from the L30. The L30 supports the configuration of eight transmission and reception datasets, allowing for the optimization of data transfer between devices.

Items programmed for dataset 1 and 2 will have changes in their status transmitted as soon as the change is detected. Datasets 1 and 2 should be used for high-speed transmission of data that is required for applications such as transfer tripping, blocking, and breaker fail initiate. At least one digital status value needs to be configured in the required dataset to enable transmission of configured data. Configuring analog data only to dataset 1 or 2 will not activate transmission.

Items programmed for datasets 3 through 8 will have changes in their status transmitted at a maximum rate of every 100 ms. Datasets 3 through 8 will regularly analyze each data item configured within them every 100 ms to identify if any changes have been made. If any changes in the data items are detected, these changes will be transmitted through a GOOSE message. If there are no changes detected during this 100 ms period, no GOOSE message will be sent.

For all datasets 1 through 8, the integrity GOOSE message will still continue to be sent at the pre-configured rate even if no changes in the data items are detected.

The GOOSE functionality was enhanced to prevent the relay from flooding a communications network with GOOSE messages due to an oscillation being created that is triggering a message.

The L30 has the ability of detecting if a data item in one of the GOOSE datasets is erroneously oscillating. This can be caused by events such as errors in logic programming, inputs improperly being asserted and de-asserted, or failed station components. If erroneously oscillation is detected, the L30 will stop sending GOOSE messages from the dataset for a minimum period of one second. Should the oscillation persist after the one second time-out period, the L30 will continue to block transmission of the dataset. The L30 will assert the **MAINTENANCE ALERT: GGIO Ind XXX oscill** self-test error message on the front panel display, where **XXX** denotes the data item detected as oscillating.

For versions 5.70 and higher, the L30 supports four retransmission schemes: aggressive, medium, relaxed, and heartbeat. The aggressive scheme is only supported in fast type 1A GOOSE messages (GOOSEOut 1 and GOOSEOut 2). For slow GOOSE messages (GOOSEOut 3 to GOOSEOut 8) the aggressive scheme is the same as the medium scheme.

The table shows details about each scheme. Times are maximum values. Retransmitted messages can occur faster than the times listed.

**Table 5–7: GOOSE RETRANSMISSION SCHEMES**

| SCHEME | SQ NUM | TIME FROM THE EVENT | TIME BETWEEN MESSAGES | COMMENT | TIME ALLOWED TO LIVE IN MESSAGE |
|---|---|---|---|---|---|
| Aggressive | 0 | 0 ms | 0 ms | Event | 2000 ms |
| | 1 | 4 ms | 4 ms | T1 | 2000 ms |
| | 2 | 8 ms | 4 ms | T1 | 2000 ms |
| | 3 | 16 ms | 8 ms | T2 | Heartbeat * 4.5 |
| | 4 | Heartbeat | Heartbeat | T0 | Heartbeat * 4.5 |
| | 5 | Heartbeat | Heartbeat | T0 | Heartbeat * 4.5 |
| Medium | 0 | 0 ms | 0 ms | Event | 2000 ms |
| | 1 | 16 ms | 16 ms | T1 | 2000 ms |
| | 2 | 32 ms | 16 ms | T1 | 2000 ms |
| | 3 | 64 ms | 32 ms | T2 | Heartbeat * 4.5 |
| | 4 | Heartbeat | Heartbeat | T0 | Heartbeat * 4.5 |
| | 5 | Heartbeat | Heartbeat | T0 | Heartbeat * 4.5 |
| Relaxed | 0 | 0 ms | 0 ms | Event | 2000 ms |
| | 1 | 100 ms | 100 ms | T1 | 2000 ms |
| | 2 | 200 ms | 100 ms | T1 | 2000 ms |
| | 3 | 700 ms | 500 ms | T2 | Heartbeat * 4.5 |
| | 4 | Heartbeat | Heartbeat | T0 | Heartbeat * 4.5 |
| | 5 | Heartbeat | Heartbeat | T0 | Heartbeat * 4.5 |
| Heartbeat | 0 | 0 ms | 0 ms | Event | 2000 ms |
| | 1 | Heartbeat | Heartbeat | T1 | 2000 ms |
| | 2 | Heartbeat | Heartbeat | T1 | 2000 ms |
| | 3 | Heartbeat | Heartbeat | T2 | Heartbeat * 4.5 |
| | 4 | Heartbeat | Heartbeat | T0 | Heartbeat * 4.5 |
| | 5 | Heartbeat | Heartbeat | T0 | Heartbeat * 4.5 |

The configurable GOOSE feature is recommended for applications that require GOOSE data transfer between UR-series IEDs and devices from other manufacturers. Fixed GOOSE is recommended for applications that require GOOSE data transfer between UR-series IEDs.

IEC 61850 GOOSE messaging contains a number of configurable parameters, all of which must be correct to achieve the successful transfer of data. It is critical that the configured datasets at the transmission and reception devices are an exact match in terms of data structure, and that the GOOSE addresses and name strings match exactly. Manual configuration is possible, but third-party substation configuration software may be used to automate the process. The EnerVista UR Setup software can produce IEC 61850 ICD files and import IEC 61850 SCD files produced by a substation configurator (as outlined in the IEC 61850 appendix).

The following example illustrates the configuration required to transfer IEC 61850 data items between two devices. The general steps required for transmission configuration are:

1. Configure the transmission dataset.
2. Configure the GOOSE service settings.
3. Configure the data.

The general steps required for reception configuration are:

1. Configure the reception dataset.
2. Configure the GOOSE service settings.
3. Configure the data.

This example shows how to configure the transmission and reception of three IEC 61850 data items: a single point status value, its associated quality flags, and a floating point analog value.

The following procedure illustrates the transmission configuration.

1. Configure the transmission dataset by making the following changes in the **PRODUCT SETUP** ⇨⇩ **COMMUNICATION** ⇨⇩ **IEC 61850 PROTOCOL** ⇨ **GSSE/GOOSE CONFIGURATION** ⇨ **TRANSMISSION** ⇨⇩ **CONFIGURABLE GOOSE** ⇨ **CONFIGURABLE GOOSE 1** ⇨⇩ **CONFIG GSE 1 DATASET ITEMS** settings menu:
   - Set **ITEM 1** to “GGIO1.ST.Ind1.q” to indicate quality flags for GGIO1 status indication 1.
   - Set **ITEM 2** to “GGIO1.ST.Ind1.stVal” to indicate the status value for GGIO1 status indication 1.
   - Set **ITEM 3** to “MMXU1.MX.Hz.mag.f” to indicate the analog frequency magnitude for MMXU1 (the metered frequency for SRC1).

   The transmission dataset now contains a quality flag, a single point status Boolean value, and a floating point analog value. The reception dataset on the receiving device must exactly match this structure.
2. Configure the GOOSE service settings by making the following changes in the **PRODUCT SETUP** ⇨⇩ **COMMUNICATION** ⇨⇩ **IEC 61850 PROTOCOL** ⇨ **GSSE/GOOSE CONFIGURATION** ⇨ **TRANSMISSION** ⇨⇩ **CONFIGURABLE GOOSE** ⇨ **CONFIGURABLE GOOSE 1** settings menu:
   - Set **CONFIG GSE 1 FUNCTION** to “Enabled”.
   - Set **CONFIG GSE 1 ID** to an appropriate descriptive string (the default value is “GOOSEOut_1”).
   - Set **CONFIG GSE 1 DST MAC** to a multicast address (for example, 01 00 00 12 34 56).
   - Set the **CONFIG GSE 1 VLAN PRIORITY**; the default value of “4” is OK for this example.
   - Set the **CONFIG GSE 1 VLAN ID** value; the default value is “0”, but some switches may require this value to be “1”.
   - Set the **CONFIG GSE 1 ETYPE APPID** value. This setting represents the ETHERTYPE application ID and must match the configuration on the receiver (the default value is “0”).
   - Set the **CONFIG GSE 1 CONFREV** value. This value changes automatically as described in IEC 61850 part 7-2. For this example it can be left at its default value.
3. Configure the data by making the following changes in the **PRODUCT SETUP** ⇨⇩ **COMMUNICATION** ⇨⇩ **IEC 61850 PROTOCOL** ⇨ **GGIO1 STATUS CONFIGURATION** settings menu:
   - Set **GGIO1 INDICATION 1** to a FlexLogic operand used to provide the status of GGIO1.ST.Ind1.stVal (for example, a contact input, virtual input, a protection element status, etc.).
4. Configure the MMXU1 Hz Deadband by making the following changes in the **PRODUCT SETUP** ⇨⇩ **COMMUNICATION** ⇨⇩ **IEC 61850 PROTOCOL** ⇨⇩ **MMXU DEADBANDS**⇨⇩ **MMXU1 DEADBANDS** settings menu:
   - Set **MMXU1 HZ DEADBAND** to “0.050%”. This will result in an update to the MMXU1.MX.mag.f analog value with a change greater than 45 mHz, from the previous MMXU1.MX.mag.f value, in the source frequency.

The L30 must be rebooted (control power removed and re-applied) before these settings take effect.

The following procedure illustrates the reception configuration.

1. Configure the reception dataset by making the following changes in the **PRODUCT SETUP** ⇨⇩ **COMMUNICATION** ⇨⇩ **IEC 61850 PROTOCOL** ⇨ **GSSE/GOOSE CONFIGURATION** ⇨⇩ **RECEPTION** ⇨⇩ **CONFIGURABLE GOOSE** ⇨ **CONFIGURABLE GOOSE 1** ⇨⇩ **CONFIG GSE 1 DATASET ITEMS** settings menu:
   - Set **ITEM 1** to “GGIO3.ST.Ind1.q” to indicate quality flags for GGIO3 status indication 1.
   - Set **ITEM 2** to “GGIO3.ST.Ind1.stVal” to indicate the status value for GGIO3 status indication 1.
   - Set **ITEM 3** to “GGIO3.MX.AnIn1.mag.f” to indicate the analog magnitude for GGIO3 analog input 1.

   The reception dataset now contains a quality flag, a single point status Boolean value, and a floating point analog value. This matches the transmission dataset configuration above.
2. Configure the GOOSE service settings by making the following changes in the **INPUTS/OUTPUTS** ⇨⇩ **REMOTE DEVICES** ⇨⇩ **REMOTE DEVICE 1** settings menu:
   - Set **REMOTE DEVICE 1 ID** to match the GOOSE ID string for the transmitting device. Enter “GOOSEOut_1”.

– Set **REMOTE DEVICE 1 ETYPE APPID** to match the ETHERTYPE application ID from the transmitting device. This is "0" in the example above.

– Set the **REMOTE DEVICE 1 DATASET** value. This value represents the dataset number in use. Since we are using configurable GOOSE 1 in this example, program this value as "GOOSEIn 1".

3. Configure the Boolean data by making the following changes in the **INPUTS/OUTPUTS ⇨⇩ REMOTE INPUTS ⇨⇩ REMOTE INPUT 1** settings menu:

   – Set **REMOTE IN 1 DEVICE** to "GOOSEOut_1".

   – Set **REMOTE IN 1 ITEM** to "Dataset Item 2". This assigns the value of the GGIO3.ST.Ind1.stVal single point status item to remote input 1.

4. Configure the analog data by making the following changes in the **INPUTS/OUTPUTS ⇨⇩ IEC 61850 GOOSE ANALOG INPUTS** settings menu:

   – Set the **IEC61850 GOOSE ANALOG INPUT 1 DEFAULT VALUE** to "60.000".

   – Enter "Hz" for the **IEC61850 GOOSE ANALOG INPUT 1 UNITS** setting.

The GOOSE analog input 1 can now be used as a FlexAnalog value in a FlexElement or in other settings. The L30 must be rebooted (control power removed and re-applied) before these settings take effect.

The value of GOOSE analog input 1 in the receiving device will be determined by the MMXU1.MX.Hz.mag.f value in the sending device. This MMXU value is determined by the source 1 frequency value and the MMXU Hz deadband setting of the sending device.

Remote input 1 can now be used in FlexLogic equations or other settings. The L30 must be rebooted (control power removed and re-applied) before these settings take effect.

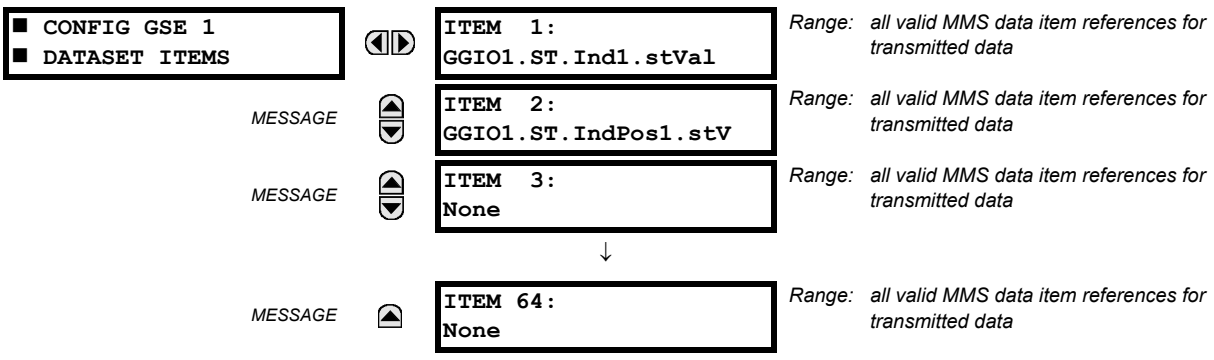
The value of remote input 1 (Boolean on or off) in the receiving device will be determined by the GGIO1.ST.Ind1.stVal value in the sending device. The above settings will be automatically populated by the EnerVista UR Setup software when a complete SCD file is created by third party substation configurator software.

For intercommunication between L30 IEDs, the fixed (DNA/UserSt) dataset can be used. The DNA/UserSt dataset contains the same DNA and UserSt bit pairs that are included in GSSE messages. All GOOSE messages transmitted by the L30 (DNA/UserSt dataset and configurable datasets) use the IEC 61850 GOOSE messaging services (for example, VLAN support).

NOTE

Set the **CONFIG GSE 1 FUNCTION** function to "Disabled" when configuration changes are required. Once changes are entered, return the **CONFIG GSE 1 FUNCTION** to "Enabled" and restart the unit for changes to take effect.

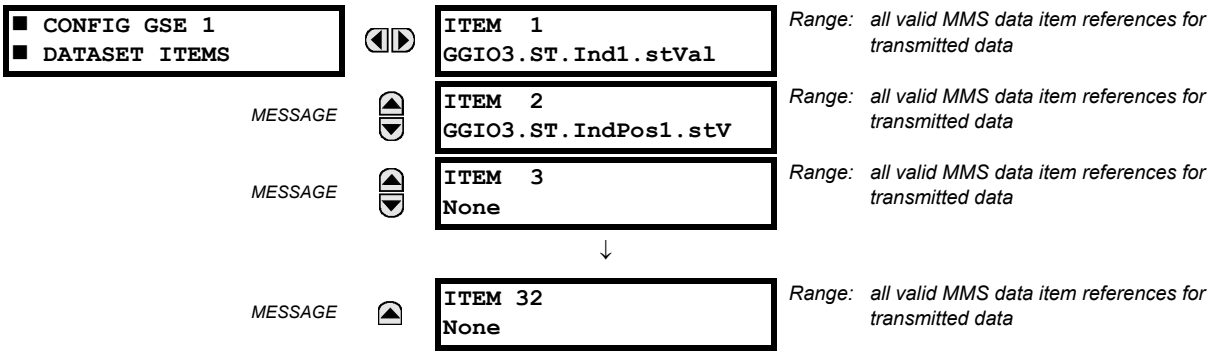
**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨ TRANSMISSION ⇨⇩ CONFIGURABLE GOOSE ⇨ CONFIGURABLE GOOSE 1(8) ⇨⇩ CONFIG GSE 1(64) DATA ITEMS**




To create a configurable GOOSE dataset that contains an IEC 61850 Single Point Status indication and its associated quality flags, the following dataset items can be selected: "GGIO1.ST.Ind1.stVal" and "GGIO1.ST.Ind1.q". The L30 will then create a dataset containing these two data items. The status value for GGIO1.ST.Ind1.stVal is determined by the FlexLogic operand assigned to GGIO1 indication 1. Changes to this operand will result in the transmission of GOOSE messages containing the defined dataset.

The main reception menu is applicable to configurable GOOSE only and contains the configurable GOOSE dataset items for reception:

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨ RECEPTION ⇨⇩ CONFIGURABLE GOOSE ⇨ CONFIGURABLE GOOSE 1(16) ⇨⇩ CONFIG GSE 1(32) DATA ITEMS




The configurable GOOSE settings allow the L30 to be configured to receive a number of different datasets within IEC 61850 GOOSE messages. Up to 16 different configurable datasets can be configured for reception. This is useful for inter-communication between L30 IEDs and devices from other manufacturers that support IEC 61850.

For intercommunication between L30 IEDs, the fixed (DNA/UserSt) dataset can be used. The DNA/UserSt dataset contains the same DNA and UserSt bit pairs that are included in GSSE messages.

To set up a L30 to receive a configurable GOOSE dataset that contains two IEC 61850 single point status indications, the following dataset items can be selected (for example, for configurable GOOSE dataset 1): “GGIO3.ST.Ind1.stVal” and “GGIO3.ST.Ind2.stVal”. The L30 will then create a dataset containing these two data items. The Boolean status values from these data items can be utilized as remote input FlexLogic operands. First, the **REMOTE DEVICE 1(16) DATASET** setting must be set to contain dataset “GOOSEIn 1” (that is, the first configurable dataset). Then **REMOTE IN 1(16) ITEM** settings must be set to “Dataset Item 1” and “Dataset Item 2”. These remote input FlexLogic operands will then change state in accordance with the status values of the data items in the configured dataset.

Double-point status values may be included in the GOOSE dataset. Received values are populated in the GGIO3.ST.IndPos1.stVal and higher items.

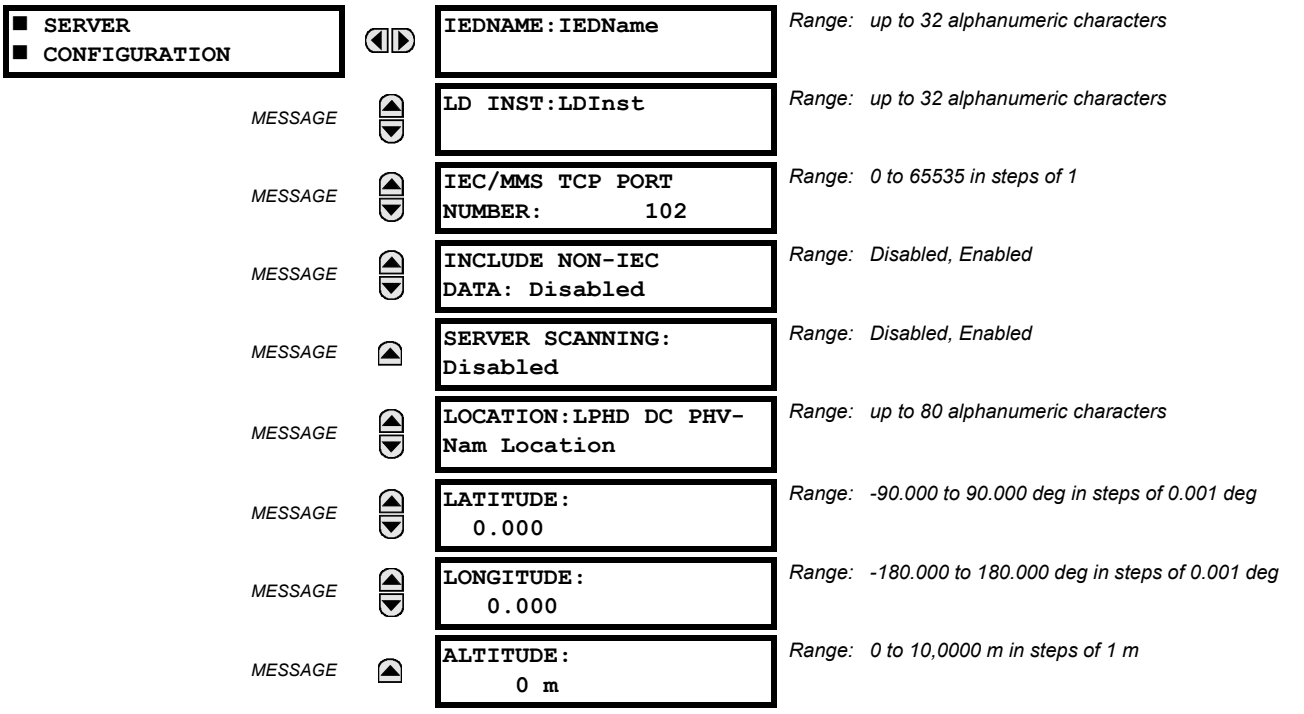
Floating point analog values originating from MMXU logical nodes may be included in GOOSE datasets. Deadband (non-instantaneous) values can be transmitted. Received values are used to populate the GGIO3.MX.AnIn1 and higher items. Received values are also available as FlexAnalog parameters (GOOSE analog In1 and up).

NOTE

GGIO3.MX.AnIn1 to GGIO3.MX.AnIn32 can only be used once for all 16 reception datasets.

The main menu for the IEC 61850 server configuration is shown below.

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ SERVER CONFIGURATION**




The **IEDNAME** and **LD INST** settings represent the MMS domain name (IEC 61850 logical device) where all IEC/MMS logical nodes are located. Valid characters for these values are upper and lowercase letters, numbers, and the underscore (_) character, and the first character in the string must be a letter. This conforms to the IEC 61850 standard. The **LOCATION** is a variable string and can be composed of ASCII characters. This string appears within the PhyName of the LPHD node.

The **IEC/MMS TCP PORT NUMBER** setting allows the user to change the TCP port number for MMS connections. The **INCLUDE NON-IEC DATA** setting determines whether or not the "UR" MMS domain will be available. This domain contains a large number of UR-series specific data items that are not available in the IEC 61850 logical nodes. This data does not follow the IEC 61850 naming conventions. For communications schemes that strictly follow the IEC 61850 standard, this setting should be "Disabled".

NOTE

When a 0 value is involved in a change, the changes to the **IEC/MMS TCP PORT NUMBER** setting take effect when the L30 is restarted.

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

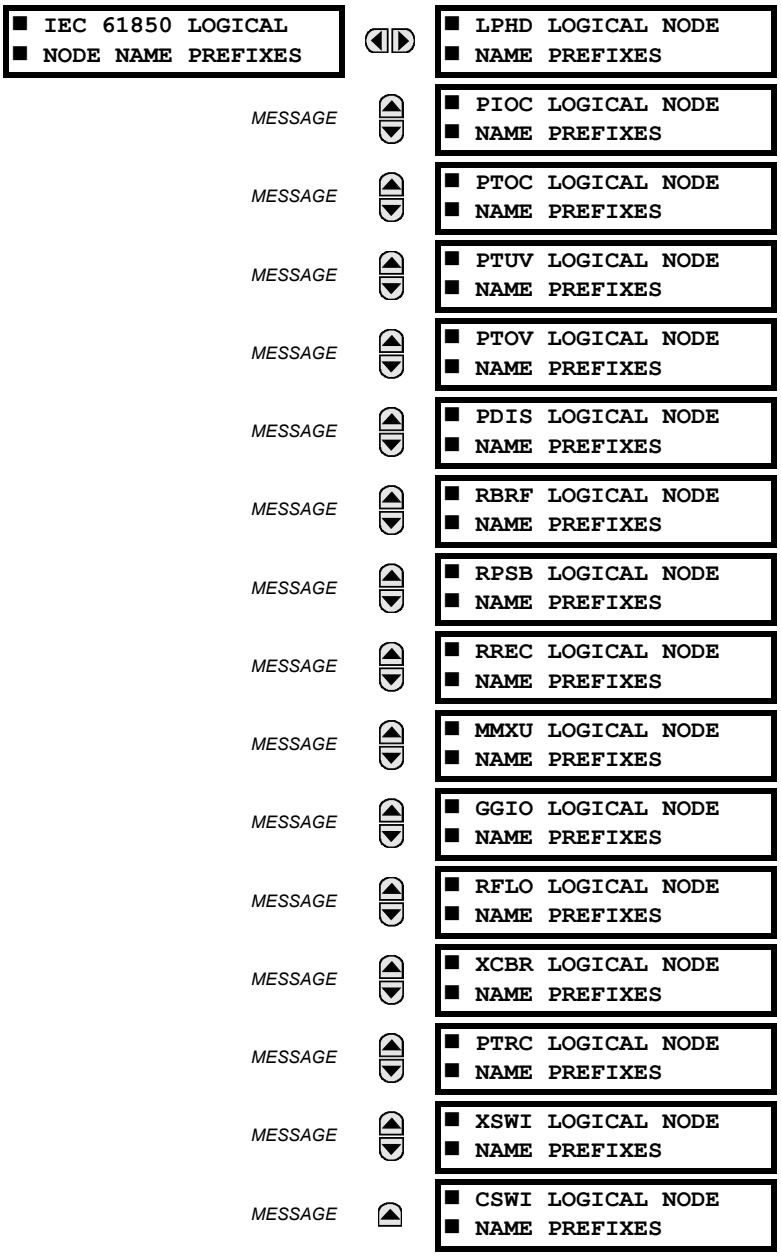
The **SERVER SCANNING** feature should be set to "Disabled" when IEC 61850 client/server functionality is not required. IEC 61850 has two modes of functionality: GOOSE/GSSE inter-device communication and client/server communication. If the GOOSE/GSSE functionality is required without the IEC 61850 client server feature, then server scanning can be disabled to increase CPU resources. When server scanning is disabled, there is no updating of the IEC 61850 logical node status values in the L30. Clients are still able to connect to the server (L30 relay), but most data values are not updated. This setting does not affect GOOSE/GSSE operation.

NOTE

Changes to the **IEDNAME** setting, **LD INST** setting, and GOOSE dataset take effect when the L30 is restarted.

The main menu for the IEC 61850 logical node name prefixes is shown below.

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ IEC 61850 LOGICAL NODE NAME PREFIXES

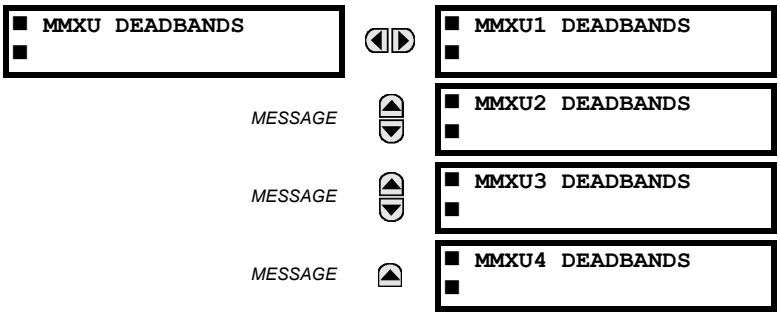



The IEC 61850 logical node name prefix settings are used to create name prefixes to uniquely identify each logical node. For example, the logical node “PTOC1” may have the name prefix “abc”. The full logical node name will then be “abcMMXU1”. Valid characters for the logical node name prefixes are upper and lowercase letters, numbers, and the underscore (_) character, and the first character in the prefix must be a letter. This conforms to the IEC 61850 standard.

Changes to the logical node prefixes will not take effect until the L30 is restarted.

The main menu for the IEC 61850 MMXU deadbands is shown below.

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ MMXU DEADBANDS



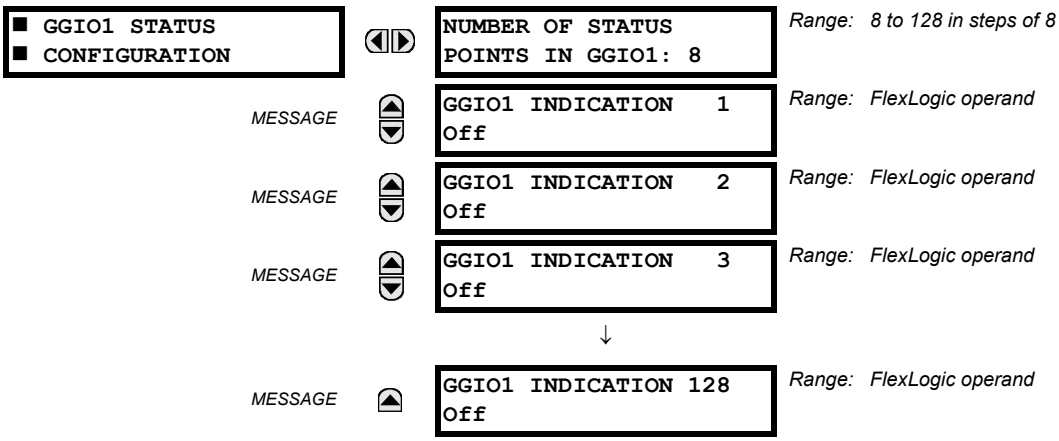

The MMXU deadband settings represent the deadband values used to determine when the update the MMXU “mag” and “cVal” values from the associated “instmag” and “instcVal” values. The “mag” and “cVal” values are used for the IEC 61850 buffered and unbuffered reports. These settings correspond to the associated “db” data items in the CF functional constraint of the MMXU logical node, as per the IEC 61850 standard. According to IEC 61850-7-3, the db value “shall represent the percentage of difference between the maximum and minimum in units of 0.001%”. Thus, it is important to know the maximum value for each MMXU measured quantity, since this represents the 100.00% value for the deadband.

The minimum value for all quantities is 0; the maximum values are as follows:

- phase current: 46 × phase CT primary setting
- neutral current: 46 × ground CT primary setting
- voltage: 275 × VT ratio setting
- power (real, reactive, and apparent): 46 × phase CT primary setting × 275 × VT ratio setting
- frequency: 90 Hz
- power factor: 2

The GGIO1 status configuration points are shown below:

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ GGIO1 STATUS CONFIGURATION




The **NUMBER OF STATUS POINTS IN GGIO1** setting specifies the number of “Ind” (single point status indications) that are instantiated in the GGIO1 logical node. Changes to the **NUMBER OF STATUS POINTS IN GGIO1** setting will not take effect until the L30 is restarted.

The GGIO2 control configuration points are shown below:

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ GGIO2 CONTROL CONFIGURATION ⇨ GGIO2 CF SPSCO 1(64)

The GGIO2 control configuration settings are used to set the control model for each input. The available choices are "0" (status only), "1" (direct control), and "2" (SBO with normal security). The GGIO2 control points are used to control the L30 virtual inputs.

The GGIO4 analog configuration points are shown below:

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ GGIO4 ANALOG CONFIGURATION**

```
■ GGIO4 ANALOG
■ CONFIGURATION
```

```
NUMBER OF ANALOG
POINTS IN GGIO4:  8
```

*Range: 4 to 32 in steps of 4*

MESSAGE

```
■ GGIO4 ANALOG  1
■ MEASURED VALUE
```

MESSAGE

```
■ GGIO4 ANALOG  2
■ MEASURED VALUE
```

MESSAGE

```
■ GGIO4 ANALOG  3
■ MEASURED VALUE
```

↓

MESSAGE

```
■ GGIO4 ANALOG 32
■ MEASURED VALUE
```

The **NUMBER OF ANALOG POINTS** setting determines how many analog data points will exist in GGIO4. When this value is changed, the L30 must be rebooted in order to allow the GGIO4 logical node to be re-instantiated and contain the newly configured number of analog points.

The measured value settings for each of the 32 analog values are shown below.

**PATH: SETTINGS ⇨ PRODUCT... ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ GGIO4 ANALOG CONFIGURATION ⇨ GGIO4 ANALOG 1(32) MEASURED VALUE**

```
■ GGIO4 ANALOG  1
■ MEASURED VALUE
```

```
ANALOG IN  1 VALUE:
Off
```

*Range: any FlexAnalog value*

MESSAGE

```
ANALOG IN  1 DB:
100.000%
```

*Range: 0.000 to 100.000 in steps of 0.001*

MESSAGE

```
ANALOG IN  1 MIN:
0.000
```

*Range: –1000000000.000 to 1000000000.000 in steps of 0.001*

MESSAGE

```
ANALOG IN  1 MAX:
1000000.000
```

*Range: –1000000000.000 to 1000000000.000 in steps of 0.001*

These settings are configured as follows.

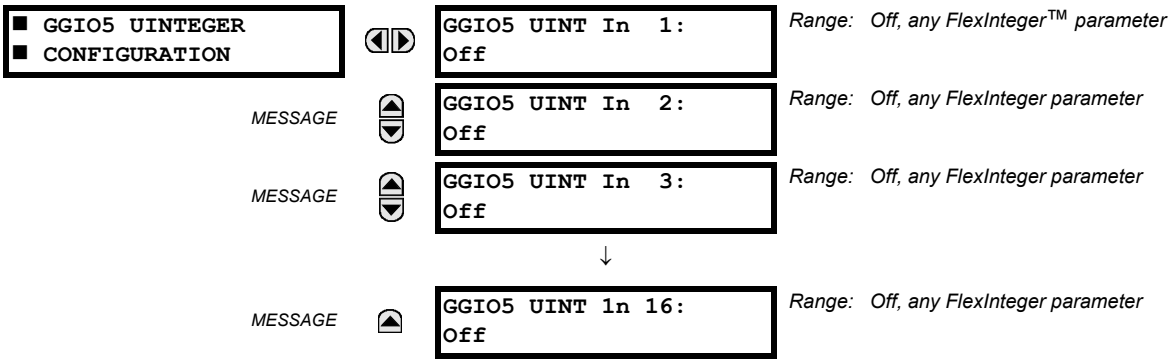
- **ANALOG IN 1 VALUE**: This setting selects the FlexAnalog value to drive the instantaneous value of each GGIO4 analog status value (GGIO4.MX.AnIn1.instMag.f).
- **ANALOG IN 1 DB**: This setting specifies the deadband for each analog value. Refer to IEC 61850-7-1 and 61850-7-3 for details. The deadband is used to determine when to update the deadbanded magnitude from the instantaneous magnitude. The deadband is a percentage of the difference between the maximum and minimum values.
- **ANALOG IN 1 MIN**: This setting specifies the minimum value for each analog value. Refer to IEC 61850-7-1 and 61850-7-3 for details. This minimum value is used to determine the deadband. The deadband is used in the determination of the deadbanded magnitude from the instantaneous magnitude.
- **ANALOG IN 1 MAX**: This setting defines the maximum value for each analog value. Refer to IEC 61850-7-1 and 61850-7-3 for details. This maximum value is used to determine the deadband. The deadband is used in the determination of the deadbanded magnitude from the instantaneous magnitude.

NOTE

Note that the **ANALOG IN 1 MIN** and **ANALOG IN 1 MAX** settings are stored as IEEE 754 / IEC 60559 floating point numbers. Because of the large range of these settings, not all values can be stored. Some values may be rounded to the closest possible floating point number.

The GGIO5 integer configuration points are shown below:

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ GGIO5 ANALOG CONFIGURATION



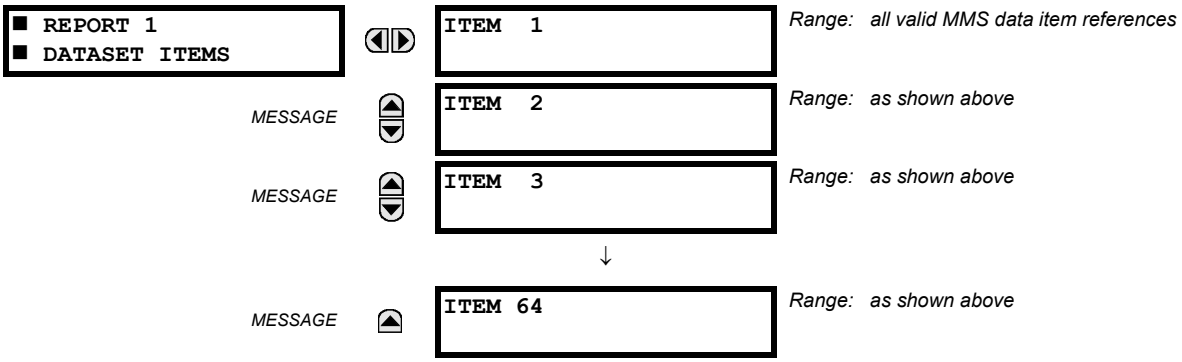

The GGIO5 logical node allows IEC 61850 client access to integer data values. This allows access to as many as 16 unsigned integer value points, associated timestamps, and quality flags. The method of configuration is similar to that of GGIO1 (binary status values). The settings allow the selection of FlexInteger values for each GGIO5 integer value point.

It is intended that clients use GGIO5 to access generic integer values from the L30. Additional settings are provided to allow the selection of the number of integer values available in GGIO5 (1 to 16), and to assign FlexInteger values to the GGIO5 integer inputs. The following setting is available for all GGIO5 configuration points.

- **GGIO5 UINT IN 1 VALUE**: This setting selects the FlexInteger value to drive each GGIO5 integer status value (GGIO5.ST.UIntIn1). This setting is stored as an 32-bit unsigned integer value.

The report control configuration settings are shown below:

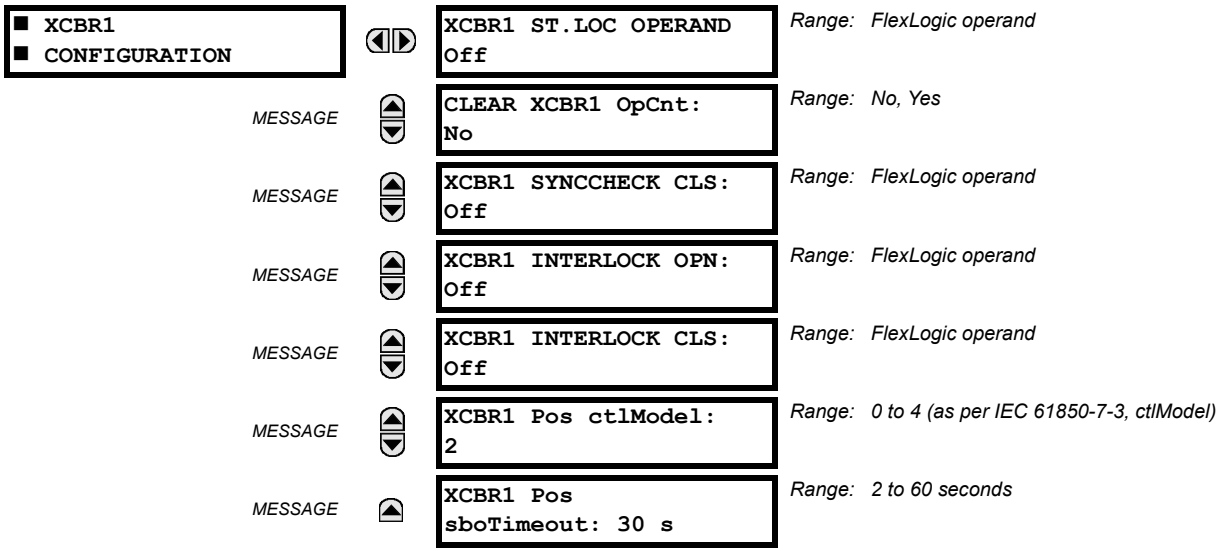
PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ REPORT CONTROL CONFIGURATION ⇨ CONFIGURABLE REPORT 1 ⇨ REPORT 1 DATASET ITEMS




To create the dataset for logical node LN, program the **ITEM 1** to **ITEM 64** settings to a value from the list of IEC 61850 data attributes supported by the L30. Changes to the dataset will only take effect when the L30 is restarted. It is recommended to use reporting service from logical node LLN0 if a user needs some (but not all) data from already existing GGIO1, GGIO4, and MMXU4 points and their quantity is not greater than 64 minus the number items in this dataset.

The breaker configuration settings are shown below. Changes to these values take effect when the UR is restarted:

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ XCBR CONFIGURATION ⇨ XCBR1(6) CONFIGURATION**




The XCBR1 ST.LOC OPERAND setting is used to inhibit 61850 control commands to close or open breaker through UR Breaker Control element. See the Breaker Control element logic diagram for more information.

The CLEAR XCBR1 OpCnt setting allows clearing the breaker operating counter. As breakers operate by opening and closing, the XCBR operating counter status attribute (OpCnt) increments with every operation. Frequent breaker operation can result in very large OpCnt values over time. This setting allows the OpCnt to be reset to “0” for XCBR1.

The XCBR1 SYNCCHECK CLS setting is used to supervise a close command with a synchrocheck condition within XCBR logical node. If a Close with SynchroCheck is requested (through a SelectWithValue service) and the SynchroCheck condition is not satisfied, a Negative Response (-Rsp) is issued with the REASON CODE of Blocked-by-synchrocheck.

The XCBR1 INTERLOCK OPN/CLS settings are used to assign an operand, which is linked into the EnaOpn or EnaCls INTERLOCKED inputs respectively of the XCBR. When this operand is asserted, XCBR logical node inhibits execution of the open and close commands respectively. If select before operate (SBO) with Extended Security is requested and Interlock condition exists, the UR responds with a Negative response (-Rsp) with the Reason Code Blocked-by-interlocking.

The XCBR1 Pos ctlModel setting is used to select control model per IEC 61850-7-3. The following control models are supported by URs:

0 — Status only

1 — Direct control with normal security (direct-operate)

2 — SBO control with normal security (operate-once)

3 — Direct control with enhanced security (direct-operate)

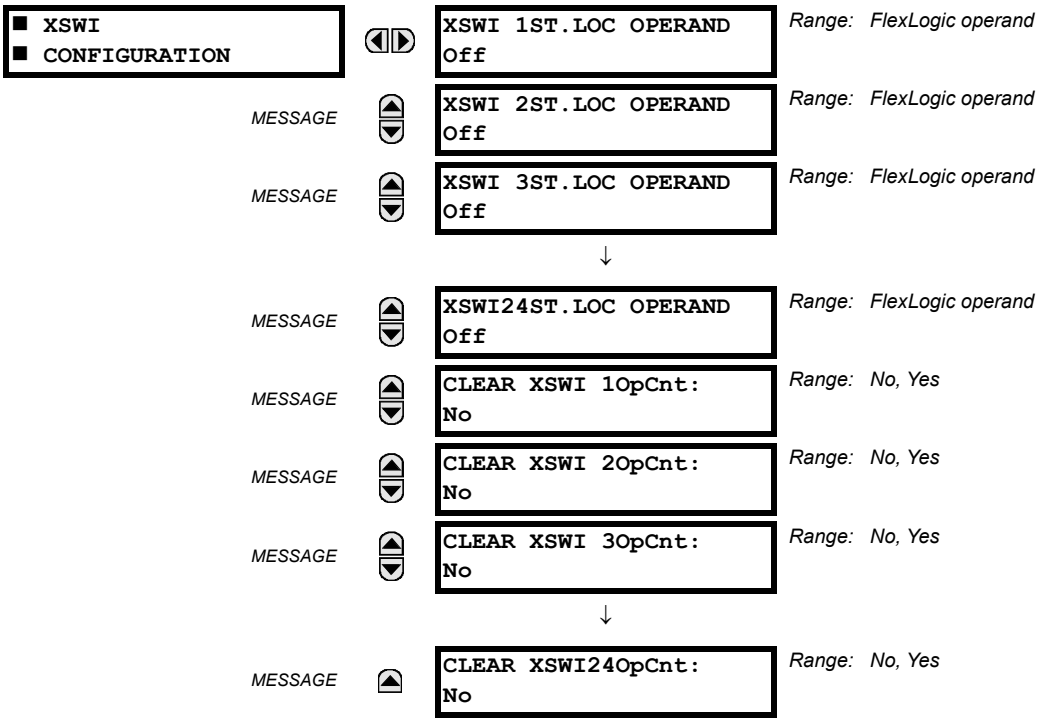
4 — SBO control with enhanced security (operate-once)

See IEC 61850-7-2 for complete details on these control models.

The XCBR1 Pos sboTimeout setting is used to select SBO timeout value. To be successful, the IEC 61850 "operate" command must be executed after the "select" command within the XCBR1 Pos sboTimeout setting value.

The disconnect switch configuration settings are shown below. Changes to these values will not take effect until the UR is restarted:

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ XSWI CONFIGURATION**



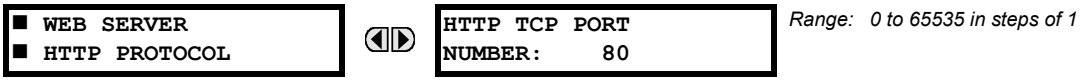

The **CLEAR XSWI1 OPCNT** setting represents the disconnect switch operating counter. As disconnect switches operate by opening and closing, the XSWI operating counter status attribute (OpCnt) increments with every operation. Frequent switch operation may result in very large OpCnt values over time. This setting allows the OpCnt to be reset to "0" for XSWI 1.

NOTE

Since GSSE/GOOSE messages are multicast Ethernet by specification, they are not usually be forwarded by network routers. However, GOOSE messages may be forwarded by routers if the router has been configured for VLAN functionality.

### m) WEB SERVER HTTP PROTOCOL

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ WEB SERVER HTTP PROTOCOL**




The L30 contains an embedded web server and is capable of transferring web pages to a web browser such as Internet Explorer or Firefox. The web pages are organized as a series of menus that can be accessed starting at the L30 "Main Menu". Web pages are available showing IEC 60870-5-104 points lists, Modbus registers, event records, fault reports, and so on. First connect the UR and a computer to an Ethernet network, then enter the IP address of the L30 Ethernet port employed into the "Address" box of the web browser.

NOTE

When the port is set to 0, the change takes effect when the L30 is restarted.

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

### n) TFTP PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ TFTP PROTOCOL

```
■ TFTP PROTOCOL
■
```

```
TFTP MAIN UDP PORT
NUMBER:    69
```
*Range: 0 to 65535 in steps of 1*

MESSAGE

```
TFTP DATA UDP PORT 1
NUMBER:    0
```
*Range: 0 to 65535 in steps of 1*

MESSAGE

```
TFTP DATA UDP PORT 2
NUMBER:    0
```
*Range: 0 to 65535 in steps of 1*

The Trivial File Transfer Protocol (TFTP) can be used to transfer files from the L30 over a network. The L30 operates as a TFTP server. TFTP client software is available from various sources, including Microsoft Windows NT. The `dir.txt` file obtained from the L30 contains a list and description of all available files (event records, oscillography, etc.).

NOTE

When the **TFTP MAIN UDP PORT NUMBER** is set to 0, the change takes effect when the L30 is restarted.

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

### o) IEC 60870-5-104 PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 60870-5-104 PROTOCOL

```
■ IEC 60870-5-104
■ PROTOCOL
```

```
IEC TCP PORT
NUMBER: 2404
```
*Range: 0 to 65535 in steps of 1*

MESSAGE

```
■ IEC NETWORK
■ CLIENT ADDRESSES
```
*Range: see sub-menu below*

MESSAGE

```
IEC COMMON ADDRESS
OF ASDU:    0
```
*Range: 0 to 65535 in steps of 1*

MESSAGE

```
IEC CYCLIC DATA
PERIOD:    60 s
```
*Range: 1 to 65535 s in steps of 1*

MESSAGE

```
IEC CURRENT DEFAULT
THRESHOLD: 30000
```
*Range: 0 to 100000000 in steps of 1*

MESSAGE

```
IEC VOLTAGE DEFAULT
THRESHOLD: 30000
```
*Range: 0 to 100000000 in steps of 1*

MESSAGE

```
IEC POWER DEFAULT
THRESHOLD: 30000
```
*Range: 0 to 100000000 in steps of 1*

MESSAGE

```
IEC ENERGY DEFAULT
THRESHOLD: 30000
```
*Range: 0 to 100000000 in steps of 1*

MESSAGE

```
IEC PF DEFAULT
THRESHOLD: 30000
```
*Range: 0 to 100000000 in steps of 1*

MESSAGE

```
IEC OTHER DEFAULT
THRESHOLD: 30000
```
*Range: 0 to 100000000 in steps of 1*

MESSAGE

```
IEC REDUNDANCY
ENABLED: No
```
*Range: No, Yes*

The L30 supports the IEC 60870-5-104 protocol. This protocol is enabled when the SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨ PROTOCOL setting is set to IEC 60870-5-104. The L30 can be used as an IEC 60870-5-104 slave device connected to a maximum of two masters (usually either an RTU or a SCADA master station). Since the L30 maintains two sets of IEC 60870-5-104 data change buffers, no more than two masters should actively communicate with the L30 at one time.

The **IEC ------- DEFAULT THRESHOLD** settings are used to determine when to trigger spontaneous responses containing M_ME_NC_1 analog data. These settings group the L30 analog data into types: current, voltage, power, energy, and other. Each setting represents the default threshold value for all M_ME_NC_1 analog points of that type. For example, to trigger spontaneous responses from the L30 when any current values change by 15 A, the **IEC CURRENT DEFAULT THRESHOLD** setting should be set to 15. Note that these settings are the default values of the deadbands. P_ME_NC_1 (parameter of measured value, short floating point value) points can be used to change threshold values, from the default, for each individual M_ME_NC_1 analog point. Whenever power is removed and re-applied to the L30, the default thresholds are in effect.

The **IEC REDUNDANCY** setting decides whether multiple client connections are accepted or not. If redundancy is set to Yes, two simultaneous connections can be active at any given time.

**IEC TCP PORT NUMBER**: When set to 0, the change takes effect when the L30 is restarted.

**IEC COMMON ADDRESS OF ASDU**: The change takes effect when the L30 is restarted.

**IEC CYCLIC DATA PERIOD**: The change takes effect when the L30 is restarted.

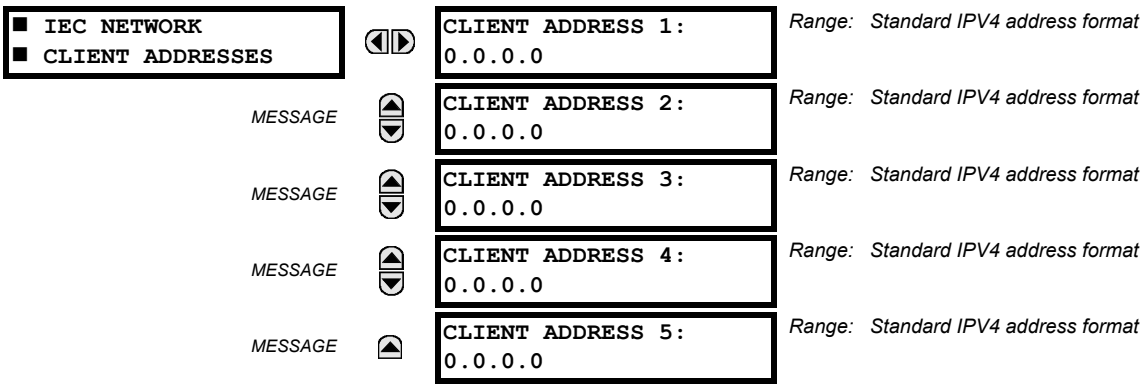
NOTE

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

NOTE

The L30 relay does not support energy metering. As such, the **IEC ENERGY DEFAULT THRESHOLD** setting is not applicable.

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 60870-5-104 PROTOCOL ⇨⇩ IEC NETWORK CLIENT ADDRESSES**

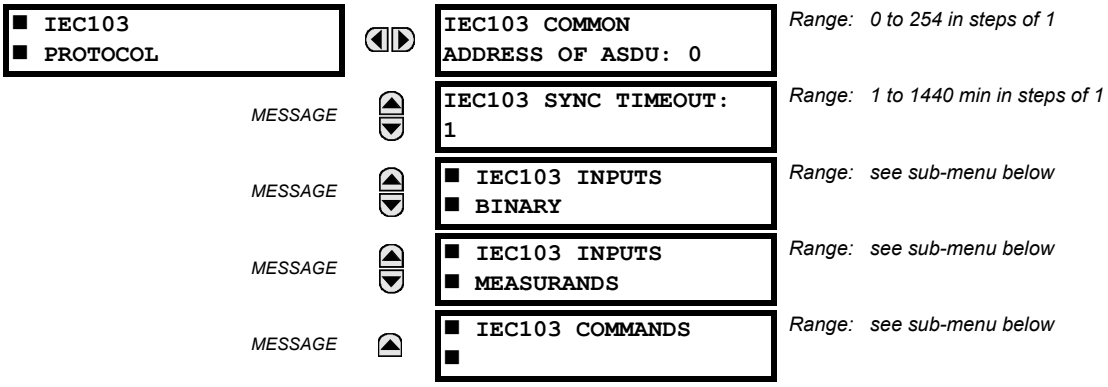



The L30 can specify a maximum of five clients for its IEC 104 connections. These are IP addresses for the controllers to which the L30 can connect.

A maximum of two simultaneous connections are supported at any given time.

### p) IEC 60870-5-103 PROTOCOL

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 60870-5-103**



The L30 is provided with optional IEC 60870-5-103 communications capability. This feature is specified as a software option at the time of ordering. See the *Order Codes* section in chapter 2 for details.

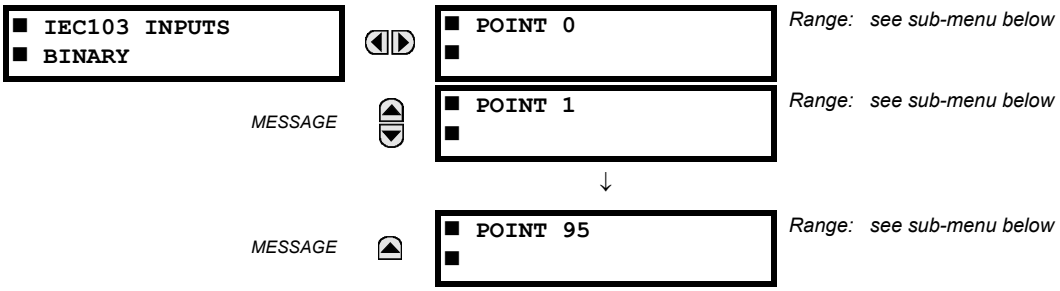
The IEC 60870-5-103 protocol is enabled when the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨ PROTOCOL** setting is set to IEC 60870-5-103.

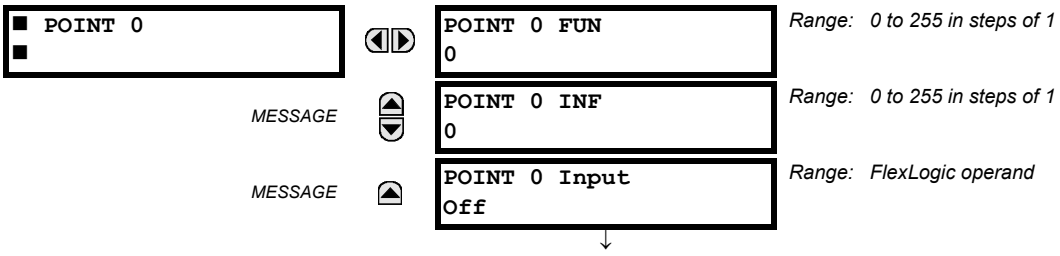
**IEC103 COMMON ADDRESS OF ASDU**: This setting uniquely defines this L30 on the serial line. Select an ID between 0 and 254. This ID does not need to be in sequential order for all stations that communicate with a controller, but it is recommended. Note that RS485 only allows a maximum of 32 slave stations on a communication line, so the entire range of 254 addresses is never exhausted.

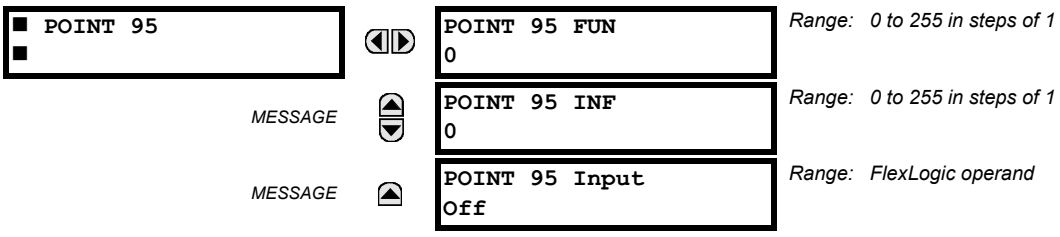
**IEC103 SYNC TIMEOUT**: This setting defines the time that the L30 waits for a synchronization message. The L30 synchronizes its clock using all available sources, with the source synching more frequently overwriting the time of the other sources. Since the synchronization message received from the IEC 60870-5-103 master is less frequent than IRIG-B, PTP, or SNTP, its time is overwritten by these three sources, if any of them is active. If the synchronization timeout occurs and none of IRIG-B, PTP, or SNTP is active, the L30 sets the invalid bit in the time stamp of a time-tagged message.

The settings for the remaining menus are outlined as follows.

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC60870-5-103 ⇨ IEC103 INPUTS BINARY**




The binary input points are mapped using elements from a list of possible FlexLogic operands. A maximum of 96 binary inputs (points) can be mapped this way.

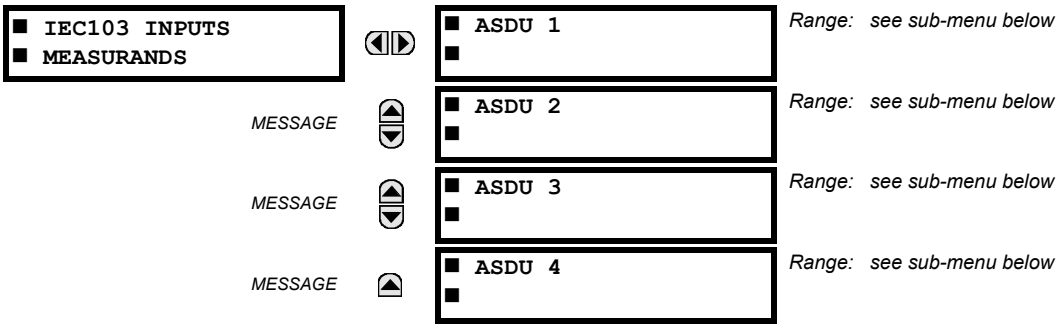
The IEC60870-5-103 point list always starts with point 0 and ends at the first "Off" value. Since the IEC 60870-5-103 point list must be in a continuous block, any points assigned after the first "Off" point are ignored.

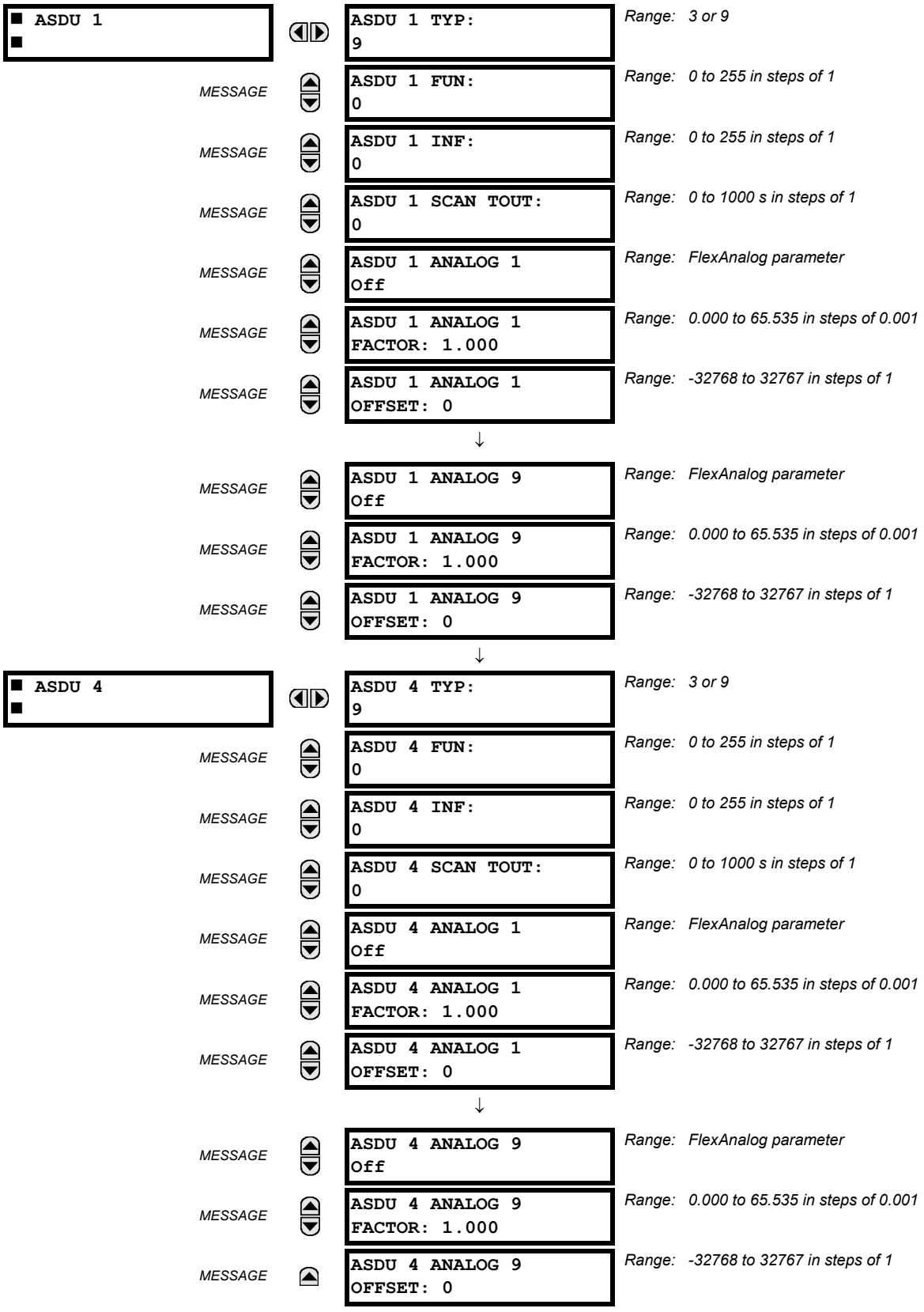
For each defined point, set appropriate values for the Function Type (FUN) and Information Number (INF), which form the Information Object Identifier field of the ASDU, as defined in IEC60870-5-103.

The binary input points are sent as Class 1 data. They are sent either as a response to a general interrogation received from the controller or reported spontaneously. Spontaneous transmission occurs as a response to cyclic Class 2 requests. If the L30 wants to transmit Class 1 data at that time, it demands access for Class 1 data transmission (ACD=1 in the control field of the response).

For any change to take effect, restart the relay.

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC60870-5-103 ⇨ IEC103 INPUTS MEASURANDS**




ASDU 1
ASDU 1 TYP:
9
Range: 3 or 9
MESSAGE
ASDU 1 FUN:
0
Range: 0 to 255 in steps of 1
MESSAGE
ASDU 1 INF:
0
Range: 0 to 255 in steps of 1
MESSAGE
ASDU 1 SCAN TOUT:
0
Range: 0 to 1000 s in steps of 1
MESSAGE
ASDU 1 ANALOG 1
Off
Range: FlexAnalog parameter
MESSAGE
ASDU 1 ANALOG 1
FACTOR: 1.000
Range: 0.000 to 65.535 in steps of 0.001
MESSAGE
ASDU 1 ANALOG 1
OFFSET: 0
Range: -32768 to 32767 in steps of 1
MESSAGE
ASDU 1 ANALOG 9
Off
Range: FlexAnalog parameter
MESSAGE
ASDU 1 ANALOG 9
FACTOR: 1.000
Range: 0.000 to 65.535 in steps of 0.001
MESSAGE
ASDU 1 ANALOG 9
OFFSET: 0
Range: -32768 to 32767 in steps of 1
ASDU 4
ASDU 4 TYP:
9
Range: 3 or 9
MESSAGE
ASDU 4 FUN:
0
Range: 0 to 255 in steps of 1
MESSAGE
ASDU 4 INF:
0
Range: 0 to 255 in steps of 1
MESSAGE
ASDU 4 SCAN TOUT:
0
Range: 0 to 1000 s in steps of 1
MESSAGE
ASDU 4 ANALOG 1
Off
Range: FlexAnalog parameter
MESSAGE
ASDU 4 ANALOG 1
FACTOR: 1.000
Range: 0.000 to 65.535 in steps of 0.001
MESSAGE
ASDU 4 ANALOG 1
OFFSET: 0
Range: -32768 to 32767 in steps of 1
MESSAGE
ASDU 4 ANALOG 9
Off
Range: FlexAnalog parameter
MESSAGE
ASDU 4 ANALOG 9
FACTOR: 1.000
Range: 0.000 to 65.535 in steps of 0.001
MESSAGE
ASDU 4 ANALOG 9
OFFSET: 0
Range: -32768 to 32767 in steps of 1

The configuration menu allows a maximum of four ASDUs containing measurands.

Measurands are sent as a response to Class 2 requests, which are cyclic requests coming from the master.

**TYPE IDENTIFICATION (TYP)**: The configuration field TYP indicates how many measurands are present in the corresponding ASDU. Each ASDU can take either 4 or 9 measurands maximum, depending on the type identification (3 respectively 9). For any change to take effect, restart the relay.

**FUNCTION TYPE (FUN) AND INFORMATION NUMBER (INF)**: These two fields form the Information Object Identifier of the ASDU as defined in IEC60870-103. For any change to take effect, restart the relay.

**SCAN TIMEOUT (SCAN TOUT)**: This is the cyclic period used by the L30 to decide when a measurand ASDU is included in a response. The measurand is sent as response to a Class 2 request when the corresponding timeout expires. The default value 0 means 500 ms.

**ANALOG #**: This field contains the actual measurand to be sent in the response to the master. The measurands can be mapped using elements from a list of FlexAnalog operands. The measurands sent are voltage, current, power, power factor, and frequency. If any other FlexAnalog is chosen, the L30 sends 0 instead of its value. Note that the power is transmitted in KW, not W. Measurands are transmitted as ASDU 3 or ASDU 9 (type identification value set to measurands I, respectively measurands II).

Each IEC60870-5-103 measurands list ends at the first unconfigured ("Off") value. Any measurand assigned after the first "Off" value is ignored.

At least one measurand per ASDU must be configured in order to configure the following ASDU. For example, the user can configure only one measurand for each ASDU, but the user is not allowed to skip ASDU2 and configure measurands in ASDU3.

For any change to take effect, restart the relay.

**ANALOG # FACTOR AND OFFSET**: For each measurand included in the ASDU, a factor and offset can also be configured. The factor and offset allow for scaling to be performed on measurands. The final measurement sent to the IEC60870-103 master is then "a*x + b", where x is the measurand, a is the multiplying factor and b is the offset. The master has to perform the reversed operation in order to retrieve the actual value if such scaling is done. By default a = 1 and b = 0, so no scaling is done if these values are left at their defaults. Examples of when scaling is appropriate are as follows:

- If the measured value contains decimals and it is important to preserve the resolution. Since the format for transmitting the measurand does not permit decimals, a factor a>1 can be applied before transmission. For example, a frequency F=59.9Hz can be transmitted as Ft = 10 * F = 10 * 59.9 = 599. In this case a = 10, b = 0. The master receives 599 and has to divide by 10 to retrieve the real value 59.9.
- If the measured value is larger than what fits in the format defined in IEC103. The format defined in the standard allows for signed integers up to 4095. By offsetting, unsigned integers up to 4096 + 4095 = 8191 are supported. Scaling using factors <1 can be required in such cases. The calculation is outlined in the IEC60870-5-103 appendix. Two examples follow, where you decide factors a and b.

  Example 1: Nominal power Pn = 100MW = 100000KW (power is transmitted in KW)

  Since P can be both positive and negative:

  Transmitted power Pt = (4095/(Pn*2.4)) * P = (4095/(100000 * 2.4) ) * P

  = 0.017 * P

  **a = 0.017**

  **b = 0**

  Pt = 0.017 * P

  For a max power 100000KW * 2.4 = 240000KW, we transmit

  Pt = 0.017 * 240000 = 4080

  A value above 240 MW is indicated by overflow.

  Example 2: Nominal voltage Vn = 500000V

  Since RMS voltage V can be only positive:

Transmitted voltage Vt = (8191/(Vn*2.4)) * V - 4096 =

= (8191/(500000 * 2.4) ) * V - 4096 = 0.0068 * V - 4096

a = 0.0068

Since the step is in increments of 0.001, we round it at:

**a = 0.006**

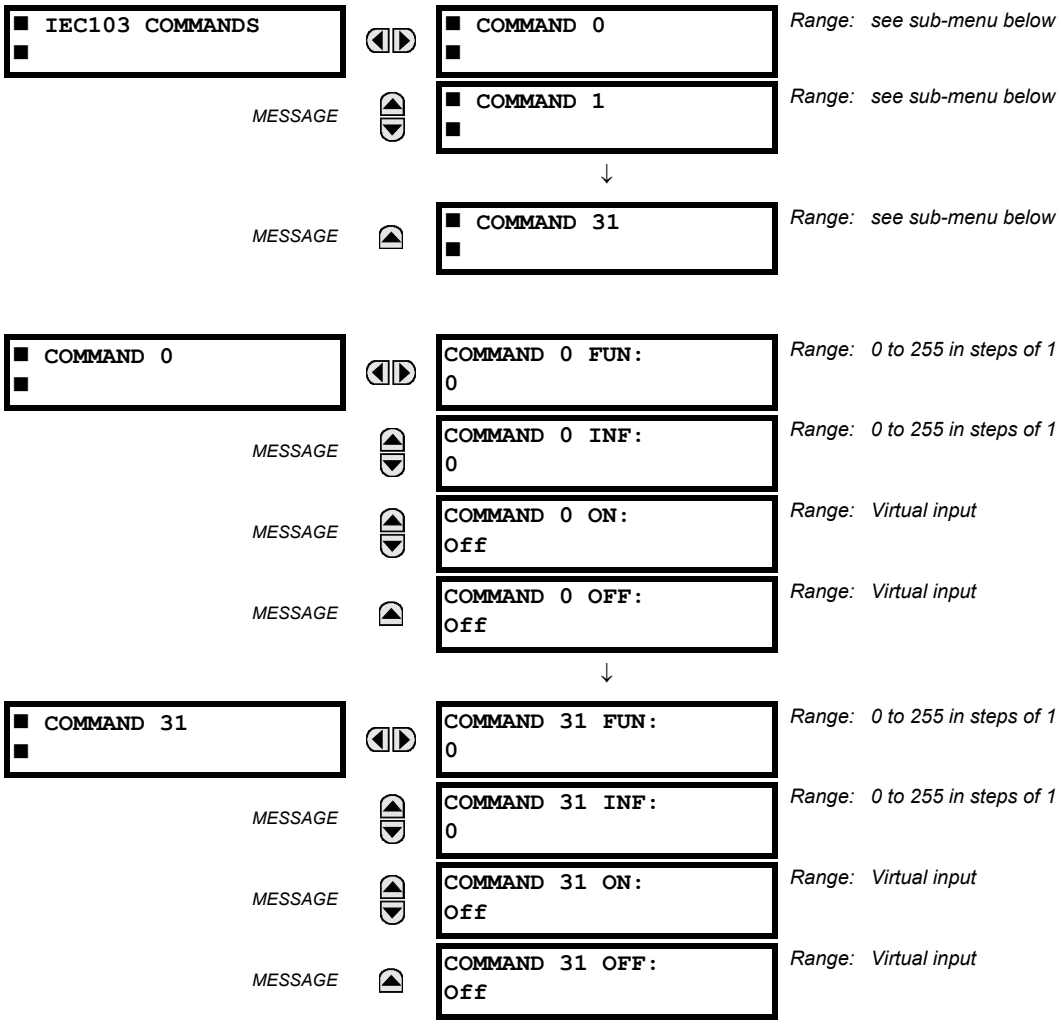
**b = -4096**

Vt = 0.006 * V - 4096

For max voltage 500000V * 2.4 = 1200000V, we transmit

Vt = 0.006 * 1200000 - 4096 = 7200 - 4096 = 3104

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC60870-5-103 ⇨ IEC103 COMMANDS**




Commands are received as General Command (Type Identification 20). The user can configure which action to perform when an ASDU command comes.

A list of available mappings is provided on the L30. This includes 64 virtual inputs (see the following table). The ON and OFF for the same ASDU command can be mapped to different virtual inputs.

Each command is identified by the unique combination made by the function type (FUN), and information number (INF). If the master sends an ASDU command that does not have the FUN and INF of any configured command, the relay rejects it.

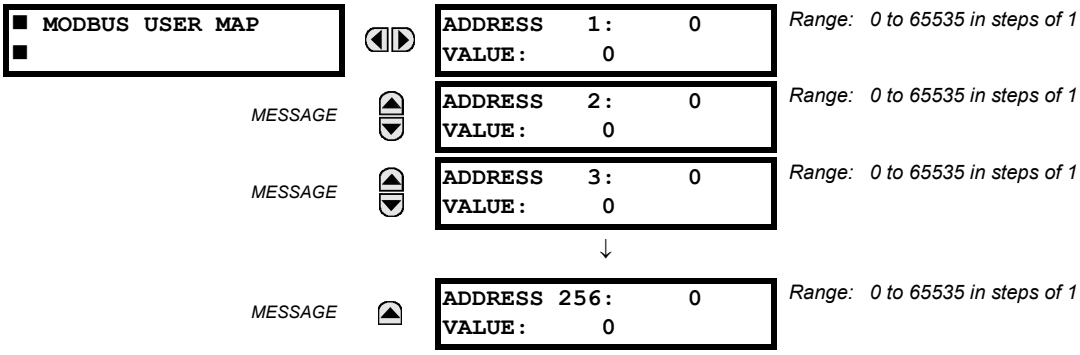
**Table 5–8: COMMANDS MAPPING TABLE**

| DESCRIPTION | VALUE |
|---|---|
| Off | 0 |
| Virtual Input 1 | 1 |
| Virtual Input 2 | 2 |
| ... | |
| Virtual Input 64 | 64 |

For any change to take effect, restart the relay.

### 5.2.5 MODBUS USER MAP

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ MODBUS USER MAP**

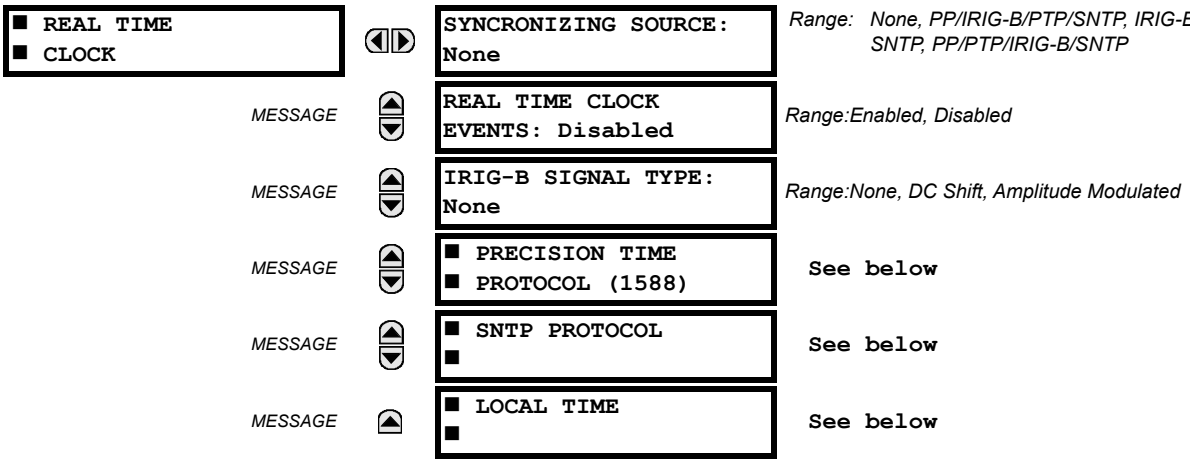



The Modbus user map provides read-only access for up to 256 registers. To obtain a memory map value, enter the desired address in the **ADDRESS** line (converted from hex to decimal format). The corresponding value displays in the **VALUE** line. A value of "0" in subsequent register **ADDRESS** lines automatically returns values for the previous **ADDRESS** lines incremented by "1". An address value of "0" in the initial register means "none" and values of "0" display for all registers. Different **ADDRESS** values can be entered as required in any of the register positions.

### 5.2.6 REAL TIME CLOCK

#### a) MAIN MENU

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK**




The relay contains a real time clock (RTC) to create timestamps for communications protocols as well as for historical data, such as event records and oscillography. When the relay restarts, the RTC initializes from an onboard battery-backed clock, which has the same accuracy as an electronic watch, approximately ±1 minute per month (~23 ppm). Once the RTC is synchronized with the Precision Time Protocol (PTP), IRIG-B, or SNTP, its accuracy approaches that of the synchronizing time delivered to the relay. While the RTC is not synchronized via PTP or IRIG-B, or the relay determines than it has an

offset possibly greater than 10 µs from the international time standard, the CLOCK UNSYNCHRONIZED FlexLogic operand is activated. When the L30/L90 channel asymmetry function is used, the relay's real time clock must be synchronized to an external time source using PTP or IRIG-B, typically from a global positioning system (GPS) receiver.

The **SYNCHRONIZING SOURCE** setting displays when the relay includes the IEEE 1588 software option. The setting configures the priority sequence of the time synchronization source, to determine which of the available external time sources to use for time synchronization. A setting of None causes the RTC and the synchrophasor clock to free-run until the clock is changed from the front panel or from communications protocols. A setting of PP/IRIG-B/PTP/SNTP, IRIG-B/PP/PTP/SNTP, or PP/PTP/IRIG-B/SNTP causes the relay to track the first source named that is enabled and operational, or free-run if none of these are available. Here, PP means a time source that is strictly compliant with PP, and PTP means a time source that is not strictly compliant with PP. When a time source fails or recovers, the relay automatically transfers synchronization as required by this setting.

When the relay does not have the IEEE 1588 software option and this setting does not display, it uses IRIG-B when enabled and operational, then failing that SNTP when configured and operational, and otherwise it free-runs unless the clock is changed from the front panel or from communications protocols.

Whenever a time synchronization message is received through any of the active protocols, the UR clock updates. However, given that IEC 60870-5-103, IEC 60870-5-104, Modbus, and DNP are low accuracy time synchronization methods, avoid their use for synchronization when better accuracy time protocols, such as IRIG-B and PTP, are active in the system.

See the **COMMANDS ⇨SET DATE AND TIME** menu section of this manual to manually set the RTC.

The **REAL TIME CLOCK EVENTS** setting allows changes to the date and/or time to be captured in the event record. The event records the RTC time before the adjustment. A Date/Time Changed event is generated when:

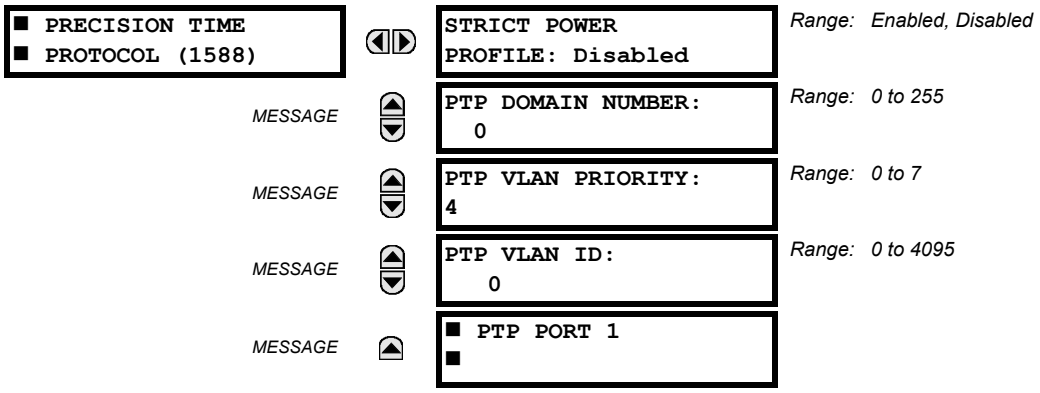
- The real time clock changed from SNTP/PTP/IRIG-B and the time difference is more than one second
- The real time clock changed from the front panel or via Modbus register. The relay always generates this event regardless of the time difference.
- The Daylight Saving Time (DST) setting gets enabled and the current relay time is already in the DST zone
- The real time clock enters or leaves DST

To enable IRIG-B synchronization, the input **IRIG-B SIGNAL TYPE** must be set to DC Shift or Amplitude Modulated. IRIG-B synchronization can be disabled by making this setting None. When IRIG-B is enabled and active, clock synchronization by communication protocols. (DNP, IEC 60870-5-103, IEC 60870-5-104) is blocked, and clock synchronization from the front panel and over Modbus is always enabled.

To configure and enable PTP and/or SNTP, or to set local time parameters (for example time zone, daylight savings), use the following sections.

### b) PRECISION TIME PROTOCOL (1588)

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK ⇨⇩ PRECISION TIME PROTOCOL (1588)**



PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK ⇨⇩ PRECISION TIME PROTOCOL (1588) ⇨⇩ PTP PORT 1(3)

MESSAGE

```
PORT 1 PTP FUNCTION:
Disabled
```

Range: Enabled, Disabled

MESSAGE

```
PORT 1 PATH DELAY
ADDER:      0 ns
```

Range: 0 to 60 000 ns in steps of 1

MESSAGE

```
PORT 1 PATH DELAY
ASYMMETRY:      0 ns
```

Range: –1 000 to +1 000 ns in steps of 1

The UR supports the Precision Time Protocol (PTP) specified in IEEE Std 1588 2008 using the Power Profile (PP) specified in IEEE Std C37.238 2011. This enables the relay to synchronize to the international time standard over an Ethernet network that implements PP.

The relay can be configured to operate on some PTP networks that are not strictly PP. Time accuracy can be less than specified for a PP network. Tolerated deviations from strict PP include 1) missing declaration of PP compliance in the messages, 2) connection to a network device that does not support the PTP peer delay mechanism, 3) jitter substantially greater than 1 µs in received event messages, and 4) certain non-compliant announce and sync message update rates.

NOTE

The relay implements PTP according to IEEE Std 1588 2008 and the equivalent IEC 61588:2009(E), sometimes referred to as version 2 PTP. It does not support the previous version of the standard (version 1).

PTP is a protocol that allows multiple clocks in a network to synchronize with one another. It permits synchronization accuracies better than 1 ns, but this requires each and every component in the network achieve very high levels of accuracy and a very high baud rate, faster than normally used for relay communications. When operating over a generic Ethernet network, time error may amount to 1 ms or more. PP is a profile of PTP which specifies a limited subset of PTP suitable for use in power system protection, control, automation and data communication applications, and thereby facilitates interoperability between different vendor's clocks and switches. PP specifies a worst-case delivered time error of less than 1 µs over a 16-hop network.

In a PTP system and in a PP system, the clocks automatically organize themselves into a master-slave synchronization hierarchy with the "best" clock available making itself the "grandmaster" at the top of the hierarchy; all others make themselves "slaves" and track the grandmaster. Typically the grandmaster clock receives its time from GPS satellites or some other link to the international time standard. If the grandmaster fails, the next "best" clock available in the domain assumes the grandmaster role. Should a clock on starting up discover it is "better" that the present grandmaster, it assumes the grandmaster role and the previous grandmaster reverts to slave. The L30 qualification mechanism accepts a potential master clock as a new grandmaster, when in a four-second interval it has received three announce messages from it, all better than the present grandmaster clock and better than any other announce in this interval.

Time messages issued by the grandmaster are delayed as they pass through the network both due to the finite speed of the signal in the interconnecting fiber or wire, and due to processing delays in the Ethernet switches. Each clock and switch implementing PP measures the propagation delay to each of its PP neighbors, and compensates for these delays in the time received. Each network device implementing PP measures the processing delay it introduces in each time message and compensates for this delay in the time it transmits. As a result, the time delivered to end-devices such as the UR are virtually identical to the grandmaster time. Should one of the network devices in the hierarchy not fully implement PP, the associated propagation delay and/or latency may not be compensated for, and the time received at the end-device could be in error by more than 100 µs.

See the **Settings > Product Setup > Real Time Clock** section of this manual for a description of when time values received via PTP are used to update the relay's real time clock.

The following settings are available for configuring the relay for PTP.

**STRICT POWER PROFILE**

- Power profile (IEEE Std C37.238 2011) requires that the relay only select as a grandmaster power profile compliant clocks, that the delivered time have worst-case error of ±1 µs, and that the peer delay mechanism be implemented. With the strict power profile setting enabled, the relay will only select as master clocks displaying the IEEE_C37_238 identification codes. It will use a port only when the peer delay mechanism is operational. With the strict power profile setting disabled, the relay will use clocks without the power profile identification when no power profile clocks are present, and will use ports even if the peer delay mechanism is non-operational.
- This setting applies to all of the relay's PTP capable ports.

**PTP DOMAIN NUMBER**

- This setting should be set to the domain number of the grandmaster-capable clock(s) to be synchronized to. A network may support multiple time distribution domains, each distinguished with a unique domain number. More commonly, there is a single domain using the default domain number zero.
- This setting applies to all of the relay's PTP capable ports.

**PTP VLAN PRIORITY**

- This setting selects the value of the priority field in the 802.1Q VLAN tag in request messages issued by the relay's peer delay mechanism. In compliance with PP the default VLAN priority is 4, but it is recommended that in accordance with PTP it be set to 7.
- Depending on the characteristics of the device to which the relay is directly linked, VLAN Priority may have no effect.
- This setting applies to all of the relay's PTP capable ports.

**PTP VLAN ID**

- This setting selects the value of the ID field in the 802.1Q VLAN tag in request messages issued by the relay's peer delay mechanism. It is provided in compliance with PP. As these messages have a destination address that indicates they are not to be bridged, their VLAN ID serves no function, and so may be left at its default value.
- Depending on the characteristics of the device to which the relay is directly linked, VLAN ID may have no effect.
- This setting applies to all of the relay's PTP capable ports.

**PORT 1 ... 3 FUNCTION**

- While this port setting is selected to disabled, PTP is disabled on this port. The relay does not generate or listen to PTP messages on this port.



**PORT 1 ... 3 PATH DELAY ADDER**

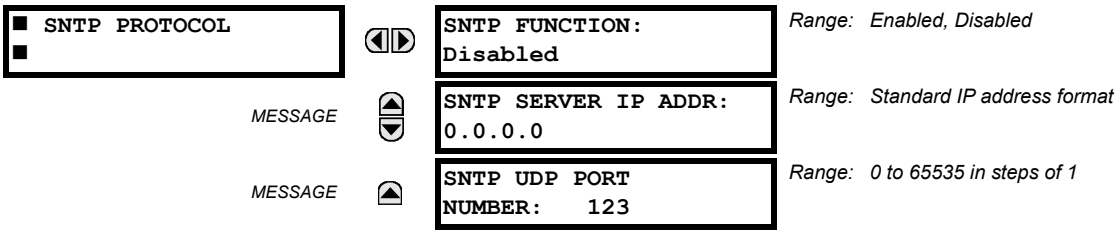
- The time delivered by PTP is advanced by the time value in this setting prior to the time being used to synchronize the relay's real time clock. This is to compensate to the extent practical for time delivery delays not compensated for in the network. In a fully compliant PP network, the peer delay and the processing delay mechanisms compensate for all the delays between the grandmaster and the relay. In such networks, this setting should be zero.
- In networks containing one or more switches and/or clocks that do not implement both of these mechanisms, not all delays are compensated, so the time of message arrival at the relay will be later than the time indicated in the message. This setting can be used to approximately compensate for this delay. However, as the relay is not aware of network switching that dynamically changes the amount of uncompensated delay, there is no setting that will always completely correct for uncompensated delay. A setting can be chosen that will reduce worst-case error to half of the range between minimum and maximum uncompensated delay, if these values are known.

**PORT 1 ... 3 PATH DELAY ASYMMETRY**

- This setting corresponds to "delayAsymmetry" in PTP, which is used by the peer delay mechanism to compensate for any difference in the propagation delay between the two directions of a link. Except in unusual cases, the two fibers are of essentially identical length and composition, so this setting should be set to zero.
- In unusual cases where the length of the link is different in different directions, this setting should be set to the number of nanoseconds the Ethernet propagation delay to the relay is longer than the mean of path propagation delays to and from the relay. For instance, if it is known say from the physical length of the fibers and the propagation speed in the fibers that the delay from the relay to the Ethernet switch it is connected to is 9 000 ns and the that the delay from the switch to the relay is 11 000 ns, then the mean delay is 10 000 ns, and the path delay asymmetry is 11000 - 10000 = +1000 ns.

### c) SNTP PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK ⇨⇩ SNTP PROTOCOL




The L30 supports the Simple Network Time Protocol specified in RFC-2030. With SNTP, the L30 can obtain clock time over an Ethernet network. The L30 acts as an SNTP client to receive time values from an SNTP/NTP server, usually a dedicated product using a GPS receiver to provide an accurate time. UR series relays support unicast, broadcast, multicast, and any-cast SNTP functionality.

The **SNTP FUNCTION** setting enables or disabled the SNTP feature on the L30.

To use SNTP in unicast mode, **SNTP SERVER IP ADDR** must be set to the SNTP/NTP server IP address. Once this address is set and **SNTP FUNCTION** is "Enabled," the L30 attempts to obtain time values from the SNTP/NTP server. Since many time values are obtained and averaged, it generally takes three to four minutes until the L30 clock is closely synchronized with the SNTP/NTP server. It takes up to two minutes for the L30 to signal an SNTP self-test error if the server is offline.

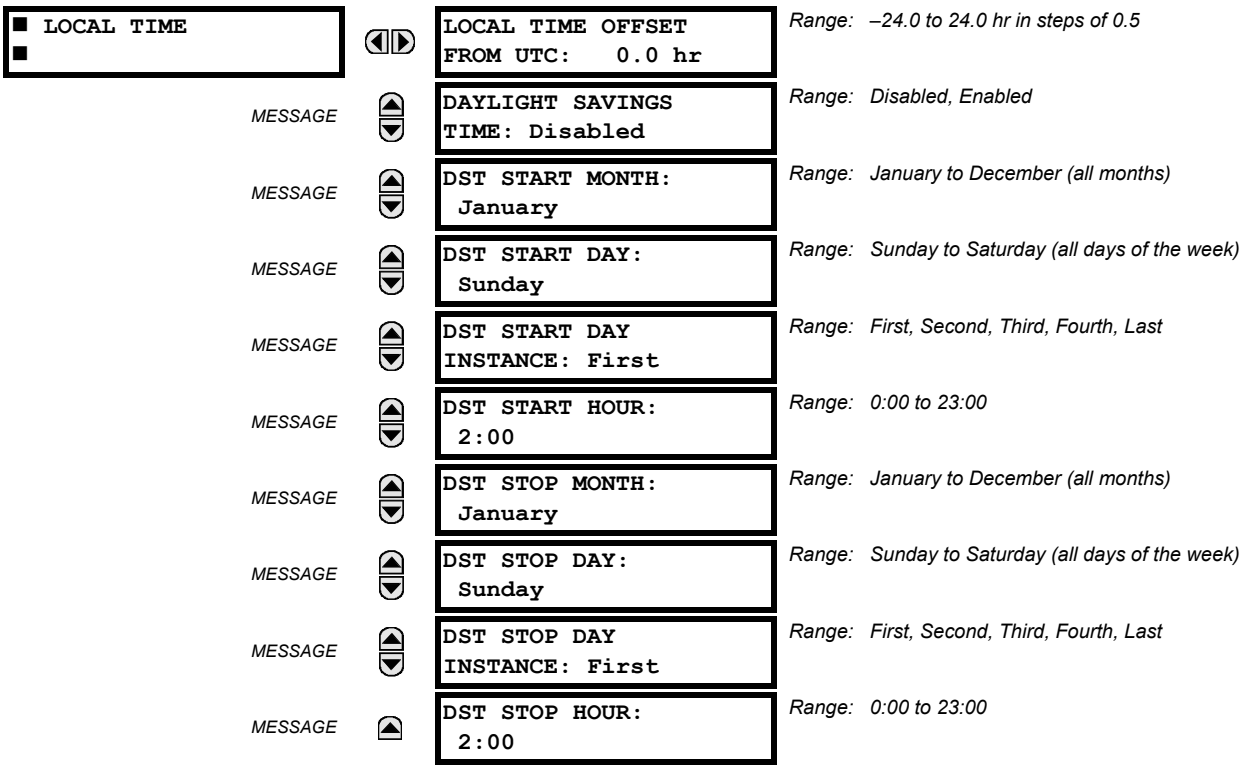
To use SNTP in broadcast mode, set the **SNTP SERVER IP ADDR** setting to "0.0.0.0" and **SNTP FUNCTION** to "Enabled." The L30 then listens to SNTP messages sent to the "all ones" broadcast address for the subnet. The L30 waits up to 18 minutes (>1024 seconds) without receiving an SNTP broadcast message before signaling an SNTP self-test error.

The **SNTP UDP PORT NUMBER** is 123 for normal SNTP operation. If SNTP is not required, close the port by setting it to 0.

NOTE When the **SNTP UDP PORT NUMBER** is set to 0, the change takes effect when the L30 is restarted.

### d) LOCAL TIME

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK ⇨⇩ LOCAL TIME



The UR device maintains two times: local time and Universal Coordinated Time (UTC). Local time can be provided by IRIG-B signals. UTC time is provided by SNTP servers.

The real-time clock (RTC) and time stamps reported in historical records and communication protocols can be incorrect if the Local Time settings are not configured properly.

See the IRIG-B section in the Installation chapter for guidance on these settings when using an IRIG-B source that sets the IRIG-B control bits according to IEEE Std 1344-1995.

The **LOCAL TIME OFFSET FROM UTC** setting is used to specify the local time zone offset from UTC (Greenwich Mean Time) in hours. Time zones in the eastern hemisphere have positive values; time zones in the western hemisphere have negative values. A value of zero causes the relay to use UTC for local time. This setting has two uses. When the system RTC is synchronized with a communications protocol providing only local time or it is free-running, the offset setting is used to calculate UTC from the local time these provide. When the RTC is synchronized with a communications protocol providing only UTC (such as PTP or SNTP), the time offset setting is used to determine local time from the UTC provided. PTP ALTERNATE_TIME_OFFSET_INDICATOR TLVs are not used to calculate local time.

The **DAYLIGHT SAVINGS TIME (DST)** settings can be used to allow the relay to follow the DST rules of the local time zone. Note that when IRIG-B time synchronization is active, the local time in the IRIG-B signal contains any daylight savings time offset and so the DST settings are ignored. Note that the following items do not include the DST: Time of Day Timer Start Time; Time of Day Timer Stop Time; Event Recorder Last Cleared Date; Source x Demand VAR Maximum Date; Source x Demand WATT Maximum Date; Source x Demand VA Maximum Date; Source x Demand Ia Maximum Date; Source x Demand Ib Maximum Date; Source x Demand Ic Maximum Date; PMU x Last Cleared Date; PMU One-Shot Time; Data Logger Newest Time; Data Logger Oldest Time; Oscillography Last Cleared Date; Last Settings Change Date; User Programmable Fault Report Cleared Date; Digital Counter x Frozen Time Stamp; HIZ RMS Capture x Time; and HIZ Capture x Time.



## 5.2.7 FAULT REPORTS

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FAULT REPORTS ⇨ FAULT REPORT 1**

| | | | |
|---|---|---|---|
| ■ FAULT REPORT 1 ■ | ◀▶ | FAULT REPORT 1 SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* ▲▼ | FAULT REPORT 1 TRIG: Off | *Range: FlexLogic operand* |
| | *MESSAGE* ▲▼ | FAULT REPORT 1 Z1 MAG: 3.00 Ω | *Range: 0.01 to 250.00 ohms in steps of 0.01* |
| | *MESSAGE* ▲▼ | FAULT REPORT 1 Z1 ANGLE: 75° | *Range: 25 to 90° in steps of 1* |
| | *MESSAGE* ▲▼ | FAULT REPORT 1 Z0 MAG: 9.00 Ω | *Range: 0.01 to 650.00 ohms in steps of 0.01* |
| | *MESSAGE* ▲▼ | FAULT REPORT 1 Z0 ANGLE: 75° | *Range: 25 to 90° in steps of 1* |
| | *MESSAGE* ▲▼ | FAULT REPORT 1 LINE LENGTH UNITS: km | *Range: km, miles* |
| | *MESSAGE* ▲▼ | FAULT REP 1 LENGTH (km ): 100.0 | *Range: 0.0 to 2000.0 in steps of 0.1* |
| | *MESSAGE* ▲▼ | FAULT REPORT 1 VT SUBSTITUTION: None | *Range: None, I0, V0* |
| | *MESSAGE* ▲▼ | FAULT REP 1 SYSTEM Z0 MAG: 2.00 Ω | *Range: 0.01 to 650.00 ohms in steps of 0.01* |
| | *MESSAGE* ▲ | FAULT REP 1 SYSTEM Z0 ANGLE: 75° | *Range: 25 to 90° in steps of 1* |

The L30 relay supports one fault report and an associated fault locator. The signal source and trigger condition, as well as the characteristics of the line or feeder, are entered in this menu.

The fault report stores data, in non-volatile memory, pertinent to an event when triggered. The captured data contained in the `FaultReport.txt` file includes:

- Fault report number.
- Name of the relay, programmed by the user.
- Firmware revision of the relay.
- Date and time of trigger.
- Name of trigger (specific operand).
- Line or feeder ID via the name of a configured signal source.
- Active setting group at the time of trigger.
- Pre-fault current and voltage phasors (two cycles before either a 50DD disturbance associated with fault report source or the trigger operate). Once a disturbance is detected, pre-fault phasors hold for 3 seconds waiting for the fault report trigger. If trigger does not occur within this time, the values are cleared to prepare for the next disturbance.
- Fault current and voltage phasors (one cycle after the trigger).
- Elements operated at the time of triggering.
- Events: 9 before trigger and 7 after trigger (only available via the relay webpage).
- Fault duration times for each breaker (created by the breaker arcing current feature).

The captured data also includes the fault type and the distance to the fault location, as well as the reclose shot number (when applicable) To include fault duration times in the fault report, the user must enable and configure breaker arcing current feature for each of the breakers. Fault duration is reported on a per-phase basis.

The relay allows locating faults, including ground faults, from delta-connected VTs. In this case, the missing zero-sequence voltage is substituted either by the externally provided neutral voltage (broken delta VT) connected to the auxiliary voltage channel of a VT bank, or by the zero-sequence voltage approximated as a voltage drop developed by the zero-sequence current, and user-provided zero-sequence equivalent impedance of the system behind the relay.

The trigger can be any FlexLogic operand, but in most applications it is expected to be the same operand, usually a virtual output, that is used to drive an output relay to trip a breaker. To prevent the overwriting of fault events, the disturbance detector should not be used to trigger a fault report. A FAULT RPT TRIG event is automatically created when the report is triggered.

If a number of protection elements are ORed to create a fault report trigger, the first operation of any element causing the OR gate output to become high triggers a fault report. However, If other elements operate during the fault and the first operated element has not been reset (the OR gate output is still high), the fault report is not triggered again. Considering the reset time of protection elements, there is very little chance that fault report can be triggered twice in this manner. As the fault report must capture a usable amount of pre and post-fault data, it can not be triggered faster than every 20 ms.

Each fault report is stored as a file; the relay capacity is fifteen (15) files. An sixteenth (16th) trigger overwrites the oldest file.

The EnerVista UR Setup software is required to view all captured data. The relay faceplate display can be used to view the date and time of trigger, the fault type, the distance location of the fault, and the reclose shot number.

The **FAULT REPORT 1 SOURCE** setting selects the source for input currents and voltages and disturbance detection.

The **FAULT 1 REPORT TRIG** setting assigns the FlexLogic operand representing the protection element/elements requiring operational fault location calculations. The distance to fault calculations are initiated by this signal. The **FAULT REPORT 1 Z1 MAG** and **FAULT REPORT 1 Z0 MAG** impedances are entered in secondary ohms.

The **FAULT REPORT 1 VT SUBSTITUTION** setting shall be set to “None” if the relay is fed from wye-connected VTs. If delta-connected VTs are used, and the relay is supplied with the neutral (3V0) voltage, this setting shall be set to “V0”. The method is still exact, as the fault locator would combine the line-to-line voltage measurements with the neutral voltage measurement to re-create the line-to-ground voltages. See the **ACTUAL VALUES** ⇨⇩ **RECORDS** ⇨ **FAULT REPORTS** menu for additional details. It required to configure the delta and neutral voltages under the source indicated as input for the fault report. Also, the relay will check if the auxiliary signal configured is marked as “Vn” by the user (under VT setup), and inhibit the fault location if the auxiliary signal is labeled differently.

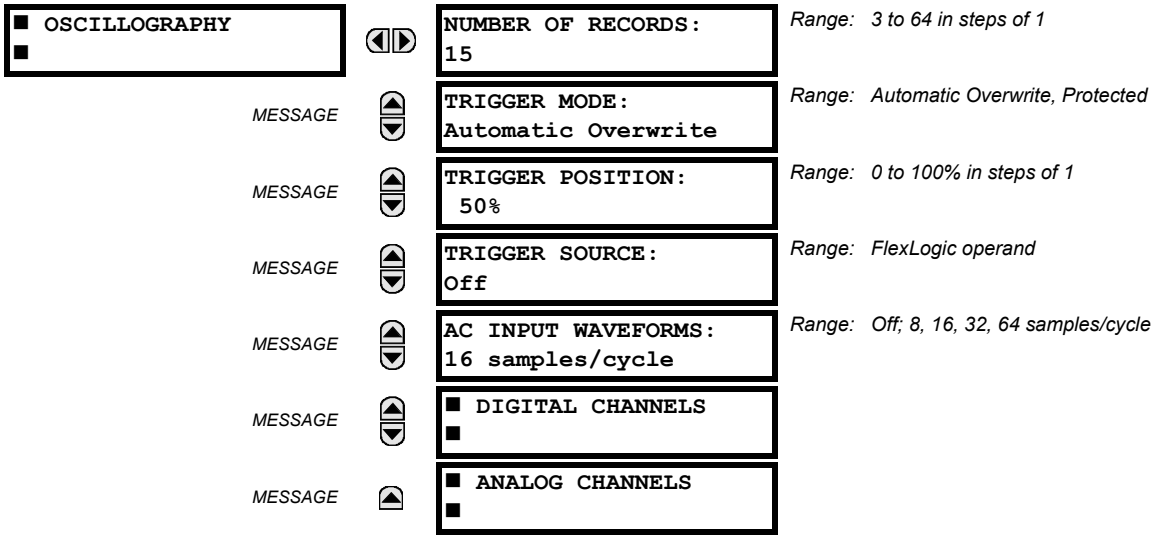
If the broken-delta neutral voltage is not available to the relay, an approximation is possible by assuming the missing zero-sequence voltage to be an inverted voltage drop produced by the zero-sequence current and the user-specified equivalent zero-sequence system impedance behind the relay: V0 = –Z0 × I0. In order to enable this mode of operation, the **FAULT REPORT 1 VT SUBSTITUTION** setting shall be set to "I0".

The **FAULT REP 1 SYSTEM Z0 MAG** and **FAULT REP 1 SYSTEM Z0 ANGLE** settings are used only when the **VT SUBSTITUTION** setting value is "I0". The magnitude is to be entered in secondary ohms. This impedance is an average system equivalent behind the relay. It can be calculated as zero-sequence Thevenin impedance at the local bus with the protected line/feeder disconnected. The method is accurate only if this setting matches perfectly the actual system impedance during the fault. If the system exhibits too much variability, this approach is questionable and the fault location results for single-line-to-ground faults shall be trusted with accordingly. It should be kept in mind that grounding points in vicinity of the installation impact the system zero-sequence impedance (grounded loads, reactors, zig-zag transformers, shunt capacitor banks, etc.).

## 5.2.8 OSCILLOGRAPHY

### a) MAIN MENU

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ OSCILLOGRAPHY**




Oscillography records contain waveforms captured at the sampling rate as well as other relay data at the point of trigger. Oscillography records are triggered by a programmable FlexLogic operand. Multiple oscillography records can be captured simultaneously.

The **NUMBER OF RECORDS** is selectable, but the number of cycles captured in a single record varies considerably based on other factors, such as sample rate and the number of operational modules. There is a fixed amount of data storage for oscillography; the more data captured, the less the number of cycles captured per record. See the **ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ OSCILLOGRAPHY** menu to view the number of cycles captured per record. The following table provides sample configurations with corresponding cycles/record. The minimum number of oscillographic records is three.

**Table 5–9: OSCILLOGRAPHY CYCLES/RECORD EXAMPLE**

| RECORDS | CT/VTS | SAMPLE RATE | DIGITAL CHANNELS | ANALOG CHANNELS | CYCLES PER RECORD |
|---|---|---|---|---|---|
| 3 | 1 | 32 | 32 | 16 | 2399 |
| 3 | 1 | 64 | 32 | 16 | 1450 |
| 16 | 1 | 32 | 32 | 16 | 666 |
| 16 | 1 | 64 | 32 | 16 | 402 |
| 32 | 1 | 32 | 32 | 16 | 352 |
| 32 | 1 | 64 | 32 | 16 | 213 |
| 3 | 2 | 32 | 32 | 16 | 1516 |
| 3 | 2 | 64 | 32 | 16 | 851 |
| 16 | 2 | 32 | 32 | 16 | 421 |

A new record can automatically overwrite an older record when **TRIGGER MODE** is set to "Automatic Overwrite."

Set the **TRIGGER POSITION** to a percentage of the total buffer size (for example, 10%, 50%, 75%, and so on). A trigger position of 25% consists of 25% pre- and 75% post-trigger data. The **TRIGGER SOURCE** is always captured in oscillography and can be any FlexLogic parameter (element state, contact input, virtual output, and so on). The relay sampling rate is 64 samples per cycle.

The **AC INPUT WAVEFORMS** setting determines the sampling rate at which AC input signals (that is, current and voltage) are stored. Reducing the sampling rate allows longer records to be stored. This setting has no effect on the internal sampling rate of the relay which is always 64 samples per cycle; that is, it has no effect on the fundamental calculations of the device.

NOTE When changes are made to the oscillography settings, all existing oscillography records are cleared.

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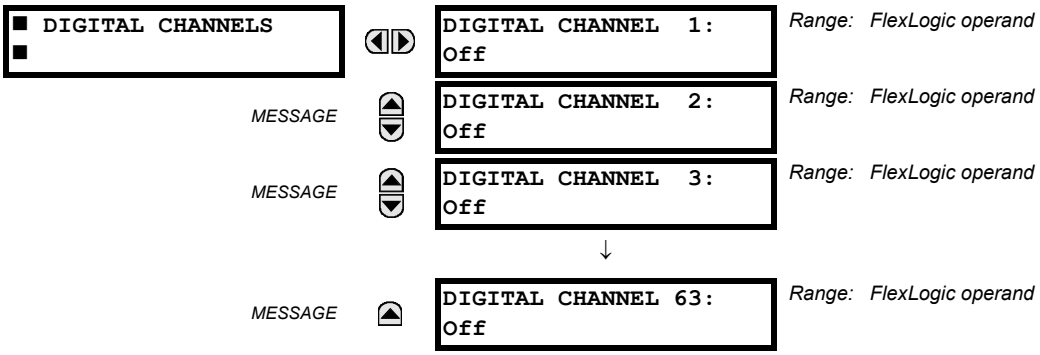
### b) DIGITAL CHANNELS

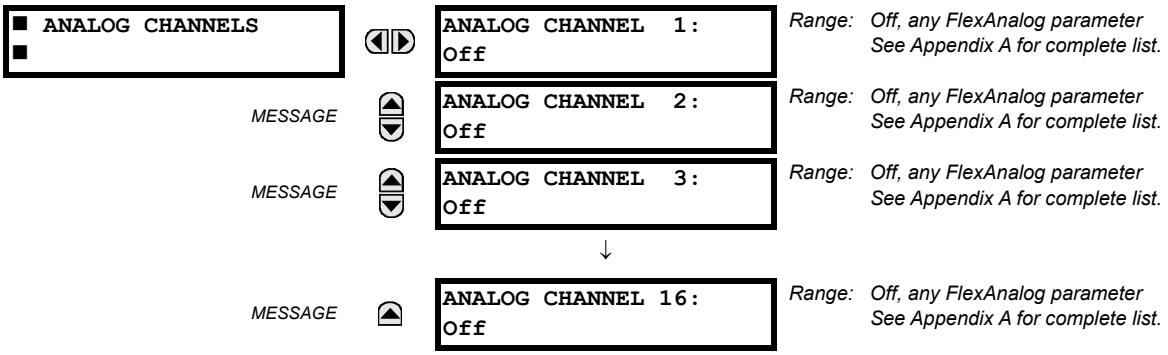
**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ OSCILLOGRAPHY ⇨⇩ DIGITAL CHANNELS**




A **DIGITAL 1(63) CHANNEL** setting selects the FlexLogic operand state recorded in an oscillography trace. The length of each oscillography trace depends in part on the number of parameters selected here. Parameters set to "Off" are ignored. Upon startup, the relay will automatically prepare the parameter list.

### c) ANALOG CHANNELS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ OSCILLOGRAPHY ⇨⇩ ANALOG CHANNELS




These settings select the metering actual value recorded in an oscillography trace. The length of each oscillography trace depends in part on the number of parameters selected here. Parameters set to "Off" are ignored. The parameters available in a given relay are dependent on:

- The type of relay,
- The type and number of CT/VT hardware modules installed, and
- The type and number of analog input hardware modules installed.

Upon startup, the relay will automatically prepare the parameter list. A list of all possible analog metering actual value parameters is presented in Appendix A: FlexAnalog Parameters. The parameter index number shown in any of the tables is used to expedite the selection of the parameter on the relay display. It can be quite time-consuming to scan through the list of parameters via the relay keypad and display - entering this number via the relay keypad will cause the corresponding parameter to be displayed.

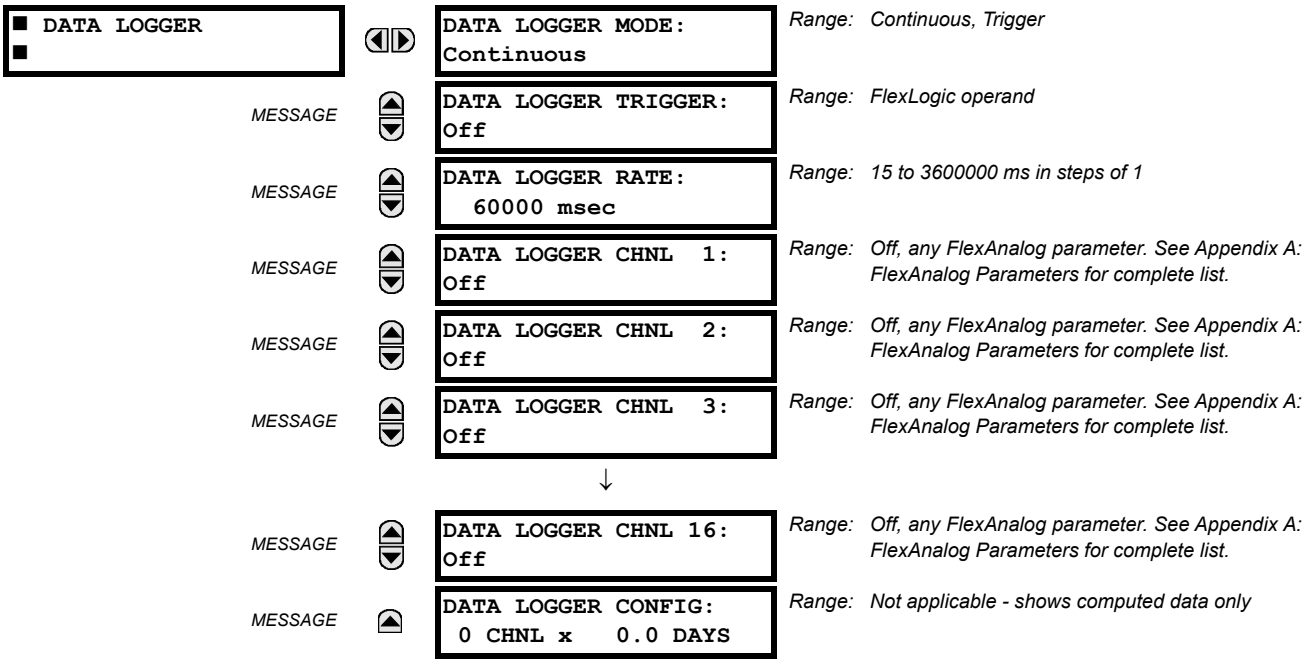
All eight CT/VT module channels are stored in the oscillography file. The CT/VT module channels are named as follows:

*<slot_letter><terminal_number>—<I* or *V><phase A*, *B*, or *C*, or *4th input>*

The fourth current input in a bank is called IG, and the fourth voltage input in a bank is called VX. For example, F2-IB designates the IB signal on terminal 2 of the CT/VT module in slot F.

If there are no CT/VT modules and analog input modules, no analog traces will appear in the file; only the digital traces will appear.

PATH: SETTINGS ⇨⇩ PRODUCT SETUP ⇨⇩ DATA LOGGER




The data logger samples and records up to 16 analog parameters at a user-defined sampling rate. This recorded data may be downloaded to EnerVista UR Setup and displayed with *parameters* on the vertical axis and *time* on the horizontal axis. All data is stored in non-volatile memory, meaning that the information is retained when power to the relay is lost.

For a fixed sampling rate, the data logger can be configured with a few channels over a long period or a larger number of channels for a shorter period. The relay automatically partitions the available memory between the channels in use. Example storage capacities for a system frequency of 60 Hz are shown in the following table.

**Table 5–10: DATA LOGGER STORAGE CAPACITY EXAMPLE**

| SAMPLING RATE | CHANNELS | DAYS | STORAGE CAPACITY |
|---|---|---|---|
| 15 ms | 1 | 0.1 | 954 s |
| | 8 | 0.1 | 120 s |
| | 9 | 0.1 | 107 s |
| | 16 | 0.1 | 60 s |
| 1000 ms | 1 | 0.7 | 65457 s |
| | 8 | 0.1 | 8182 s |
| | 9 | 0.1 | 7273 s |
| | 16 | 0.1 | 4091 s |
| 60000 ms | 1 | 45.4 | 3927420 s |
| | 8 | 5.6 | 490920 s |
| | 9 | 5 | 436380 s |
| | 16 | 2.8 | 254460 s |
| 3600000 ms | 1 | 2727.5 | 235645200 s |
| | 8 | 340.9 | 29455200 s |
| | 9 | 303 | 26182800 s |

NOTE

Changing any setting affecting data logger operation clears any data that is currently in the log.

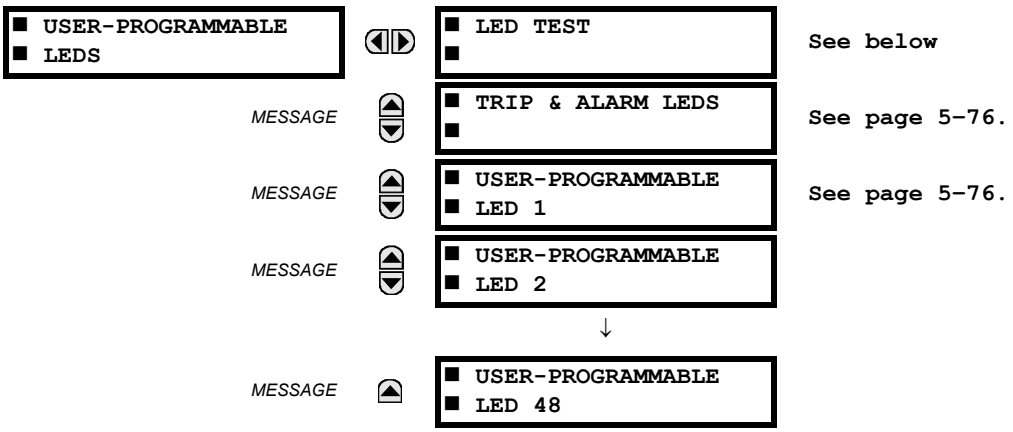
- **DATA LOGGER MODE**: This setting configures the mode in which the data logger will operate. When set to "Continuous", the data logger will actively record any configured channels at the rate as defined by the **DATA LOGGER RATE**. The data logger will be idle in this mode if no channels are configured. When set to "Trigger", the data logger will begin to record any configured channels at the instance of the rising edge of the **DATA LOGGER TRIGGER** source FlexLogic operand. *The data logger will ignore all subsequent triggers* and will continue to record data until the active record is full. Once the data logger is full a **CLEAR DATA LOGGER** command is required to clear the data logger record before a new record can be started. Performing the **CLEAR DATA LOGGER** command will also stop the current record and reset the data logger to be ready for the next trigger.
- **DATA LOGGER TRIGGER**: This setting selects the signal used to trigger the start of a new data logger record. Any FlexLogic operand can be used as the trigger source. The **DATA LOGGER TRIGGER** setting only applies when the mode is set to "Trigger".
- **DATA LOGGER RATE:** This setting selects the time interval at which the actual value data will be recorded.
- **DATA LOGGER CHNL 1(16):** This setting selects the metering actual value that is to be recorded in Channel 1(16) of the data log. The parameters available in a given relay are dependent on: the type of relay, the type and number of CT/VT hardware modules installed, and the type and number of Analog Input hardware modules installed. Upon startup, the relay will automatically prepare the parameter list. A list of all possible analog metering actual value parameters is shown in Appendix A: FlexAnalog Parameters. The parameter index number shown in any of the tables is used to expedite the selection of the parameter on the relay display. It can be quite time-consuming to scan through the list of parameters via the relay keypad/display – entering this number via the relay keypad will cause the corresponding parameter to be displayed.
- **DATA LOGGER CONFIG:** This display presents the total amount of time the Data Logger can record the channels not selected to "Off" without over-writing old data.



## 5.2.10 USER-PROGRAMMABLE LEDS

### a) MAIN MENU

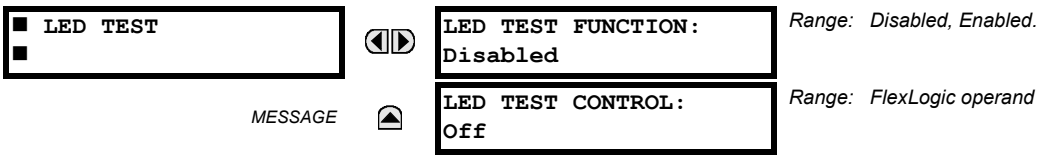
PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE LEDS




The 48 amber LEDs on relay panels 2 and 3 can be customized to illuminate when a selected FlexLogic operand is in the logic 1 state. The trip and alarm LEDs on panel 1 can also be customized in a similar manner. To ensure correct functionality of all LEDs, an LED test feature is also provided.

### b) LED TEST

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE LEDS ⇨ LED TEST



When enabled, the LED test can be initiated from any digital input or user-programmable condition such as user-programmable pushbutton. The control operand is configured under the **LED TEST CONTROL** setting. The test covers all LEDs, including the LEDs of the optional user-programmable pushbuttons.

The test consists of three stages.

1. All 62 LEDs on the relay are illuminated. This is a quick test to verify if any of the LEDs is "burned". This stage lasts as long as the control input is on, up to a maximum of 1 minute. After 1 minute, the test will end.
2. All the LEDs are turned off, and then one LED at a time turns on for 1 second, then back off. The test routine starts at the top left panel, moving from the top to bottom of each LED column. This test checks for hardware failures that lead to more than one LED being turned on from a single logic point. This stage can be interrupted at any time.
3. All the LEDs are turned on. One LED at a time turns off for 1 second, then back on. The test routine starts at the top left panel moving from top to bottom of each column of the LEDs. This test checks for hardware failures that lead to more than one LED being turned off from a single logic point. This stage can be interrupted at any time.

When testing is in progress, the LEDs are controlled by the test sequence, rather than the protection, control, and monitoring features. However, the LED control mechanism accepts all the changes to LED states generated by the relay and stores the actual LED states (on or off) in memory. When the test completes, the LEDs reflect the actual state resulting from relay response during testing. The reset pushbutton will not clear any targets when the LED Test is in progress.

A dedicated FlexLogic operand, LED TEST IN PROGRESS, is set for the duration of the test. When the test sequence is initiated, the LED TEST INITIATED event is stored in the event recorder.

The entire test procedure is user-controlled. In particular, stage 1 can last as long as necessary, and stages 2 and 3 can be interrupted. The test responds to the position and rising edges of the control input defined by the **LED TEST CONTROL** setting. The control pulses must last at least 250 ms to take effect. The following diagram explains how the test is executed.

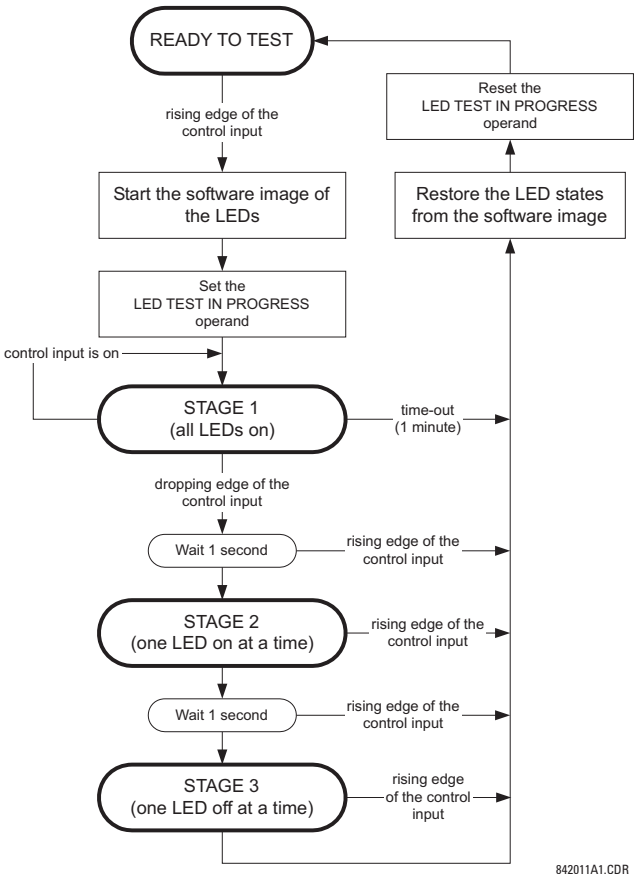



**Figure 5–9: LED TEST SEQUENCE**

**APPLICATION EXAMPLE 1:**

Assume one needs to check if any of the LEDs is "burned" through user-programmable pushbutton 1. The following settings should be applied. Configure user-programmable pushbutton 1 by making the following entries in the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE PUSHBUTTONS ⇨ USER PUSHBUTTON 1** menu:

**PUSHBUTTON 1 FUNCTION:** "Self-reset"
**PUSHBTN 1 DROP-OUT TIME:** "0.10 s"

Configure the LED test to recognize user-programmable pushbutton 1 by making the following entries in the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE LEDS ⇨ LED TEST** menu:

**LED TEST FUNCTION:** "Enabled"
**LED TEST CONTROL:** "PUSHBUTTON 1 ON"

The test will be initiated when the user-programmable pushbutton 1 is pressed. The pushbutton should remain pressed for as long as the LEDs are being visually inspected. When finished, the pushbutton should be released. The relay will then automatically start stage 2. At this point forward, test may be aborted by pressing the pushbutton.

**APPLICATION EXAMPLE 2:**

Assume one needs to check if any LEDs are "burned" as well as exercise one LED at a time to check for other failures. This is to be performed via user-programmable pushbutton 1.

After applying the settings in application example 1, hold down the pushbutton as long as necessary to test all LEDs. Next, release the pushbutton to automatically start stage 2. Once stage 2 has started, the pushbutton can be released. When stage 2 is completed, stage 3 will automatically start. The test may be aborted at any time by pressing the pushbutton.

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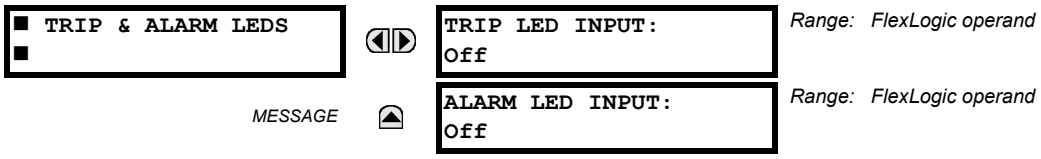
### c) TRIP AND ALARM LEDS

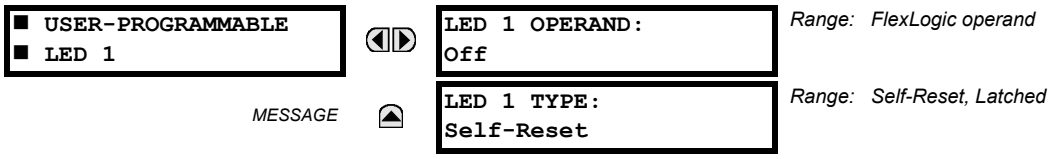
**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE LEDS ⇨⇩ TRIP & ALARM LEDS**




The trip and alarm LEDs are in the first LED column (enhanced faceplate) and on LED panel 1 (basic faceplate). Each indicator can be programmed to become illuminated when the selected FlexLogic operand is in the logic 1 state.

### d) USER-PROGRAMMABLE LED 1(48)

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE LEDS ⇨⇩ USER-PROGRAMMABLE LED 1(48)**




There are 48 amber LEDs across the relay faceplate LED panels. Each of these indicators can be programmed to illuminate when the selected FlexLogic operand is in the logic 1 state.

For the basic faceplate, the LEDs are located as follows.

- LED Panel 2: user-programmable LEDs 1 through 24
- LED Panel 3: user programmable LEDs 25 through 48

For the enhanced faceplate, the LEDs are located as follows.

- LED column 2: user-programmable LEDs 1 through 12
- LED column 3: user-programmable LEDs 13 through 24
- LED column 4: user-programmable LEDs 25 through 36
- LED column 5: user-programmable LEDs 37 through 48

See the LED Indicators section in chapter 4 for information on the location of these indexed LEDs.

The user-programmable LED settings select the FlexLogic operands that control the LEDs. If the **LED 1 TYPE** setting is "Self-Reset" (the default setting), the LED illumination will track the state of the selected LED operand. If the **LED 1 TYPE** setting is "Latched", the LED, once lit, remains so until reset by the faceplate RESET button, from a remote device via a communications channel, or from any programmed operand, even if the LED operand state de-asserts.

**Table 5–11: RECOMMENDED SETTINGS FOR USER-PROGRAMMABLE LEDS**

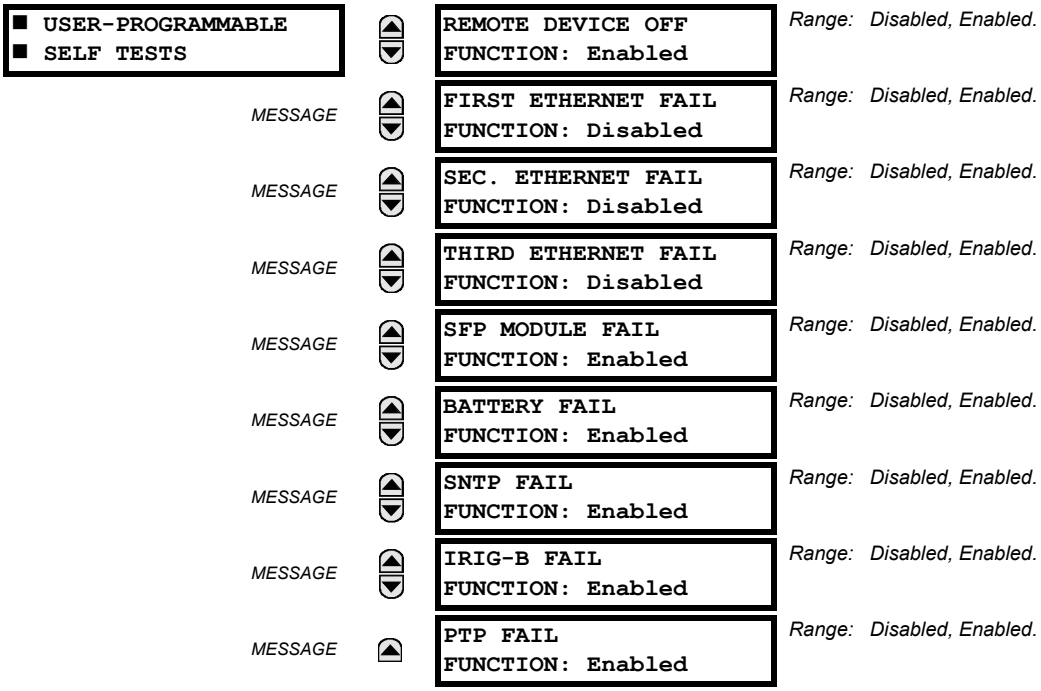
| SETTING | PARAMETER |
|---|---|
| LED 1 operand | SETTING GROUP ACT 1 |
| LED 2 operand | SETTING GROUP ACT 2 |
| LED 3 operand | SETTING GROUP ACT 3 |
| LED 4 operand | SETTING GROUP ACT 4 |
| LED 5 operand | SETTING GROUP ACT 5 |
| LED 6 operand | SETTING GROUP ACT 6 |
| LED 7 operand | Off |
| LED 8 operand | Off |
| LED 9 operand | BREAKER 1 OPEN |
| LED 10 operand | BREAKER 1 CLOSED |
| LED 11 operand | BREAKER 1 TROUBLE |
| LED 12 operand | Off |

| SETTING | PARAMETER |
|---|---|
| LED 13 operand | Off |
| LED 14 operand | BREAKER 2 OPEN |
| LED 15 operand | BREAKER 2 CLOSED |
| LED 16 operand | BREAKER 2 TROUBLE |
| LED 17 operand | SYNC 1 SYNC OP |
| LED 18 operand | SYNC 2 SYNC OP |
| LED 19 operand | Off |
| LED 20 operand | Off |
| LED 21 operand | AR ENABLED |
| LED 22 operand | AR DISABLED |
| LED 23 operand | AR RIP |
| LED 24 operand | AR LO |

### 5.2.11 USER-PROGRAMMABLE SELF-TESTS



**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE SELF TESTS**

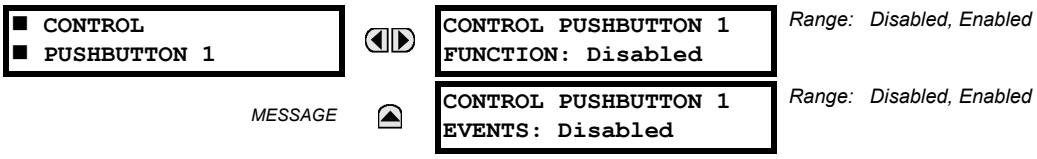



All major self-test alarms are reported automatically with their corresponding FlexLogic operands, events, and targets. Most of the minor alarms can be disabled if desired.

When in the Disabled mode, minor alarms do not assert a FlexLogic operand, write to the event recorder, or display target messages. Moreover, they do not trigger the **ANY MINOR ALARM** or **ANY SELF-TEST** messages. When in Enabled mode, minor alarms continue to function along with other major and minor alarms. See the Relay Self-Tests section in chapter 7 for information on major and minor self-test alarms.

## 5.2.12 CONTROL PUSHBUTTONS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ CONTROL PUSHBUTTONS ⇨ CONTROL PUSHBUTTON 1(7)




There are three standard control pushbuttons, labeled USER 1, USER 2, and USER 3, on the basic and enhanced front panels. These are user-programmable and can be used for various applications such as performing an LED test, switching setting groups, and invoking and scrolling though user-programmable displays.

The locations of the control pushbuttons are shown in the following figures.

**Figure 5–10: CONTROL PUSHBUTTONS (ENHANCED FACEPLATE)**

An additional four control pushbuttons are included on the basic faceplate when the L30 is ordered with the 12 user-programmable pushbutton option.

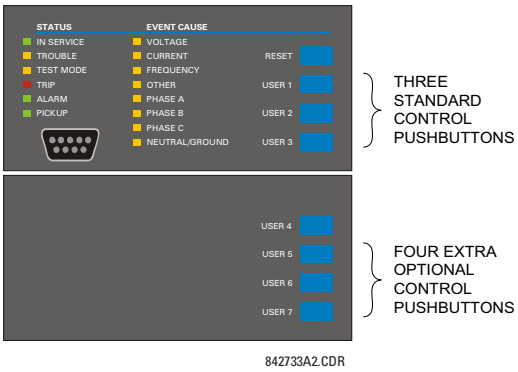



**Figure 5–11: CONTROL PUSHBUTTONS (BASIC FACEPLATE)**

Control pushbuttons are not typically used for critical operations and are not protected by the control password. However, by supervising their output operands, the user can dynamically enable or disable control pushbuttons for security reasons.

Each control pushbutton asserts its own FlexLogic operand. These operands should be configured appropriately to perform the desired function. The operand remains asserted as long as the pushbutton is pressed and resets when the pushbutton is released. A dropout delay of 100 ms is incorporated to ensure fast pushbutton manipulation will be recognized by various features that may use control pushbuttons as inputs.

An event is logged in the event record (as per user setting) when a control pushbutton is pressed. No event is logged when the pushbutton is released. The faceplate keys (including control keys) cannot be operated simultaneously – a given key must be released before the next one can be pressed.

The control pushbuttons become user-programmable only if the breaker control feature is not configured for manual control via the USER 1 through 3 pushbuttons as shown below. If configured for manual control, breaker control typically uses the larger, optional user-programmable pushbuttons, making the control pushbuttons available for other user applications.

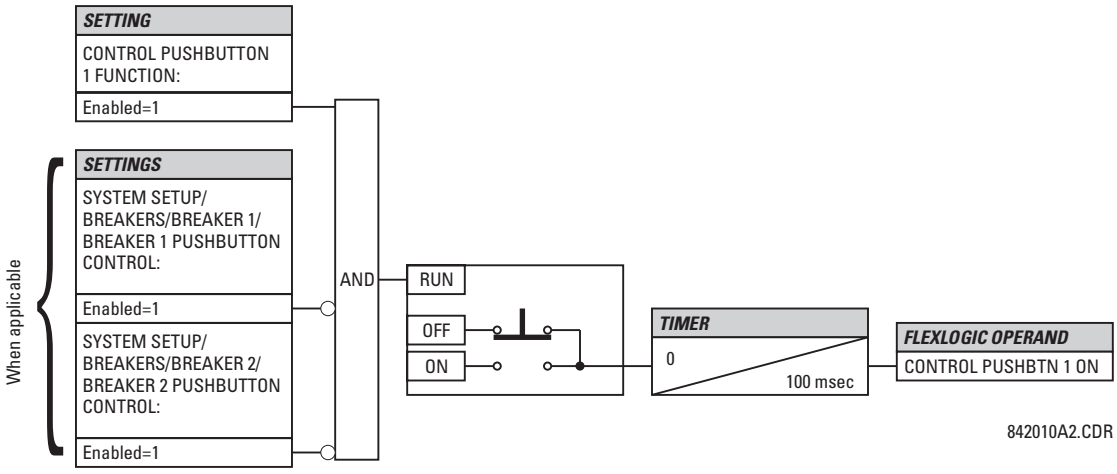



**Figure 5–12: CONTROL PUSHBUTTON LOGIC**

## 5.2.13 USER-PROGRAMMABLE PUSHBUTTONS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE PUSHBUTTONS ⇨ USER PUSHBUTTON 1(16)

| | | | |
|---|---|---|---|
| ■ USER PUSHBUTTON 1 ■ | ◀▶ | PUSHBUTTON 1 FUNCTION: Disabled | Range: Self-Reset, Latched, Disabled |
| | MESSAGE ▲▼ | PUSHBTN 1 ID TEXT: USER PB 1 | Range: Up to 20 alphanumeric characters |
| | MESSAGE ▲▼ | PUSHBTN 1 ON TEXT: USER PB 1 ON | Range: Up to 20 alphanumeric characters |
| | MESSAGE ▲▼ | PUSHBTN 1 OFF TEXT: USER PB 1 OFF | Range: Up to 20 alphanumeric characters |
| | MESSAGE ▲▼ | PUSHBTN 1 HOLD: 0.1 s | Range: 0.0 to 10.0 s in steps of 0.1 |
| | MESSAGE ▲▼ | PUSHBTN 1 SET: Off | Range: FlexLogic operand |
| | MESSAGE ▲▼ | PUSHBTN 1 RESET: Off | Range: FlexLogic operand |
| | MESSAGE ▲▼ | PUSHBTN 1 AUTORST: Disabled | Range: Disabled, Enabled |
| | MESSAGE ▲▼ | PUSHBTN 1 AUTORST DELAY: 1.0 s | Range: 0.2 to 600.0 s in steps of 0.1 |
| | MESSAGE ▲▼ | PUSHBTN 1 REMOTE: Off | Range: FlexLogic operand |
| | MESSAGE ▲▼ | PUSHBTN 1 LOCAL: Off | Range: FlexLogic operand |
| | MESSAGE ▲▼ | PUSHBTN 1 DROP-OUT TIME: 0.00 s | Range: 0 to 60.00 s in steps of 0.05 |
| | MESSAGE ▲▼ | PUSHBTN 1 LED CTL: Off | Range: FlexLogic operand |
| | MESSAGE ▲▼ | PUSHBTN 1 MESSAGE: Disabled | Range: Disabled, Normal, High Priority |
| | MESSAGE ▲ | PUSHBUTTON 1 EVENTS: Disabled | Range: Disabled, Enabled |

The L30 is provided with this optional feature, specified as an option at the time of ordering. Using the order code for your device, see the order codes in chapter 2 for details.

User-programmable pushbuttons provide an easy and error-free method of entering digital state (on, off) information. The number depends on the front panel ordered.

- Enhanced horizontal front panel — 16 user-programmable pushbuttons
- Enhanced vertical front panel — 6 user-programmable pushbuttons
- Basic horizontal front panel — 12 user-programmable pushbuttons

NOTE

User-programmable pushbuttons require a front panel with that option. If the front panel was ordered separately, update the EnerVista software under **Maintenance > Enable Pushbutton**.

The digital state can be entered locally (by directly pressing the front panel pushbutton) or remotely (via FlexLogic operands) into FlexLogic equations, protection elements, and control elements. Typical applications include breaker control, autorecloser blocking, and setting groups changes. The user-programmable pushbuttons are under the control level of password protection.

The figure shows user-configurable pushbuttons for the enhanced front panel.

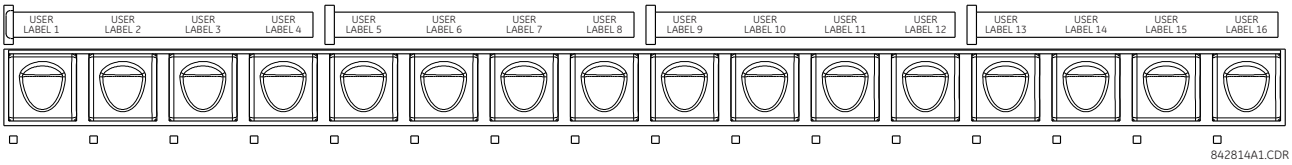



**Figure 5–13: USER-PROGRAMMABLE PUSHBUTTONS (ENHANCED FRONT PANEL)**

The following figure shows user-configurable pushbuttons for the basic front panel.

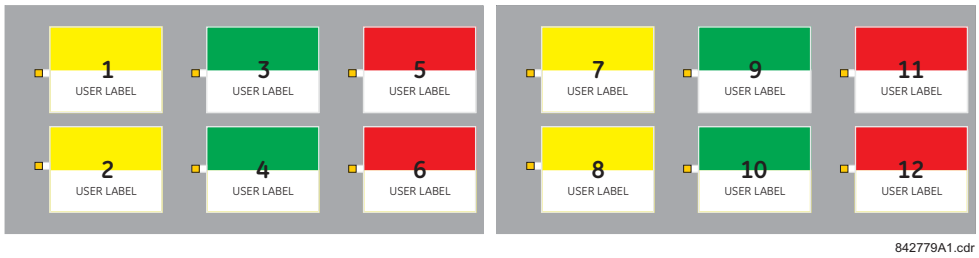



**Figure 5–14: USER-PROGRAMMABLE PUSHBUTTONS (BASIC FRONT PANEL)**

Both the basic and enhanced front panel pushbuttons can be custom labeled with a factory-provided template, available online at http://www.gegridsolutions.com/multilin. The EnerVista software can also be used to create labels for the enhanced front panel.

Each pushbutton asserts its own "On" and "Off" FlexLogic operands (for example, PUSHBUTTON 1 ON and PUSHBUTTON 1 OFF). These operands are available for each pushbutton and are used to program specific actions. If any pushbutton is active, the ANY PB ON operand is asserted.

Each pushbutton has an associated LED indicator. By default, this indicator displays the present status of the corresponding pushbutton (on or off). However, each LED indicator can be assigned to any FlexLogic operand through the **PUSHBTN 1 LED CTL** setting.

The activation and deactivation of user-programmable pushbuttons depends on whether latched or self-reset mode is programmed.

- *Latched mode*: In latched mode, a pushbutton can be set (activated) by asserting the operand assigned to the **PUSHBTN 1 SET** setting or by directly pressing the associated front panel pushbutton. The state of each pushbutton is stored in non-volatile memory and maintained through a loss of control power.

  The pushbutton is reset (deactivated) in latched mode by asserting the operand assigned to the **PUSHBTN 1 RESET** setting or by directly pressing the associated active front panel pushbutton.

  It can also be programmed to reset automatically through the **PUSHBTN 1 AUTORST** and **PUSHBTN 1 AUTORST DELAY** settings. These settings enable the autoreset timer and specify the associated time delay. The autoreset timer can be used in select-before-operate (SBO) breaker control applications, where the command type (close/open) or breaker location (feeder number) must be selected prior to command execution. The selection must reset automatically if control is not executed within a specified time period.

- *Self-reset mode*: In self-reset mode, a user-programmable pushbutton can be set (activated) by asserting the operand assigned to the PUSHBTN 1 SET setting or by pressing the front panel pushbutton. A pushbutton remains active for the time it is pressed plus the dropout time specified in the **PUSHBTN 1 DROP-OUT TIME** setting. If the pushbutton is activated via FlexLogic, the pulse duration is specified by the **PUSHBTN 1 DROP-OUT TIME** only. The time the operand remains assigned to the **PUSHBTN 1 SET** setting remains On has no effect on the pulse duration.

NOTE

The pulse duration of the remote set or local front panel pushbutton must be at least 50 ms to operate the pushbutton. This allows the user-programmable pushbuttons to properly operate during power cycling events and various system disturbances that can cause transient assertion of the operating signals.

The local and remote operation of each user-programmable pushbutton can be inhibited through the **PUSHBTN 1 LOCAL** and **PUSHBTN 1 REMOTE** settings. If local inhibit is applied, the pushbutton ignores set and reset commands executed through the front panel pushbuttons. If remote inhibit is applied, the pushbutton ignores set and reset commands executed through FlexLogic operands.

The inhibit functions are not applied to the autoreset feature. The inhibit function can be used in SBO control operations to prevent user-programmable pushbutton activation and ensuring “one-at-a-time” select operation.

The inhibit functions can also be used to prevent pushbutton activation from the accidental pressing of the front panel pushbuttons. The separate inhibit of the local and remote operation simplifies the implementation of local/remote control supervision.

Pushbutton states can be logged by the event recorder. User-defined messages can also be associated with each pushbutton and displayed when the pushbutton is activated and when in latched mode when the pushbutton deactivated.

- **PUSHBUTTON 1 FUNCTION**: This setting selects the mode of the pushbutton (Self-Reset, Latched, Disabled). If set to “Disabled,” the pushbutton is not active and the corresponding FlexLogic operands (both “On” and “Off”) are deasserted.
- **PUSHBTN 1 ID TEXT:** This setting specifies the top 20-character line of the user-programmable pushbutton message and is intended to provide ID information of the pushbutton. See the User-Definable Displays section in this chapter for instructions on how to enter alphanumeric characters from the keypad.
- **PUSHBTN 1 ON TEXT:** This setting specifies the bottom 20-character line of the user-programmable message and is displayed when the pushbutton is in the “on” position. See the User-Definable Displays section for instructions on entering alphanumeric characters from the keypad.
- **PUSHBTN 1 OFF TEXT:** This setting specifies the bottom 20-character line of the user-programmable pushbutton message and displays when the pushbutton is deactivated and the **PUSHBUTTON 1 FUNCTION** is “Latched”. A message does not display when the **PUSHBUTTON 1 FUNCTION** is “Self-reset” as the pushbutton operand status is implied to be “Off” upon its release. The length of the “Off” message is configured with the **PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES ⇨ FLASH MESSAGE TIME** setting.
- **PUSHBTN 1 HOLD**: This setting specifies the time required for a front panel pushbutton to be pressed before it is deemed active. This timer is reset upon release of the pushbutton. Note that user-programmable pushbutton operation requires the front panel pushbutton to be pressed a minimum of 56 ms for a 60 Hz system or 60 ms for a 50 Hz system. This minimum time is required prior to activating the user-programmable pushbutton hold timer.
- **PUSHBTN 1 SET**: This setting assigns the FlexLogic operand serving to activate the user-programmable pushbutton element. The duration of the incoming set signal must be at least 56 ms for a 60 Hz system or 60 ms for a 50 Hz system.
- **PUSHBTN 1 RESET**: This setting assigns the FlexLogic operand serving to deactivate the user-programmable pushbutton element. This setting is applicable only if the user-programmable pushbutton is in "Latched" mode.
- **PUSHBTN 1 AUTORST**: This setting enables the user-programmable pushbutton autoreset feature. This setting is applicable only if the pushbutton is in “Latched” mode.
- **PUSHBTN 1 AUTORST DELAY**: This setting specifies the time delay for automatic reset of the pushbutton when in "Latched" mode.
- **PUSHBTN 1 REMOTE**: This setting assigns the FlexLogic operand serving to inhibit user-programmable pushbutton operation from the operand assigned to the **PUSHBTN 1 SET** or **PUSHBTN 1 RESET** settings.
- **PUSHBTN 1 LOCAL**: This setting assigns the FlexLogic operand serving to inhibit user-programmable pushbutton operation from the front panel pushbuttons. This inhibit functionality is not applicable to pushbutton autoreset.
- **PUSHBTN 1 DROP-OUT TIME**: This setting applies only to “Self-Reset” mode and specifies the duration of the user-programmable pushbutton active status after the front panel pushbutton has been released. When activated remotely, this setting specifies the entire activation time of the pushbutton; the length of time the operand selected by PUSHBTN 1 SET remains on has no effect on the pulse duration.
- **PUSHBTN 1 LED CTL**: This setting assigns the FlexLogic operand serving to drive the front panel pushbutton LED. If this setting is “Off”, then LED operation is directly linked to the PUSHBUTTON 1 ON operand.

- **PUSHBTN 1 MESSAGE**: This setting controls the behavior of the user-programmable pushbutton that is programmed in the **PUSHBTN 1 ID** and **PUSHBTN 1 ON TEXT** settings, and the behavior of the user-programmable pushbutton off message that is programmed in the **PUSHBTN1 ID** and **PUSHBTN 1 OFF TEXT** settings.

  When set to "Disabled", user-programmable pushbutton messages do not display. Otherwise the on message displays when the user-programmable pushbutton becomes activated, and if in the "Latched" mode the off message displays when the user-programmable pushbutton becomes deactivated.

  When set to "Normal", the duration the message displays is as specified by the **FLASH MESSAGE TIME** setting.

  When set to "High Priority", the duration of the off message is as specified by the **FLASH MESSAGE TIME** setting, but the on message is displayed as long as the user-programmable pushbutton is activated. While activated, target and other messages are suppressed. To allow front panel keypad operation, when a keypad button is pressed the message is supressed for 10 seconds.

- **PUSHBUTTON 1 EVENTS**: If this setting is enabled, each user-programmable pushbutton state change is logged as an event into the event recorder.

The figures show the user-programmable pushbutton logic.

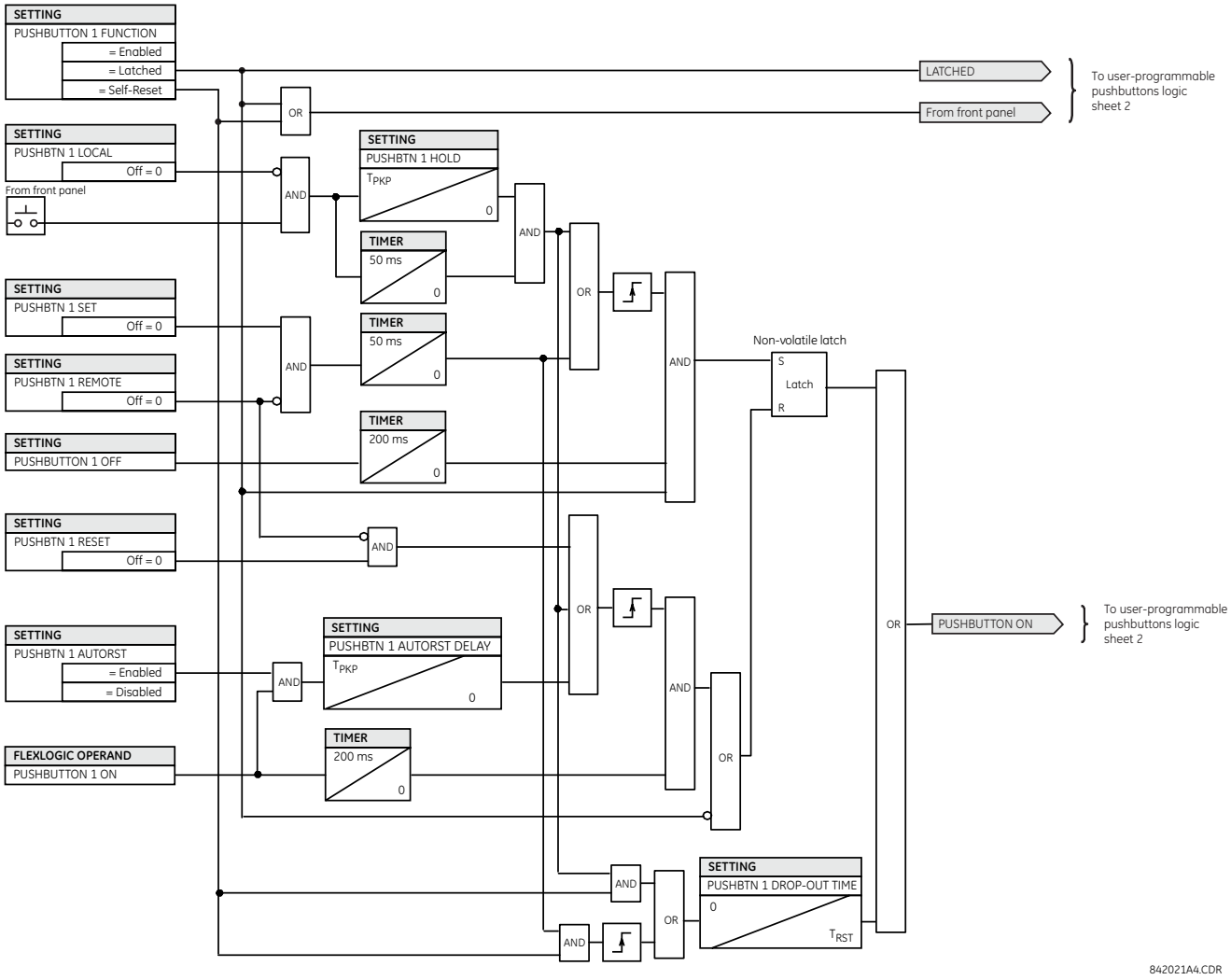



**Figure 5–15: USER-PROGRAMMABLE PUSHBUTTON LOGIC (Sheet 1 of 2)**

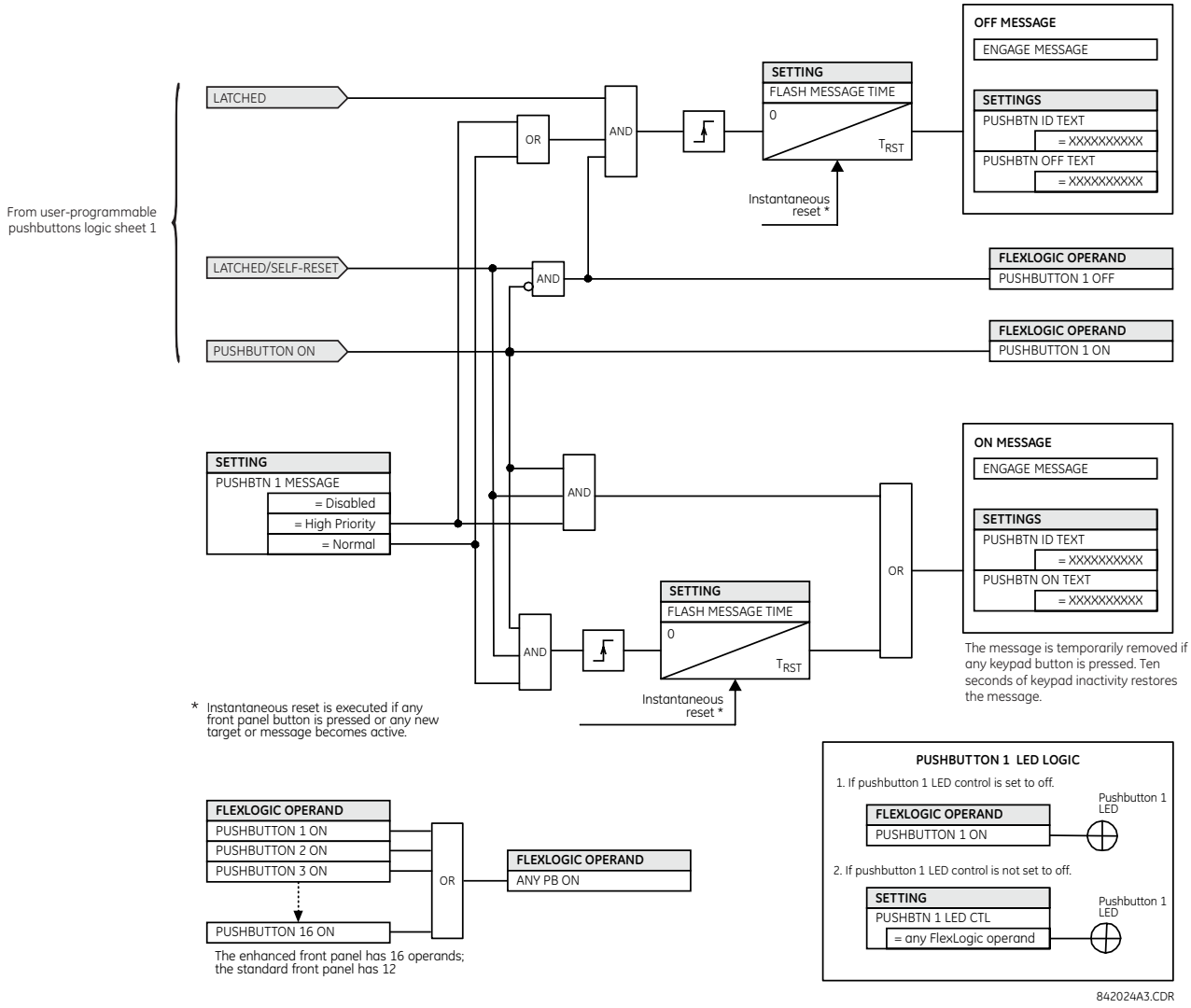
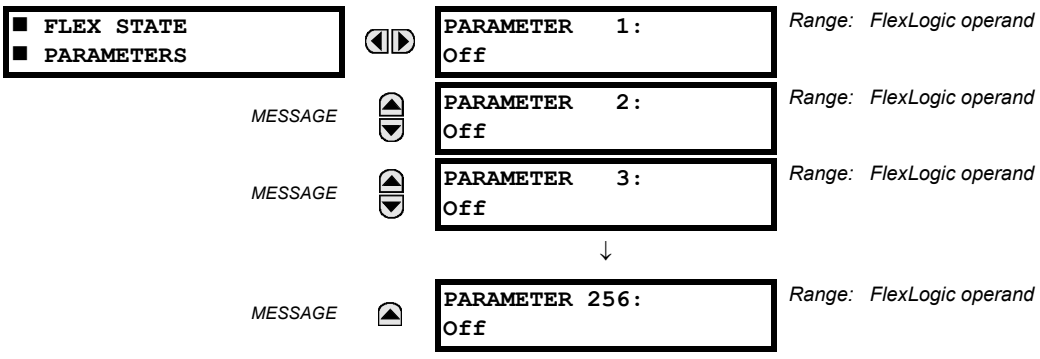



**Figure 5–16: USER-PROGRAMMABLE PUSHBUTTON LOGIC (Sheet 2 of 2)**

## 5.2.14 FLEX STATE PARAMETERS

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FLEX STATE PARAMETERS**



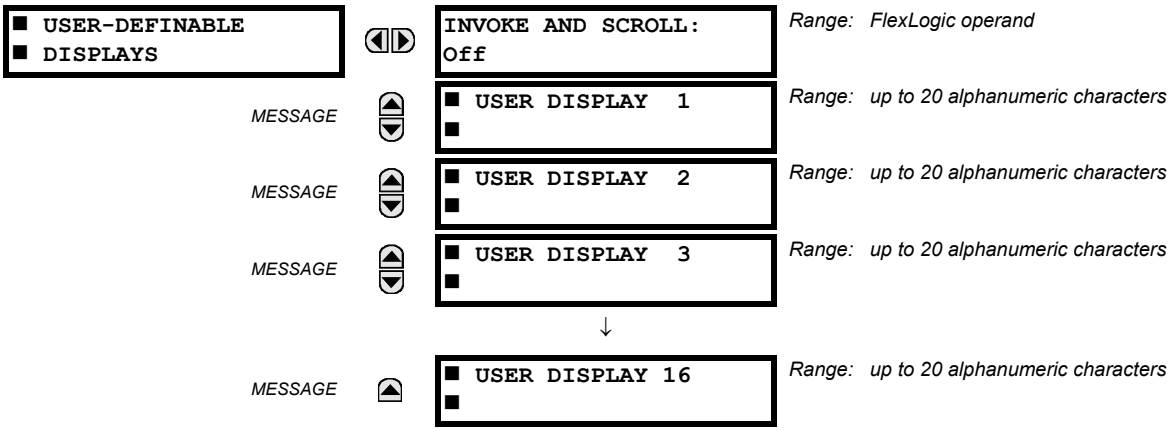
This feature provides a mechanism where any of 256 selected FlexLogic operand states can be used for efficient monitoring. The feature allows user-customized access to the FlexLogic operand states in the relay. The state bits are packed so that 16 states may be read out in a single Modbus register. The state bits can be configured so that all of the states which are of interest to the user are available in a minimum number of Modbus registers.

The state bits may be read out in the "Flex States" register array beginning at Modbus address 0900h. Sixteen states are packed into each register, with the lowest-numbered state in the lowest-order bit. There are 16 registers to accommodate the 256 state bits.

### 5.2.15 USER-DEFINABLE DISPLAYS

#### a) MAIN MENU

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-DEFINABLE DISPLAYS




This menu provides a mechanism for manually creating up to 16 user-defined information displays in a convenient viewing sequence in the **USER DISPLAYS** menu (between the **TARGETS** and **ACTUAL VALUES** top-level menus). The sub-menus facilitate text entry and Modbus register data pointer options for defining the user display content.

Once programmed, the user-definable displays can be viewed in two ways.

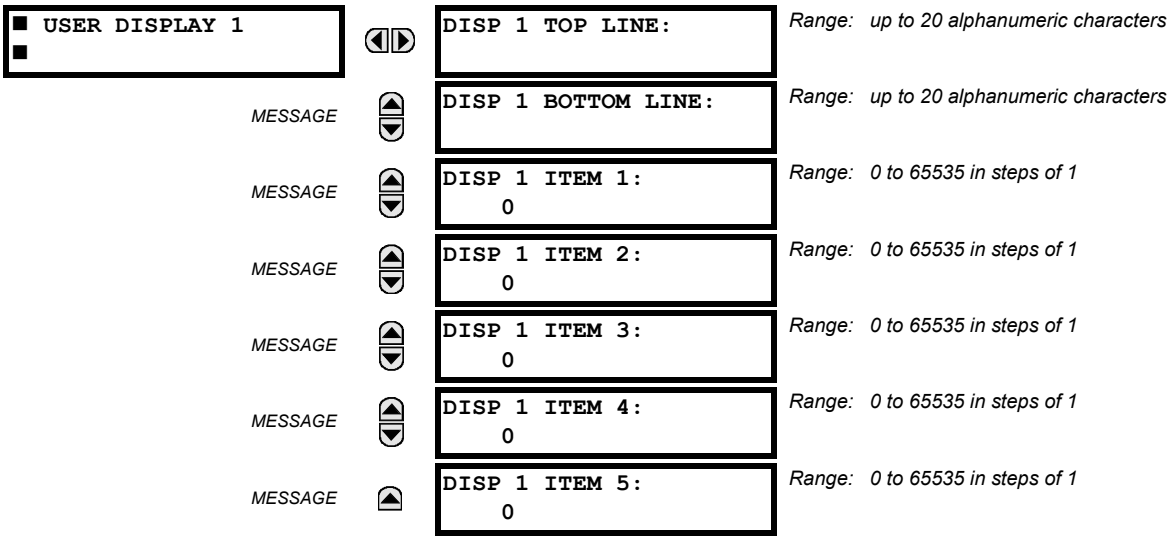
- **KEYPAD**: Use the MENU key to select the **USER DISPLAYS** menu item to access the first user-definable display (note that only the programmed screens are displayed). The screens can be scrolled using the UP and DOWN keys. The display disappears after the default message time-out period specified by the **PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES ⇨⇩ DEFAULT MESSAGE TIMEOUT** setting.
- **USER-PROGRAMMABLE CONTROL INPUT**: The user-definable displays also respond to the **INVOKE AND SCROLL** setting. Any FlexLogic operand (in particular, the user-programmable pushbutton operands), can be used to navigate the programmed displays.

  On the rising edge of the configured operand (such as when the pushbutton is pressed), the displays are invoked by showing the last user-definable display shown during the previous activity. From this moment onward, the operand acts exactly as the down key and allows scrolling through the configured displays. The last display wraps up to the first one. The **INVOKE AND SCROLL** input and the DOWN key operate concurrently.

  When the default timer expires (set by the **DEFAULT MESSAGE TIMEOUT** setting), the relay will start to cycle through the user displays. The next activity of the **INVOKE AND SCROLL** input stops the cycling at the currently displayed user display, not at the first user-defined display. The **INVOKE AND SCROLL** pulses must last for at least 250 ms to take effect.

### b) USER DISPLAY 1 THROUGH 16

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-DEFINABLE DISPLAYS ⇨ USER DISPLAY 1(16)




Any existing system display can be automatically copied into an available user display by selecting the existing display and pressing the ENTER key. The display will then prompt **ADD TO USER DISPLAY LIST?**. After selecting "Yes", a message indicates that the selected display has been added to the user display list. When this type of entry occurs, the sub-menus are automatically configured with the proper content – this content may subsequently be edited.

This menu is used to enter user-defined text and user-selected Modbus-registered data fields into the particular user display. Each user display consists of two 20-character lines (top and bottom). The tilde (~) character is used to mark the start of a data field – the length of the data field needs to be accounted for. Up to five separate data fields can be entered in a user display – the *n*th tilde (~) refers to the *n*th item.

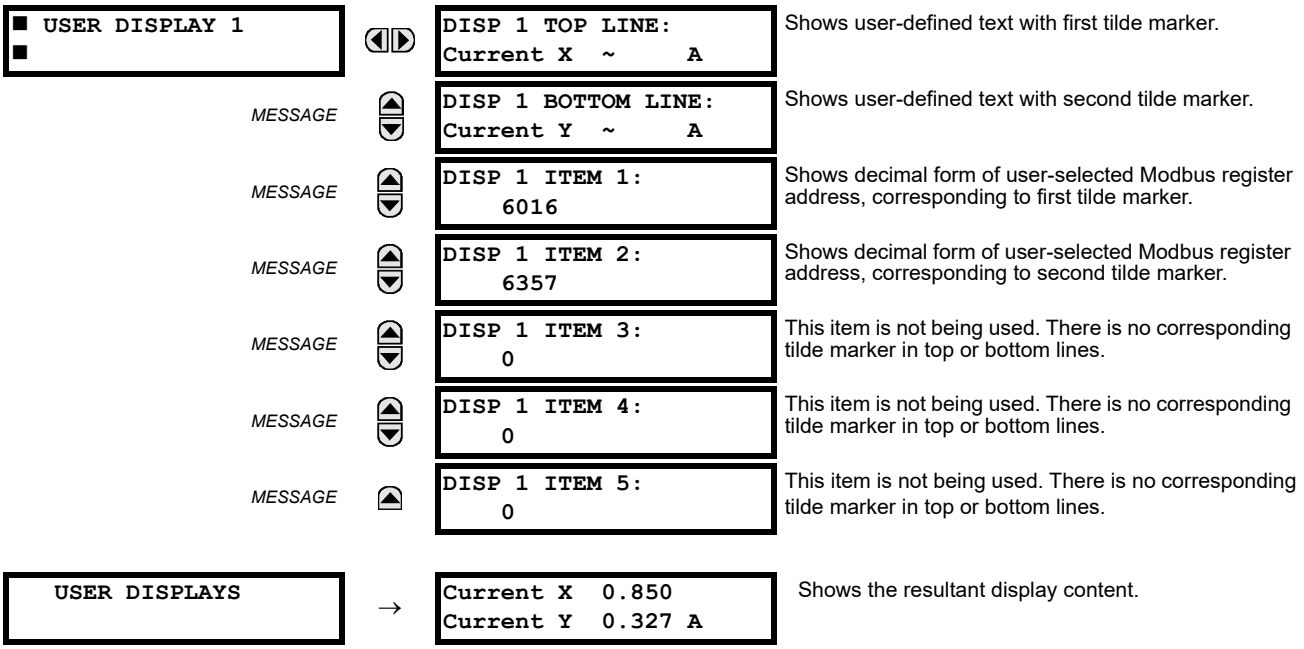
A user display may be entered from the faceplate keypad or the EnerVista UR Setup interface (preferred for convenience). The following procedure shows how to enter text characters in the top and bottom lines from the faceplate keypad:

1. Select the line to be edited.
2. Press the decimal key to enter text edit mode.
3. Use either VALUE key to scroll through the characters. A space is selected like a character.
4. Press the decimal key to advance the cursor to the next position.
5. Repeat step 3 and continue entering characters until the desired text is displayed.
6. The HELP key may be pressed at any time for context sensitive help information.
7. Press the ENTER key to store the new settings.

To enter a numerical value for any of the five items (the *decimal form* of the selected Modbus address) from the faceplate keypad, use the number keypad. Use the value of "0" for any items not being used. Use the HELP key at any selected system display (setting, actual value, or command) which has a Modbus address, to view the *hexadecimal form* of the Modbus address, then manually convert it to decimal form before entering it (EnerVista UR Setup usage conveniently facilitates this conversion).

Use the MENU key to go to the user displays menu to view the user-defined content. The current user displays will show in sequence, changing every four seconds. While viewing a user display, press the ENTER key and then select the 'Yes" option to remove the display from the user display list. Use the MENU key again to exit the user displays menu.

An example of user display setup and result is shown below:

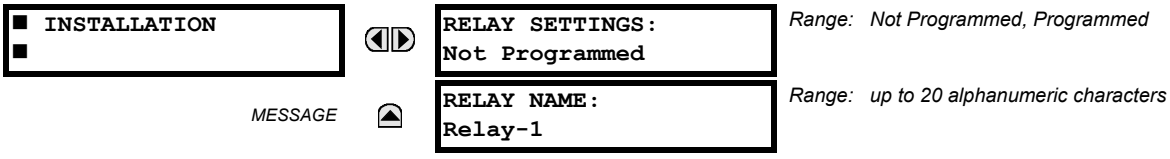



NOTE If the parameters for the top line and the bottom line items have the same units, then the unit is displayed on the bottom line only. The units are only displayed on both lines if the units specified both the top and bottom line items are different.

5

### 5.2.16 INSTALLATION

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ INSTALLATION**




To safeguard against the installation of a relay without any entered settings, the unit will not allow signaling of any output relay until **RELAY SETTINGS** is set to "Programmed". This setting is defaulted to "Not Programmed" when at the factory. The **UNIT NOT PROGRAMMED** self-test error message is displayed until the relay is put into the "Programmed" state.

The **RELAY NAME** setting allows the user to uniquely identify a relay. This name will appear on generated reports.

### 5.3.1 REMOTE RESOURCES CONFIGURATION

When L30 is ordered with a process card module as a part of HardFiber system, then an additional **Remote Resources** menu tree is available in EnerVista UR Setup software to allow configuration of the HardFiber system.

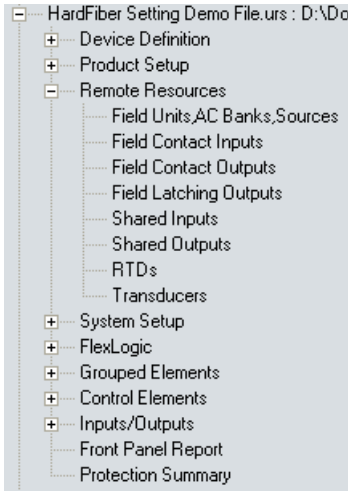



**Figure 5–17: REMOTE RESOURCES CONFIGURATION MENU**



The remote resources settings configure a L30 with a process bus module to work with HardFiber *Bricks*. Remote resources configuration is only available through the EnerVista UR Setup software, and is not available through the L30 front panel. A Brick provides eight AC measurements, along with contact inputs, DC analog inputs, and contact outputs, to be the remote interface to field equipment such as circuit breakers and transformers. The L30 with a process bus module has access to all of the capabilities of up to eight Bricks. Remote resources settings configure the point-to-point connection between specific fiber optic ports on the L30 process card and specific Brick. The relay is then configured to measure specific currents, voltages and contact inputs from those Bricks, and to control specific outputs.

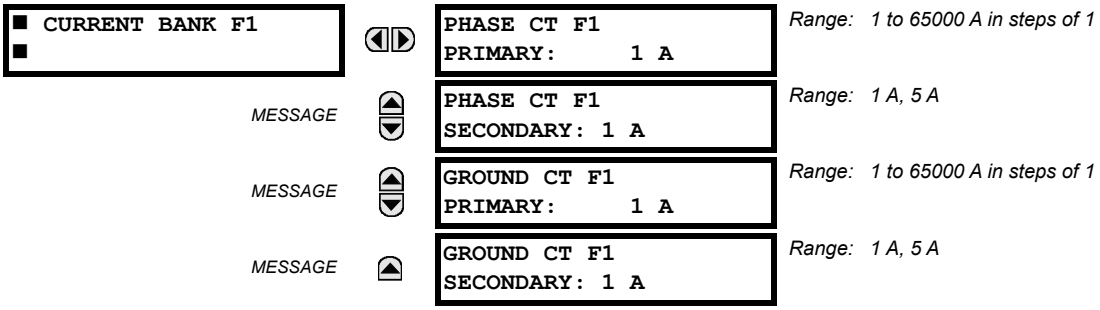
The configuration process for remote resources is straightforward and consists of the following steps.

- *Configure the field units*. This establishes the point-to-point connection between a specific port on the relay process bus module, and a specific digital core on a specific Brick. This is a necessary first step in configuring a process bus relay.
- *Configure the AC banks*. This sets the primary and secondary quantities and connections for currents and voltages. AC bank configuration also provides a provision for redundant measurements for currents and voltages, a powerful reliability improvement possible with process bus.
- *Configure signal sources*. This functionality of the L30 has not changed other than the requirement to use currents and voltages established by AC bank configuration under the remote resources menu.
- *Configure field contact inputs, field contact outputs, RTDs, and transducers as required for the application's functionality*. These inputs and outputs are the physical interface to circuit breakers, transformers, and other equipment. They replace the traditional contact inputs and outputs located at the relay to virtually eliminate copper wiring.
- *Configure shared inputs and outputs as required for the application's functionality*. Shared inputs and outputs are distinct binary channels that provide high-speed protection quality signaling between relays through a Brick.

For additional information on how to configure a relay with a process bus module, see GE publication number GEK-113658: HardFiber Process Bus System Instruction Manual.

### a) CURRENT BANKS

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨ CURRENT BANK F1(F5)




Four banks of phase and ground CTs can be set, where the current banks are denoted in the following format (*X* represents the module slot position letter):

***Xa***, where ***X*** = {**F**} and ***a*** = {**1**, **5**}

See the Introduction to AC Sources section at the beginning of this chapter for details.

These settings are critical for all features that have settings dependent on current measurements. When the relay is ordered, the CT module must be specified to include a standard or sensitive ground input. As the phase CTs are connected in wye (star), the calculated phasor sum of the three phase currents (IA + IB + IC = neutral current = 3I0) is used as the input for the neutral overcurrent elements. In addition, a zero-sequence (core balance) CT which senses current in all of the circuit primary conductors, or a CT in a neutral grounding conductor can also be used. For this configuration, the ground CT primary rating must be entered. To detect low level ground fault currents, the sensitive ground input can be used. In this case, the sensitive ground CT primary rating must be entered. Refer to chapter 3 for more details on CT connections.

Enter the rated CT primary current values. For both 1000:5 and 1000:1 CTs, the entry would be 1000. For correct operation, the CT secondary rating must match the setting (which must also correspond to the specific CT connections used).

The following example illustrates how multiple CT inputs (current banks) are summed as one source current. Given the following current banks:

- F1: CT bank with 500:1 ratio.
- F5: CT bank with 1000:1 ratio

The following rule applies:

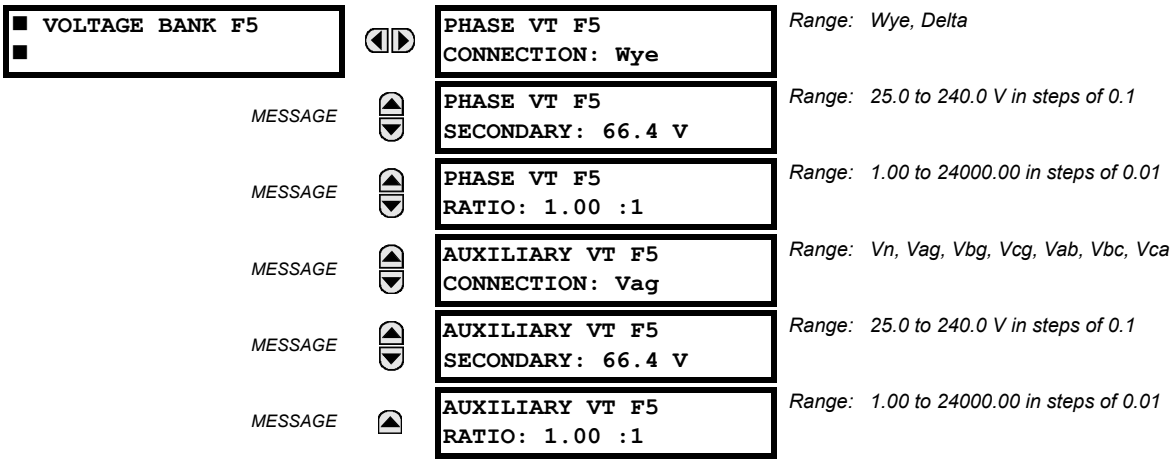
$$\text{SRC 1} = \text{F1} + \text{F5} \quad \textbf{(EQ 5.6)}$$

1 pu is the highest primary current. In this case, 1000 is entered and the secondary current from the 500:1 and 800:1 ratio CTs will be adjusted to that created by a 1000:1 CT before summation. If a protection element is set up to act on SRC 1 currents, then a pickup level of 1 pu will operate on 1000 A primary.

The same rule applies for current sums from CTs with different secondary taps (5 A and 1 A).

### b) VOLTAGE BANKS

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK F5




Two banks of phase/auxiliary VTs can be set, where voltage banks are denoted in the following format (*X* represents the module slot position letter):

***Xa***, where ***X*** = {**F**} and ***a*** = {**5**}

See the Introduction to AC Sources section at the beginning of this chapter for details.

With VTs installed, the relay can perform voltage measurements as well as power calculations. Enter the **PHASE VT F5 CONNECTION** made to the system as "Wye" or "Delta". An open-delta source VT connection would be entered as "Delta".

NOTE

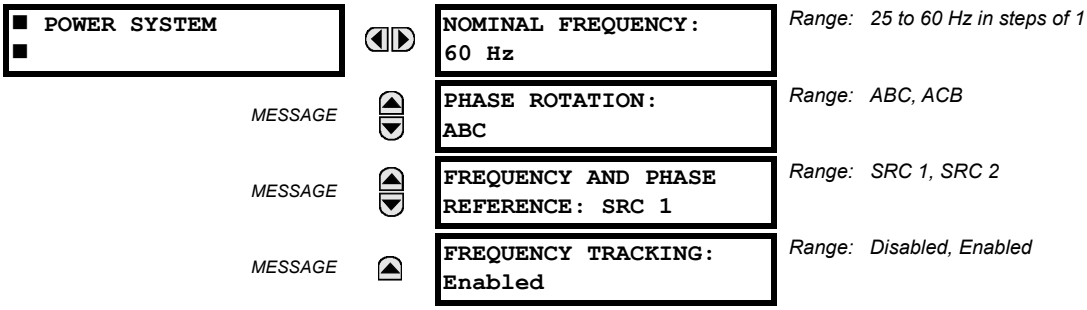
The nominal **PHASE VT F5 SECONDARY** voltage setting is the voltage across the relay input terminals when nominal voltage is applied to the VT primary.

For example, on a system with a 13.8 kV nominal primary voltage and with a 14400:120 volt VT in a delta connection, the secondary voltage would be 115; that is, (13800 / 14400) × 120. For a wye connection, the voltage value entered must be the phase to neutral voltage which would be 115 / $\sqrt{3}$ = 66.4.

On a 14.4 kV system with a delta connection and a VT primary to secondary turns ratio of 14400:120, the voltage value entered would be 120; that is, 14400 / 120.

## 5.4.2 POWER SYSTEM

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM




The power system **NOMINAL FREQUENCY** value is used as a default to set the digital sampling rate if the system frequency cannot be measured from available signals. This may happen if the signals are not present or are heavily distorted. Before reverting to the nominal frequency, the frequency tracking algorithm holds the last valid frequency measurement for a safe period of time while waiting for the signals to reappear or for the distortions to decay. After changing this setting, restart the relay using **Maintenance > Reboot Relay Command**.

NOTE

The nominal system frequency should be selected as 50 Hz or 60 Hz only. The **FREQUENCY AND PHASE REFERENCE** setting, used as a reference for calculating all angles, must be identical for all terminals. Whenever the 87L function is "Enabled", the frequency tracking function is disabled, and frequency tracking is driven by the L30 algorithm (see the Theory of Operation chapter). Whenever the 87L function is "Disabled", the frequency tracking mechanism reverts to the UR-series mechanism which uses the **FREQUENCY TRACKING** setting to provide frequency tracking for all other elements and functions.

The phase sequence of the power system is required to properly calculate sequence components and power parameters. The **PHASE ROTATION** setting matches the power system phase sequence. Note that this setting informs the relay of the actual system phase sequence, either ABC or ACB. CT and VT inputs on the relay, labeled as A, B, and C, must be connected to system phases A, B, and C for correct operation.

The **FREQUENCY AND PHASE REFERENCE** setting determines which signal source is used (and hence which AC signal) for phase angle reference. The AC signal used is prioritized based on the AC inputs that are configured for the signal source: phase voltages takes precedence, followed by auxiliary voltage, then phase currents, and finally ground current.

For three phase selection, phase A is used for angle referencing ($V_{\text{ANGLE REF}} = V_A$), while Clarke transformation of the phase signals is used for frequency metering and tracking ($V_{\text{FREQUENCY}} = (2V_A - V_B - V_C)/3$) for better performance during fault, open pole, and VT and CT fail conditions.

The phase reference and frequency tracking AC signals are selected based upon the Source configuration, regardless of whether or not a particular signal is actually applied to the relay.

Phase angle of the reference signal always displays zero degrees and all other phase angles are relative to this signal. If the pre-selected reference signal is not measurable at a given time, the phase angles are not referenced.

The phase angle referencing is done via a phase locked loop, which can synchronize independent UR-series relays if they have the same AC signal reference. This results in very precise correlation of phase angle indications between different UR-series relays.



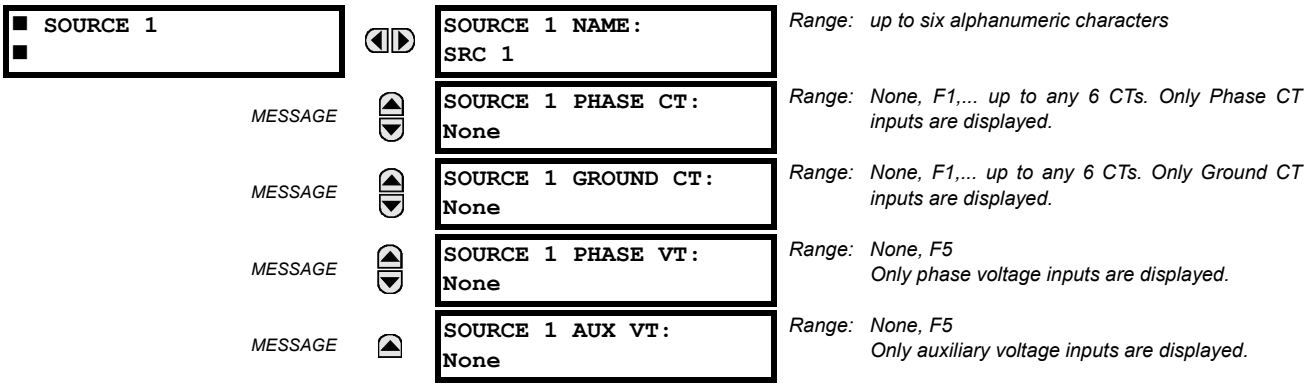
NOTE

**FREQUENCY TRACKING** is set to **"**Disabled**"** only in unusual circumstances; consult the factory for special variable-frequency applications.

The frequency tracking feature functions only when the L30 is in the "Programmed" mode. If the L30 is "Not Programmed", then metering values are available but can exhibit significant errors.

## 5.4.3 SIGNAL SOURCES

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES ⇨ SOURCE 1(2)**




Identical menus are available for each source. The "SRC 1" text can be replaced by with a user-defined name appropriate for the associated source.

The first letter in the source identifier represents the module slot position. The number directly following this letter represents either the first bank of four channels (1, 2, 3, 4) called "1" or the second bank of four channels (5, 6, 7, 8) called "5" in a particular CT/VT module. See the Introduction to AC Sources section at the beginning of this chapter for details on this concept.

It is possible to select the sum of all CT combinations. The first channel displayed is the CT to which all others will be referred. For example, the selection “F1+F5” indicates the sum of each phase from channels “F1” and “F5”, scaled to whichever CT has the higher ratio. Selecting “None” hides the associated actual values.

The approach used to configure the AC sources consists of several steps; first step is to specify the information about each CT and VT input. For CT inputs, this is the nominal primary and secondary current. For VTs, this is the connection type, ratio and nominal secondary voltage. Once the inputs have been specified, the configuration for each source is entered, including specifying which CTs are summed together.

**User selection of AC parameters for comparator elements:**

CT/VT modules automatically calculate all current and voltage parameters from the available inputs. Users must select the specific input parameters to be measured by every element in the relevant settings menu. The internal design of the element specifies which type of parameter to use and provides a setting for source selection. In elements where the parameter may be either fundamental or RMS magnitude, such as phase time overcurrent, two settings are provided. One setting specifies the source, the second setting selects between fundamental phasor and RMS.

**AC input actual values:**

The calculated parameters associated with the configured voltage and current inputs are displayed in the current and voltage sections of actual values. Only the phasor quantities associated with the actual AC physical input channels will be displayed here. All parameters contained within a configured source are displayed in the sources section of the actual values.

**DISTURBANCE DETECTORS (INTERNAL):**

The disturbance detector (ANSI 50DD) element is a sensitive current disturbance detector that detects any disturbance on the protected system. The 50DD function is used directly in some elements in the relay, for example VT Fuse Failure detector or Fault Report. It can also be used to supervise current-based elements to prevent maloperation as a result of the wrong settings or external CT wiring problem. A disturbance detector is provided for each source.



The 50DD function responds to the changes in magnitude of the sequence currents. The disturbance detector scheme logic is as follows:

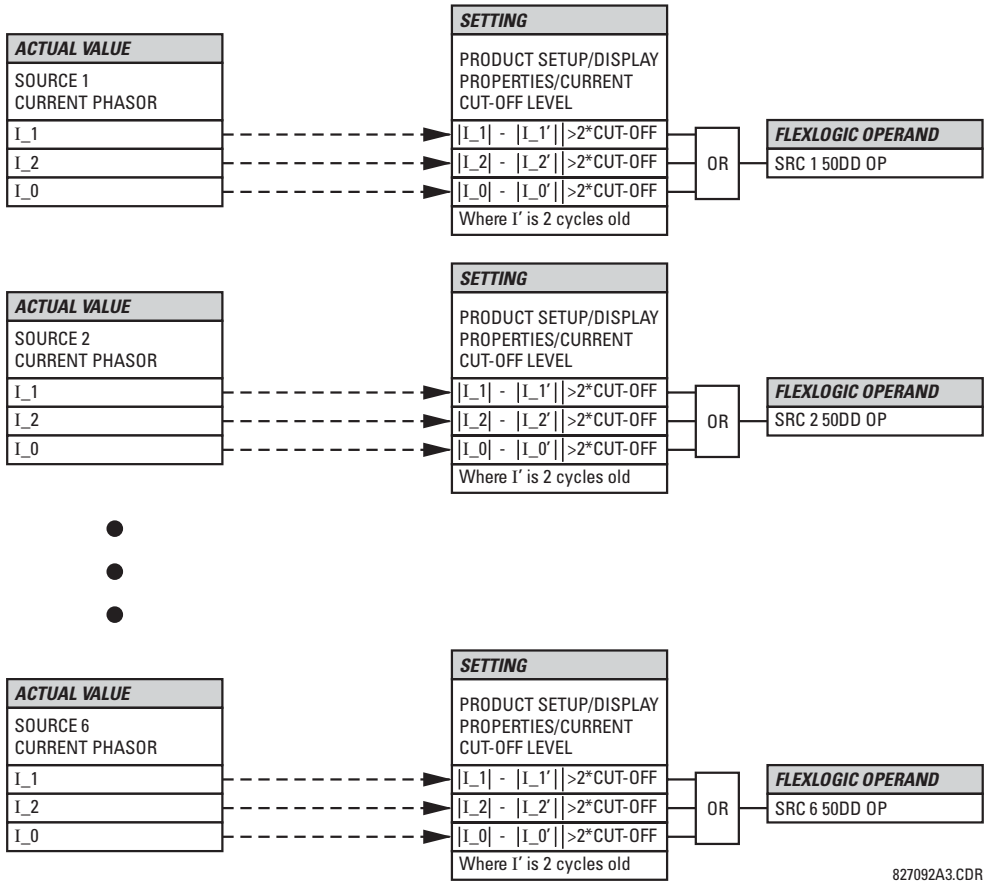



**Figure 5–18: DISTURBANCE DETECTOR LOGIC DIAGRAM**

The disturbance detector responds to the change in currents of twice the current cut-off level. The default cut-off threshold is 0.02 pu; thus by default the disturbance detector responds to a change of 0.04 pu. The metering sensitivity setting (**PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES ⇨⇩ CURRENT CUT-OFF LEVEL**) controls the sensitivity of the disturbance detector accordingly.

**EXAMPLE USE OF SOURCES:**

An example of the use of sources is shown in the diagram below. A relay could have the following hardware configuration:

| ***INCREASING SLOT POSITION LETTER -->*** | | |
|---|---|---|
| **CT/VT MODULE 1** | **CT/VT MODULE 2** | **CT/VT MODULE 3** |
| CTs | VTs | not applicable |

This configuration could be used on a two-winding transformer, with one winding connected into a breaker-and-a-half system. The following figure shows the arrangement of sources used to provide the functions required in this application, and the CT/VT inputs that are used to provide the data.

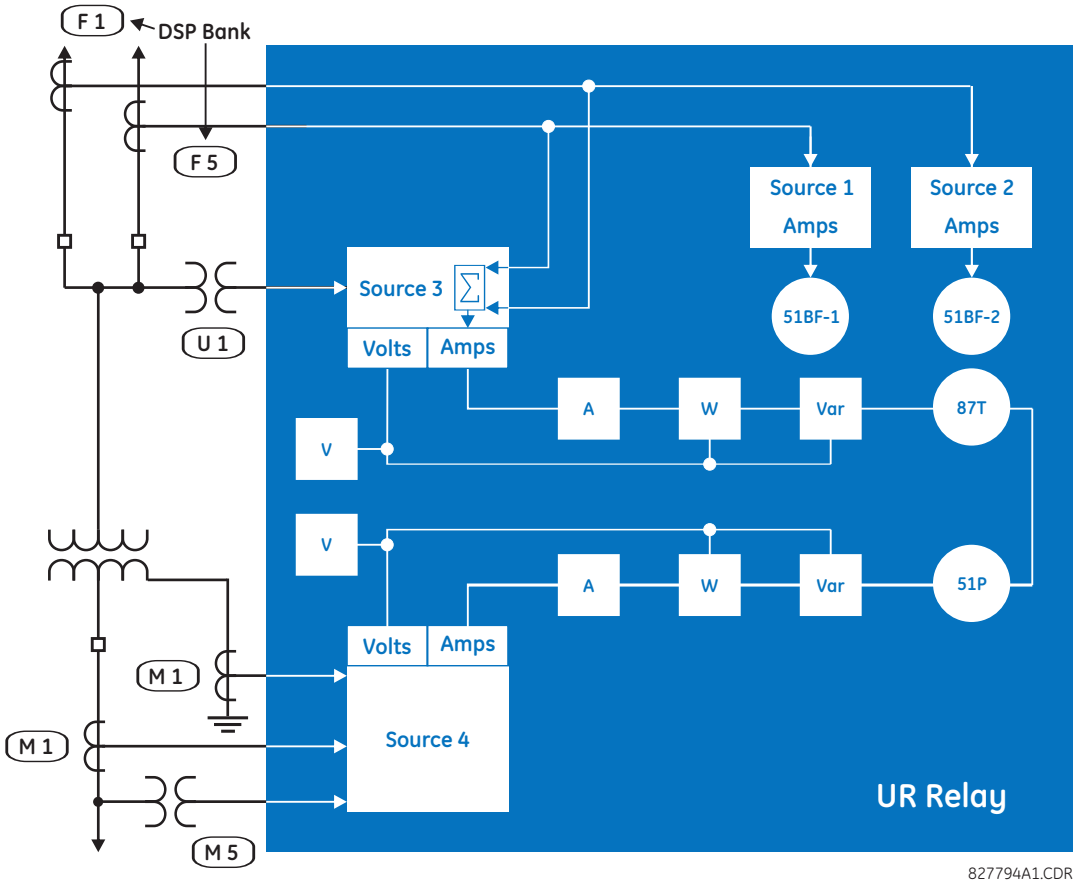
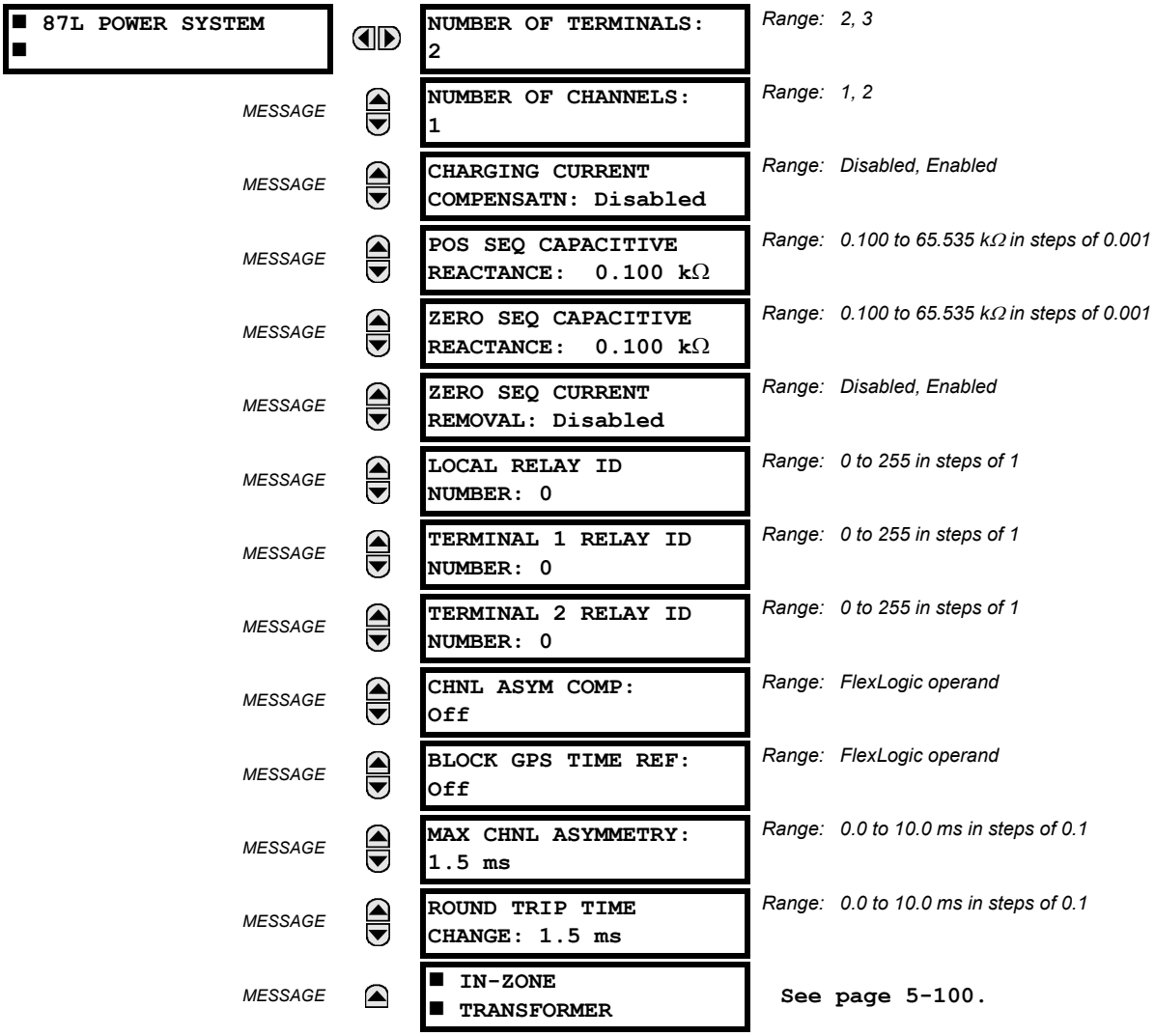



Figure 5–19: EXAMPLE USE OF SOURCES

| | Y LV | D HV | AUX |
|---|---|---|---|
| | SRC 1 | SRC 2 | SRC 3 |
| Phase CT | M1 | F1+F5 | None |
| Ground CT | M1 | None | None |
| Phase VT | M5 | None | None |
| Aux VT | None | None | U1 |

### a) MAIN MENU

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ 87L POWER SYSTEM




NOTE

Any changes to the L30 power system settings change the protection system configuration. As such, the 87L protection at all L30 protection system terminals must be temporarily disabled to allow the relays to acknowledge the new settings.

- **NUMBER OF TERMINALS:** This setting is the number of the terminals of the associated protected line.
- **NUMBER OF CHANNELS:** This setting should correspond to the type of communications module installed. If the relay is applied on two terminal lines with a single communications channel, this setting should be selected as "1". For a two terminal line with a second redundant channel for increased dependability, or for three terminal line applications, this setting should be selected as "2".
- **CHARGING CURRENT COMPENSATION:** This setting enables and disables the charging current calculations and corrections of current phasors. The voltage signals used for charging current compensation are taken from the source assigned with the **CURRENT DIFF SIGNAL SOURCE 1** setting. As such, it's critical to ensure that three-phase line voltage is assigned to this source. The following diagram shows possible configurations.

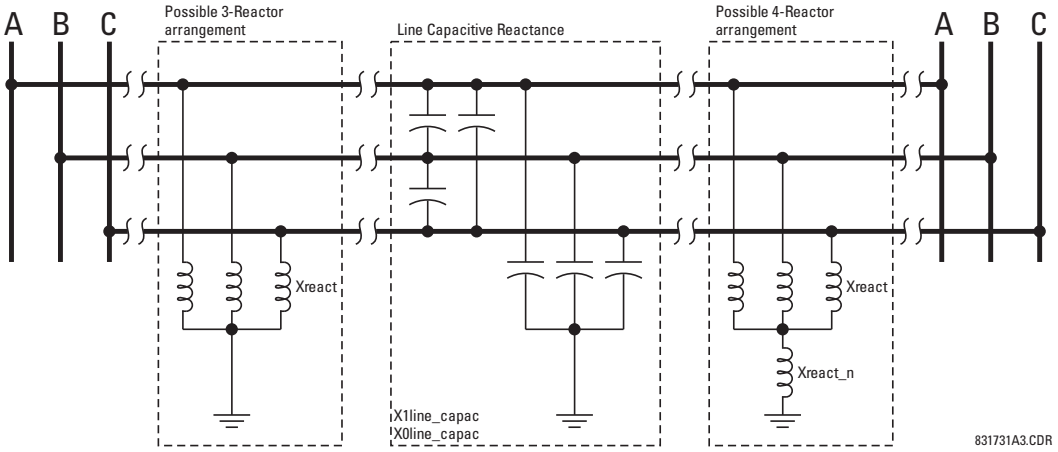



**Figure 5–20: CHARGING CURRENT COMPENSATION CONFIGURATIONS**

- **POSITIVE and ZERO SEQUENCE CAPACITIVE REACTANCE:** The values of positive and zero-sequence capacitive reactance of the protected line are required for charging current compensation calculations. The line capacitive reactance values should be entered in **primary kohms** for the total line length. Details of the charging current compensation algorithm can be found in Chapter 8: *Theory of operation*.

  If shunt reactors are also installed on the line, the resulting value entered in the **POS SEQ CAPACITIVE REACTANCE** and **ZERO SEQ CAPACITIVE REACTANCE** settings should be calculated as follows:

  1. **Three-reactor arrangement:** three identical line reactors ($X_{react}$) solidly connected phase to ground:

$$X_{C1} = \frac{X_{1line\_capac} \cdot X_{react}}{X_{react} - X_{1line\_capac}} \quad , X_{C0} = \frac{X_{0line\_capac} \cdot X_{react}}{X_{react} - X_{0line\_capac}} \qquad \textbf{(EQ 5.7)}$$

  2. **Four-reactor arrangement:** three identical line reactors ($X_{react}$) wye-connected with the fourth reactor ($X_{react\_n}$) connected between reactor-bank neutral and the ground.

$$X_{C1} = \frac{X_{1line\_capac} \cdot X_{react}}{X_{react} - X_{1line\_capac}} \quad , X_{C0} = \frac{X_{0line\_capac} \cdot (X_{react} + 3X_{react\_n})}{X_{react} + 3X_{react\_n} - X_{0line\_capac}} \qquad \textbf{(EQ 5.8)}$$

  $X_{1line\_capac}$ = the total line positive-sequence capacitive reactance
  $X_{0line\_capac}$ = the total line zero-sequence capacitive reactance
  $X_{react}$ = the total reactor inductive reactance per phase. If identical reactors are installed at both line ends, the value of the inductive reactance is divided by 2 (or 3 for a three-terminal line) before using in the above equations. If the reactors installed at both ends of the line are different, the following equations apply:

  1. **For 2 terminal line:** $X_{react} = 1 \Big/ \left( \frac{1}{X_{react\_terminal1}} + \frac{1}{X_{react\_terminal2}} \right)$
  2. **For 3 terminal line:** $X_{react} = 1 \Big/ \left( \frac{1}{X_{react\_terminal1}} + \frac{1}{X_{react\_terminal2}} + \frac{1}{X_{react\_terminal3}} \right)$

  $X_{react\_n}$ = the total neutral reactor inductive reactance. If identical reactors are installed at both line ends, the value of the inductive reactance is divided by 2 (or 3 for a three-terminal line) before using in the above equations. If the reactors installed at both ends of the line are different, the following equations apply:

  1. **For 2 terminal line:** $X_{react\_n} = 1 \Big/ \left( \frac{1}{X_{react\_n\_terminal1}} + \frac{1}{X_{react\_n\_terminal2}} \right)$
  2. **For 3 terminal line:** $X_{react\_n} = 1 \Big/ \left( \frac{1}{X_{react\_n\_terminal1}} + \frac{1}{X_{react\_\_n\_terminal2}} + \frac{1}{X_{react\_n\_terminal3}} \right)$

NOTE

Charging current compensation calculations should be performed for an arrangement where the VTs are connected to the line side of the circuit; otherwise, opening the breaker at one end of the line will cause a calculation error.

Differential current is significantly decreased when **CHARGING CURRENT COMPENSATION** is "Enabled" and the proper reactance values are entered. The effect of charging current compensation is viewed in the **METERING ⇨⇩ 87L DIFFERENTIAL CURRENT** actual values menu. This effect is very dependent on CT and VT accuracy.

- **ZERO-SEQUENCE CURRENT REMOVAL:** This setting facilitates application of the L30 to transmission lines with one or more tapped transformers without current measurement at the taps. If the tapped transformer is connected in a grounded wye on the line side, it becomes a source of the zero-sequence current for external ground faults. As the transformer current is not measured by the L30 protection system, the zero-sequence current would create a spurious differential signal and may cause a false trip.

  If enabled, this setting forces the L30 to remove zero-sequence current from the phase currents prior to forming their differential signals, ensuring protection stability on external ground faults. However, zero-sequence current removal may cause all three phases to trip for internal ground faults. Consequently, a phase selective operation of the L30 is not retained if the setting is enabled. This does not impose any limitation, as single-pole tripping is not recommended for lines with tapped transformers. Refer to chapter 9 for guidelines.

- **LOCAL (TERMINAL 1 and TERMINAL 2) ID NUMBER:** In installations using multiplexers or modems for communication, it is desirable to ensure the data used by the relays protecting a given line comes from the correct relays. The L30 performs this check by reading the ID number contained in the messages sent by transmitting relays and comparing this ID to the programmed correct ID numbers by the receiving relays. This check is used to block the differential element of a relay, if the channel is inadvertently set to loopback mode, by recognizing its own ID on a received channel. If an incorrect ID is found on a either channel during normal operation, the FlexLogic operand 87 CH1(2) ID FAIL is set, driving the event with the same name. The result of channel identification is also available in **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ VALIDITY OF CHANNEL CONFIGURATION** for commissioning purposes. The default value "0" at local relay ID setting indicates that the channel ID number is not to be checked. Refer to the *Current differential* section in this chapter for additional information.

  For two-terminal applications, only the **LOCAL ID NUMBER** and **TERMINAL 1 ID NUMBER** should be used. The **TERMINAL 2 ID NUMBER** is used for three-terminal applications.

- **CHNL ASYM COMP:** This setting enables/disables channel asymmetry compensation. The compensation is based on absolute time referencing provided by GPS-based clocks via the Precision Time Protocol or IRIG-B. Use this feature on multiplexed channels where channel asymmetry can be expected and which otherwise causes errors in current differential calculations. The feature takes effect if all terminals are provided with reliable GPS clock signals. If the GPS clock signal is lost at any terminal of the current differential protection system, or the real time clock not configured, then the compensation is not calculated. If the compensation is in place prior to losing the GPS time reference, the last (memorized) correction is applied as long as the value of **CHNL ASYM COMP** is "On". See chapter 9 for additional information.

  The GPS-based compensation for channel asymmetry can take three different effects:

  - If the **CHNL ASYM COMP** selected FlexLogic operand is "Off", compensation is not applied and the L30 uses only the ping-pong technique.
  - If the **CHNL ASYM COMP** selected FlexLogic operand is "On" and all terminals have a valid time reference, then compensation is applied and the L30 effectively uses GPS time referencing tracking channel asymmetry if the latter fluctuates.
  - If **CHNL ASYM COMP** is "On" and not all terminals have a valid time reference, then compensation is not applied (if the system was not compensated prior to the problem), or the memorized (last valid) compensation is used if compensation was in effect prior to the problem.

  A terminal is considered to have a valid time reference while the BLOCK GPS TIME REF selected FlexLogic operand is Off and the LOCAL GPS TROUBLE signal is Off. The LOCAL GPS TROUBLE signal is On if the real time clock is not locked to global time via PP, PTP, or DC Shift IRIG-B. It is also On if locked via Amplitude Modulated IRIG-B, and if locked via PP or PTP and indicated clock accuracy is less than 250 µs.

The **CHNL ASYM COMP** setting dynamically turns the GPS compensation on and off. A FlexLogic operand that combines several factors is typically used. The L30 protection system does not incorporate any pre-defined way of treating certain conditions, such as failure of the GPS receiver, loss of satellite signal, channel asymmetry prior to the loss of reference time, or change of the round trip time prior to loss of the time reference. Virtually any philosophy can be programmed by selecting the **CHNL ASYM COMP** setting. Factors to consider are:

- *Fail-safe output of the GPS receiver*. Some receivers may be equipped with the fail-safe output relay. The L30 system requires a maximum error of 250 μs. The fail-safe output of the GPS receiver may be connected to the local L30 via an input contact. In the case of GPS receiver fail, the channel compensation function can be effectively disabled by using the input contact in conjunction with the **BLOCK GPS TIME REF** (GPS) setting.
- *Channel asymmetry prior to losing the GPS time reference*. This value is measured by the L30 and a user-programmable threshold is applied to it. The corresponding FlexLogic operands are produced if the asymmetry is above the threshold (87L DIFF MAX 1 ASYM and 87L DIFF 2 MAX ASYM). These operands can be latched in FlexLogic and combined with other factors to decide, upon GPS loss, if the relays continue to compensate using the memorized correction. Typically, one may decide to keep compensating if the pre-existing asymmetry was low.
- *Change in the round trip travel time*. This value is measured by the L30 and a user-programmable threshold applied to it. The corresponding FlexLogic operands are produced if the delta change is above the threshold (87L DIFF 1 TIME CHNG and 87L DIFF 2 TIME CHNG). These operands can be latched in FlexLogic and combined with other factors to decide, upon GPS loss, if the relays continue to compensate using the memorized correction. Typically, one may decide to disable compensation if the round trip time changes.

- **BLOCK GPS TIME REF:** This setting signals to the L30 that the time reference is not valid. The time reference may be not accurate due to problems with the GPS receiver. The user must to be aware of the case when a GPS satellite receiver loses its satellite signal and reverts to its own calibrated crystal oscillator. In this case, accuracy degrades in time and may eventually cause relay misoperation. Verification from the manufacturer of receiver accuracy not worse than 250 μs and the presence of an alarm contact indicating loss of the satellite signal is strongly recommended. If the time reference accuracy cannot be guaranteed, it should be relayed to the L30 via contact inputs and GPS compensation effectively blocked using the contact position in conjunction with the **BLOCK GPS TIME REF** setting. This setting is typically a signal from the GPS receiver signaling problems or time inaccuracy.

  Some GPS receivers can supply erroneous IRIG-B signals during power-up and before locking to satellites. If the receiver's failsafe contact opens during power-up (allowing for an erroneous IRIG-B signal), then set a dropout delay up to 15 minutes (depending on GPS receiver specifications) to the failsafe contact via FlexLogic to prevent incorrect relay response.
- **MAX CHNL ASYMMETRY:** This setting detects excessive channel asymmetry. The same threshold is applied to both the channels, while the following per-channel FlexLogic operands are generated: 87L DIFF 1 MAX ASYM and 87L DIFF 2 MAX ASYM. These operands can be used to alarm on problems with communication equipment and/or to decide whether channel asymmetry compensation remains in operation should the GPS-based time reference be lost. Channel asymmetry is measured if both terminals of a given channel have valid time reference.

  If the memorized asymmetry value is much greater than expected (indicating a significant problem with GPS clock timing), then this operand can be also used to block GPS compensation, forcing the relay to use the memorized asymmetry value.
- **ROUND TRIP TIME CHANGE:** This setting detects changes in round trip time. This threshold is applied to both channels, while the 87L DIFF 1 TIME CHNG and 87L DIFF 2 TIME CHNG ASYM per-channel FlexLogic operands are generated. These operands can be used to alarm on problems with communication equipment and/or to decide whether channel asymmetry compensation remains in operation should the GPS-based time reference be lost.
- **LOCAL GPS TROUBLE**: This signal is On when any of the following conditions are present:
  - The best clock selector (BCS) selection is none or SNTP
  - The BCS selection is IRIG-B and the IRIG-B SIGNAL TYPE setting is Amplitude Modulated
  - The RTC and/or the synchrophasor clock are not synchronized to the selected synchronizing source. This can possibly occur on power up, when transferring between sources, and when the selected source's holdover timer times out.
  - The quality bits in the messages from the a PTP source used for synchronizing indicate worst-case error greater than 250 μs, or accuracy less than 250 μs, or unknown accuracy/error (that is, not locked to an international time standard). Apply 2 security counts (2 seconds) to both set and reset of this operand when change is based on accuracy. There is no corresponding quality test for IRIG-B sources here.

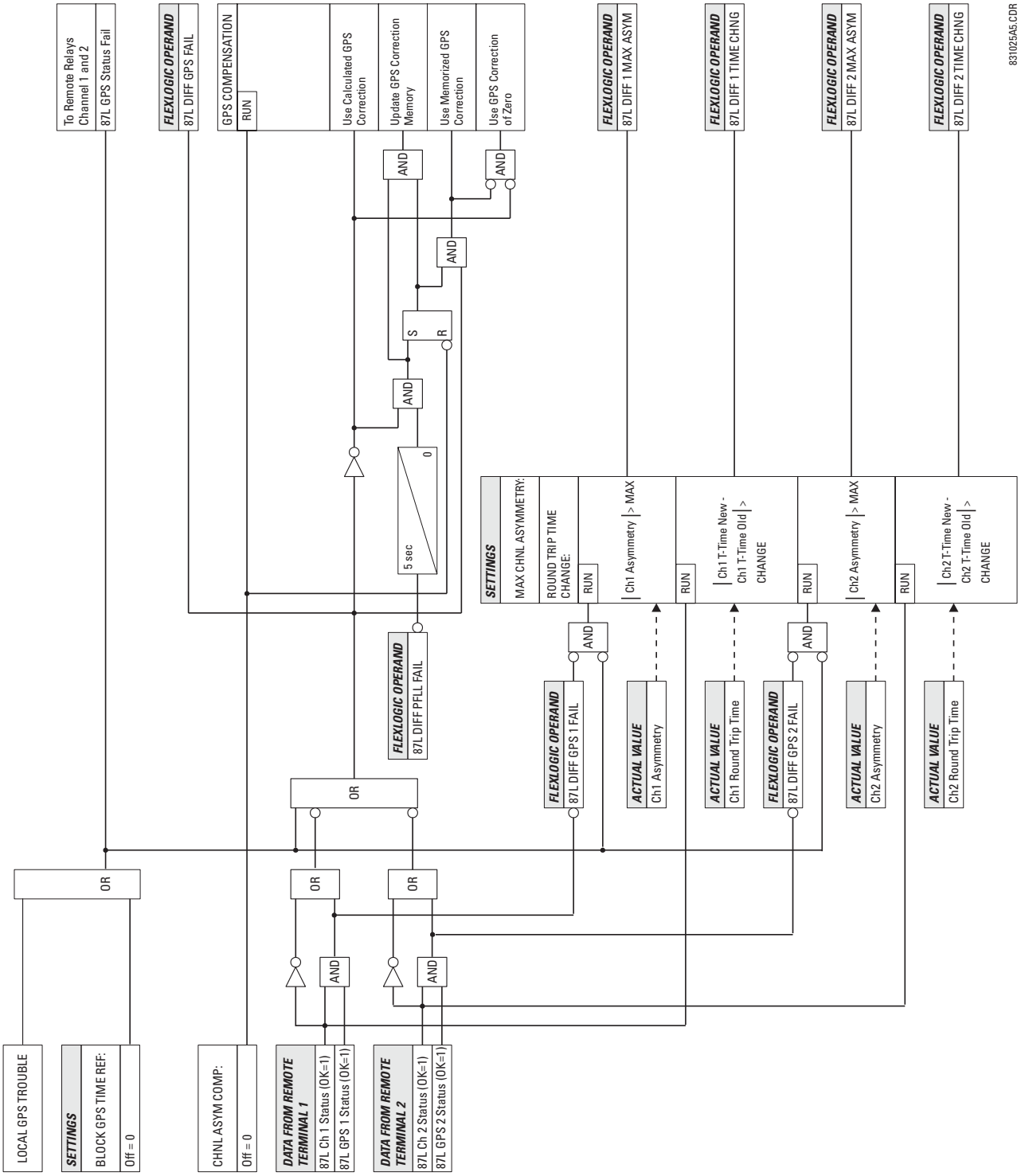



**Figure 5–21: CHANNEL ASYMMETRY COMPENSATION LOGIC**

### b) IN-ZONE TRANSFORMER

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ 87L POWER SYSTEM ⇨⇩ IN-ZONE TRANSFORMER

```
■ IN-ZONE
■ TRANSFORMER
```

MESSAGE

```
IN-ZONE TRANSFORMER
CONNECTION: None
```

*Range: None, 0 to 330° lag in steps of 30°*

```
TRANSFORMER LOCATION:
Local-Tap
```

*Range: Local-Tap, Rem1-Tap, Rem2-Tap*

The in-zone transformer settings described below ensure that the 87L element correctly applies magnitude and phase compensation for the in-zone transformer. To accommodate for the difference in CT ratios at line terminals, the SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ LINE DIFFERENTIAL ELEMENTS ⇨ CURRENT DIFFERENTIAL ⇨⇩ CURRENT DIFF CT TAP setting should be used. It is important to properly program the in-zone transformer setting for all terminals to ensure correct 87L performance.

- **IN-ZONE TRANSFORMER CONNECTION**: This setting is used to indicate the presence and group connection of the in-zone transformer. The winding angle selection specifies the phase shift of the remote terminal side winding with respect to the local terminal side winding. For example, for the Dy1 group where the delta winding is connected to the local terminal side, and wye winding is connected to the remote terminal side, you need to select “30° lag” for the local terminal side. (At the remote terminal relay, select “330° lag” for this transformer group connection.) If there is no in-zone transformer connected, then program this setting as “None” (note that the “0° lag” value does not correspond to “None”). Only one in-zone transformer is allowed for both two-terminal and three-terminal applications. Enabling in-zone transformer functionality forces the L30 to automatically remove the zero-sequence component from all terminals currents. It also disables ground differential 87LG functionality and zero-sequence current removal functionality defined by the **ZERO SEQ CURRENT REMOVAL** setting.

  The In-Zone Transformer software option enables line differential devices to support a power transformer between line terminals. If there is no power transformer between terminals, none of the L30 relays should have the In-zone transformer software option. UR firmware versions 6.06, 7.20, and later allow using devices with In-Zone Tx on one terminal and without In-Zone Tx on the other terminals on schemes with no power transformer between line terminals, provided devices with In-Zone Tx are set to "TX connection = None."

- **TRANSFORMER LOCATION**: This setting selects the transformer location and is applicable only if the **TRANSFORMER CONNECTION** setting is not programmed as “None”.
  - Select the “Local-Tap” value if the transformer is present between the local terminal and the tap point or for two-terminal applications.
  - Select the “Rem1-Tap” if the transformer is present between remote terminal 1 and the tap point.
  - Select the “Rem2-Tap” if the transformer is present between remote terminal 2 and the tap point.

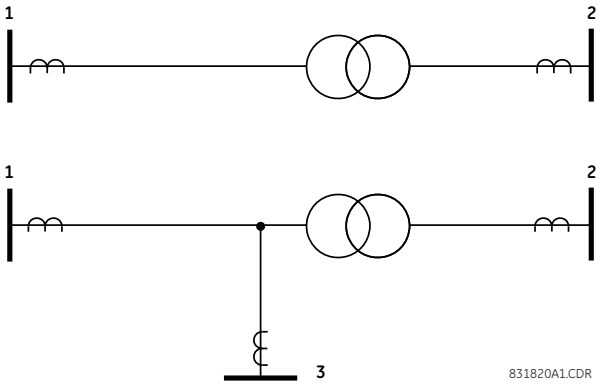



**Figure 5–22: ILLUSTRATION OF IN-ZONE TRANSFORMER FOR TWO-TERMINAL AND THREE-TERMINAL LINES**

NOTE

When the L90 ordered has in-zone functionality, it does not support the multi-ended fault locator.

Do not set the **IN-ZONE TRANSFORMER CONNECTION** setting to "None" at one terminal and set other terminals to a value other than "None." 87L is blocked under these circumstances.

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ BREAKERS ⇨ BREAKER 1(2)

| | | | |
|---|---|---|---|
| ■ BREAKER 1 ■ | | BREAKER 1 FUNCTION: Disabled | Range: Disabled, Enabled |
| | MESSAGE | BREAKER1 PUSH BUTTON CONTROL: Disabled | Range: Disabled, Enabled |
| | MESSAGE | BREAKER 1 NAME: Bkr 1 | Range: up to 6 alphanumeric characters |
| | MESSAGE | BREAKER 1 MODE: 3-Pole | Range: 3-Pole, 1-Pole |
| | MESSAGE | BREAKER 1 OPEN: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER 1 BLK OPEN: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER 1 CLOSE: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER 1 BLK CLOSE: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER1 ΦA/3P CLSD: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER1 ΦA/3P OPND: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER 1 ΦB CLOSED: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER 1 ΦB OPENED: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER 1 ΦC CLOSED: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER 1 ΦC OPENED: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER 1 Toperate: 0.070 s | Range: 0.000 to 65.535 s in steps of 0.001 |
| | MESSAGE | BREAKER 1 EXT ALARM: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER 1 ALARM DELAY: 0.000 s | Range: 0.000 to 65.535 s in steps of 0.001 |
| | MESSAGE | MANUAL CLOSE RECAL1 TIME: 0.000 s | Range: 0.000 to 65.535 s in steps of 0.001 |
| | MESSAGE | BREAKER 1 OUT OF SV: Off | Range: FlexLogic operand |
| | MESSAGE | BREAKER 1 EVENTS: Disabled | Range: Disabled, Enabled |

A description of the operation of the breaker control and status monitoring features is provided in chapter 4. Only information concerning programming of the associated settings is covered here. These features are provided for two or more breakers; a user may use only those portions of the design relevant to a single breaker, which must be breaker 1.

The number of breaker control elements is dependent on the number of CT/VT modules specified with the L30. The following settings are available for each breaker control element.

- **BREAKER 1 FUNCTION:** This setting enables and disables the operation of the breaker control feature.
- **BREAKER1 PUSH BUTTON CONTROL:** Set to "Enable" to allow faceplate push button operations.
- **BREAKER 1 NAME:** Assign a user-defined name (up to six characters) to the breaker. This name will be used in flash messages related to breaker 1.
- **BREAKER 1 MODE:** This setting selects "3-Pole" mode, where all breaker poles are operated simultaneously, or "1-Pole" mode where all breaker poles are operated either independently or simultaneously.
- **BREAKER 1 OPEN:** This setting selects an operand that creates a programmable signal to operate an output relay to open breaker 1.
- **BREAKER 1 BLK OPEN**: This setting selects an operand that prevents opening of the breaker. This setting can be used for select-before-operate functionality or to block operation from a panel switch or from SCADA.
- **BREAKER 1 CLOSE:** This setting selects an operand that creates a programmable signal to operate an output relay to close breaker 1.
- **BREAKER 1 BLK CLOSE**: This setting selects an operand that prevents closing of the breaker. This setting can be used for select-before-operate functionality or to block operation from a panel switch or from SCADA.
- **BREAKER1 ΦA/3P CLOSED:** This setting selects an operand, usually a contact input connected to a breaker auxiliary position tracking mechanism. This input should be a normally-open 52/a status input to create a logic 1 when the breaker is closed. If the **BREAKER 1 MODE** setting is selected as "3-Pole", this setting selects a single input as the operand used to track the breaker open or closed position. If the mode is selected as "1-Pole", the input mentioned above is used to track phase A and the **BREAKER 1 ΦB** and **BREAKER 1 ΦC** settings select operands to track phases B and C, respectively.
- **BREAKER1 ΦA/3P OPND:** This setting selects an operand, usually a contact input, that should be a normally-closed 52/b status input to create a logic 1 when the breaker is open. If a separate 52/b contact input is not available, then the inverted BREAKER 1 CLOSED status signal can be used.
- **BREAKER 1 ΦB CLOSED:** If the mode is selected as three-pole, this setting has no function. If the mode is selected as single-pole, this input is used to track the breaker phase B closed position as above for phase A.
- **BREAKER 1 ΦB OPENED:** If the mode is selected as three-pole, this setting has no function. If the mode is selected as single-pole, this input is used to track the breaker phase B opened position as above for phase A.
- **BREAKER 1 ΦC CLOSED:** If the mode is selected as three-pole, this setting has no function. If the mode is selected as single-pole, this input is used to track the breaker phase C closed position as above for phase A.
- **BREAKER 1 ΦC OPENED:** If the mode is selected as three-pole, this setting has no function. If the mode is selected as single-pole, this input is used to track the breaker phase C opened position as above for phase A.
- **BREAKER 1 TOPERATE**: This setting specifies the required interval to overcome transient disagreement between the 52/a and 52/b auxiliary contacts during breaker operation. If transient disagreement still exists after this time has expired, the BREAKER 1 BAD STATUS FlexLogic operand is asserted from alarm or blocking purposes.
- **BREAKER 1 EXT ALARM:** This setting selects an operand, usually an external contact input, connected to a breaker alarm reporting contact.
- **BREAKER 1 ALARM DELAY:** This setting specifies the delay interval during which a disagreement of status among the three-pole position tracking operands will not declare a pole disagreement. This allows for non-simultaneous operation of the poles.
- **MANUAL CLOSE RECAL1 TIME:** This setting specifies the interval required to maintain setting changes in effect after an operator has initiated a manual close command to operate a circuit breaker.
- **BREAKER 1 OUT OF SV:** Selects an operand indicating that breaker 1 is out-of-service.

NOTE

IEC 61850 functionality is permitted when the L30 is in "Programmed" mode and not in the local control mode.

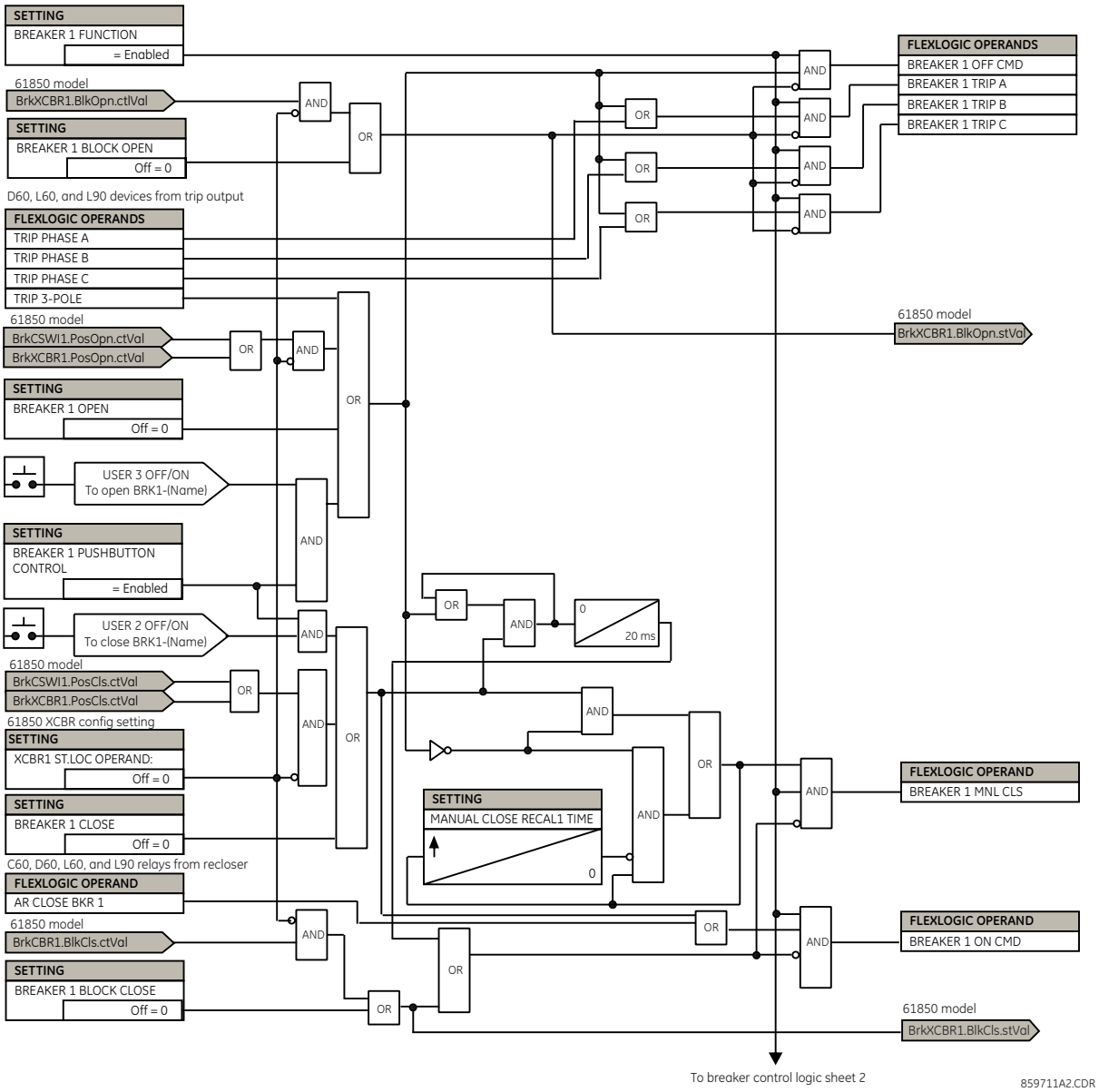



**Figure 5–23: DUAL BREAKER CONTROL SCHEME LOGIC (Sheet 1 of 2)**

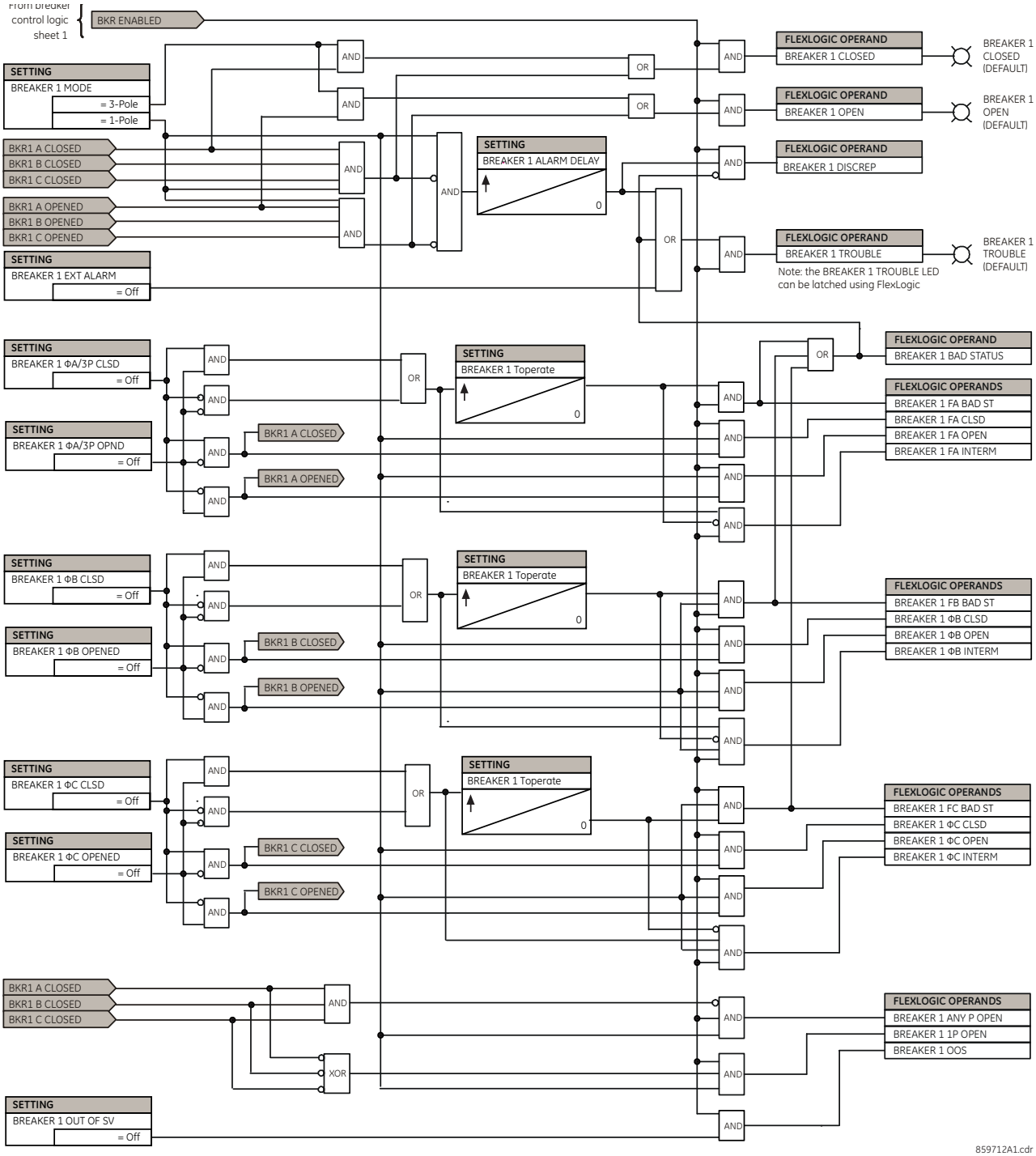
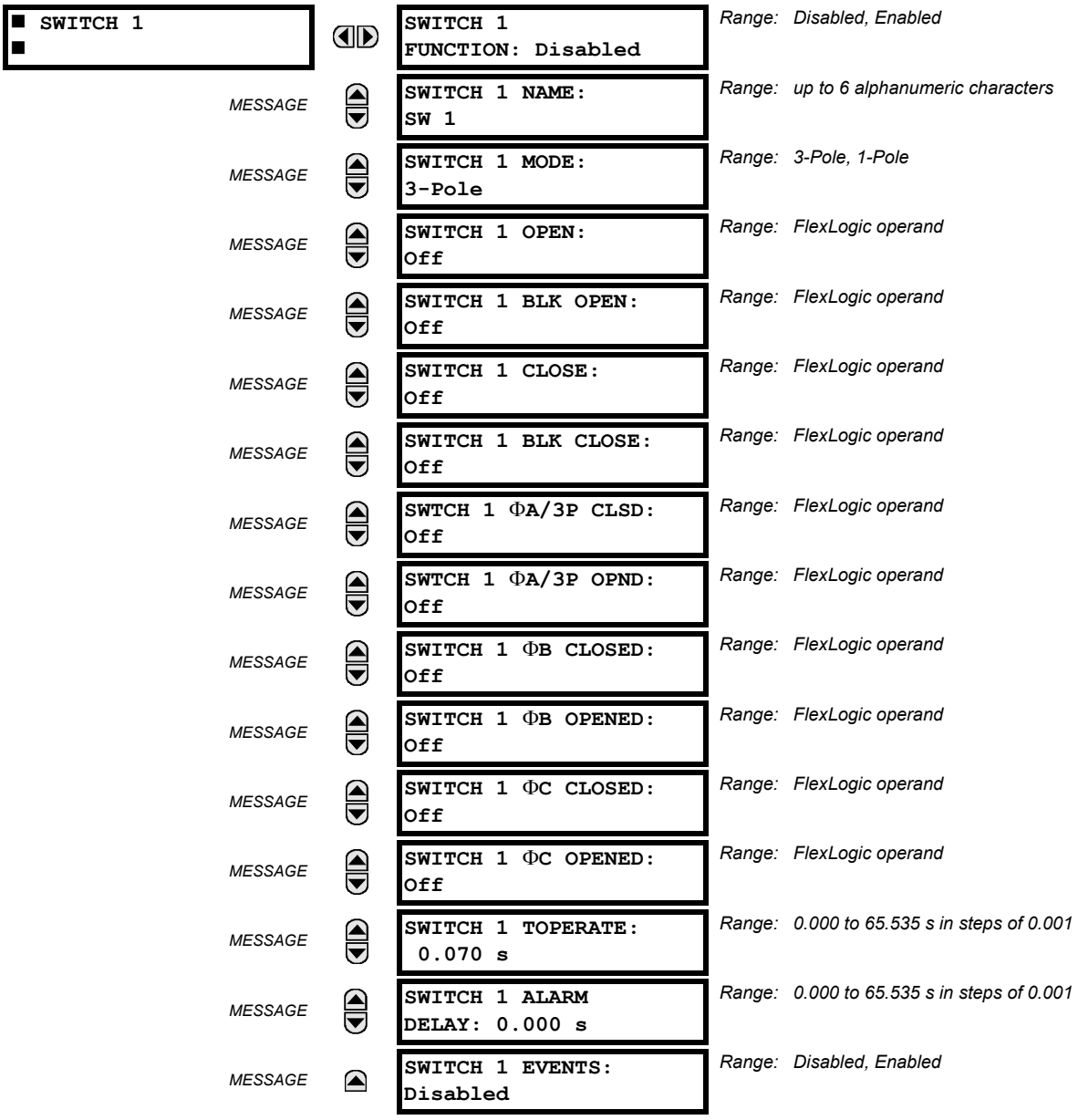



**Figure 5–24: DUAL BREAKER CONTROL SCHEME LOGIC (Sheet 2 of 2)**

The breaker element has direct hard-coded connections to IEC 61850 model as shown in the logic diagram. This allows remote open/close operation of each breaker, using either CSWI or XCBR IEC 61850 logical nodes. IEC 61850 select-before-operate functionality, local/remote switch functionality along with a blocking of open/close commands are provided. Note that IEC 61850 commands are event-driven and dwell time for these is one protection pass only. If you want to maintain the close/open command for a certain time, do so either on the contact outputs using the "Seal-in" setting or in FlexLogic.

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SWITCHES ⇨ SWITCH 1(8)




The disconnect switch control element contains the auxiliary logic for status and serves as the interface for opening and closing of disconnect switches from SCADA or through the front panel interface. The disconnect switch control element can be used to create interlocking functionality. For greater security in determination of the switch pole position, both the 89/a and 89/b auxiliary contacts are used with reporting of the discrepancy between them. The number of available disconnect switches is four per breaker.

To use this element, configure the contact outputs that open and close the disconnect switch to use FlexLogic operands SWITCH 1 OFF CMD and SWITCH 1 ON CMD, and configure the disconnect switch control element's inputs as outlined here.

- **SWITCH 1 FUNCTION:** This setting enables and disables the operation of the disconnect switch element.
- **SWITCH 1 NAME:** Assign a user-defined name (up to six characters) to the disconnect switch. This name will be used in flash messages related to disconnect switch 1.

- **SWITCH 1 MODE:** This setting selects "3-Pole" mode, where disconnect switch poles have a single common auxiliary switch, or "1-Pole" mode where each disconnect switch pole has its own auxiliary switch.
- **SWITCH 1 OPEN:** This setting selects an operand that when activated, and unless blocked, initiates the disconnect switch 1 open command.
- **SWITCH 1 BLK OPEN**: This setting selects an operand that prevents initiation of the disconnect switch 1 command. This setting can be used for blocking disconnect switch opening for instance when switchyard monitoring indicates current exceeding the switch's interrupting rating can be flowing through the switch.
- **SWITCH 1 CLOSE:** This setting selects an operand that when activated, and unless blocked, initiates the disconnect switch 1 close command.
- **SWITCH 1 BLK CLOSE**: This setting selects an operand that prevents initiation of disconnect switch 1 close commands. This setting can be used for blocking disconnect switch closing, for instance to prevent closing into a closed ground switch.
- **SWTCH 1 ΦA/3P CLSD:** This setting selects an operand, usually a contact input connected to a disconnect switch auxiliary position tracking mechanism. This input is for a normally-open 89/a status input that creates a logic 1 when the disconnect switch is closed. If the **SWITCH 1 MODE** setting is selected as "3-Pole", this setting selects a single 89/a input as the operand used to track the disconnect switch open or closed position. If the mode is selected as "1-Pole", the input mentioned above is used to track phase A and the **SWITCH 1 ΦB** and **SWITCH 1 ΦC** settings select operands to track phases B and C, respectively.
- **SWTCH 1 ΦA/3P OPND:** This setting selects an operand, usually a contact input, that is for a normally-closed 89/b status input that creates a logic 1 when the disconnect switch is open. If a separate 89/b contact input is not available, then an inverted 89/a status signal can be used.
- **SWITCH 1 ΦB CLOSED:** If the mode is selected as three-pole, this setting has no function. If the mode is selected as single-pole, this input is used to track the disconnect switch phase B closed position as above for phase A.
- **SWITCH 1 ΦB OPENED:** If the mode is selected as three-pole, this setting has no function. If the mode is selected as single-pole, this input is used to track the disconnect switch phase B opened position as above for phase A.
- **SWITCH 1 ΦC CLOSED:** If the mode is selected as three-pole, this setting has no function. If the mode is selected as single-pole, this input is used to track the disconnect switch phase C closed position as above for phase A.
- **SWITCH 1 ΦC OPENED:** If the mode is selected as three-pole, this setting has no function. If the mode is selected as single-pole, this input is used to track the disconnect switch phase C opened position as above for phase A.
- **SWITCH 1 TOPERATE**: This setting specifies the required interval to overcome transient disagreement between the 89/a and 89/b auxiliary contacts during disconnect switch operation. If transient disagreement still exists after this time has expired, the SWITCH 1 BAD STATUS FlexLogic operand is asserted for alarm or blocking purposes.
- **SWITCH 1 ALARM DELAY:** This setting specifies the delay interval during which a disagreement of status among the pole position tracking operands will not declare a pole disagreement. This allows for non-simultaneous operation of the poles.

NOTE

IEC 61850 functionality is permitted when the L30 is in "Programmed" mode and not in the local control mode.

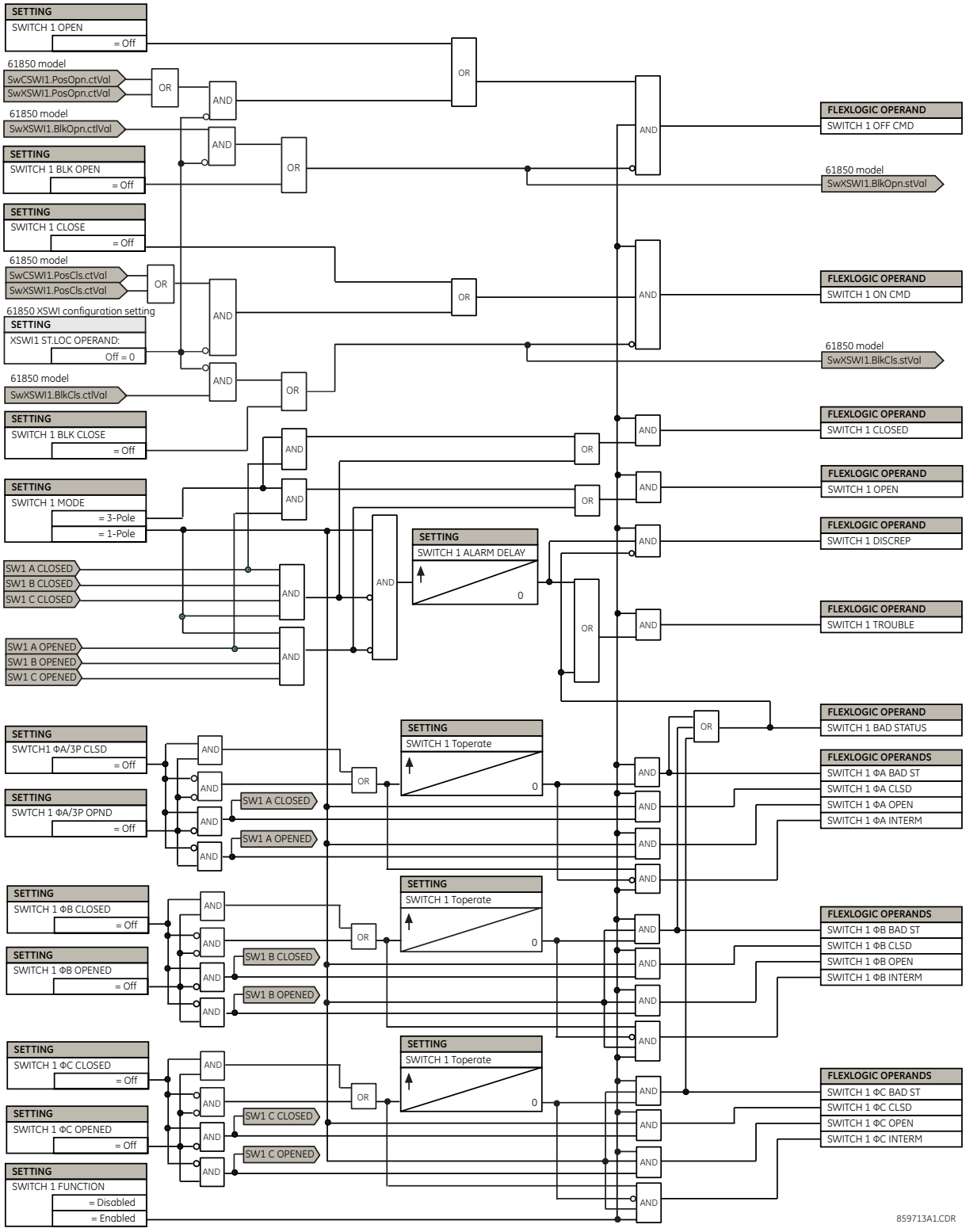


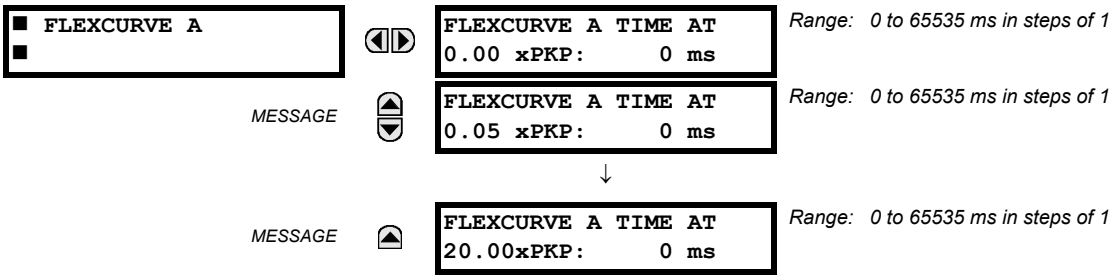

**Figure 5–25: DISCONNECT SWITCH SCHEME LOGIC**

The switch element has direct hard-coded connections to IEC 61850 model as shown in the logic diagram. This allows remote open/close operation of each switch, using either CSWI or XSWI IEC 61850 logical nodes. IEC 61850 select-before-operate functionality, local/remote switch functionality along with a blocking open/close commands are provided. Note that IEC 61850 commands are event-driven and dwell time for these is one protection pass only. If you want to maintain close/open command for a certain time, do so either on the contact outputs using the "Seal-in" setting or in FlexLogic.

## 5.4.7 FLEXCURVES

### a) SETTINGS

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ FLEXCURVES ⇨ FLEXCURVE A(D)**




FlexCurves A through D have settings for entering times to reset and operate at the following pickup levels: 0.00 to 0.98 and 1.03 to 20.00. This data is converted into two continuous curves by linear interpolation between data points. To enter a custom FlexCurve, enter the reset and operate times (using the VALUE keys) for each selected pickup point (using the MESSAGE UP/DOWN keys) for the desired protection curve (A, B, C, or D).

5

**Table 5–12: FLEXCURVE TABLE**

| RESET | TIME MS | RESET | TIME MS | OPERATE | TIME MS | OPERATE | TIME MS | OPERATE | TIME MS | OPERATE | TIME MS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | | 0.68 | | 1.03 | | 2.9 | | 4.9 | | 10.5 | |
| 0.05 | | 0.70 | | 1.05 | | 3.0 | | 5.0 | | 11.0 | |
| 0.10 | | 0.72 | | 1.1 | | 3.1 | | 5.1 | | 11.5 | |
| 0.15 | | 0.74 | | 1.2 | | 3.2 | | 5.2 | | 12.0 | |
| 0.20 | | 0.76 | | 1.3 | | 3.3 | | 5.3 | | 12.5 | |
| 0.25 | | 0.78 | | 1.4 | | 3.4 | | 5.4 | | 13.0 | |
| 0.30 | | 0.80 | | 1.5 | | 3.5 | | 5.5 | | 13.5 | |
| 0.35 | | 0.82 | | 1.6 | | 3.6 | | 5.6 | | 14.0 | |
| 0.40 | | 0.84 | | 1.7 | | 3.7 | | 5.7 | | 14.5 | |
| 0.45 | | 0.86 | | 1.8 | | 3.8 | | 5.8 | | 15.0 | |
| 0.48 | | 0.88 | | 1.9 | | 3.9 | | 5.9 | | 15.5 | |
| 0.50 | | 0.90 | | 2.0 | | 4.0 | | 6.0 | | 16.0 | |
| 0.52 | | 0.91 | | 2.1 | | 4.1 | | 6.5 | | 16.5 | |
| 0.54 | | 0.92 | | 2.2 | | 4.2 | | 7.0 | | 17.0 | |
| 0.56 | | 0.93 | | 2.3 | | 4.3 | | 7.5 | | 17.5 | |
| 0.58 | | 0.94 | | 2.4 | | 4.4 | | 8.0 | | 18.0 | |
| 0.60 | | 0.95 | | 2.5 | | 4.5 | | 8.5 | | 18.5 | |
| 0.62 | | 0.96 | | 2.6 | | 4.6 | | 9.0 | | 19.0 | |
| 0.64 | | 0.97 | | 2.7 | | 4.7 | | 9.5 | | 19.5 | |
| 0.66 | | 0.98 | | 2.8 | | 4.8 | | 10.0 | | 20.0 | |

NOTE

The relay using a given FlexCurve applies linear approximation for times between the user-entered points. Special care must be applied when setting the two points that are close to the multiple of pickup of 1; that is, 0.98 pu and 1.03 pu. It is recommended to set the two times to a similar value; otherwise, the linear approximation may result in undesired behavior for the operating quantity that is close to 1.00 pu.

### b) FLEXCURVE CONFIGURATION WITH ENERVISTA UR SETUP

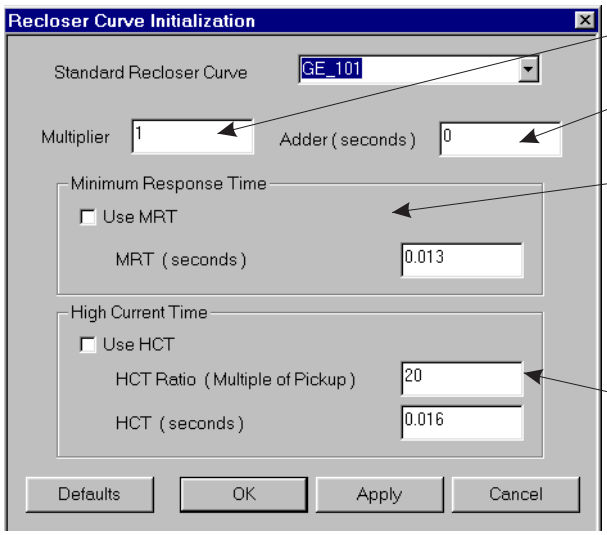
The EnerVista UR Setup software allows for easy configuration and management of FlexCurves and their associated data points. Prospective FlexCurves can be configured from a selection of standard curves to provide the best approximate fit, then specific data points can be edited afterwards. Alternately, curve data can be imported from a specified file (.csv format) by selecting the **Import Data From** EnerVista UR Setup setting.

Curves and data can be exported, viewed, and cleared by clicking the appropriate buttons. FlexCurves are customized by editing the operating time (ms) values at pre-defined per-unit current multiples. Note that the pickup multiples start at zero (implying the "reset time"), operating time below pickup, and operating time above pickup.

### c) RECLOSER CURVE EDITING

Recloser curve selection is special in that recloser curves can be shaped into a composite curve with a minimum response time and a fixed time above a specified pickup multiples. There are 41 recloser curve types supported. These definite operating times are useful to coordinate operating times, typically at higher currents and where upstream and downstream pro-

tective devices have different operating characteristics. The recloser curve configuration window shown below appears when the Initialize From EnerVista UR Setup setting is set to “Recloser Curve” and the **Initialize FlexCurve** button is clicked.




**Multiplier:** Scales (multiplies) the curve operating times

**Addr:** Adds the time specified in this field (in ms) to each *curve* operating time value.

**Minimum Response Time (MRT):** If enabled, the MRT setting defines the shortest operating time even if the curve suggests a shorter time at higher current multiples. A composite operating characteristic is effectively defined. For current multiples lower than the intersection point, the curve dictates the operating time; otherwise, the MRT does. An information message appears when attempting to apply an MRT shorter than the minimum curve time.

**High Current Time:** Allows the user to set a pickup multiple from which point onwards the operating time is fixed. This is normally only required at higher current levels. The **HCT Ratio** defines the high current pickup multiple; the **HCT** defines the operating time.

842721A1.CDR

**Figure 5–26: RECLOSER CURVE INITIALIZATION**

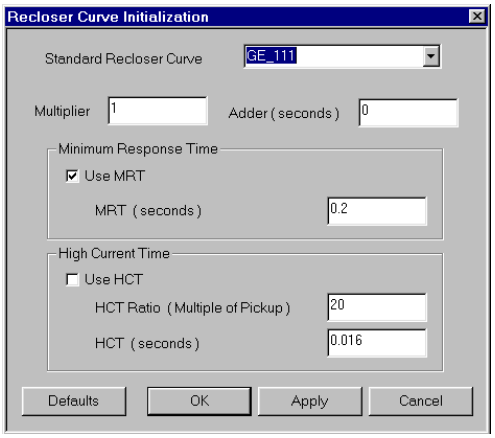


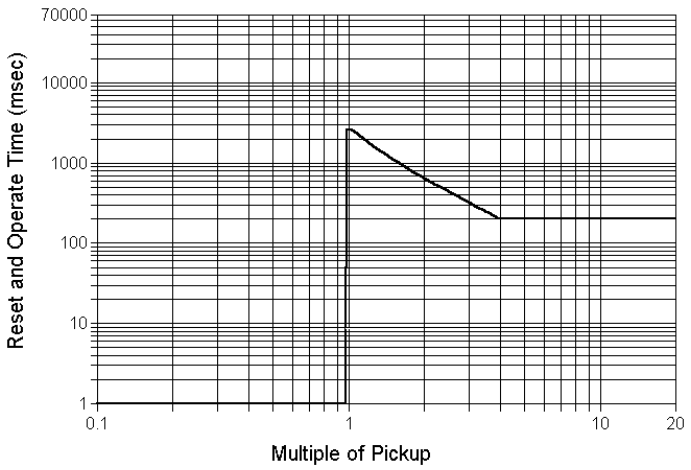
NOTE

The multiplier and adder settings only affect the curve portion of the characteristic and not the MRT and HCT settings. The HCT settings override the MRT settings for multiples of pickup greater than the HCT ratio.

### d) EXAMPLE

A composite curve can be created from the GE_111 standard with MRT = 200 ms and HCT initially disabled and then enabled at eight times pickup with an operating time of 30 ms. At approximately four times pickup, the curve operating time is equal to the MRT and from then onwards the operating time remains at 200 ms (see below).




842719A1.CDR

**Figure 5–27: COMPOSITE RECLOSER CURVE WITH HCT DISABLED**

With the HCT feature enabled, the operating time reduces to 30 ms for pickup multiples exceeding eight times pickup.

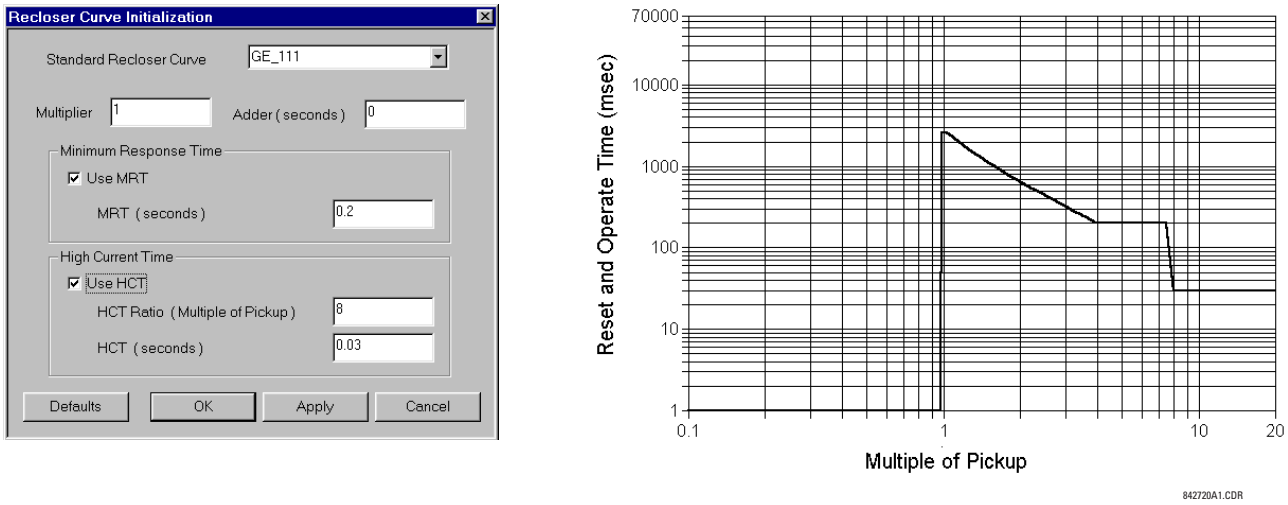



**Figure 5–28: COMPOSITE RECLOSER CURVE WITH HCT ENABLED**

NOTE

Configuring a composite curve with an increase in operating time at increased pickup multiples is not allowed. If this is attempted, the EnerVista UR Setup software generates an error message and discards the proposed changes.

### e) STANDARD RECLOSER CURVES

The standard recloser curves available for the L30 are displayed in the following graphs.

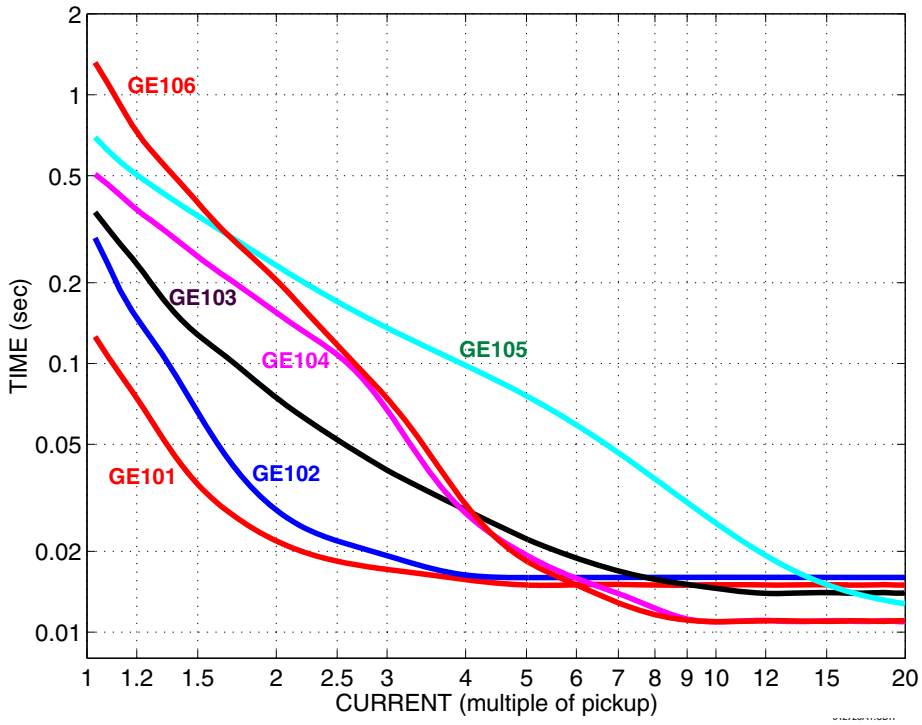



**Figure 5–29: RECLOSER CURVES GE101 TO GE106**

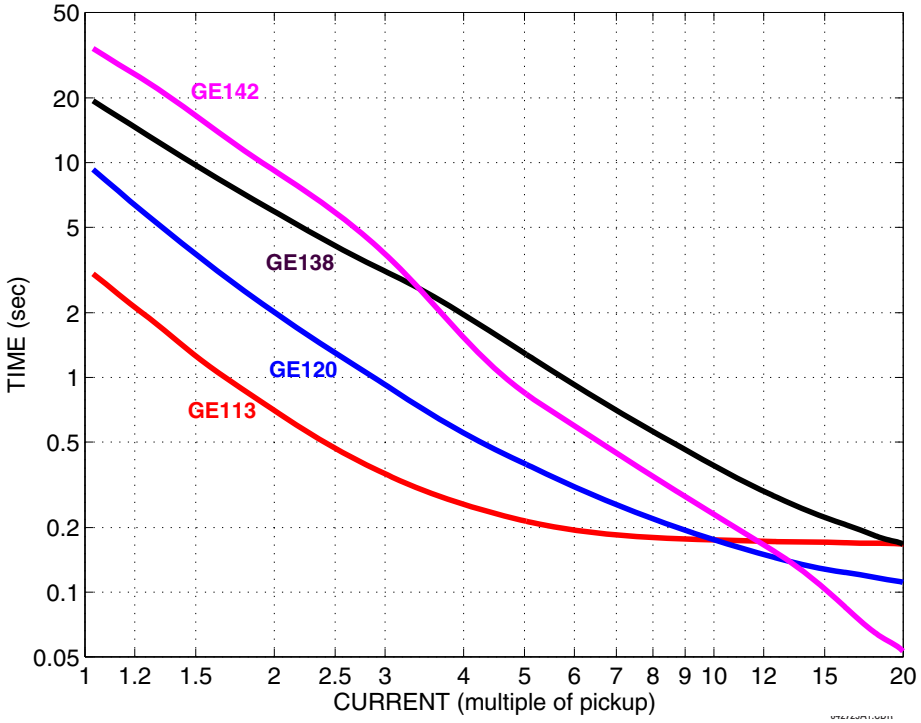



Figure 5–30: RECLOSER CURVES GE113, GE120, GE138 AND GE142

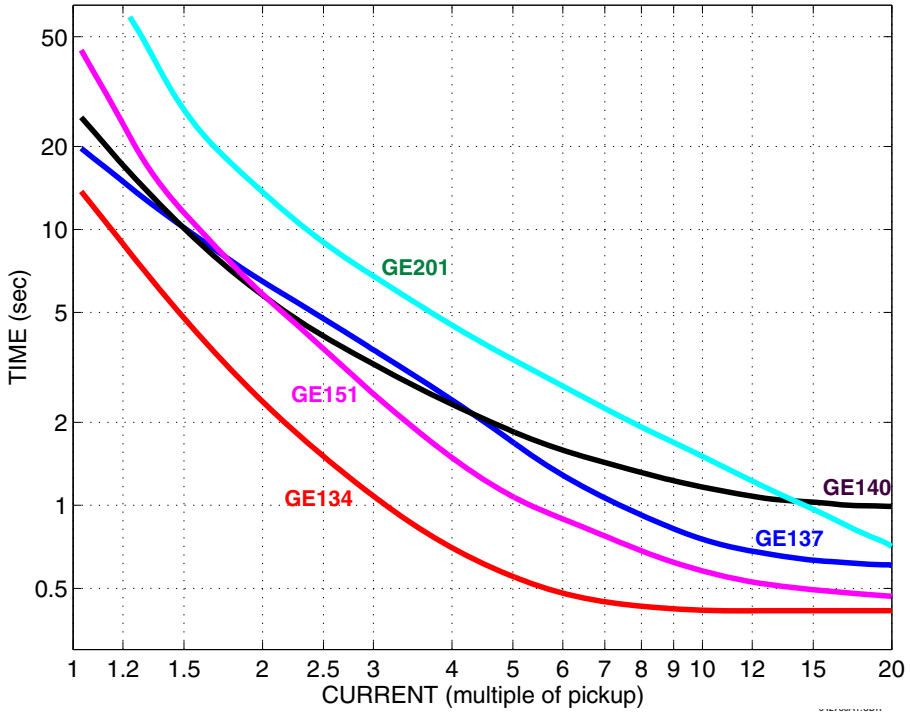



Figure 5–31: RECLOSER CURVES GE134, GE137, GE140, GE151 AND GE201

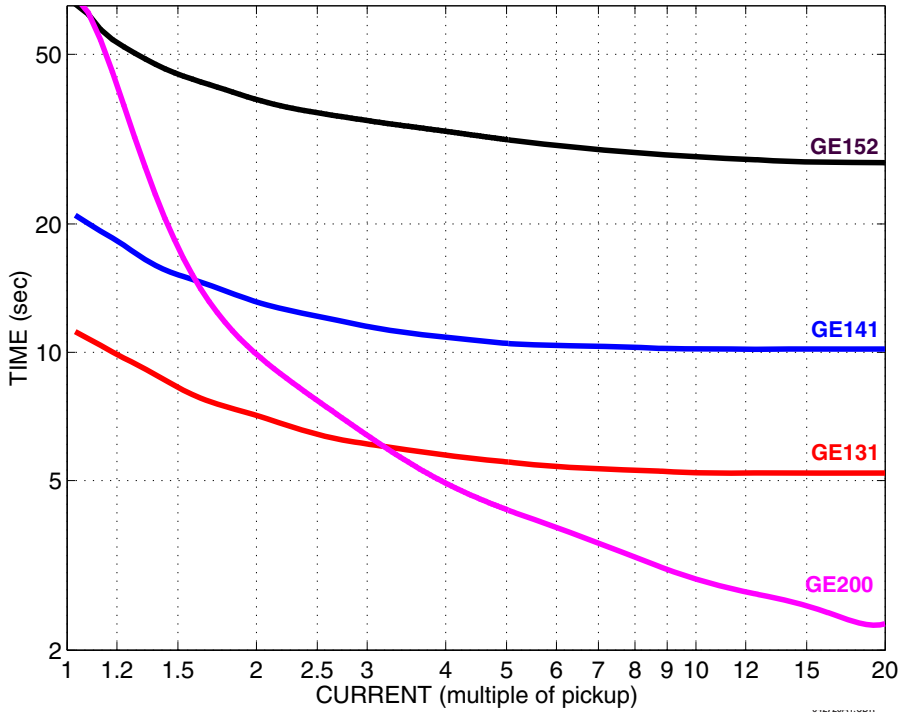



**Figure 5–32: RECLOSER CURVES GE131, GE141, GE152, AND GE200**

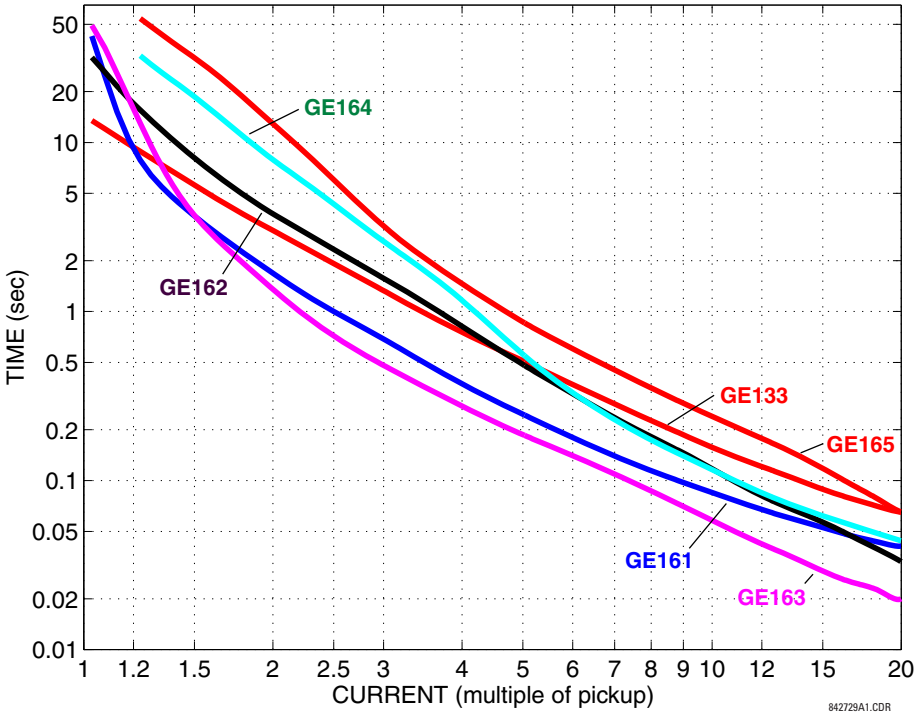



**Figure 5–33: RECLOSER CURVES GE133, GE161, GE162, GE163, GE164 AND GE165**

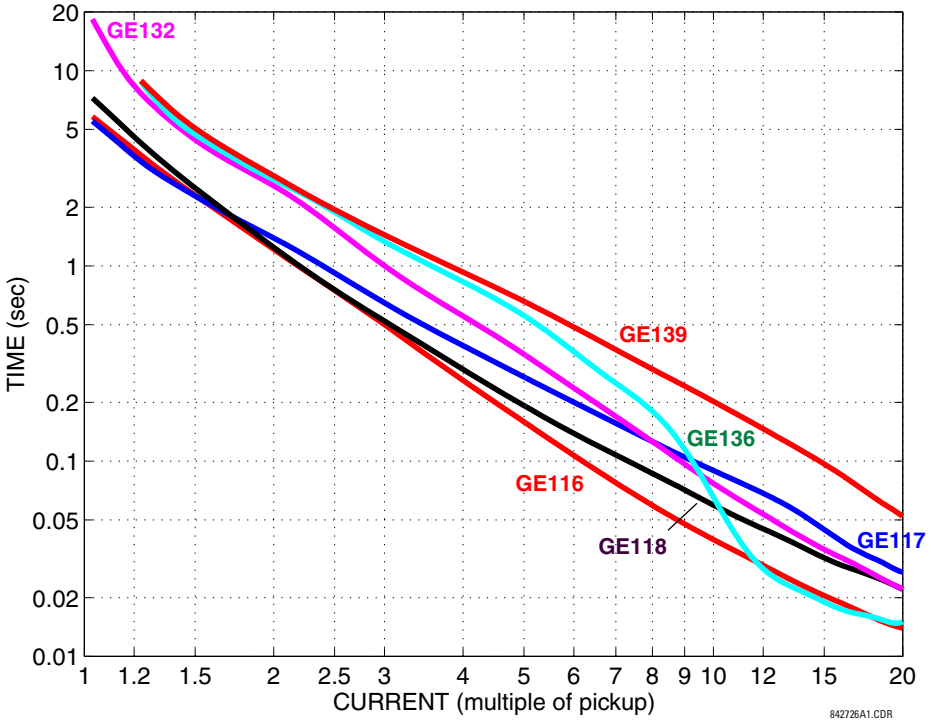



Figure 5–34: RECLOSER CURVES GE116, GE117, GE118, GE132, GE136, AND GE139

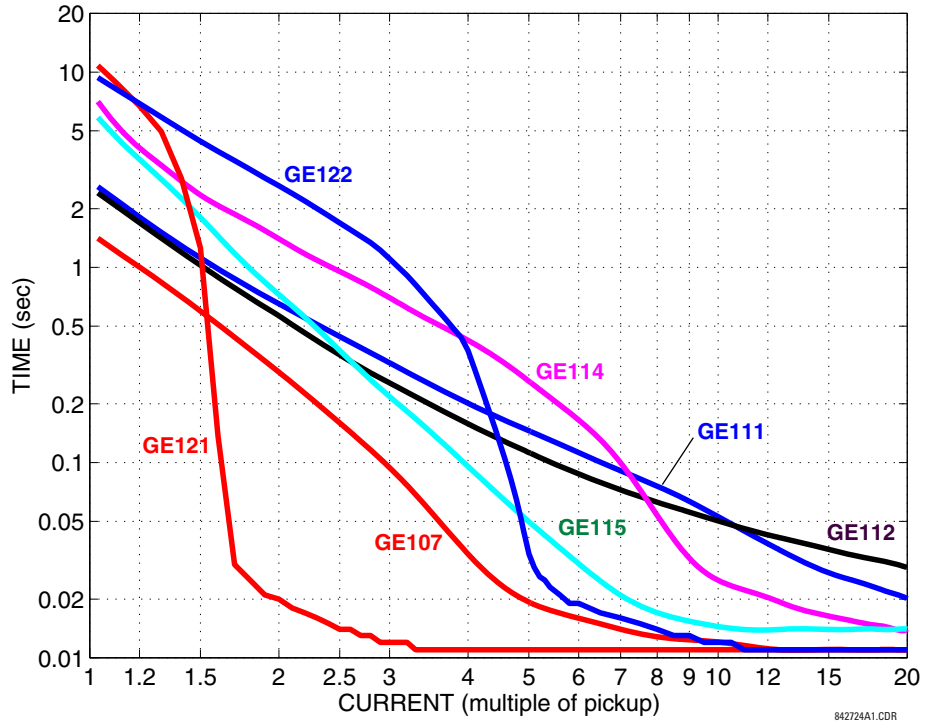



Figure 5–35: RECLOSER CURVES GE107, GE111, GE112, GE114, GE115, GE121, AND GE122

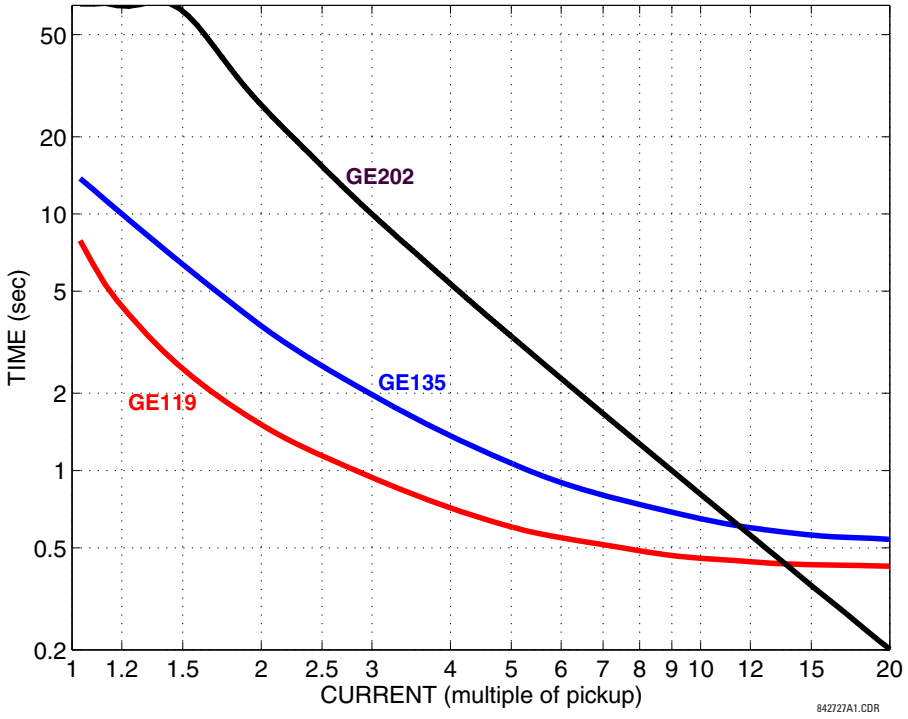



**Figure 5–36: RECLOSER CURVES GE119, GE135, AND GE202**



## 5.4.8 PHASOR MEASUREMENT UNIT

### a) MAIN MENU

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT UNIT**

| | | | |
|---|---|---|---|
| ■ PHASOR MEASUREMENT<br>■ UNIT | | ■ PHASOR MEASUREMENT<br>■ UNIT 1 | See below. |
| | *MESSAGE* | ■ PMU AGGREGATOR 1<br>■ | See page 5–134. |
| | *MESSAGE* | ■ IEC 90-5 MSVCB 1<br>■ CONFIGURATION | See page 5–136. |

SOFTWARE OPTION

The L30 is provided with an optional phasor measurement unit feature. This feature is specified as a software option at the time of ordering. The number of phasor measurement units available can also depend on this option. Using the order code for your device, see the order codes in chapter 2 for details.**UR Synchrophasor Implementation**

**PHASORS** are used within protection relays. If these phasors are referenced to a common time base they are referred to as a **SYNCHROPHASOR**. A vastly improved method for tracking power system dynamic phenomena for improved power system monitoring, protection, operation, and control can be realized if Synchrophasors from different locations within the power system are networked to a central location.

The L30 offers PMU features over two communication standards, IEC 61850-9-5 and IEEE C37.118. The figure shows complete Synchrophasor implementation.

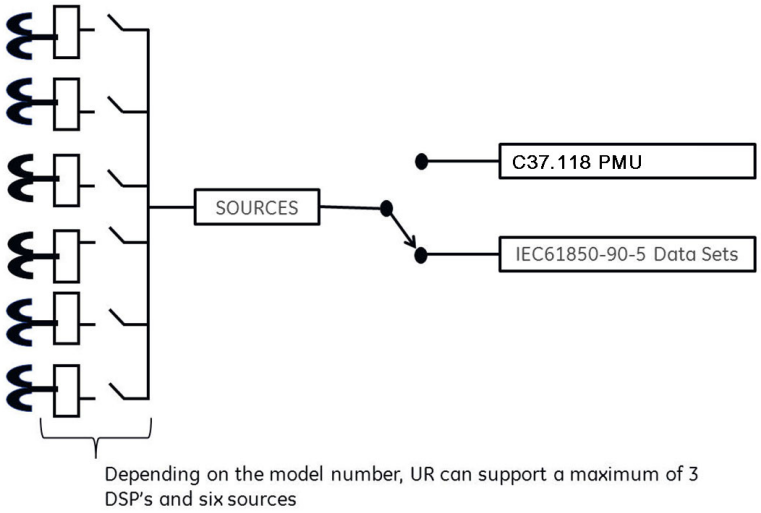



**Figure 5–37: COMPLETE SYNCHROPHASOR IMPLEMENTATION**

5

### UR Implementation of IEC 61850-90-5

Synchrophasor data as measured and calculated by phasor measurement units (PMUs) is used to assess the condition of the electrical power network. The IEEE C37.118 standards define synchrophasors and related message formats to transmit synchrophasor data. Synchrophasor streaming via IEEE C37.118 has proven to work but the desire to have a communication mechanism that is compliant with the concept of IEC 61850 has led to the development of IEC 61850-90-5. The IEC 61850-90-5 standard defines the packet structure for multicast routing of streamed Sampled Value (SV) known as R-SV.

Firmware versions 7.0 and above have a 90-5 based R-SV implementation equivalent in structure and configuration to that of the existing IEEE C37.118 implementation of firmware version 6.0, that is, synchrophasor data at rates up to 60 Hz for metering and 120 Hz for protection class synchrophasors. The following two figures depict the general data flow for the generation of synchrophasor data for IEC 61850-90-5. In the first figure, when IEC 61850-90-5 is selected all real and virtual sources are available for the IEC 61850-90-5 PMUs.

The number of PMUs and aggregators vary by product, as outlined in the table.

**Table 5–13: IMPLEMENTATION BY MODEL NUMBER**

| MODEL | NUMBER OF PMUS | NUMBER OF AGGREGATORS | COMMENT |
|---|---|---|---|
| N60 | 1, 2, 4, or 6 | 1 with 1 PMU<br>2 with 2 or 4 PMUs<br>4 with 6 PMUs | Number of PMUs is ordered using software options |
| C60 | 2 | 2 | |
| D60, F60, G60, L30, L90, T60 | 1 | 1 | |

The figure shows an example of an N60 using four Logical Device PMUs (Logical Device 2 through 5) and four aggregators. The control blocks for the aggregators are located in LD1. A 64 char LDName setting is provided.

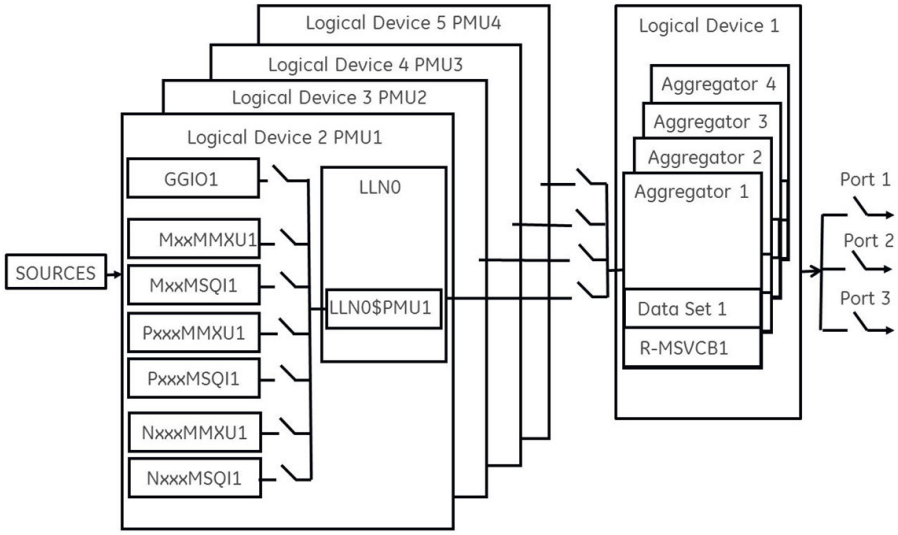



**Figure 5–38: N60 EXAMPLE FOR FOUR LOGICAL DEVICE PMUS**

NOTE

Precise time input to the relay from the international time standard, via either IRIG-B or PTP, is vital for correct synchrophasor measurement and reporting. For IRIG-B, a DC level shift IRIG-B receiver must be used for the phasor measurement unit to output proper synchrophasor values.

Depending on the applied filter, the Synchrophasors that are produced by PMUs are classified as either P (protection) or M (Measurement) class Synchrophasors. Synchrophasors available within the UR that have no filtering applied are classified as NONE, which within the standard is classified as PRES OR UNKNOWN under the Calculation Method - ClcMth. Each Logical Device PMU supports one MxxMMXU, MxxMSQI, PxxxMMXU , PxxxMSQI, NxxMMXU, and one NxxMSQI logical node.

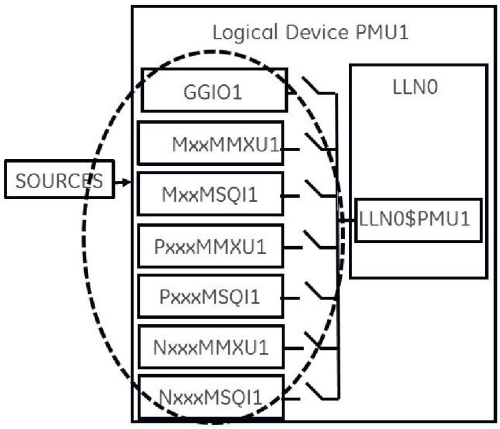



**Figure 5–39: LOGICAL NODES SUPPORTED IN EACH LOGICAL DEVICE**

The following is a summary of LNs that are in each Logical Device (LD2 through LD7):

- PxxxMMXU1 ClcMth = P-Class (Note Vaux is mapped to Vneut of MMXU)
- PxxxMSQI1 ClcMth = P-CLASS
- MxxMMXU1 ClcMth = M-Class (Note Vaux is mapped to Vneut of MMXU)
- MxxMSQI1 ClcMth = M-CLASS
- NxxMMXU1 ClcMth = M-Class (Note Vaux is mapped to Vneut of MMXU)

- NxxMSQI1 ClcMth = M-CLASS

- GGIO1 which contains 16 digital status indication points and 16 analog points. The Analog GGIO values are selectable from any FlexAnalog value in the UR.

NOTE The Synchro Logical Nodes in an LD report at the same rate as set in the PMUn Basic Configuration setting. This is reflected in the instantiation of the Data Object – SmpRate in the msvcb## of LLN0 in the LD1. SmpRate is a Read Only Integer Status (INS).

When the first PMU from any LD is mapped into an aggregator, the aggregator inherits the Sample Rate (SmpRate) and IEEE C37.118 Class (P or M) of that PMU. The value of the SmpRate DO in the Report Control Block is set based on the value of the Sample Rate in the PMU. The Class of the Dataset are mapped into the MSVID of the Dataset (see text below for the overall name of the MSVID). If other PMUs are mapped into the same aggregator with different Sample Rates or from different classes, then a Self-Test error (DatSetErr) is set and dataset transmission is blocked.

A setting value – MSVID – is created with a maximum input range of 56 characters (=64 less 6 for the IDCode less 2 for the Class).

The value of MSVID in the dataset is a concatenation of the aggregator IDCode and the MSVID setting value in the format: MSVID-AggregatorIDCode-CLASS where CLASS is P, M, or N (for None) – depending on the Class of the first PMU included in the Aggregator.

NOTE Synchrophasor Rectangular Format and Integer data types are NOT supported in IEC 61850-90-5 (only supported with IEEE C37.118) and not to set — GGIO1 which contains 16 digital status indication points — aggregated as a 16 bit bitstring and 16 analog points. The Analog GGIO values are selectable from any FlexAnalog value in the UR. For version 7.0 and later the description fields for the phasors, analog and digital channels are populated with the 16 character name field provided within the Basic Configuration menu. Additionally, the names of the 16 binary points are implemented as numbered descriptions — d1, d2, d3, and so on. The number of descriptions are equal to the number of bits configured in the 16 bit digital status word.

NOTE All bitstrings less than or equal to 32 bits in length map into a 32 bit bitstring in an IEC 61850-90-5 dataset.

NOTE The Value of the Nominal Frequency of the chassis is instantiated as a DO in LPHD of LD1. The value is named HzNom and is an Integer Status (INS).

The UR also supports the option to apply no filtering to the synchrophasors. If no filtering is applied (PMU Class = None), according to the standard, the ClcMth attribute is PRES. The semantic of the ClcMth used is not carried in the individual DO and so it is recommended that one of letters of the prefix on the instantiated LNs be set to “P” or “M” accordingly in order to differentiate. For version 7.0 and later, only FCDA data is supported. The *Implementation by Model Number* table earlier describes the maximum size of each PMU data set for version 7.2 and later using FCDA data (non-structured data).

**EXAMPLE: PROTECTION SYNCHROPHASORS DATA SET WITH REPORTING RATE 60 FRAMES/SECOND**

This example gives the protection synchrophasors data set with a reporting rate of 60 frames per second (P60MMXU1). See the figure earlier, Logical Nodes Supported in Each Logical Device. This data or list of items, as shown in the following figure, is not available to the UR setup program but is available to be mapped by the user into a selected aggregator or aggregators dataset. The logical device name (LDName) of each PMU LD is a 64 character user setting. The IEEE C37.118 STN and IDCode is to be mapped as a concatenated value in the (d)escription field of LPL CDC of the NamPlt DO in LLN0. The mapping is implemented as STN-IDCode (text string).

From each PMU, the user selects the phasor information of interest that is mapped into the selected aggregator datset(s). For version 7.0 and later only FCDA data is supported.

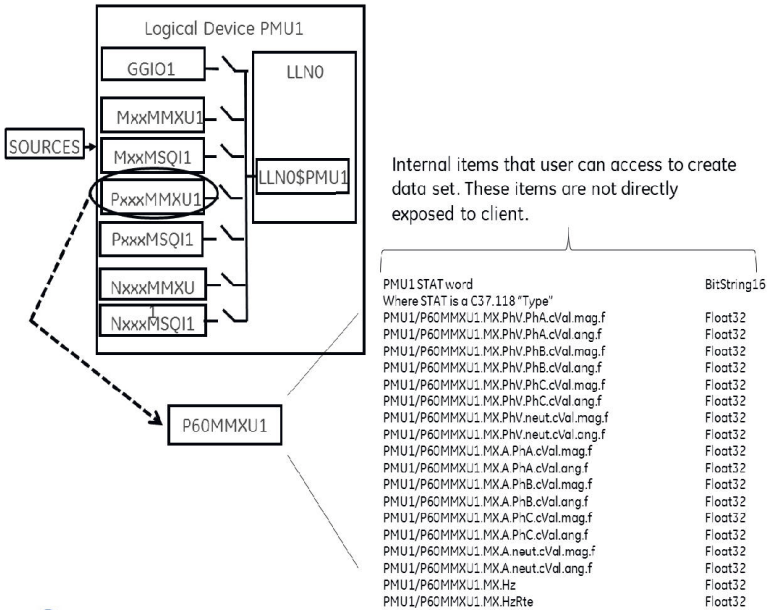



**Figure 5–40: DATA SET CREATED FROM USER SELECTED INTERNAL ITEMS**

5

### EXAMPLE: THE CREATION OF DIFFERENT DATA SETS

The aggregators allow the aggregation of phasors from multiple PMUs (with the same reporting rate) into a single custom data set to optimize bandwidth when streaming.

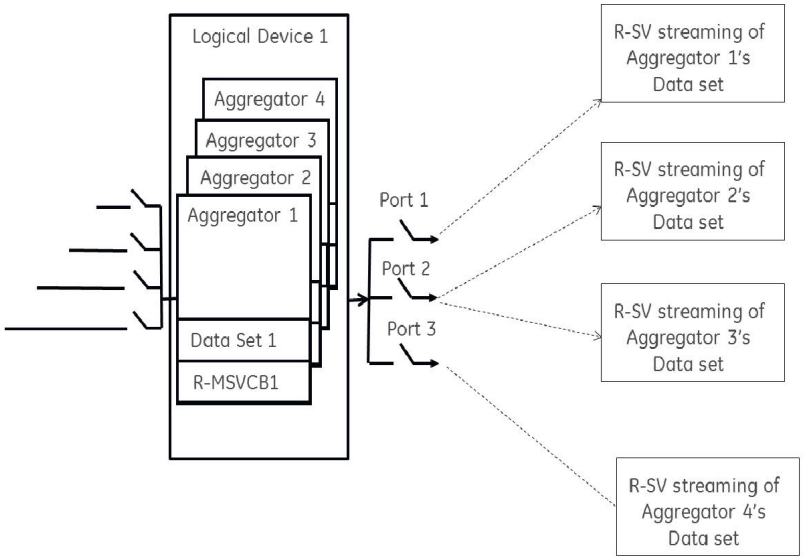



**Figure 5–41: EXAMPLE OF AGGREGATOR DATA SETS**

### CONFIGURATION EXAMPLE: CFG-2 BASED CONFIGURATION (USING IEC 61850-90-5)

The L30 is expected to send the CFG-2 file (IEEE C37.118 config. file) upon request from the upstream synchrophasor devices (for example, P30) without stopping R-SV multicasting, as shown in the figure below. The primary domain controller (PDC) does not need to use a stop/start data stream command if the UR protocol is set to IEC 61850-90-5 prior to requesting the configuration via CFG-2 (IEEE C37.118 config. file). The CFG-2 request from the P30 can be on TCP/IP or UDP/IP, however, R-SV data streaming is only UDP multicasts (not TCP).

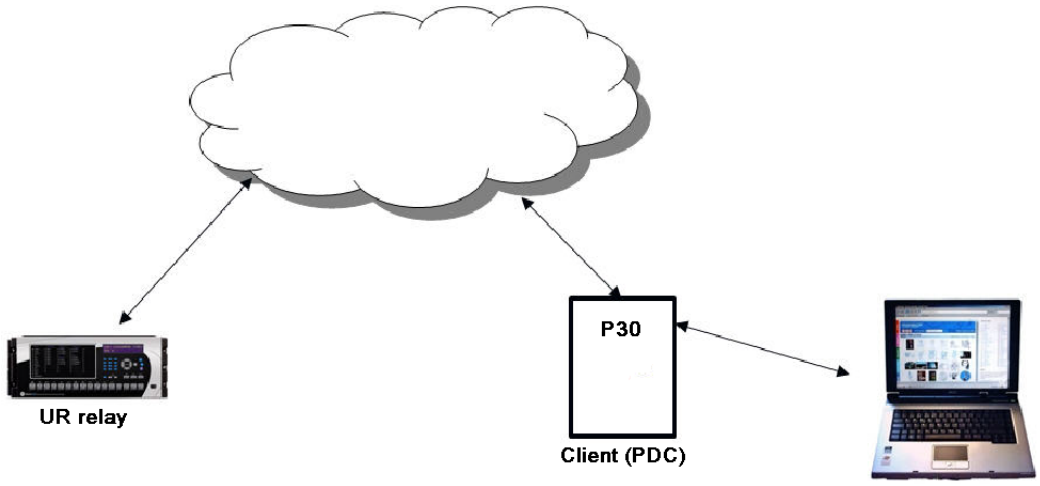



Figure 5–42: CFG-2 BASED CONFIGURATION SOLUTION



### MODIFICATION OF SYNC WORD IN CFG-2 FOR TR 90-5 DATA SETS

In the CFG-2 file, all relevant information about the data being streamed is included. However, this file does not include the fact that it describes a 90-5 dataset or the number of Application Service Data Units (datasets). In order to communicate this information via the CFG-2 file for a given aggregator, when the aggregator is set to 90-5, the version number of the CFG-2 file (found in bits 0-3 of the frame SYNC word, which should presently be set to 2) is set as follows:

| VALUE (DECIMAL) | # OF ASDUS |
|---|---|
| 11 | 1 |
| 12 | 2 |
| 13 | 3 |
| 14 | 4 |

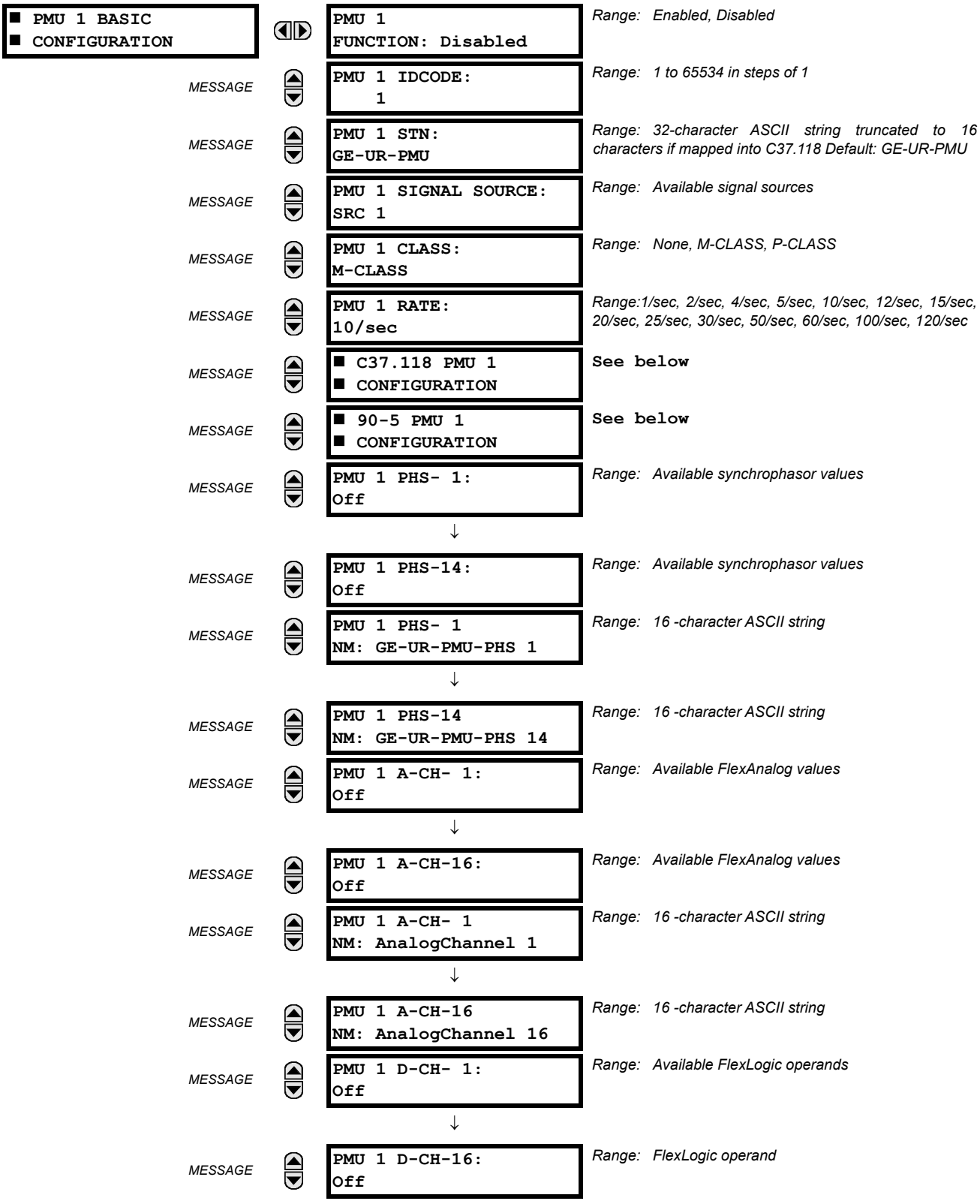
The PMU settings are organized in logical groups as follows. For correct PMU operation, upgrade the firmware to the latest v7.2x release; consult the v7.2x Release Notes for information.

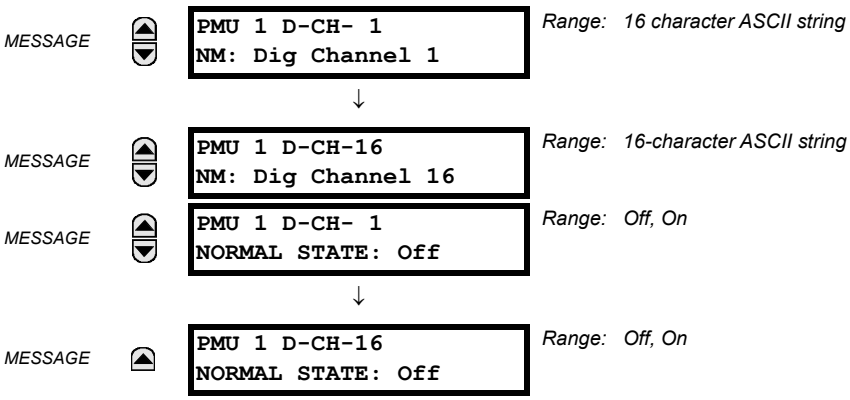
PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT UNIT ⇨⇩ PHASOR MEASUREMENT UNIT 1

| | | | |
|---|---|---|---|
| ■ PHASOR MEASUREMENT<br>■ UNIT 1 | ◀▶ | ■ PMU 1 BASIC<br>■ CONFIGURATION | See page 5-121. |
| *MESSAGE* | ▲▼ | ■ PMU 1<br>■ CALIBRATION | See page 5-125. |
| *MESSAGE* | ▲▼ | ■ PMU 1<br>■ TRIGGERING | See page 5-126. |
| *MESSAGE* | ▲ | ■ PMU 1<br>■ RECORDING | See page 5-134. |

## b) BASIC CONFIGURATION

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT UNIT ⇨ PHASOR MEASUREMENT UNIT1 ⇨ PMU 1 BASIC CONFIGURATION






This section contains basic phasor measurement unit (PMU) data, such as functions, source settings, and names.

- **PMU 1 FUNCTION**: This setting enables the LOGICAL Device PMU 1 functionality. Use this setting to permanently enable or disable the feature.
- **PMU 1 IDCODE**: This setting assigns a numerical ID to the PMU. It corresponds to the IDCODE field of the data, configuration, header, and command frames of the IEEE C37.118 protocol. The PMU uses this value when sending data, configuration, and header frames; and it responds to this value when receiving the command frame. This is used when only data from one PMU is present.
- **PMU 1 STN**: This setting assigns an alphanumeric ID to the PMU station. It corresponds to the STN field of the configuration frame of the IEEE C37.118 protocol. This value is a 16-character ASCII string as per the IEEE C37.118 standard.
- **PMU 1 SIGNAL SOURCE**: This setting specifies one of the available L30 signal sources for processing in the PMU. Note that any combination of voltages and currents can be configured as a source. The current channels can be configured as sums of physically connected currents. This facilitates PMU applications in breaker-and-a-half, ring-bus, and similar arrangements. The PMU feature calculates voltage phasors for actual voltage (A, B, C, and auxiliary) and current (A, B, C, and ground) channels of the source, as well as symmetrical components (0, 1, and 2) of both voltages and currents. When configuring communication and recording features of the PMU, the user can select, from the above superset, the content to be sent out or recorded. When one source is selected by one PMU, it cannot be selected by another PMU.
- **PMU 1 CLASS**: This setting selects the synchrophasor class. Note that a reporting rate of 100 or 120 can only be selected for class P synchrophasors and if the system frequency is 50 or 60 Hz, respectively.
- **PMU 1 RATE**: This setting specifies the reporting rate for the network (Ethernet) port. This value applies to all PMU streams of the device that are assigned to transmit over this aggregator. For a system frequency of 60 Hz (50 Hz), the L30 generates a reporting mismatch message if the selected rate is not set as 10 Hz, 12 Hz, 15 Hz, 20 Hz, 30 Hz, 60 Hz, or 120 Hz (or 10 Hz, 25 Hz, 50 Hz or 100 Hz when the system frequency is 50 Hz) when entered via the keypad or software; and the L30 stops the transmission of reports. Note that 4 Hz is not allowed for an M-class 50 Hz system.

- **PMU 1 PHS-1** to **PMU 1 PHS-14**: These settings specify synchrophasors to be transmitted from the superset of all synchronized measurements. The table outlines available synchrophasor values.

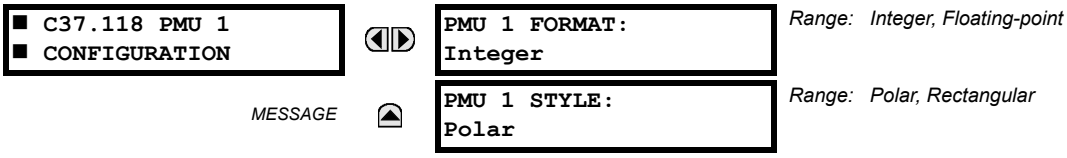
| SELECTION | MEANING |
|---|---|
| Va | First voltage channel, either Va or Vab |
| Vb | Second voltage channel, either Vb or Vbc |
| Vc | Third voltage channel, either Vc or Vca |
| Vx | Fourth voltage channel |
| Ia | Phase A current, physical channel or summation as per the source settings |
| Ib | Phase B current, physical channel or summation as per the source settings |
| Ic | Phase C current, physical channel or summation as per the source settings |
| Ig | Fourth current channel, physical or summation as per the source settings |
| V1 | Positive-sequence voltage, referenced to Va |
| V2 | Negative-sequence voltage, referenced to Va |
| V0 | Zero-sequence voltage |
| I1 | Positive-sequence current, referenced to Ia |
| I2 | Negative-sequence current, referenced to Ia |
| I0 | Zero-sequence current |

These settings allow for optimizing the frame size and maximizing transmission channel usage, depending on a given application. Select "Off" to suppress transmission of a given value.

- **PMU 1 PHS-1 NM** to **PMU 1 PHS-14 NM**: These settings allow for custom naming of the synchrophasor channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame. These names are typically based on station, bus, or breaker names.
- **PMU 1 A-CH-1** to **PMU 1 A-CH-16**: These settings specify any analog data measured by the relay to be included as a user-selectable analog channel of the data frame. Up to 16 analog channels can be configured to send any FlexAnalog value from the relay. Examples include frequency, rate of frequency change, active and reactive power, per phase or three-phase power, power factor, temperature via RTD inputs, and THD. The configured analog values are sampled concurrently with the synchrophasor instant and sent as 32-bit floating-point values scaled to Engineering units.
- **PMU 1 A-CH-1 NM** to **PMU 1 A-CH-16 NM**: These settings allow for custom naming of the analog channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame.
- **PMU 1 D-CH-1** to **PMU 1 D-CH-16**: These settings specify any digital flag measured by the relay to be included as a user-selectable digital channel of the data frame. Up to 16 digital channels can be configured to send any FlexLogic operand from the relay. The configured digital flags are sampled concurrently with the synchrophasor instant. These values are mapped into a two-byte integer number, with byte 1 LSB corresponding to the digital channel 1 and byte 2 MSB corresponding to digital channel 16.
- **PMU 1 D-CH-1 NM** to **PMU 1 D-CH-16 NM**: These settings allow for custom naming of the digital channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame.
- **PMU 1 D-CH-1 NORMAL STATE** to **PMU 1 D-CH-16 NORMAL STATE**: These settings allow for specifying a *normal state* for each digital channel. These states are transmitted in configuration frames to the data concentrator.

### C37.118 PMU 1 CONFIGURATION

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT UNIT ⇨ PHASOR MEASUREMENT UNIT1 ⇨ PMU 1 BASIC CONFIGURATION ⇨ C37.118 PMU 1 CONFIGURATION**




**PMU 1 FORMAT**: This setting selects whether synchrophasors are reported as 16-bit integers or 32-bit IEEE floating point numbers. This setting complies with bit-1 of the FORMAT field of the IEEE C37.118 configuration frame. This setting applies to synchrophasors only; the user-selectable FlexAnalog channels are always transmitted as 16-bit integer values.

**PMU 1 STYLE**: This setting selects whether synchrophasors are reported in rectangular (real and imaginary) coordinates or in polar (magnitude and angle) coordinates. This setting complies with bit-0 of the FORMAT field of the IEEE C37.118 configuration frame.

NOTE With 90-5 PMU, the FORMAT and STYLE are Floating-point and Polar respectively, as specified in the IEC 61850 standard.

### IEC 61850–90–5 PMU 1 CONFIGURATION

PATH: SETTINGS ⇨⇩ SSYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT UNIT ⇨ PHASOR MEASUREMENT UNIT1 ⇨ PMU 1 BASIC CONFIGURATION ⇨ 90 – 5 PMU 1 CONFIGURATION

| | | |
|---|---|---|
| ■ 90–5 PMU 1<br>■ CONFIGURATION | ◀▶ | PMU 1 LDINST:<br>PMU1 |

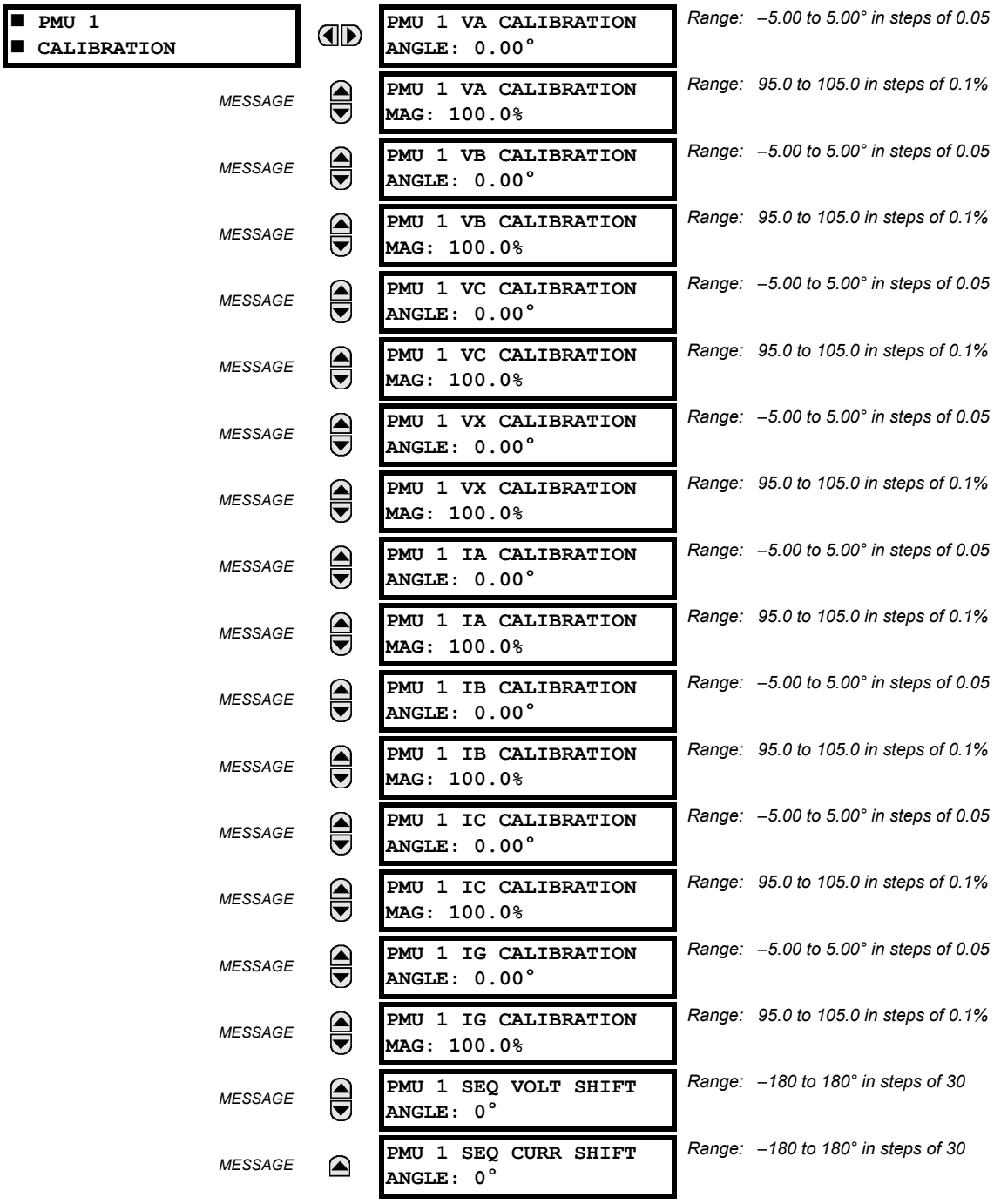
*Range: 64 char ASCII text*

**PMU1 LDINST**: A user-defined visible string (maximum 64 char ASCII test) to assign Logical Device (LD) Inst for a PMU LD.

NOTE As per IEC 61850-6 standard specification, the PMU LD Name is the concatenated combination (to total 64 characters) of IED Name (specified in IEC 61850 Server Settings) appended with PMU X LDINST string.

### c) PMU CALIBRATION

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT UNIT ⇨⇩ PHASOR MEASUREMENT UNIT 1 ⇨⇩ PMU 1 CALIBRATION




This menu contains user angle and magnitude calibration data for the phasor measurement unit (PMU). This data is combined with the factory adjustments to shift the phasors for better accuracy.

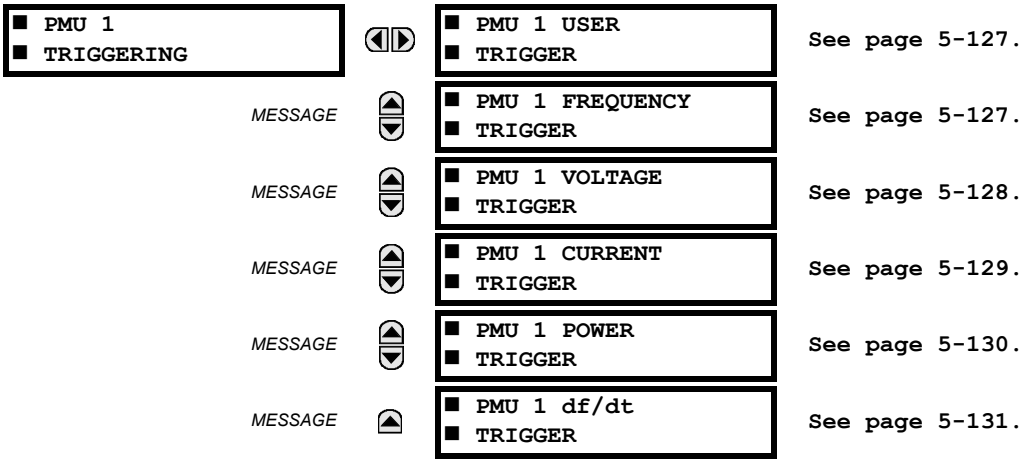
- **PMU 1 VA... IG CALIBRATION ANGLE**: These settings recognize applications with protection class voltage and current sources, and allow the user to calibrate each channel (four voltages and four currents) individually to offset errors introduced by VTs, CTs, and cabling. The setting values are effectively added to the measured angles. Therefore, enter a positive correction of the secondary signal lags the true signal; and negative value if the secondary signal leads the true signal.

- **PMU 1 VA... IG CALIBRATION MAGNITUDE**: These settings recognize applications with protection class voltage and current sources, and allow the user to calibrate each channel (four voltages and four currents) individually to offset errors introduced by VTs, CTs. The setting values are effectively a multiplier of the measured magnitudes. Therefore, enter a multiplier greater than 100% of the secondary signal increases the true signal; and a multiplier less than 100% value of the secondary signal reduces the true signal.
- **PMU 1 SEQ VOLT SHIFT ANGLE**: This setting allows correcting positive- and negative-sequence voltages for vector groups of power transformers located between the PMU voltage point, and the reference node. This angle is effectively added to the positive-sequence voltage angle, and subtracted from the negative-sequence voltage angle. Note that:
  1. When this setting is not "0°", the phase and sequence voltages do not agree. Unlike sequence voltages, the phase voltages cannot be corrected in a general case, and therefore are reported as measured.
  2. When receiving synchrophasor data at multiple locations, with possibly different reference nodes, it can be more beneficial to allow the central locations to perform the compensation of sequence voltages.
  3. This setting applies to PMU data only. The L30 calculates symmetrical voltages independently for protection and control purposes without applying this correction.
  4. When connected to line-to-line voltages, the PMU calculates symmetrical voltages with the reference to the AG voltage, and not to the physically connected AB voltage (see the Metering Conventions section in Chapter 6).
- **PMU 1 SEQ CURR SHIFT ANGLE**: This setting allows correcting positive and negative-sequence currents for vector groups of power transformers located between the PMU current point and the reference node. The setting has the same meaning for currents as the **PMU 1 SEQ VOLT SHIFT ANGLE** setting has for voltages. Normally, the two correcting angles are set identically, except rare applications when the voltage and current measuring points are located at different windings of a power transformer.



### d) PMU TRIGGERING OVERVIEW

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR... ⇨⇩ PHASOR MEASUREMENT UNIT 1 ⇨⇩ PMU 1 TRIGGERING




Each logical phasor measurement unit (PMU) contains five triggering mechanisms to facilitate triggering of the associated PMU recorder, or cross-triggering of other PMUs of the system. They are:

- Overfrequency and underfrequency
- Overvoltage and undervoltage
- Overcurrent
- Overpower
- High rate of change of frequency

The pre-configured triggers can be augmented with a user-specified condition built freely using programmable logic of the relay. The entire triggering logic is refreshed once every two power system cycles.

All five triggering functions and the user-definable condition are consolidated (ORed) and connected to the PMU recorder. Each trigger can be programmed to log its operation into the event recorder, and to signal its operation via targets. The five triggers drive the STAT bits of the data frame to inform the destination of the synchrophasor data regarding the cause of trigger. The following convention is adopted to drive bits 11, 3, 2, 1, and 0 of the STAT word.

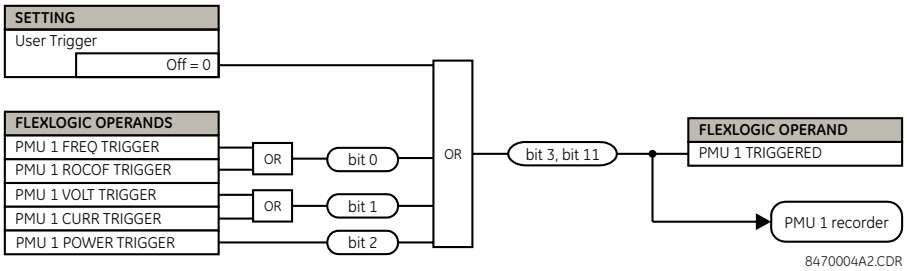



**Figure 5–43: STAT BITS LOGIC**

The trigger reset (drop-off) timer is available for all five triggering functions (FREQ, ROCOF, VOLT, CURR, POWER) in individual trigger settings under the TRIGGER DPO TIME setting. This asserts individual trigger operand and overall PMU x TRIGGERED operand with stat bits 3 and 11 for a fixed interval defined by this setting. If it is required that PMU x TRIGGERED operand with stat bits 3 and 11 stay longer than the individual reset timer, then use the PMU x USER TRIGGER setting assigned with appropriate elements and FlexLogic. In short, in case of USER TRIGGER, the drop-off time needs to be implemented using FlexLogic.

### e) USER TRIGGERING

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT... ⇨⇩ PMU 1 TRIGGERING ⇨⇩ PMU 1 USER TRIGGER**

| | | | |
|---|---|---|---|
| ■ PMU 1 USER<br>■ TRIGGER | ⇔ | PMU 1 USER TRIGGER:<br>Off | *Range: FlexLogic operands* |

The user trigger allows customized triggering logic to be constructed from FlexLogic. The entire triggering logic is refreshed once every two power system cycles.

### f) FREQUENCY TRIGGERING

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT... ⇨⇩ PMU 1 TRIGGERING ⇨⇩ PMU 1 FREQUENCY TRIGGER**

| | | | |
|---|---|---|---|
| ■ PMU 1 FREQUENCY<br>■ TRIGGER | ⇔ | PMU 1 FREQ TRIGGER<br>FUNCTION: Disabled | *Range: Enabled, Disabled* |
| *MESSAGE* | ⇕ | PMU 1 FREQ TRIGGER<br>LOW-FREQ: 49.00 Hz | *Range: 20.00 to 70.00 Hz in steps of 0.01* |
| *MESSAGE* | ⇕ | PMU 1 FREQ TRIGGER<br>HIGH-FREQ: 61.00 Hz | *Range: 20.00 to 70.00 Hz in steps of 0.01* |
| *MESSAGE* | ⇕ | PMU 1 FREQ TRIGGER<br>PKP TIME: 0.10 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| *MESSAGE* | ⇕ | PMU 1 FREQ TRIGGER<br>DPO TIME: 1.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| *MESSAGE* | ⇕ | PMU 1 FREQ TRIG BLK:<br>Off | *Range: FlexLogic operand* |
| *MESSAGE* | ⇕ | PMU 1 FREQ TRIGGER<br>TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| *MESSAGE* | ⇑ | PMU 1 FREQ TRIGGER<br>EVENTS: Disabled | *Range: Enabled, Disabled* |

The trigger responds to the frequency signal of the phasor measurement unit (PMU) source. The frequency is calculated from among phase voltages, auxiliary voltage, phase currents and ground current, in this hierarchy, depending on the source configuration as per L30 standards. This element requires that the frequency be above the minimum measurable value. If the frequency is below this value, such as when the circuit is de-energized, the trigger drops out.

- **PMU 1 FREQ TRIGGER LOW-FREQ**: This setting specifies the low threshold for the abnormal frequency trigger. The comparator applies a 0.02 Hz hysteresis.
- **PMU 1 FREQ TRIGGER HIGH-FREQ**: This setting specifies the high threshold for the abnormal frequency trigger. The comparator applies a 0.02 Hz hysteresis.
- **PMU 1 FREQ TRIGGER PKP TIME**: This setting can be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.
- **PMU 1 FREQ TRIGGER DPO TIME**: This setting can be used to extend the trigger after the situation returned to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

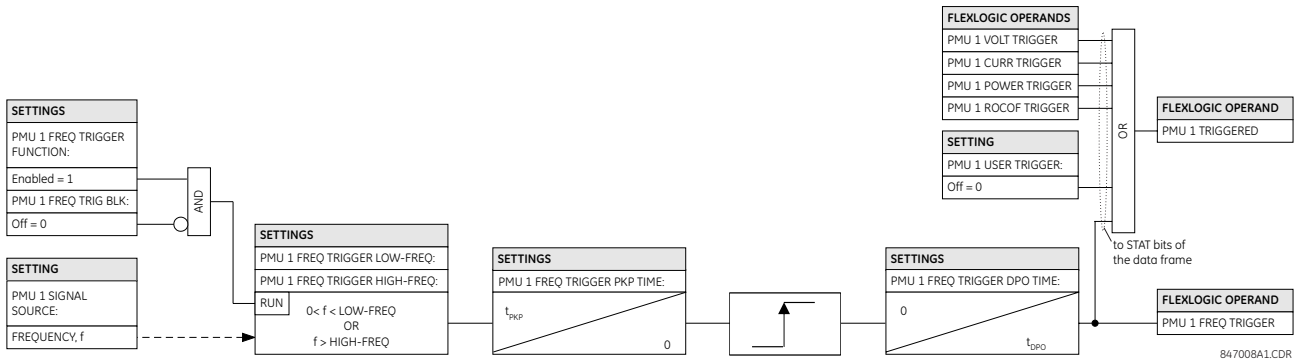



**Figure 5–44: FREQUENCY TRIGGER SCHEME LOGIC**

### g) VOLTAGE TRIGGERING

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT... ⇨⇩ PMU 1 TRIGGERING ⇨⇩ PMU 1 VOLTAGE TRIGGER**

```
■ PMU 1 VOLTAGE
■ TRIGGER
```

```
PMU 1 VOLT TRIGGER
FUNCTION: Disabled
```
*Range: Enabled, Disabled*

*MESSAGE*
```
PMU 1 VOLT TRIGGER
LOW-VOLT: 0.800 pu
```
*Range: 0.250 to 1.250 pu in steps of 0.001*

*MESSAGE*
```
PMU 1 VOLT TRIGGER
HIGH-VOLT: 1.200 pu
```
*Range: 0.750 to 1.750 pu in steps of 0.001*

*MESSAGE*
```
PMU 1 VOLT TRIGGER
PKP TIME: 0.10 s
```
*Range: 0.00 to 600.00 s in steps of 0.01*

*MESSAGE*
```
PMU 1 VOLT TRIGGER
DPO TIME: 1.00 s
```
*Range: 0.00 to 600.00 s in steps of 0.01*

*MESSAGE*
```
PMU 1 VOLT TRIG BLK:
Off
```
*Range: FlexLogic operand*

*MESSAGE*
```
PMU 1 VOLT TRIGGER
TARGET: Self-reset
```
*Range: Self-reset, Latched, Disabled*

*MESSAGE*
```
PMU 1 VOLT TRIGGER
EVENTS: Disabled
```
*Range: Enabled, Disabled*

This element responds to abnormal voltage. Separate thresholds are provided for low and high voltage. In terms of signaling its operation, the element does not differentiate between the undervoltage and overvoltage events. The trigger responds to the phase voltage signal of the phasor measurement unit (PMU) source. All voltage channels (A, B, and C or AB, BC, and CA) are processed independently and can trigger the recorder. A minimum voltage supervision of 0.1 pu is implemented to prevent pickup on a de-energized circuit, similarly to the undervoltage protection element.

- **PMU 1 VOLT TRIGGER LOW-VOLT**: This setting specifies the low threshold for the abnormal voltage trigger, in per-unit of the PMU source. 1 pu is a nominal voltage value defined as the nominal secondary voltage times VT ratio. The comparator applies a 1% hysteresis.
- **PMU 1 VOLT TRIGGER HIGH-VOLT**: This setting specifies the high threshold for the abnormal voltage trigger, in per-unit of the PMU source. 1 pu is a nominal voltage value defined as the nominal secondary voltage times VT ratio. The comparator applies a 1% hysteresis.
- **PMU 1 VOLT TRIGGER PKP TIME**: This setting can bused to filter out spurious conditions and avoid unnecessary triggering of the recorder.
- **PMU 1 VOLT TRIGGER DPO TIME**: This setting can be used to extend the trigger after the situation returned to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

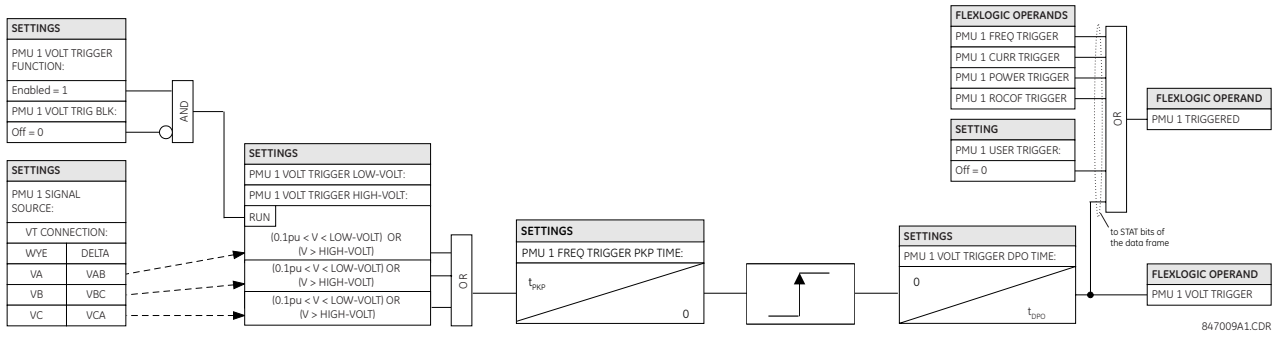



**Figure 5–45: VOLTAGE TRIGGER SCHEME LOGIC**

### h) CURRENT TRIGGERING

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT... ⇨⇩ PMU 1 TRIGGERING ⇨⇩ PMU 1 CURRENT TRIGGER**

| | | | |
|---|---|---|---|
| ■ PMU 1 CURRENT TRIGGER | ◀▶ | PMU 1 CURR TRIGGER FUNCTION: Disabled | *Range: Enabled, Disabled* |
| | *MESSAGE* ▲▼ | PMU 1 CURR TRIGGER PICKUP: 1.800 pu | *Range: 0.100 to 30.000 pu in steps of 0.001* |
| | *MESSAGE* ▲▼ | PMU 1 CURR TRIGGER PKP TIME: 0.10 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* ▲▼ | PMU 1 CURR TRIGGER DPO TIME: 1.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* ▲▼ | PMU 1 CURR TRIG BLK: Off | *Range: FlexLogic operand* |
| | *MESSAGE* ▲▼ | PMU 1 CURR TRIGGER TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* ▲ | PMU 1 CURR TRIGGER EVENTS: Disabled | *Range: Enabled, Disabled* |

This element responds to elevated current. The trigger responds to the phase current signal of the phasor measurement unit (PMU) source. All current channel (A, B, and C) are processed independently and could trigger the recorder.

- **PMU 1 CURR TRIGGER PICKUP**: This setting specifies the pickup threshold for the overcurrent trigger, in per unit of the PMU source. A value of 1 pu is a nominal primary current. The comparator applies a 3% hysteresis.
- **PMU 1 CURR TRIGGER PKP TIME**: This setting can be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.
- **PMU 1 CURR TRIGGER DPO TIME**: This setting can be used to extend the trigger after the situation returned to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

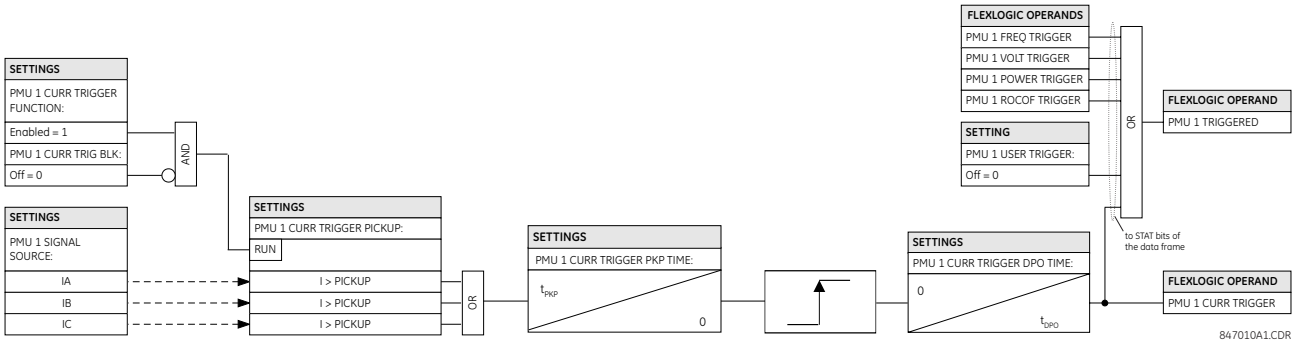



**Figure 5–46: CURRENT TRIGGER SCHEME LOGIC**

5

### i) POWER TRIGGERING

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT... ⇨⇩ PMU 1 TRIGGERING ⇨⇩ PMU 1 POWER TRIGGER**

| | | | |
|---|---|---|---|
| ■ PMU 1 POWER<br>■ TRIGGER | | PMU 1 POWER TRIGGER<br>FUNCTION: Disabled | *Range: Enabled, Disabled* |
| | *MESSAGE* | PMU 1 POWER TRIGGER<br>ACTIVE: 1.250 pu | *Range: 0.250 to 3.000 pu in steps of 0.001* |
| | *MESSAGE* | PMU 1 POWER TRIGGER<br>REACTIVE: 1.250 pu | *Range: 0.250 to 3.000 pu in steps of 0.001* |
| | *MESSAGE* | PMU 1 POWER TRIGGER<br>APPARENT: 1.250 pu | *Range: 0.250 to 3.000 pu in steps of 0.001* |
| | *MESSAGE* | PMU 1 POWER TRIGGER<br>PKP TIME: 0.10 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | PMU 1 POWER TRIGGER<br>DPO TIME: 1.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | PMU 1 PWR TRIG BLK:<br>Off | *Range: FlexLogic operand* |
| | *MESSAGE* | PMU 1 POWER TRIGGER<br>TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | PMU 1 POWER TRIGGER<br>EVENTS: Disabled | *Range: Enabled, Disabled* |

This element responds to abnormal power. Separate thresholds are provided for active, reactive, and apparent powers. In terms of signaling its operation the element does not differentiate between the three types of power. The trigger responds to the single-phase and three-phase power signals of the phasor measurement unit (PMU) source.

- **PMU 1 POWER TRIGGER ACTIVE**: This setting specifies the pickup threshold for the active power of the source. For single-phase power, 1 pu is a product of 1 pu voltage and 1 pu current, or the product of nominal secondary voltage, the VT ratio and the nominal primary current. For the three-phase power, 1 pu is three times that for a single-phase power. The comparator applies a 3% hysteresis.

- **PMU 1 POWER TRIGGER REACTIVE**: This setting specifies the pickup threshold for the reactive power of the source. For single-phase power, 1 pu is a product of 1 pu voltage and 1 pu current, or the product of nominal secondary voltage, the VT ratio and the nominal primary current. For the three-phase power, 1 pu is three times that for a single-phase power. The comparator applies a 3% hysteresis.
- **PMU 1 POWER TRIGGER APPARENT**: This setting specifies the pickup threshold for the apparent power of the source. For single-phase power, 1 pu is a product of 1 pu voltage and 1 pu current, or the product of nominal secondary voltage, the VT ratio and the nominal primary current. For the three-phase power, 1 pu is three times that for a single-phase power. The comparator applies a 3% hysteresis.
- **PMU 1 POWER TRIGGER PKP TIME**: This setting can be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.
- **PMU 1 POWER TRIGGER DPO TIME**: This setting can be used to extend the trigger after the situation returned to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

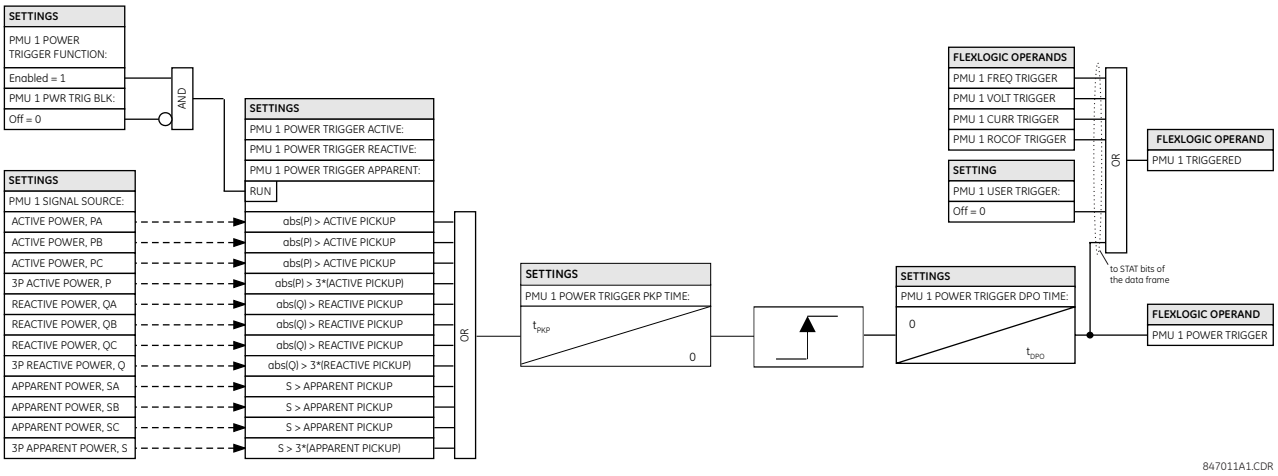



**Figure 5–47: POWER TRIGGER SCHEME LOGIC**

### j) DF/DT TRIGGERING

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT... ⇨⇩ PMU 1 TRIGGERING ⇨⇩ PMU 1 df/dt TRIGGER**

| | | | |
|---|---|---|---|
| ■ PMU 1 df/dt<br>■ TRIGGER | | PMU 1 df/dt TRIGGER<br>FUNCTION: Disabled | *Range: Enabled, Disabled* |
| | *MESSAGE* | PMU 1 df/dt TRIGGER<br>RAISE: 0.25 Hz/s | *Range: 0.10 to 15.00 Hz/s in steps of 0.01* |
| | *MESSAGE* | PMU 1 df/dt TRIGGER<br>FALL: 0.25 Hz/s | *Range: 0.10 to 15.00 Hz/s in steps of 0.01* |
| | *MESSAGE* | PMU 1 df/dt TRIGGER<br>PKP TIME: 0.10 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | PMU 1 df/dt TRIGGER<br>DPO TIME: 1.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | PMU 1 df/dt TRG BLK:<br>Off | *Range: FlexLogic operand* |
| | *MESSAGE* | PMU 1 df/dt TRIGGER<br>TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | PMU 1 df/dt TRIGGER<br>EVENTS: Disabled | *Range: Enabled, Disabled* |

This element responds to frequency rate of change. Separate thresholds are provided for rising and dropping frequency. The trigger responds to the rate of change of frequency (df/dt) of the phasor measurement unit (PMU) source.

- **PMU 1 df/dt TRIGGER RAISE**: This setting specifies the pickup threshold for the rate of change of frequency in the raising direction (positive df/dt). The comparator applies a 4% hysteresis.
- **PMU 1 df/dt TRIGGER FALL**: This setting specifies the pickup threshold for the rate of change of frequency in the falling direction (negative df/dt). The comparator applies a 4% hysteresis.
- **PMU 1 df/dt TRIGGER PKP TIME**: This setting can be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.
- **PMU 1 df/dt TRIGGER DPO TIME**: This setting can be used to extend the trigger after the situation returned to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

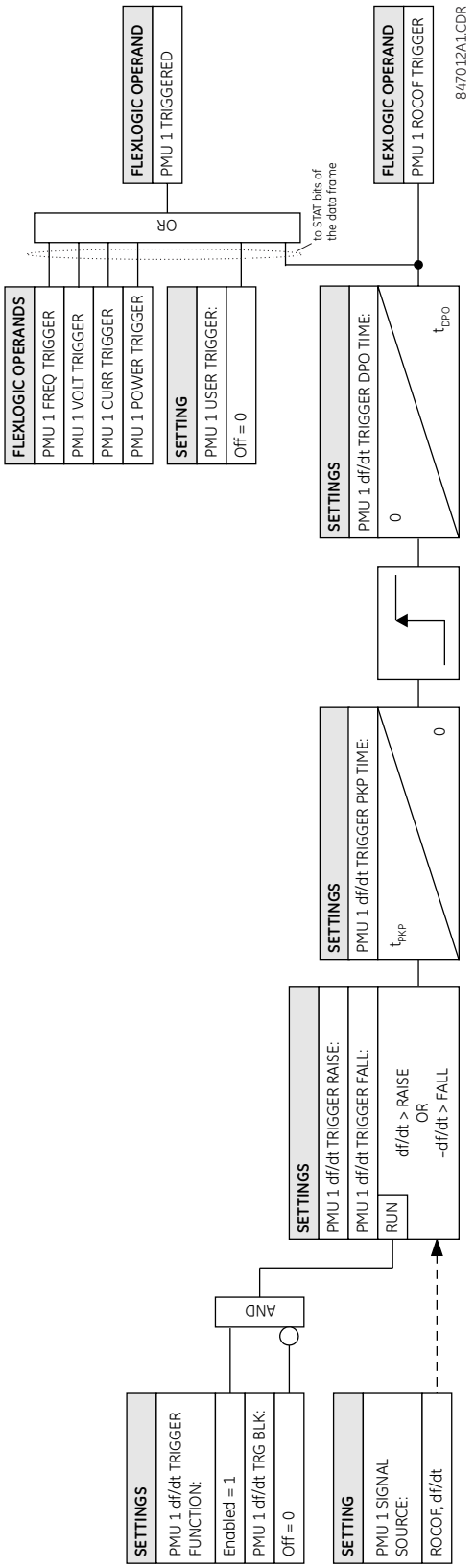
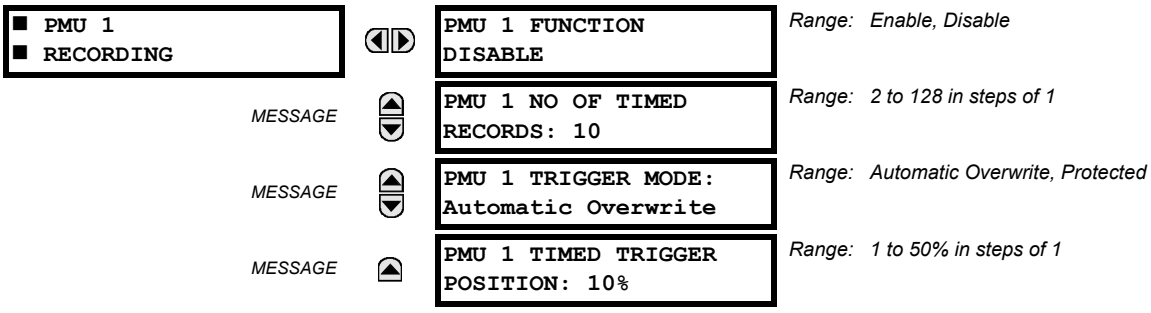



**Figure 5–48: RATE OF CHANGE OF FREQUENCY TRIGGER SCHEME LOGIC**

### k) PMU RECORDING

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨ PHASOR MEASUREMENT⇨⇩ PHASOR MEASUREMENT UNIT1 ⇩ RECORDING PMU1




The length of the PMU record is variable and depends on some settings and configuration, such as **PMU 1 NO OF TIMED RECORDS**, **PMU 1 RATE**, number of Synchrophasors, Analogs and Digitals configured in each PMU. There is a fixed amount of data storage for PMU recording; the more records captured, the less the recording length captured per record. See the ACTUAL VALUES ⇨ RECORDS ⇨⇩ PMU RECORDS ⇨ PMU 1 RECORDING menu to view the actual PMU record length captured per record. The following table provides sample configurations with corresponding seconds per record. The minimum number of PMU records is two. The third to fifth columns is the number of configured values recorded in each record.

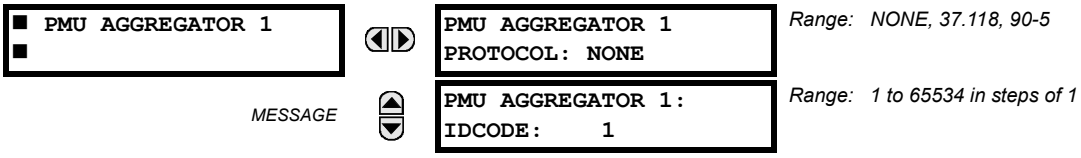
**Table 5–14: PMU RECORD LENGTH EXAMPLE**

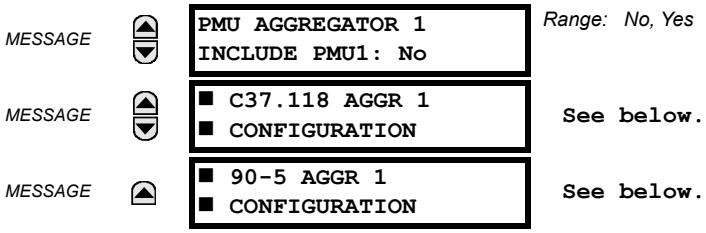
| RECORDS | FRAMES PER SECOND | SYNCHROPHASORS | ANALOGS | DIGITALS | RECORD LENGTH (SECONDS) |
|---|---|---|---|---|---|
| 3 | 30 | 14 | 8 | 16 | 590.4 |
| 16 | 30 | 14 | 8 | 16 | 138.9 |
| 32 | 30 | 14 | 8 | 16 | 71.5 |
| 64 | 30 | 14 | 8 | 16 | 36.3 |
| 3 | 60 | 14 | 8 | 16 | 295.2 |
| 16 | 60 | 14 | 8 | 16 | 69.4 |
| 32 | 60 | 14 | 8 | 16 | 35.7 |
| 64 | 60 | 14 | 8 | 16 | 18.1 |

- **PMU 1 FUNCTION**: This setting enables or disables the recorder for PMU 1. The rate is fixed at the reporting rate set within the aggregator (that is, Aggregator 1).
- **PMU 1 NO OF TIMED RECORDS**: This setting specifies the number of timed records that are available for a given logical PMU 1. The length of each record is equal to the available memory divided by the content size and number of records. As the number of records is increased the available storage for each record is reduced. The relay supports a maximum of 128 records in either timed or forced mode.
- **PMU 1 TRIGGER MODE**: This setting specifies what happens when the recorder uses its entire available memory storage. Under the “Automatic Overwrite”, the last record is erased to facilitate new recording, when triggered. Under the “Protected” selection, the recorder stops creating new records when the entire memory is used up by the old uncleared records.
- **PMU 1 TIMED TRIGGER POSITION**: This setting specifies the amount of pre-trigger data as a percent of the entire record. This setting applies only to the timed mode of recording.

### l) AGGREGATORS

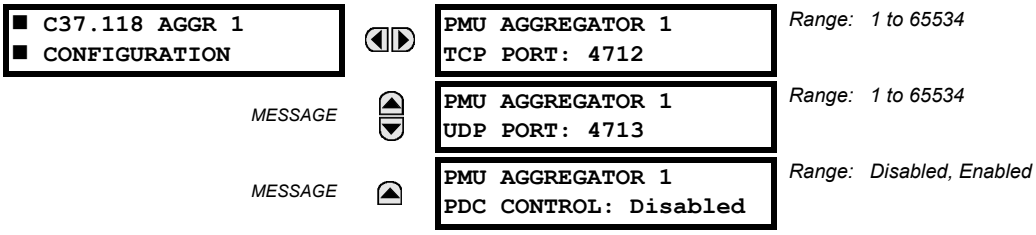
PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT UNIT ⇨⇩ PMU AGGREGATOR 1



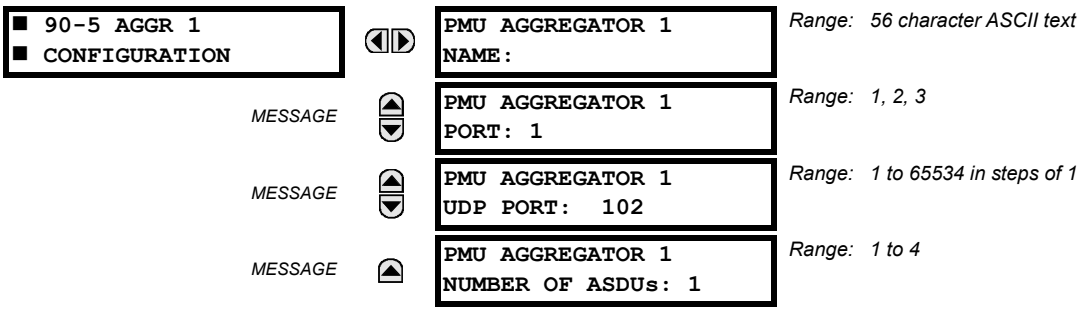



NOTE When the protocol selection is set via the software or keypad, all aggregators whose protocol is not set to None are set to the last protocol saved (that is, IEEE C37.118 or IEC 61850-90-5) to any aggregators, as both IEEE C37.118 and IEC 61850-90-5 simultaneous streaming is not possible.

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT UNIT ⇨⇩ PMU AGGREGATOR 1 ⇨⇩ C37.118 AGGR 1 CONFIGURATION**




**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT UNIT ⇨⇩ PMU AGGREGATOR 1 ⇨⇩ 90-5 AGGR 1 CONFIGURATION**




- **PMU AGGREGATOR 1 PROTOCOL**: This setting selects if the IEEE C37.118 or IEC 61850-90-5 standard is used. Because one protocol is supported at a time in a device, this setting applies to all PMU aggregators.
- **PMU AGGREGATOR 1 IDCODE**: Numeric identifier of the Aggregator / PDC function. In an IEEE C37.118 output stream, this identifies the ID of the aggregator, which is only used if there is more than 1 PMU mapped into an aggregator.
- **PMU AGGREGATOR 1 PMU1**: If set to “Yes” aggregator 1 includes the PMU 1 data set in the reporting data stream. AGGREGATOR 1 does not include PMU 1 data set in the report if set to “No”.

NOTE Only PMUs with same reporting rate can be assigned to the same PMU AGGREGATOR.

### C37.118 AGGREGATOR 1 CONFIGURATION

- **PMU AGGREGATOR 1 TCP PORT**: This setting selects the TCP port number to be used by this aggregator for network reporting. All ports, even those of unused aggregators, must be valid and unique to avoid port number collisions.
- **PMU AGGREGATOR 1 UDP PORT**: This setting selects the UDP port number to be used by this aggregator for network reporting. All ports, even those of unused aggregators, must be valid and unique to avoid port number collisions.
- **PMU AGGREGATOR 1 PDC CONTROL**: The synchrophasor standard allows for user-defined controls originating at the PDC, to be executed on the PMU. The control is accomplished via an extended command frame. The relay decodes the first word of the extended field, EXTFRAME, to drive 16 dedicated FlexLogic operands. Each aggregator supports 16 FlexLogic operands as shown in the table. The operands are asserted for 5 seconds following reception of

the command frame. If the new command frame arrives within the 5 second period, the FlexLogic operands are updated, and the 5 second timer is restarted. This setting enables or disables the control. When enabled, all 16 operands for each aggregator are active; when disabled all 16 operands for each aggregator remain reset.

**Table 5–15: FLEXLOGIC OPERANDS SUPPORTED BY AGGREGATOR**

| OPERAND TYPE | OPERAND SYNTAX | OPERAND DESCRIPTION |
|---|---|---|
| ELEMENT: Synchrophasor, phasor data, concentrator | AGTR1 PDC CNTRL 1 | Phasor data concentrator asserts control bit 1, as received via the network. |
| as above | AGTR1 PDC CNTRL 2 | Phasor data concentrator asserts control bit 2 as received via the network. |
| as above | AGTR1 PDC CNTRL 3 | Phasor data concentrator asserts control bit 3 as received via the network. |
| | ↓ | |
| as above | AGTR1 PDC CNTRL 16 | Phasor data concentrator asserts control bit 16, as received via the network. |
| as above | AGTR2 PDC CNTRL 1 | Phasor data concentrator asserts control bit 1 as received via the network |
| as above | AGTR2 PDC CNTRL 2 | Phasor data concentrator asserts control bit 2 as received via the network |
| as above | AGTR2 PDC CNTRL 3 | Phasor data concentrator asserts control bit 3 as received via the network. |
| | ↓ | |
| as above | AGTR1 PDC CNTRL 16 | Phasor data concentrator asserts control bit 16, as received via the network. |



**IEC 61850-90-5 AGGREGATOR 1 CONFIGURATION**

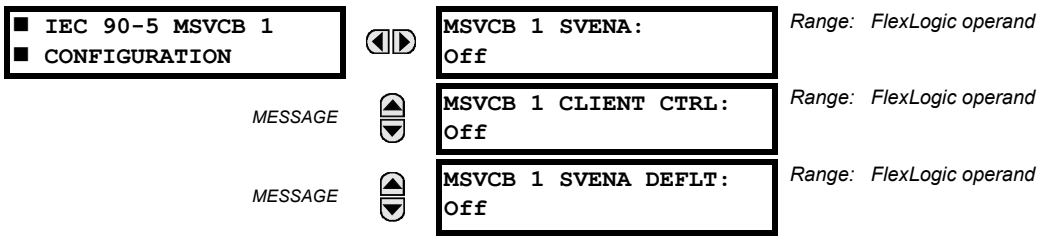
- **PMU AGGREGATOR 1 NAME:** A user-defined visible string of characters (maximum 56) to identify the source of the stream. This value, concatenated with the Aggregator IDCode and Aggregator Class of Service, is mapped into the IEC 61850 MSVID filed in the output stream. The field allows 65 characters, but uses the first 56 characters.
- **AGGREGATOR 1 PHYSICAL PORT:** This setting determines the physical ports through which the synchrophasor traffic is transmitted. The range is 1, 2, 3.
- **PMU AGGREGATOR 1 UDP:** This setting selects the UDP port number that is used by this dataset for network reporting. A default setting value for IEC 6150-90-5 is provided.
- **PMU AGGREGATOR 1 NUMBER OF ASDUs:** This setting sets the number of Application Service Data Units (ASDUs) from 1 through to 4.

**Table 5–16: NUMBER OF ASDU**

| SETTINGS FOR ASDU | TRANSMISSION |
|---|---|
| 1 | ASDU at T0 (current values) |
| 2 | ASDU at T-1 (previous values) + ASDU at T0 (current values) |
| 3 | ASDU at T-2 (previous values) + ASDU at T-1 (previous values) + ASDU at T0 (current values) |
| 4 | ASDU at T-3 (previous values) + ASDU at T-2 (previous values) + ASDU at T-1 (previous values) + ASDU at T0 (current values) |

### m) CONTROL BLOCKS

**PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ PHASOR MEASUREMENT UNIT ⇨⇩ IEC 90–5 MSVCB 1 CONFIGURATION**



MESSAGE
MSVCB 1 CONFREV:
1
Range: 1 to 4294967295

MESSAGE
MSVCB 1 PRIORITY:
4
Range: 0 to 7

MESSAGE
MSVCB 1 DSCP CLASS:
Expedited Forwarding
Range: None, Expedited Forwarding

MESSAGE
MSVCB 1 VLAN ID:
0
Range: 0 to 4095

MESSAGE
MSVCB 1 APPID:
0
Range: 0 to 16383

MESSAGE
MSVCB 1 DEST IP:
224.0.0.0
Range: 0 to 255.255.255.255

MESSAGE
MSVCB 1 SECURITY:
0
Range: 0 to 2

- **MSVCB 1 SVENA:** The SV Stream Control is set by either toggling an assigned FlexLogic operand or a remote client write, to start and stop the streaming of R-SV frames. If remote client control is disabled, a negative response is provided to the client in response to a write attempt. A FlexLogic operand (SvEna) is provided for each Aggregator that reflects the state of the SvEna control where "1"= Enabled and "0"=Disabled. The logic for setting the SvEna control bit is shown in the following figure.

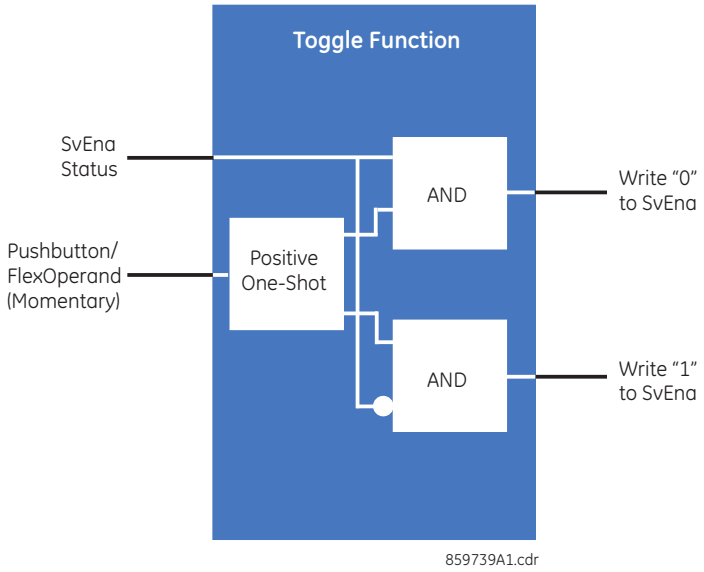



**Figure 5–49: LOGIC FOR SETTING SVENA CONTROL BIT**

- **MSVCB 1 CLIENT CTRL:** This setting determines if a client can write to the reserve bit. When the assigned FlexLogic operand is a logic 1 state, remote clients can write to both the reserve bit and the SvEna bit. When the FlexLogic operand is a logic 0 state, the remote client writes to the reserve bit, the SvEna is rejected by the UR, and a negative response with the appropriate Service Error is returned to the client.
- **MSVCB 1 SVENA DEFLT:** This setting sets the default state of the stream (On or Off) on power-up or restart.
- **MSVCB 1 CONFREV:** The relay increments the Configuration revision every time the configuration is changed. This setting allows the user to reset the configuration back to 1 or a value from 1 to 4294967295.
- **MSVCB 1 PRIORITY:** A value from 0 through 7: The default value is 4.
- **MSVCB 1 DSCP Class:** The value represents the IPv4 Differentiated Services (formerly called TypeOfService) value. The default value is set for Expedited Forwarding (101110B (46 or 2EH). This value provides priority routing, when supported in the routers.

- **MSVCB 1 VLAN ID:** A range of values limited from 0 to 4095.
- **MSVCB 1 APPID:** This setting allows the selection of a specific application ID for each sending device.
- **MSVCB 1 DEST IP:** This is the destination multicast address IP address that is entered in Standard IPV4 address format. The valid range for IPv4 is from 224.0.0.0 to 239.255.255.255, but the UR does not test the address entered.
- **MSVCB 1 SECURITY:** This setting selects the level of security and authentication used, as outlined in the following table, and is in the form of an enumeration as per standard. The range is 0 to 2.

NOTE

Shaded settings in the table are not supported in firmware 7.0.

| ENUMERATION | AUTHENTICATION | ENCRYPTION |
|---|---|---|
| 0 | no | no |
| 1 | yes | no |
| 2 | yes | yes |

### 5.5.1 INTRODUCTION TO FLEXLOGIC

To provide maximum flexibility to the user, the arrangement of internal digital logic combines fixed and user-programmed parameters. Logic upon which individual features are designed is fixed, and all other logic, from digital input signals through elements or combinations of elements to digital outputs, is variable. The user has complete control of all variable logic through FlexLogic. In general, the system receives analog and digital inputs which it uses to produce analog and digital outputs. The major sub-systems of a generic UR-series relay involved in this process are shown below.

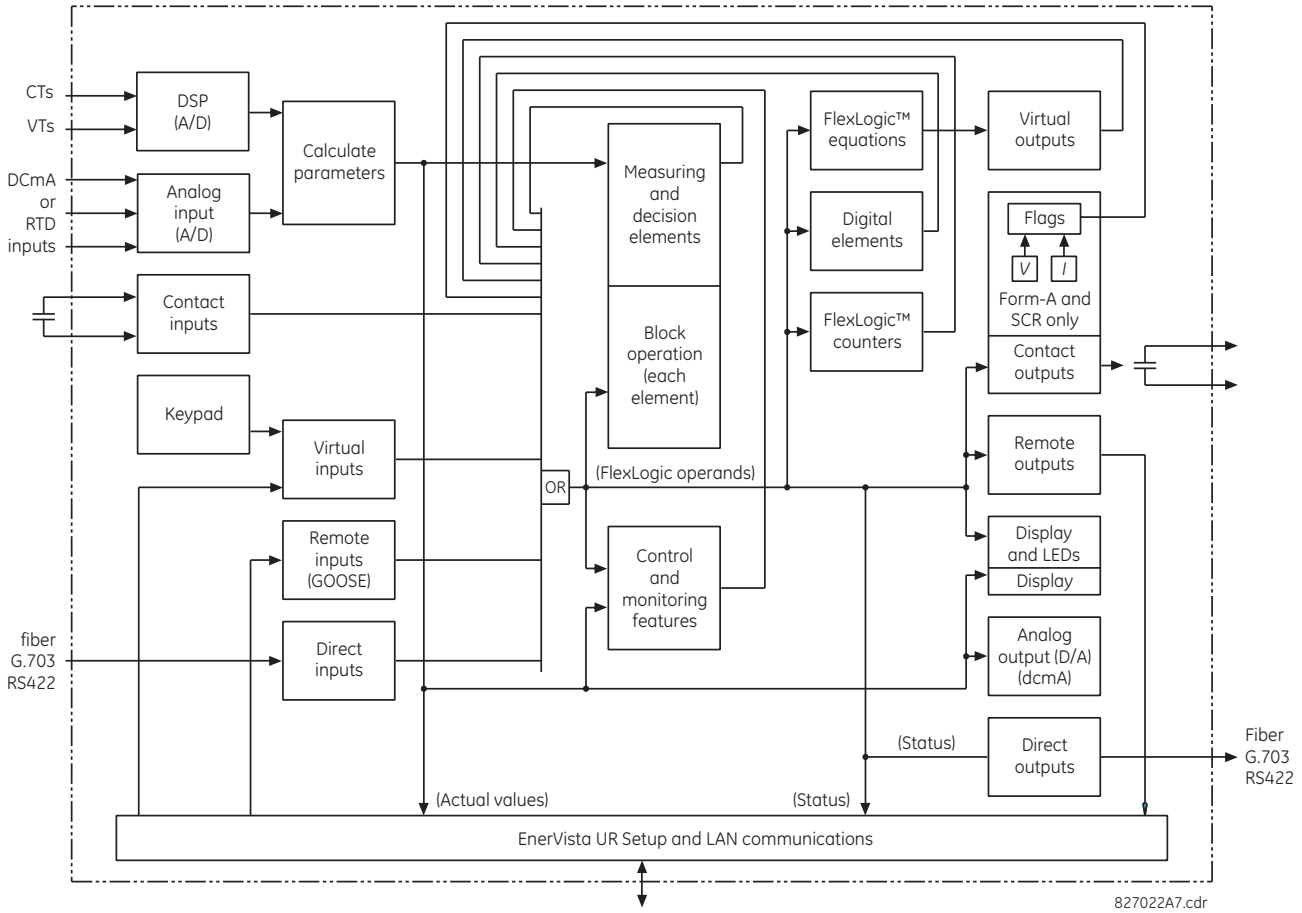



**Figure 5–50: UR ARCHITECTURE OVERVIEW**

The states of all digital signals used in the L30 are represented by flags (or FlexLogic operands, which are described later in this section). A digital "1" is represented by a 'set' flag. Any external contact change-of-state can be used to block an element from operating, as an input to a control feature in a FlexLogic equation, or to operate a contact output. The state of the contact input can be displayed locally or viewed remotely via the communications facilities provided. If a simple scheme where a contact input is used to block an element is desired, this selection is made when programming the element. This capability also applies to the other features that set flags: elements, virtual inputs, remote inputs, schemes, and human operators.

If more complex logic than presented above is required, it is implemented via FlexLogic. For example, if it is desired to have the closed state of contact input H7a and the operated state of the phase undervoltage element block the operation of the phase time overcurrent element, the two control input states are programmed in a FlexLogic equation. This equation ANDs the two control inputs to produce a virtual output which is then selected when programming the phase time overcurrent to be used as a blocking input. Virtual outputs can only be created by FlexLogic equations.

Traditionally, protective relay logic has been relatively limited. Any unusual applications involving interlocks, blocking, or supervisory functions had to be hard-wired using contact inputs and outputs. FlexLogic minimizes the requirement for auxiliary components and wiring while making more complex schemes possible.

The logic that determines the interaction of inputs, elements, schemes and outputs is field programmable through the use of logic equations that are sequentially processed. The use of virtual inputs and outputs in addition to hardware is available internally and on the communication ports for other relays to use (distributed FlexLogic).

FlexLogic allows users to customize the relay through a series of equations that consist of *operators* and *operands*. The operands are the states of inputs, elements, schemes and outputs. The operators are logic gates, timers and latches (with set and reset inputs). A system of sequential operations allows any combination of specified operands to be assigned as inputs to specified operators to create an output. The final output of an equation is a numbered register called a *virtual output*. Virtual outputs can be used as an input operand in any equation, including the equation that generates the output, as a seal-in or other type of feedback.

A FlexLogic equation consists of parameters that are either operands or operators. Operands have a logic state of 1 or 0. Operators provide a defined function, such as an AND gate or a Timer. Each equation defines the combinations of parameters to be used to set a Virtual Output flag. Evaluation of an equation results in either a 1 (=ON, i.e. flag set) or 0 (=OFF, i.e. flag not set). Each equation is evaluated at least 4 times every power system cycle.

Some types of operands are present in the relay in multiple instances; e.g. contact and remote inputs. These types of operands are grouped together (for presentation purposes only) on the faceplate display. The characteristics of the different types of operands are listed in the table below.

**Table 5–17: L30 FLEXLOGIC OPERAND TYPES**

| OPERAND TYPE | STATE | EXAMPLE FORMAT | CHARACTERISTICS [INPUT IS '1' (= ON) IF...] |
|---|---|---|---|
| Contact Input | On | Cont Ip On | Voltage is presently applied to the input (external contact closed) |
| | Off | Cont Ip Off | Voltage is presently not applied to the input (external contact open) |
| Contact Output (type Form-A contact only) | Contact Closed | Cont Op 1 Closed | Contact output is closed |
| | Current On | Cont Op 1 Ion | Current is flowing through the contact |
| | Voltage On | Cont Op 1 VOn | Voltage exists across the contact |
| | Voltage Off | Cont Op 1 VOff | Voltage does not exists across the contact |
| Direct Input | On | DIRECT INPUT 1 On | The direct input is presently in the ON state |
| Element (Analog) | Pickup | PHASE TOC1 PKP | The tested parameter is presently above the pickup setting of an element which responds to rising values or below the pickup setting of an element which responds to falling values |
| | Dropout | PHASE TOC1 DPO | This operand is the logical inverse of the above PKP operand |
| | Operate | PHASE TOC1 OP | The tested parameter has been above/below the pickup setting of the element for the programmed delay time, or has been at logic 1 and is now at logic 0 but the reset timer has not finished timing |
| | Block | PHASE TOC1 BLK | The output of the comparator is set to the block function |
| Element (Digital) | Pickup | Dig Element 1 PKP | The input operand is at logic 1 |
| | Dropout | Dig Element 1 DPO | This operand is the logical inverse of the above PKP operand |
| | Operate | Dig Element 1 OP | The input operand has been at logic 1 for the programmed pickup delay time, or has been at logic 1 for this period and is now at logic 0 but the reset timer has not finished timing |
| Element (Digital Counter) | Higher than | Counter 1 HI | The number of pulses counted is above the set number |
| | Equal to | Counter 1 EQL | The number of pulses counted is equal to the set number |
| | Lower than | Counter 1 LO | The number of pulses counted is below the set number |
| Fixed | On | On | Logic 1 |
| | Off | Off | Logic 0 |
| Remote Input | On | REMOTE INPUT 1 On | The remote input is presently in the ON state |
| Virtual Input | On | Virt Ip 1 On | The virtual input is presently in the ON state |
| Virtual Output | On | Virt Op 1 On | The virtual output is presently in the set state (i.e. evaluation of the equation which produces this virtual output results in a "1") |

The operands available for this relay are listed alphabetically by types in the following table.

**Table 5–18: L30 FLEXLOGIC OPERANDS (Sheet 1 of 7)**

| OPERAND TYPE | OPERAND SYNTAX | OPERAND DESCRIPTION |
|---|---|---|
| CONTROL PUSHBUTTONS | CONTROL PUSHBTN 1 ON<br>CONTROL PUSHBTN 2 ON<br>CONTROL PUSHBTN 3 ON<br>CONTROL PUSHBTN 4 ON<br>CONTROL PUSHBTN 5 ON<br>CONTROL PUSHBTN 6 ON<br>CONTROL PUSHBTN 7 ON | Control pushbutton 1 is being pressed<br>Control pushbutton 2 is being pressed<br>Control pushbutton 3 is being pressed<br>Control pushbutton 4 is being pressed<br>Control pushbutton 5 is being pressed<br>Control pushbutton 6 is being pressed<br>Control pushbutton 7 is being pressed |
| CYBERSENTRY | ROLE ADMIN ACT<br>ROLE SUPERVISOR ACT<br>ROLE ENGINEER ACT<br>ROLE OPERATOR ACT<br>ROLE OBSERVER ACT<br>AUTHENTICATION FAIL<br>UNAUTH FW ATTEMPT<br>UNAUTH SETTING WRITE | Administrator role is active and is set to true when that is the case<br>Supervisor role is active and is set to true when that is the case<br>Engineer role is active and is set to true when that is the case<br>Operator role is active and is set to true when that is the case<br>Observer role is active and is set to true when that is the case<br>Operand set for Failed Authentication self-test and alarm<br>Operand set for firmware lock self-test and alarm<br>Operand set for settings lock self-test and alarm |
| ELEMENT: 50DD supervision | 50DD SV | Disturbance detector has operated |
| ELEMENT: 87L current differential | 87L DIFF OP<br>87L DIFF RECVD DTT<br>87L DIFF KEY DTT<br>87L DIFF PFLL FAIL<br>87L DIFF CH ASYM DET<br>87L DIFF CH1 FAIL<br>87L DIFF CH2 FAIL<br>87L DIFF CH1 LOSTPKT<br>87L DIFF CH2 LOSTPKT<br>87L DIFF CH1 CRCFAIL<br>87L DIFF CH2 CRCFAIL<br>87L DIFF CH1 ID FAIL<br>87L DIFF CH2 ID FAIL<br>87L DIFF GPS FAIL<br>87L DIFF 1 MAX ASYM<br>87L DIFF 2 MAX ASYM<br>87L DIFF 1 TIME CHNG<br>87L DIFF 2 TIME CHNG<br>87L DIFF GPS 1 FAIL<br>87L DIFF GPS 2 FAIL<br>87L DIFF BLOCKED<br>87L DIFF PKP G<br>87L DIFF OP G | At least one phase of current differential is operated<br>Direct transfer trip has been received<br>Direct transfer trip is keyed<br>Phase and frequency lock loop (PFLL) has failed<br>Channel asymmetry greater than 1.5 ms detected<br>Channel 1 has failed<br>Channel 2 has failed<br>Exceeded maximum lost packet threshold on channel 1<br>Exceeded maximum lost packet threshold on channel 2<br>Exceeded maximum CRC error threshold on channel 1<br>Exceeded maximum CRC error threshold on channel 2<br>The ID check for a peer L30 on channel 1 has failed<br>The ID check for a peer L30 on channel 2 has failed<br>The GPS signal failed or is not configured properly at any terminal<br>Asymmetry on channel 1 exceeded preset value<br>Asymmetry on channel 2 exceeded preset value<br>Change in round trip delay on channel 1 exceeded preset value<br>Change in round trip delay on channel 2 exceeded preset value<br>GPS failed at remote terminal 1 (channel 1)<br>GPS failed at remote terminal 1 (channel 2)<br>The 87L function is blocked due to communication problems<br>The ground differential element has picked up<br>The ground differential element has operated |
| ELEMENT: 87L in-zone transformer compensation | 87L HARM2 A OP<br>87L HARM2 B OP<br>87L HARM2 C OP | Asserted when phase A of second harmonic of the transformer magnetizing inrush current inhibits the current differential element from operating<br>Asserted when phase B of second harmonic of the transformer magnetizing inrush current inhibits the current differential element from operating<br>Asserted when phase C of second harmonic of the transformer magnetizing inrush current inhibits the current differential element from operating |
| ELEMENT: Autoreclose (per CT bank) | AR1 ENABLED<br>AR1 RIP<br>AR1 LO<br>AR1 BLK FROM MAN CLS<br>AR1 CLOSE<br>AR1 SHOT CNT=0<br>AR1 SHOT CNT=1<br>AR1 SHOT CNT=2<br>AR1 SHOT CNT=3<br>AR1 SHOT CNT=4<br>AR1 DISABLED | Autoreclose 1 is enabled<br>Autoreclose 1 is in progress<br>Autoreclose 1 is locked out<br>Autoreclose 1 is temporarily disabled<br>Autoreclose 1 close command is issued<br>Autoreclose 1 shot count is 0<br>Autoreclose 1 shot count is 1<br>Autoreclose 1 shot count is 2<br>Autoreclose 1 shot count is 3<br>Autoreclose 1 shot count is 4<br>Autoreclose 1 is disabled |
| | AR2 | Same set of operands as shown for AR1 |
| ELEMENT: Auxiliary overvoltage | AUX OV1 PKP<br>AUX OV1 DPO<br>AUX OV1 OP | Auxiliary overvoltage element has picked up<br>Auxiliary overvoltage element has dropped out<br>Auxiliary overvoltage element has operated |
| ELEMENT: Auxiliary undervoltage | AUX UV1 PKP<br>AUX UV1 DPO<br>AUX UV1 OP | Auxiliary undervoltage element has picked up<br>Auxiliary undervoltage element has dropped out<br>Auxiliary undervoltage element has operated |
| ELEMENT: Breaker arcing | BKR ARC 1 OP<br>BKR ARC 1 DPO<br>BKR ARC 2 OP<br>BKR ARC 2 DPO | Breaker arcing current 1 has operated<br>Breaker arcing current 1 has dropped out<br>Breaker arcing current 2 has operated<br>Breaker arcing current 2 has dropped out |

**Table 5–18: L30 FLEXLOGIC OPERANDS (Sheet 2 of 7)**

| OPERAND TYPE | OPERAND SYNTAX | OPERAND DESCRIPTION |
|---|---|---|
| ELEMENT<br>Breaker failure | BKR FAIL 1 RETRIPA<br>BKR FAIL 1 RETRIPB<br>BKR FAIL 1 RETRIPC<br>BKR FAIL 1 RETRIP<br>BKR FAIL 1 T1 OP<br>BKR FAIL 1 T2 OP<br>BKR FAIL 1 T3 OP<br>BKR FAIL 1 TRIP OP | Breaker failure 1 re-trip phase A (only for 1-pole schemes)<br>Breaker failure 1 re-trip phase B (only for 1-pole schemes)<br>Breaker failure 1 re-trip phase C (only for 1-pole schemes)<br>Breaker failure 1 re-trip 3-phase<br>Breaker failure 1 timer 1 is operated<br>Breaker failure 1 timer 2 is operated<br>Breaker failure 1 timer 3 is operated<br>Breaker failure 1 trip is operated |
| | BKR FAIL 2 | Same set of operands as shown for BKR FAIL 1 |
| ELEMENT:<br>Breaker control | BREAKER 1 OFF CMD<br>BREAKER 1 ON CMD<br>BREAKER 1 ΦA BAD ST<br>BREAKER 1 ΦA INTERM<br>BREAKER 1 ΦA CLSD<br>BREAKER 1 ΦA OPEN<br>BREAKER 1 ΦB BAD ST<br>BREAKER 1 ΦB INTERM<br>BREAKER 1 ΦB CLSD<br>BREAKER 1 ΦB OPEN<br>BREAKER 1 ΦC BAD ST<br>BREAKER 1 ΦC INTERM<br>BREAKER 1 ΦC CLSD<br>BREAKER 1 ΦC OPEN<br>BREAKER 1 BAD STATUS<br>BREAKER 1 CLOSED<br>BREAKER 1 OPEN<br>BREAKER 1 DISCREP<br>BREAKER 1 TROUBLE<br>BREAKER 1 MNL CLS<br>BREAKER 1 TRIP A<br>BREAKER 1 TRIP B<br>BREAKER 1 TRIP C<br>BREAKER 1 ANY P OPEN<br>BREAKER 1 ONE P OPEN<br>BREAKER 1 OOS | Breaker 1 open command initiated<br>Breaker 1 close command initiated<br>Breaker 1 phase A bad status is detected (discrepancy between the 52/a and 52/b contacts)<br>Breaker 1 phase A intermediate status is detected (transition from one position to another)<br>Breaker 1 phase A is closed<br>Breaker 1 phase A is open<br>Breaker 1 phase B bad status is detected (discrepancy between the 52/a and 52/b contacts)<br>Breaker 1 phase B intermediate status is detected (transition from one position to another)<br>Breaker 1 phase B is closed<br>Breaker 1 phase B is open<br>Breaker 1 phase C bad status is detected (discrepancy between the 52/a and 52/b contacts)<br>Breaker 1 phase C intermediate status is detected (transition from one position to another)<br>Breaker 1 phase C is closed<br>Breaker 1 phase C is open<br>Breaker 1 bad status is detected on any pole<br>Breaker 1 is closed<br>Breaker 1 is open<br>Breaker 1 has discrepancy<br>Breaker 1 trouble alarm<br>Breaker 1 manual close<br>Breaker 1 trip phase A command<br>Breaker 1 trip phase B command<br>Breaker 1 trip phase C command<br>At least one pole of breaker 1 is open<br>Only one pole of breaker 1 is open<br>Breaker 1 is out of service |
| | BREAKER 2 | Same set of operands as shown for BREAKER 1 |
| ELEMENT:<br>Broken conductor | BROKEN CONDUCT 1 OP<br>BROKEN CONDUCT 1 PKP | Asserted when the broken conductor 1 element operates<br>Asserted when the broken conductor 1 element picks up |
| | BROKEN CONDUCT 2 | Same set of operands as shown for BROKEN CONDUCTOR 1 |
| ELEMENT:<br>CT fail | CT FAIL 1 PKP<br>CT FAIL 1 OP | CT fail has picked up<br>CT fail has dropped out |
| | CT FAIL 2 | Same set of operands as per CT FAIL 1 |
| ELEMENT:<br>Digital counters | Counter 1 HI<br>Counter 1 EQL<br>Counter 1 LO | Digital counter 1 output is ‘more than’ comparison value<br>Digital counter 1 output is ‘equal to’ comparison value<br>Digital counter 1 output is ‘less than’ comparison value |
| | Counter 2 to 8 | Same set of operands as shown for Counter 1 |
| ELEMENT:<br>Digital elements | Dig Element 1 PKP<br>Dig Element 1 OP<br>Dig Element 1 DPO | Digital Element 1 is picked up<br>Digital Element 1 is operated<br>Digital Element 1 is dropped out |
| | Dig Element 2 to 48 | Same set of operands as shown for Dig Element 1 |
| ELEMENT:<br>FlexElements | FxE 1 PKP<br>FxE 1 OP<br>FxE 1 DPO | FlexElement 1 has picked up<br>FlexElement 1 has operated<br>FlexElement 1 has dropped out |
| | FxE 2 to 8 | Same set of operands as shown for FxE 1 |
| ELEMENT:<br>Ground instantaneous overcurrent | GROUND IOC1 PKP<br>GROUND IOC1 OP<br>GROUND IOC1 DPO | Ground instantaneous overcurrent 1 has picked up<br>Ground instantaneous overcurrent 1 has operated<br>Ground instantaneous overcurrent 1 has dropped out |
| | GROUND IOC2 to 4 | Same set of operands as shown for GROUND IOC 1 |

**Table 5–18: L30 FLEXLOGIC OPERANDS (Sheet 3 of 7)**

| OPERAND TYPE | OPERAND SYNTAX | OPERAND DESCRIPTION |
|---|---|---|
| ELEMENT: Ground time overcurrent | GROUND TOC1 PKP<br>GROUND TOC1 OP<br>GROUND TOC1 DPO | Ground time overcurrent 1 has picked up<br>Ground time overcurrent 1 has operated<br>Ground time overcurrent 1 has dropped out |
| | GROUND TOC2 | Same set of operands as shown for GROUND TOC1 |
| ELEMENT Non-volatile latches | LATCH 1 ON<br>LATCH 1 OFF | Non-volatile latch 1 is ON (Logic = 1)<br>Non-volatile latch 1 is OFF (Logic = 0) |
| | LATCH 2 to 16 | Same set of operands as shown for LATCH 1 |
| ELEMENT: Negative-sequence instantaneous overcurrent | NEG SEQ IOC1 PKP<br>NEG SEQ IOC1 OP<br>NEG SEQ IOC1 DPO | Negative-sequence instantaneous overcurrent 1 has picked up<br>Negative-sequence instantaneous overcurrent 1 has operated<br>Negative-sequence instantaneous overcurrent 1 has dropped out |
| | NEG SEQ IOC2 | Same set of operands as shown for NEG SEQ IOC1 |
| ELEMENT: Negative-sequence overvoltage | NEG SEQ OV1 PKP<br>NEG SEQ OV1 DPO<br>NEG SEQ OV1 OP | Negative-sequence overvoltage element has picked up<br>Negative-sequence overvoltage element has dropped out<br>Negative-sequence overvoltage element has operated |
| | NEG SEQ OV2 to 3 | Same set of operands as shown for NEG SEQ OV1 |
| ELEMENT: Negative-sequence time overcurrent | NEG SEQ TOC1 PKP<br>NEG SEQ TOC1 OP<br>NEG SEQ TOC1 DPO | Negative-sequence time overcurrent 1 has picked up<br>Negative-sequence time overcurrent 1 has operated<br>Negative-sequence time overcurrent 1 has dropped out |
| | NEG SEQ TOC2 | Same set of operands as shown for NEG SEQ TOC1 |
| ELEMENT: Neutral instantaneous overcurrent | NEUTRAL IOC1 PKP<br>NEUTRAL IOC1 OP<br>NEUTRAL IOC1 DPO | Neutral instantaneous overcurrent 1 has picked up<br>Neutral instantaneous overcurrent 1 has operated<br>Neutral instantaneous overcurrent 1 has dropped out |
| | NEUTRAL IOC2 to 4 | Same set of operands as shown for NEUTRAL IOC1 |
| ELEMENT: Neutral time overcurrent | NEUTRAL TOC1 PKP<br>NEUTRAL TOC1 OP<br>NEUTRAL TOC1 DPO | Neutral time overcurrent 1 has picked up<br>Neutral time overcurrent 1 has operated<br>Neutral time overcurrent 1 has dropped out |
| | NEUTRAL TOC2 | Same set of operands as shown for NEUTRAL TOC1 |
| ELEMENT: Neutral directional overcurrent | NTRL DIR OC1 FWD<br>NTRL DIR OC1 REV | Neutral directional overcurrent 1 forward has operated<br>Neutral directional overcurrent 1 reverse has operated |
| | NTRL DIR OC2 | Same set of operands as shown for NTRL DIR OC1 |
| ELEMENT: Synchrophasor phasor data concentrator | PDC NETWORK CNTRL 1<br>PDC NETWORK CNTRL 2<br>↓<br>PDC NETWORK CNTRL 16 | Phasor data concentrator asserts control bit 1 as received via the network<br>Phasor data concentrator asserts control bit 2 as received via the network<br>↓<br>Phasor data concentrator asserts control bit 16 as received via the network |
| ELEMENT: Phase directional overcurrent | PH DIR1 BLK A<br>PH DIR1 BLK B<br>PH DIR1 BLK C<br>PH DIR1 BLK | Phase A directional 1 block<br>Phase B directional 1 block<br>Phase C directional 1 block<br>Phase directional 1 block |
| | PH DIR2 | Same set of operands as shown for PH DIR1 |
| ELEMENT: Phase instantaneous overcurrent | PHASE IOC1 PKP<br>PHASE IOC1 OP<br>PHASE IOC1 DPO<br>PHASE IOC1 PKP A<br>PHASE IOC1 PKP B<br>PHASE IOC1 PKP C<br>PHASE IOC1 OP A<br>PHASE IOC1 OP B<br>PHASE IOC1 OP C<br>PHASE IOC1 DPO A<br>PHASE IOC1 DPO B<br>PHASE IOC1 DPO C | At least one phase of phase instantaneous overcurrent 1 has picked up<br>At least one phase of phase instantaneous overcurrent 1 has operated<br>All phases of phase instantaneous overcurrent 1 have dropped out<br>Phase A of phase instantaneous overcurrent 1 has picked up<br>Phase B of phase instantaneous overcurrent 1 has picked up<br>Phase C of phase instantaneous overcurrent 1 has picked up<br>Phase A of phase instantaneous overcurrent 1 has operated<br>Phase B of phase instantaneous overcurrent 1 has operated<br>Phase C of phase instantaneous overcurrent 1 has operated<br>Phase A of phase instantaneous overcurrent 1 has dropped out<br>Phase B of phase instantaneous overcurrent 1 has dropped out<br>Phase C of phase instantaneous overcurrent 1 has dropped out |
| | PHASE IOC2 to 4 | Same set of operands as shown for PHASE IOC1 |

**Table 5–18: L30 FLEXLOGIC OPERANDS (Sheet 4 of 7)**

| OPERAND TYPE | OPERAND SYNTAX | OPERAND DESCRIPTION |
|---|---|---|
| ELEMENT: Phase overvoltage | PHASE OV1 PKP | At least one phase of overvoltage 1 has picked up |
| | PHASE OV1 OP | At least one phase of overvoltage 1 has operated |
| | PHASE OV1 DPO | All phases of overvoltage 1 have dropped out |
| | PHASE OV1 PKP A | Phase A of overvoltage 1 has picked up |
| | PHASE OV1 PKP B | Phase B of overvoltage 1 has picked up |
| | PHASE OV1 PKP C | Phase C of overvoltage 1 has picked up |
| | PHASE OV1 OP A | Phase A of overvoltage 1 has operated |
| | PHASE OV1 OP B | Phase B of overvoltage 1 has operated |
| | PHASE OV1 OP C | Phase C of overvoltage 1 has operated |
| | PHASE OV1 DPO A | Phase A of overvoltage 1 has dropped out |
| | PHASE OV1 DPO B | Phase B of overvoltage 1 has dropped out |
| | PHASE OV1 DPO C | Phase C of overvoltage 1 has dropped out |
| | PHASE OV2 to 3 | Same set of operands as shown for PHASE OV1 |
| ELEMENT: Phase time overcurrent | PHASE TOC1 PKP | At least one phase of phase time overcurrent 1 has picked up |
| | PHASE TOC1 OP | At least one phase of phase time overcurrent 1 has operated |
| | PHASE TOC1 DPO | All phases of phase time overcurrent 1 have dropped out |
| | PHASE TOC1 PKP A | Phase A of phase time overcurrent 1 has picked up |
| | PHASE TOC1 PKP B | Phase B of phase time overcurrent 1 has picked up |
| | PHASE TOC1 PKP C | Phase C of phase time overcurrent 1 has picked up |
| | PHASE TOC1 OP A | Phase A of phase time overcurrent 1 has operated |
| | PHASE TOC1 OP B | Phase B of phase time overcurrent 1 has operated |
| | PHASE TOC1 OP C | Phase C of phase time overcurrent 1 has operated |
| | PHASE TOC1 DPO A | Phase A of phase time overcurrent 1 has dropped out |
| | PHASE TOC1 DPO B | Phase B of phase time overcurrent 1 has dropped out |
| | PHASE TOC1 DPO C | Phase C of phase time overcurrent 1 has dropped out |
| | PHASE TOC2 | Same set of operands as shown for PHASE TOC1 |
| ELEMENT: Phase undervoltage | PHASE UV1 PKP | At least one phase of phase undervoltage 1 has picked up |
| | PHASE UV1 OP | At least one phase of phase undervoltage 1 has operated |
| | PHASE UV1 DPO | All phases of phase undervoltage 1 have dropped out |
| | PHASE UV1 PKP A | Phase A of phase undervoltage 1 has picked up |
| | PHASE UV1 PKP B | Phase B of phase undervoltage 1 has picked up |
| | PHASE UV1 PKP C | Phase C of phase undervoltage 1 has picked up |
| | PHASE UV1 OP A | Phase A of phase undervoltage 1 has operated |
| | PHASE UV1 OP B | Phase B of phase undervoltage 1 has operated |
| | PHASE UV1 OP C | Phase C of phase undervoltage 1 has operated |
| | PHASE UV1 DPO A | Phase A of phase undervoltage 1 has dropped out |
| | PHASE UV1 DPO B | Phase B of phase undervoltage 1 has dropped out |
| | PHASE UV1 DPO C | Phase C of phase undervoltage 1 has dropped out |
| | PHASE UV2 to 3 | Same set of operands as shown for PHASE UV1 |
| ELEMENT: Synchrophasor phasor measurement unit (PMU) | PMU Agg 1 SvEng On | SvEng data item in associated control block is on |
| | PMU 1 CURR TRIGGER | Overcurrent trigger of phasor measurement unit 1 has operated |
| | PMU 1 FREQ TRIGGER | Abnormal frequency trigger of phasor measurement unit 1 has operated |
| | PMU 1 POWER TRIGGER | Overpower trigger of phasor measurement unit 1 has operated |
| | PMU 1 ROCOF TRIGGER | Rate of change of frequency trigger of phasor measurement unit 1 has operated |
| | PMU 1 VOLT TRIGGER | Abnormal voltage trigger of phasor measurement unit 1 has operated |
| | PMU 1 TRIGGERED | Phasor measurement unit 1 triggered; no events or targets are generated by this operand |
| ELEMENT: Synchrophasor one-shot | PMU ONE-SHOT EXPIRED | Indicates the one-shot operation has been executed, and the present time is at least 30 seconds past the scheduled one-shot time |
| | PMU ONE-SHOT OP | Indicates the one-shot operation and remains asserted for 30 seconds afterwards |
| | PMU ONE-SHOT PENDING | Indicates the one-shot operation is pending; that is, the present time is before the scheduled one-shot time |
| ELEMENT: Selector switch | SELECTOR 1 POS Y | Selector switch 1 is in Position Y (mutually exclusive operands) |
| | SELECTOR 1 BIT 0 | First bit of the 3-bit word encoding position of selector 1 |
| | SELECTOR 1 BIT 1 | Second bit of the 3-bit word encoding position of selector 1 |
| | SELECTOR 1 BIT 2 | Third bit of the 3-bit word encoding position of selector 1 |
| | SELECTOR 1 STP ALARM | Position of selector 1 has been pre-selected with the stepping up control input but not acknowledged |
| | SELECTOR 1 BIT ALARM | Position of selector 1 has been pre-selected with the 3-bit control input but not acknowledged |
| | SELECTOR 1 ALARM | Position of selector 1 has been pre-selected but not acknowledged |
| | SELECTOR 1 PWR ALARM | Position of selector switch 1 is undetermined or restored from memory when the relay powers up and synchronizes to the three-bit input |
| | SELECTOR 2 | Same set of operands as shown above for SELECTOR 1 |

**Table 5–18: L30 FLEXLOGIC OPERANDS (Sheet 5 of 7)**

| OPERAND TYPE | OPERAND SYNTAX | OPERAND DESCRIPTION |
|---|---|---|
| ELEMENT: Setting group | SETTING GROUP ACT 1<br>SETTING GROUP ACT 2<br>SETTING GROUP ACT 3<br>SETTING GROUP ACT 4<br>SETTING GROUP ACT 5<br>SETTING GROUP ACT 6 | Setting group 1 is active<br>Setting group 2 is active<br>Setting group 3 is active<br>Setting group 4 is active<br>Setting group 5 is active<br>Setting group 6 is active |
| ELEMENT: Disturbance detector | SRC1 50DD OP<br>SRC2 50DD OP | Source 1 disturbance detector has operated<br>Source 2 disturbance detector has operated |
| ELEMENT: VTFF (Voltage transformer fuse failure) | SRC1 VT FF OP<br>SRC1 VT FF DPO<br>SRC1 VT FF VOL LOSS | Source 1 VT fuse failure detector has operated<br>Source 1 VT fuse failure detector has dropped out<br>Source 1 has lost voltage signals (V2 below 10% and V1 below 5% of nominal) |
| | SRC1 VT NEU WIRE OPEN | Source 1 VT neutral wire open detected.When the VT is connected in Delta, this function should not be enabled because there is no neutral wire for Delta connected VT. |
| | SRC2 VT FUSE FAIL | Same set of operands as shown for SRC1 VT FUSE FAIL |
| ELEMENT: Stub bus | STUB BUS OP | Stub bus is operated |
| ELEMENT: Disconnect switch | SWITCH 1 OFF CMD<br>SWITCH 1 ON CMD<br>SWITCH 1 CLOSED<br>SWITCH 1 OPEN<br>SWITCH 1 DISCREP<br>SWITCH 1 TROUBLE<br>SWITCH 1 ΦA CLSD<br>SWITCH 1 ΦA OPEN<br>SWITCH 1 ΦA BAD ST<br>SWITCH 1 ΦA INTERM<br>SWITCH 1 ΦB CLSD<br>SWITCH 1 ΦB OPEN<br>SWITCH 1 ΦB BAD ST<br>SWITCH 1 ΦB INTERM<br>SWITCH 1 ΦC CLSD<br>SWITCH 1 ΦC OPEN<br>SWITCH 1 ΦC BAD ST<br>SWITCH 1 ΦC INTERM<br>SWITCH 1 BAD STATUS | Disconnect switch 1 open command initiated<br>Disconnect switch 1 close command initiated<br>Disconnect switch 1 is closed<br>Disconnect switch 1 is open<br>Disconnect switch 1 has discrepancy<br>Disconnect switch 1 trouble alarm<br>Disconnect switch 1 phase A is closed<br>Disconnect switch 1 phase A is open<br>Disconnect switch 1 phase A bad status is detected (discrepancy between the 89/a and 89/b contacts)<br>Disconnect switch 1 phase A intermediate status is detected (transition from one position to another)<br>Disconnect switch 1 phase B is closed<br>Disconnect switch 1 phase B is open<br>Disconnect switch 1 phase B bad status is detected (discrepancy between the 89/a and 89/b contacts)<br>Disconnect switch 1 phase B intermediate status is detected (transition from one position to another)<br>Disconnect switch 1 phase C is closed<br>Disconnect switch 1 phase C is open<br>Disconnect switch 1 phase C bad status is detected (discrepancy between the 89/a and 89/b contacts)<br>Disconnect switch 1 phase C intermediate status is detected (transition from one position to another)<br>Disconnect switch 1 bad status is detected on any pole |
| | SWITCH 2 to 8 | Same set of operands as shown for SWITCH 1 |
| ELEMENT: Synchrocheck | SYNC1 DEAD S OP<br>SYNC1 DEAD S DPO<br>SYNC1 SYNC OP<br>SYNC1 SYNC DPO<br>SYNC1 CLS OP<br>SYNC1 CLS DPO<br>SYNC1 V1 ABOVE MIN<br>SYNC1 V1 BELOW MAX<br>SYNC1 V2 ABOVE MIN<br>SYNC1 V2 BELOW MAX | Synchrocheck 1 dead source has operated<br>Synchrocheck 1 dead source has dropped out<br>Synchrocheck 1 in synchronization has operated<br>Synchrocheck 1 in synchronization has dropped out<br>Synchrocheck 1 close has operated<br>Synchrocheck 1 close has dropped out<br>Synchrocheck 1 V1 is above the minimum live voltage<br>Synchrocheck 1 V1 is below the maximum dead voltage<br>Synchrocheck 1 V2 is above the minimum live voltage<br>Synchrocheck 1 V2 is below the maximum dead voltage |
| | SYNC 2 to 4 | Same set of operands as shown for SYNC 1 |
| ELEMENT: Thermal overload protection | THERMAL PROT 1 PKP<br>THERMAL PROT 1 OP | Thermal overload protection 1 picked up<br>Thermal overload protection 1 operated |
| | THERMAL PROT 2 | Same set of operands as shown for THERMAL PROT 1 |
| ELEMENT Trip bus | TRIP BUS 1 PKP<br>TRIP BUS 1 OP | Asserted when the trip bus 1 element picks up<br>Asserted when the trip bus 1 element operates |
| | TRIP BUS 2 to 6 | Same set of operands as shown for TRIP BUS 1 |
| ELEMENT: Underfrequency | UNDERFREQ 1 PKP<br>UNDERFREQ 1 OP<br>UNDERFREQ 1 DPO | Underfrequency 1 has picked up<br>Underfrequency 1 has operated<br>Underfrequency 1 has dropped out |
| | UNDERFREQ 2 to 6 | Same set of operands as shown for UNDERFREQ 1 |

**Table 5–18: L30 FLEXLOGIC OPERANDS (Sheet 6 of 7)**

| OPERAND TYPE | OPERAND SYNTAX | OPERAND DESCRIPTION |
|---|---|---|
| FIXED OPERANDS | Off | Logic = 0. Does nothing and may be used as a delimiter in an equation list; used as 'Disable' by other features. |
| | On | Logic = 1. Can be used as a test setting. |
| INPUTS/OUTPUTS: Contact inputs | Cont Ip 1 On<br>Cont Ip 2 On<br>↓<br>Cont Ip 1 Off<br>Cont Ip 2 Off<br>↓<br>Cont Ip 96 On<br>Cont Ip 96 Off | (will not appear unless ordered)<br>(will not appear unless ordered)<br>↓<br>(will not appear unless ordered)<br>(will not appear unless ordered)<br>↓<br>(will not appear unless ordered)<br>(will not appear unless ordered) |
| INPUTS/OUTPUTS: Contact outputs | Cont Op 1 Closed<br>Cont Op 1 IOn<br>Cont Op 1 VOn<br><br>Cont Op 1 VOff | Contact output is closed<br>Current is flowing through the contact<br>Voltage exists across the contact (present for contact outputs equipped with monitoring)<br>Voltage exists across the contact (present for contact outputs equipped with monitoring) |
| | Cont Op 2 to 64 | Same set of operands as shown for Cont Op 1 |
| INPUTS/OUTPUTS: Direct input | Direct I/P 1-1 On<br>↓<br>Direct I/P 1-8 On | (appears only when an inter-relay communications card is used)<br>↓<br>(appears only when inter-relay communications card is used) |
| | Direct I/P 2-1 On<br>↓<br>Direct I/P 2-8 On | (appears only when inter-relay communications card is used)<br>↓<br>(appears only when inter-relay communications card is used) |
| INPUTS/OUTPUTS: Remote double-point status inputs | RemDPS Ip 1 BAD<br>RemDPS Ip 1 INTERM<br><br>RemDPS Ip 1 OFF<br>RemDPS Ip 1 ON | Asserted while the remote double-point status input is in the bad state<br>Asserted while the remote double-point status input is in the intermediate state<br>Asserted while the remote double-point status input is off<br>Asserted while the remote double-point status input is on |
| | REMDPS Ip 2 to 5 | Same set of operands as per REMDPS 1 |
| INPUTS/OUTPUTS: Remote inputs | REMOTE INPUT 1 On<br>REMOTE INPUT 2 On<br>REMOTE INPUT 3 On<br>↓<br>REMOTE INPUT 32 On | Flag is set, logic=1<br>Flag is set, logic=1<br>Flag is set, logic=1<br>↓<br>Flag is set, logic=1 |
| INPUTS/OUTPUTS: Virtual inputs | Virt Ip 1 On<br>Virt Ip 2 On<br>Virt Ip 3 On<br>↓<br>Virt Ip 64 On | Flag is set, logic=1<br>Flag is set, logic=1<br>Flag is set, logic=1<br>↓<br>Flag is set, logic=1 |
| INPUTS/OUTPUTS: Virtual outputs | Virt Op 1 On<br>Virt Op 2 On<br>Virt Op 3 On<br>↓<br>Virt Op 96 On | Flag is set, logic=1<br>Flag is set, logic=1<br>Flag is set, logic=1<br>↓<br>Flag is set, logic=1 |
| LED INDICATORS: Fixed front panel LEDs | LED IN SERVICE<br>LED TROUBLE<br>LED TEST MODE<br>LED TRIP<br>LED ALARM<br>LED PICKUP<br>LED VOLTAGE<br>LED CURRENT<br>LED FREQUENCY<br>LED OTHER<br>LED PHASE A<br>LED PHASE B<br>LED PHASE C<br>LED NEUTRAL/GROUND | Asserted when the front panel IN SERVICE LED is on<br>Asserted when the front panel TROUBLE LED is on<br>Asserted when the front panel TEST MODE LED is on<br>Asserted when the front panel TRIP LED is on<br>Asserted when the front panel ALARM LED is on<br>Asserted when the front panel PICKUP LED is on<br>Asserted when the front panel VOLTAGE LED is on<br>Asserted when the front panel CURRENT LED is on<br>Asserted when the front panel FREQUENCY LED is on<br>Asserted when the front panel OTHER LED is on<br>Asserted when the front panel PHASE A LED is on<br>Asserted when the front panel PHASE B LED is on<br>Asserted when the front panel PHASE C LED is on<br>Asserted when the front panel NEUTRAL/GROUND LED is on |
| LED INDICATORS: LED test | LED TEST IN PROGRESS | An LED test has been initiated and has not finished |
| LED INDICATORS: User-programmable LEDs | LED USER 1 | Asserted when user-programmable LED 1 is on |
| | LED USER 2 to 48 | The operand above is available for user-programmable LEDs 2 through 48 |

**Table 5–18: L30 FLEXLOGIC OPERANDS (Sheet 7 of 7)**

| OPERAND TYPE | OPERAND SYNTAX | OPERAND DESCRIPTION |
|---|---|---|
| PASSWORD SECURITY | ACCESS LOC SETG OFF<br>ACCESS LOC SETG ON<br>ACCESS LOC CMND OFF<br>ACCESS LOC CMND ON<br>ACCESS REM SETG OFF<br>ACCESS REM SETG ON<br>ACCESS REM CMND OFF<br>ACCESS REM CMND ON<br>UNAUTHORIZED ACCESS | Asserted when local setting access is disabled<br>Asserted when local setting access is enabled<br>Asserted when local command access is disabled<br>Asserted when local command access is enabled<br>Asserted when remote setting access is disabled<br>Asserted when remote setting access is enabled<br>Asserted when remote command access is disabled<br>Asserted when remote command access is enabled<br>Asserted when a password entry fails while accessing a password protected level of the L30 |
| REMOTE DEVICES | REMOTE DEVICE 1 On<br>REMOTE DEVICE 2 On<br>REMOTE DEVICE 3 On<br>↓<br>REMOTE DEVICE 16 On | Flag is set, logic=1<br>Flag is set, logic=1<br>Flag is set, logic=1<br>↓<br>Flag is set, logic=1 |
| | REMOTE DEVICE 1 Off<br>REMOTE DEVICE 2 Off<br>REMOTE DEVICE 3 Off<br>↓<br>REMOTE DEVICE 16 Off | Flag is set, logic=1<br>Flag is set, logic=1<br>Flag is set, logic=1<br>↓<br>Flag is set, logic=1 |
| RESETTING | RESET OP<br>RESET OP (COMMS)<br>RESET OP (OPERAND)<br><br>RESET OP (PUSHBUTTON) | Reset command is operated (set by all three operands below)<br>Communications source of the reset command<br>Operand (assigned in the **INPUTS/OUTPUTS ⇨⇩ RESETTING** menu) source of the reset command<br>Reset key (pushbutton) source of the reset command |
| SELF-DIAGNOSTICS (See *Relay Self-tests* descriptions in *Chapter 7: Commands and Targets)* | ANY MAJOR ERROR<br>ANY MINOR ERROR<br>ANY SELF-TESTS<br>BATTERY FAIL<br>CLOCK UNSYNCHRONIZED<br>DIRECT DEVICE OFF<br>DIRECT RING BREAK<br>EQUIPMENT MISMATCH<br>FLEXLOGIC ERR TOKEN<br>IRIG-B FAILURE<br>LATCHING OUT ERROR<br>MAINTENANCE ALERT<br>FIRST ETHERNET FAIL<br>PROCESS BUS FAILURE<br>PTP FAILURE<br>REMOTE DEVICE OFF<br>RRTD COMM FAIL<br>SECOND ETHERNET FAIL<br>THIRD ETHERNET FAIL<br>SNTP FAILURE<br>SYSTEM EXCEPTION<br>TEMP MONITOR<br>UNIT NOT PROGRAMMED | Any of the major self-test errors generated (major error)<br>Any of the minor self-test errors generated (minor error)<br>Any self-test errors generated (generic, any error)<br>The battery is not functioning. Return power supply module to manufacturer.<br>Relay is not synchronized to the international time standard<br>A direct device is configured but not connected<br>The Direct I/O settings is for a connection that is not in a ring<br>The configuration of modules does not match the stored order code<br>A FlexLogic equation is incorrect<br>"Bad IRIG-B Signal" self-test. See Chapter 7: Commands and Targets.<br>A difference is detected between the desired and actual latch contact state<br>A subset of the minor self-test errors generated, see Chapter 7<br>Link failure detected. See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets<br>"Bad PTP Signal" self-test as described in Chapter 7<br>One or more GOOSE devices are not responding<br>See description in Chapter 7: Commands and Targets<br>See description in Chapter 7: Commands and Targets<br>See description in Chapter 7: Commands and Targets<br>SNTP server is not responding<br>See description in Chapter 7: Commands and Targets<br>Monitors ambient temperature and maximum operating temperature<br>The **Settings > Product Setup > Installation > Relay Settings** setting is not programmed |
| TEMPERATURE MONITOR | TEMP MONITOR | Asserted while the ambient temperature is greater than the maximum operating temperature (80°C) |
| USER-PROGRAMMABLE PUSHBUTTONS | PUSHBUTTON 1 ON<br>PUSHBUTTON 1 OFF<br>ANY PB ON | Pushbutton number 1 is in the “On” position<br>Pushbutton number 1 is in the “Off” position<br>Any of twelve pushbuttons is in the “On” position |
| | PUSHBUTTON 2 to 6, 12, or 16 depending on front panel | Same set of operands as PUSHBUTTON 1 |

Some operands can be re-named by the user. These are the names of the breakers in the breaker control feature, the ID (identification) of contact inputs and outputs, the ID of virtual inputs, and the ID of virtual outputs. If the user changes the default name or ID of any of these operands, the assigned name will appear in the relay list of operands. The default names are shown in the FlexLogic operands table above.

The characteristics of the logic gates are tabulated below, and the operators available in FlexLogic are listed in the Flex-Logic operators table.

**Table 5–19: FLEXLOGIC GATE CHARACTERISTICS**

| GATES | NUMBER OF INPUTS | OUTPUT IS '1' (= ON) IF... |
|---|---|---|
| NOT | 1 | input is '0' |
| OR | 2 to 16 | any input is '1' |
| AND | 2 to 16 | all inputs are '1' |
| NOR | 2 to 16 | all inputs are '0' |
| NAND | 2 to 16 | any input is '0' |
| XOR | 2 | only one input is '1' |

**Table 5–20: FLEXLOGIC OPERATORS**

| TYPE | SYNTAX | DESCRIPTION | NOTES |
|---|---|---|---|
| Editor | INSERT | Insert a parameter in an equation list. | |
| | DELETE | Delete a parameter from an equation list. | |
| End | END | The first END encountered signifies the last entry in the list of processed FlexLogic parameters. | |
| One-shot | POSITIVE ONE SHOT | One shot that responds to a positive going edge. | A 'one shot' refers to a single input gate that generates a pulse in response to an edge on the input. The output from a 'one shot' is True (positive) for only one pass through the FlexLogic equation. There is a maximum of 64 'one shots'. |
| | NEGATIVE ONE SHOT | One shot that responds to a negative going edge. | |
| | DUAL ONE SHOT | One shot that responds to both the positive and negative going edges. | |
| Logic gate | NOT | Logical NOT | Operates on the previous parameter. |
| | OR(2)<br>↓<br>OR(16) | 2 input OR gate<br>↓<br>16 input OR gate | Operates on the 2 previous parameters.<br>↓<br>Operates on the 16 previous parameters. |
| | AND(2)<br>↓<br>AND(16) | 2 input AND gate<br>↓<br>16 input AND gate | Operates on the 2 previous parameters.<br>↓<br>Operates on the 16 previous parameters. |
| | NOR(2)<br>↓<br>NOR(16) | 2 input NOR gate<br>↓<br>16 input NOR gate | Operates on the 2 previous parameters.<br>↓<br>Operates on the 16 previous parameters. |
| | NAND(2)<br>↓<br>NAND(16) | 2 input NAND gate<br>↓<br>16 input NAND gate | Operates on the 2 previous parameters.<br>↓<br>Operates on the 16 previous parameters. |
| | XOR(2) | 2 input Exclusive OR gate | Operates on the 2 previous parameters. |
| | LATCH (S,R) | Latch (set, reset): reset-dominant | The parameter preceding LATCH(S,R) is the reset input. The parameter preceding the reset input is the set input. |
| Timer | TIMER 1<br>↓<br>TIMER 32 | Timer set with FlexLogic timer 1 settings.<br>↓<br>Timer set with FlexLogic timer 32 settings. | The timer is started by the preceding parameter. The output of the timer is TIMER #. |
| Assign virtual output | = Virt Op 1<br>↓<br>= Virt Op 96 | Assigns previous FlexLogic operand to virtual output 1.<br>↓<br>Assigns previous FlexLogic operand to virtual output 96. | The virtual output is set by the preceding parameter |

### 5.5.2 FLEXLOGIC RULES

When forming a FlexLogic equation, the sequence in the linear array of parameters must follow these general rules:

1. Operands must precede the operator which uses the operands as inputs.
2. Operators have only one output. The output of an operator must be used to create a virtual output if it is to be used as an input to two or more operators.
3. Assigning the output of an operator to a virtual output terminates the equation.
4. A timer operator (for example, "TIMER 1") or virtual output assignment (for example, " = Virt Op 1") may only be used once. If this rule is broken, a syntax error will be declared.

### 5.5.3 FLEXLOGIC EVALUATION

Each equation is evaluated in the ascending order in which the parameters have been entered.

NOTE

FlexLogic provides built-in latches that by definition have a memory action, remaining in the set state after the set input has been asserted. These built-in latches are reset dominant, meaning that if logical "1" is applied to both set and reset entries simultaneously, then the output of the latch is logical "0." However, they are volatile, meaning that they reset upon removal of control power.

When making changes to FlexLogic entries in the settings, all FlexLogic equations are re-compiled whenever any new FlexLogic entry value is entered, and as a result of the re-compile all latches are reset automatically.

### 5.5.4 FLEXLOGIC EXAMPLE

This section provides an example of implementing logic for a typical application. The sequence of the steps is quite important as it should minimize the work necessary to develop the relay settings. Note that the example presented in the figure below is intended to demonstrate the procedure, not to solve a specific application situation.

In the example below, it is assumed that logic has already been programmed to produce virtual outputs 1 and 2, and is only a part of the full set of equations used. When using FlexLogic, it is important to make a note of each virtual output used – a virtual output designation (1 to 96) can only be properly assigned once.

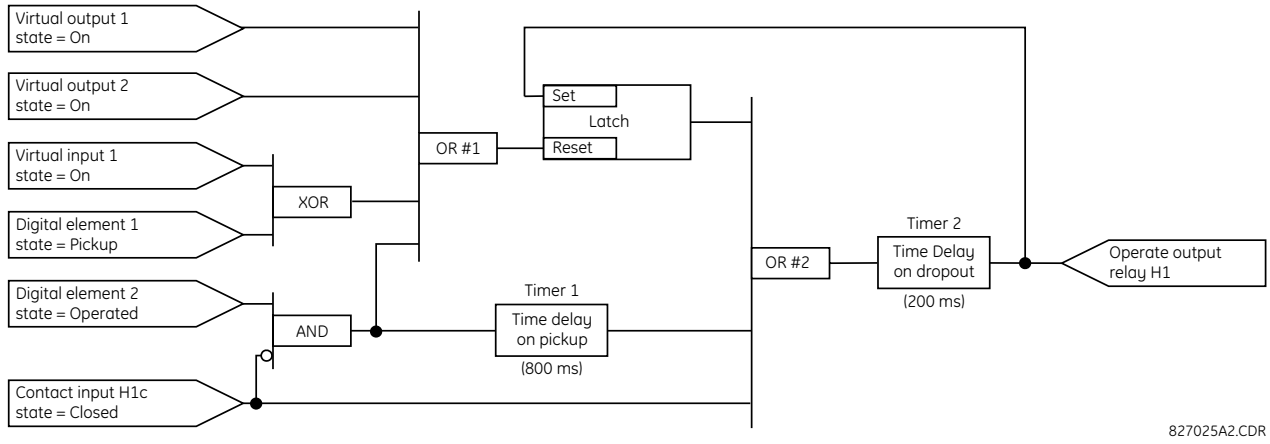



**Figure 5–51: EXAMPLE LOGIC SCHEME**

1. Inspect the example logic diagram to determine if the required logic can be implemented with the FlexLogic operators. If this is not possible, the logic must be altered until this condition is satisfied. Once this is done, count the inputs to each gate to verify that the number of inputs does not exceed the FlexLogic limits, which is unlikely but possible. If the number of inputs is too high, subdivide the inputs into multiple gates to produce an equivalent. For example, if 25 inputs to an AND gate are required, connect Inputs 1 through 16 to AND(16), 17 through 25 to AND(9), and the outputs from these two gates to AND(2).

   Inspect each operator between the initial operands and final virtual outputs to determine if the output from the operator is used as an input to more than one following operator. If so, the operator output must be assigned as a virtual output.

   For the example shown above, the output of the AND gate is used as an input to both OR#1 and Timer 1, and must therefore be made a virtual output and assigned the next available number (i.e. Virtual Output 3). The final output must also be assigned to a virtual output as virtual output 4, which will be programmed in the contact output section to operate relay H1 (that is, contact output H1).

   Therefore, the required logic can be implemented with two FlexLogic equations with outputs of virtual output 3 and virtual output 4 as shown below.

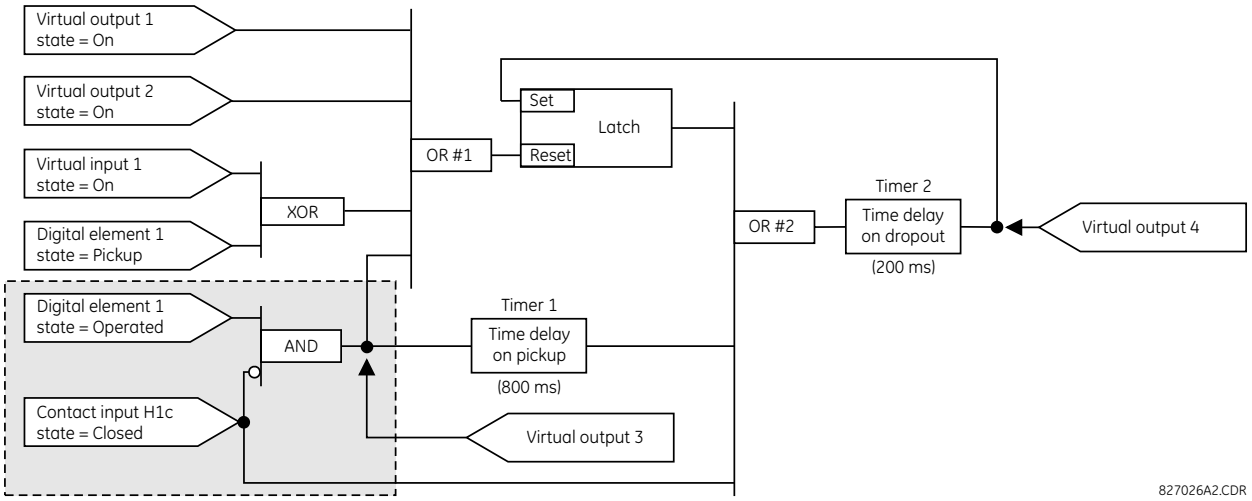



**Figure 5–52: LOGIC EXAMPLE WITH VIRTUAL OUTPUTS**

2. Prepare a logic diagram for the equation to produce virtual output 3, as this output will be used as an operand in the virtual output 4 equation (create the equation for every output that will be used as an operand first, so that when these operands are required they will already have been evaluated and assigned to a specific virtual output). The logic for virtual output 3 is shown below with the final output assigned.



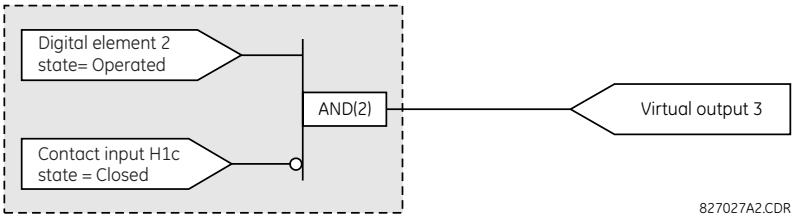



**Figure 5–53: LOGIC FOR VIRTUAL OUTPUT 3**

3. Prepare a logic diagram for virtual output 4, replacing the logic ahead of virtual output 3 with a symbol identified as virtual output 3, as shown below.

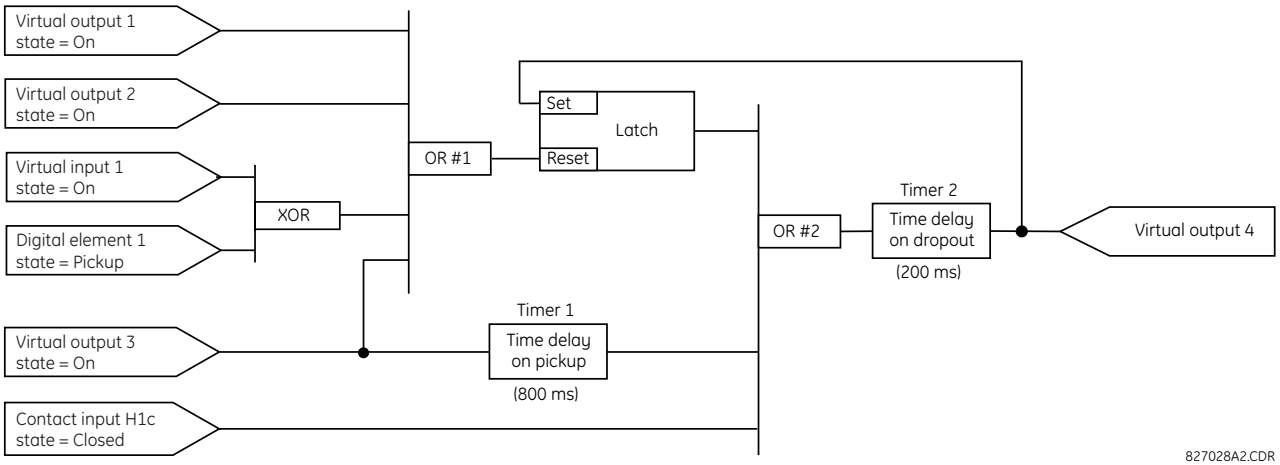



**Figure 5–54: LOGIC FOR VIRTUAL OUTPUT 4**

4. Program the FlexLogic equation for virtual output 3 by translating the logic into available FlexLogic parameters. The equation is formed one parameter at a time until the required logic is complete. It is generally easier to start at the out-

put end of the equation and work back towards the input, as shown in the following steps. It is also recommended to list operator inputs from bottom to top. For demonstration, the final output will be arbitrarily identified as parameter 99, and each preceding parameter decremented by one in turn. Until accustomed to using FlexLogic, it is suggested that a worksheet with a series of cells marked with the arbitrary parameter numbers be prepared, as shown below.

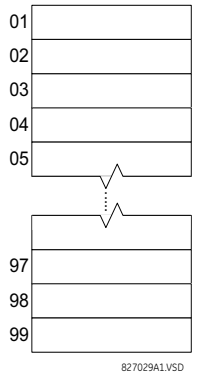



**Figure 5–55: FLEXLOGIC WORKSHEET**

5. Following the procedure outlined, start with parameter 99, as follows:

   99: The final output of the equation is virtual output 3, which is created by the operator "= Virt Op n". This parameter is therefore "= Virt Op 3."

   98: The gate preceding the output is an AND, which in this case requires two inputs. The operator for this gate is a 2-input AND so the parameter is “AND(2)”. Note that FlexLogic rules require that the number of inputs to most types of operators must be specified to identify the operands for the gate. As the 2-input AND will operate on the two operands preceding it, these inputs must be specified, starting with the lower.

   97: This lower input to the AND gate must be passed through an inverter (the NOT operator) so the next parameter is “NOT”. The NOT operator acts upon the operand immediately preceding it, so specify the inverter input next.

   96: The input to the NOT gate is to be contact input H1c. The ON state of a contact input can be programmed to be set when the contact is either open or closed. Assume for this example the state is to be ON for a closed contact. The operand is therefore “Cont Ip H1c On”.

   95: The last step in the procedure is to specify the upper input to the AND gate, the operated state of digital element 2. This operand is "DIG ELEM 2 OP".

   Writing the parameters in numerical order can now form the equation for virtual output 3:

```
[95] DIG ELEM 2 OP
[96] Cont Ip H1c On
[97] NOT
[98] AND(2)
[99] = Virt Op 3
```

It is now possible to check that this selection of parameters will produce the required logic by converting the set of parameters into a logic diagram. The result of this process is shown below, which is compared to the logic for virtual output 3 diagram as a check.

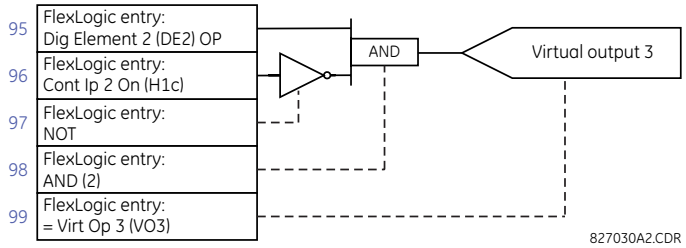



**Figure 5–56: FLEXLOGIC EQUATION FOR VIRTUAL OUTPUT 3**

6. Repeating the process described for virtual output 3, select the FlexLogic parameters for Virtual Output 4.

   99: The final output of the equation is virtual output 4 which is parameter “= Virt Op 4".

   98: The operator preceding the output is timer 2, which is operand “TIMER 2". Note that the settings required for the timer are established in the timer programming section.

   97: The operator preceding timer 2 is OR #2, a 3-input OR, which is parameter “OR(3)”.

   96: The lowest input to OR #2 is operand “Cont Ip H1c On”.

   95: The center input to OR #2 is operand “TIMER 1".

   94: The input to timer 1 is operand “Virt Op 3 On".

   93: The upper input to OR #2 is operand “LATCH (S,R)”.

   92: There are two inputs to a latch, and the input immediately preceding the latch reset is OR #1, a 4-input OR, which is parameter “OR(4)”.

   91: The lowest input to OR #1 is operand “Virt Op 3 On".

   90: The input just above the lowest input to OR #1 is operand “XOR(2)”.

   89: The lower input to the XOR is operand “DIG ELEM 1 PKP”.

   88: The upper input to the XOR is operand “Virt Ip 1 On".

   87: The input just below the upper input to OR #1 is operand “Virt Op 2 On".

   86: The upper input to OR #1 is operand “Virt Op 1 On".

   85: The last parameter is used to set the latch, and is operand “Virt Op 4 On".

   The equation for virtual output 4 is:

```
[85] Virt Op 4 On
[86] Virt Op 1 On
[87] Virt Op 2 On
[88] Virt Ip 1 On
[89] DIG ELEM 1 PKP
[90] XOR(2)
[91] Virt Op 3 On
[92] OR(4)
[93] LATCH (S,R)
[94] Virt Op 3 On
[95] TIMER 1
[96] Cont Ip H1c On
[97] OR(3)
[98] TIMER 2
[99] = Virt Op 4
```

It is now possible to check that the selection of parameters will produce the required logic by converting the set of parameters into a logic diagram. The result of this process is shown below, which is compared to the logic for virtual output 4 diagram as a check.

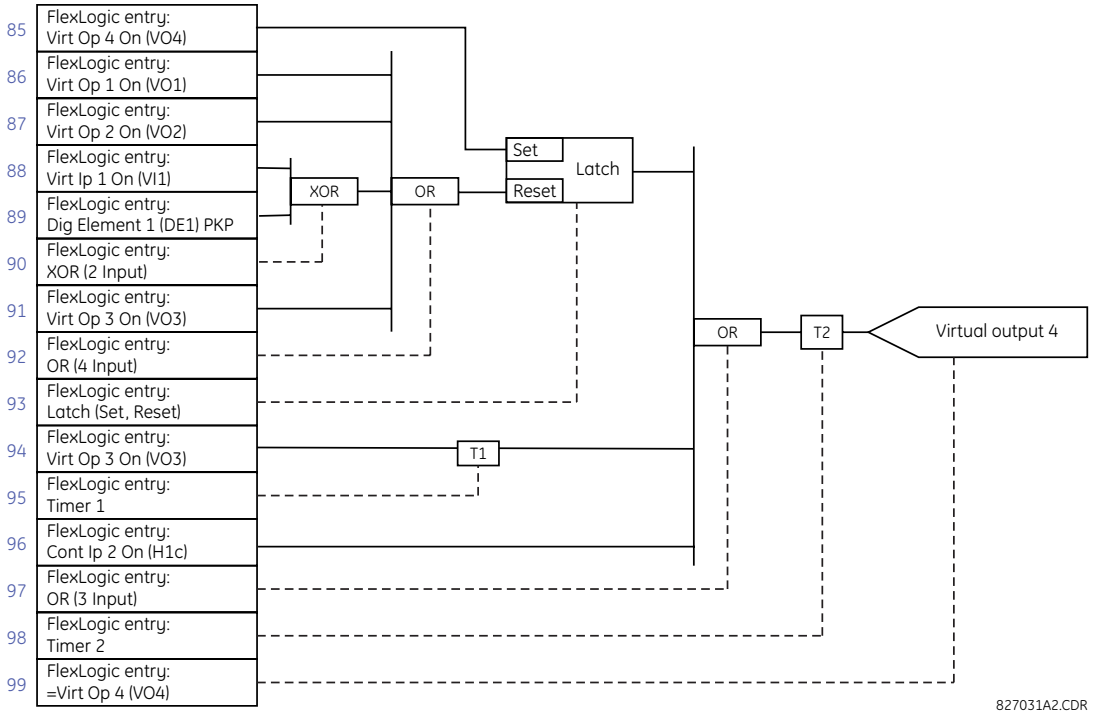



**Figure 5–57: FLEXLOGIC EQUATION FOR VIRTUAL OUTPUT 4**

7. Now write the complete FlexLogic expression required to implement the logic, making an effort to assemble the equation in an order where Virtual Outputs that will be used as inputs to operators are created before needed. In cases where a lot of processing is required to perform logic, this may be difficult to achieve, but in most cases will not cause problems as all logic is calculated at least four times per power frequency cycle. The possibility of a problem caused by sequential processing emphasizes the necessity to test the performance of FlexLogic before it is placed in service.

   In the following equation, virtual output 3 is used as an input to both latch 1 and timer 1 as arranged in the order shown below:

```
DIG ELEM 2 OP
Cont Ip H1c On
NOT
AND(2)
= Virt Op 3
Virt Op 4 On
Virt Op 1 On
Virt Op 2 On
Virt Ip 1 On
DIG ELEM 1 PKP
XOR(2)
Virt Op 3 On
OR(4)
LATCH (S,R)
Virt Op 3 On
TIMER 1
Cont Ip H1c On
OR(3)
TIMER 2
= Virt Op 4
END
```

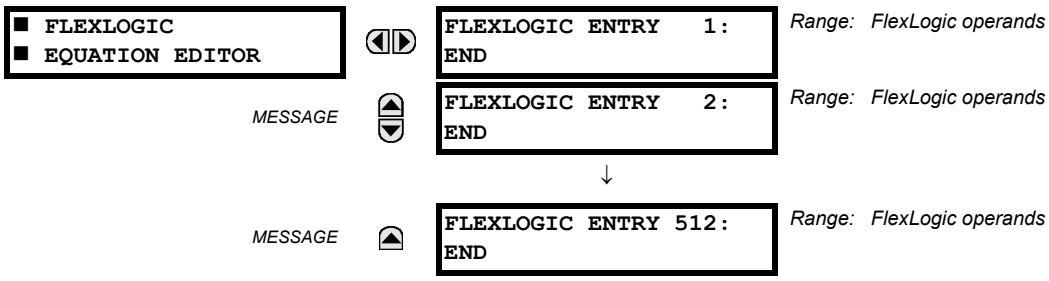
   In the expression above, the virtual output 4 input to the four-input OR is listed before it is created. This is typical of a form of feedback, in this case, used to create a seal-in effect with the latch, and is correct.

8. The logic should always be tested after it is loaded into the relay, in the same fashion as has been used in the past. Testing can be simplified by placing an "END" operator within the overall set of FlexLogic equations. The equations will then only be evaluated up to the first "END" operator.

   The "On" and "Off" operands can be placed in an equation to establish a known set of conditions for test purposes, and the "INSERT" and "DELETE" commands can be used to modify equations.

### 5.5.5 FLEXLOGIC EQUATION EDITOR

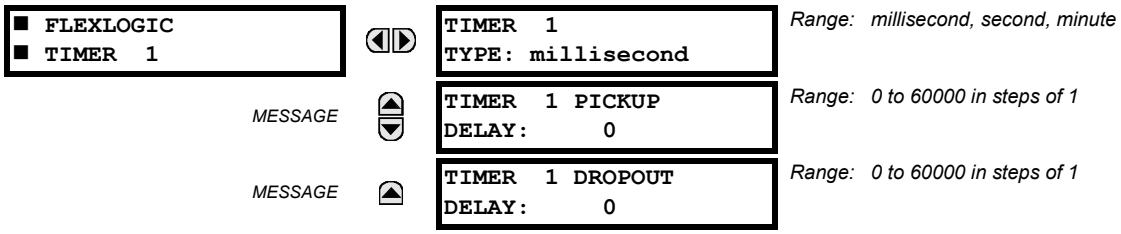
**PATH: SETTINGS ⇨⇩ FLEXLOGIC ⇨ FLEXLOGIC EQUATION EDITOR**




There are 512 FlexLogic entries available, numbered from 1 to 512, with default END entry settings. If a "Disabled" Element is selected as a FlexLogic entry, the associated state flag will never be set to '1'. The '+/–' key may be used when editing FlexLogic equations from the keypad to quickly scan through the major parameter types.

### 5.5.6 FLEXLOGIC TIMERS

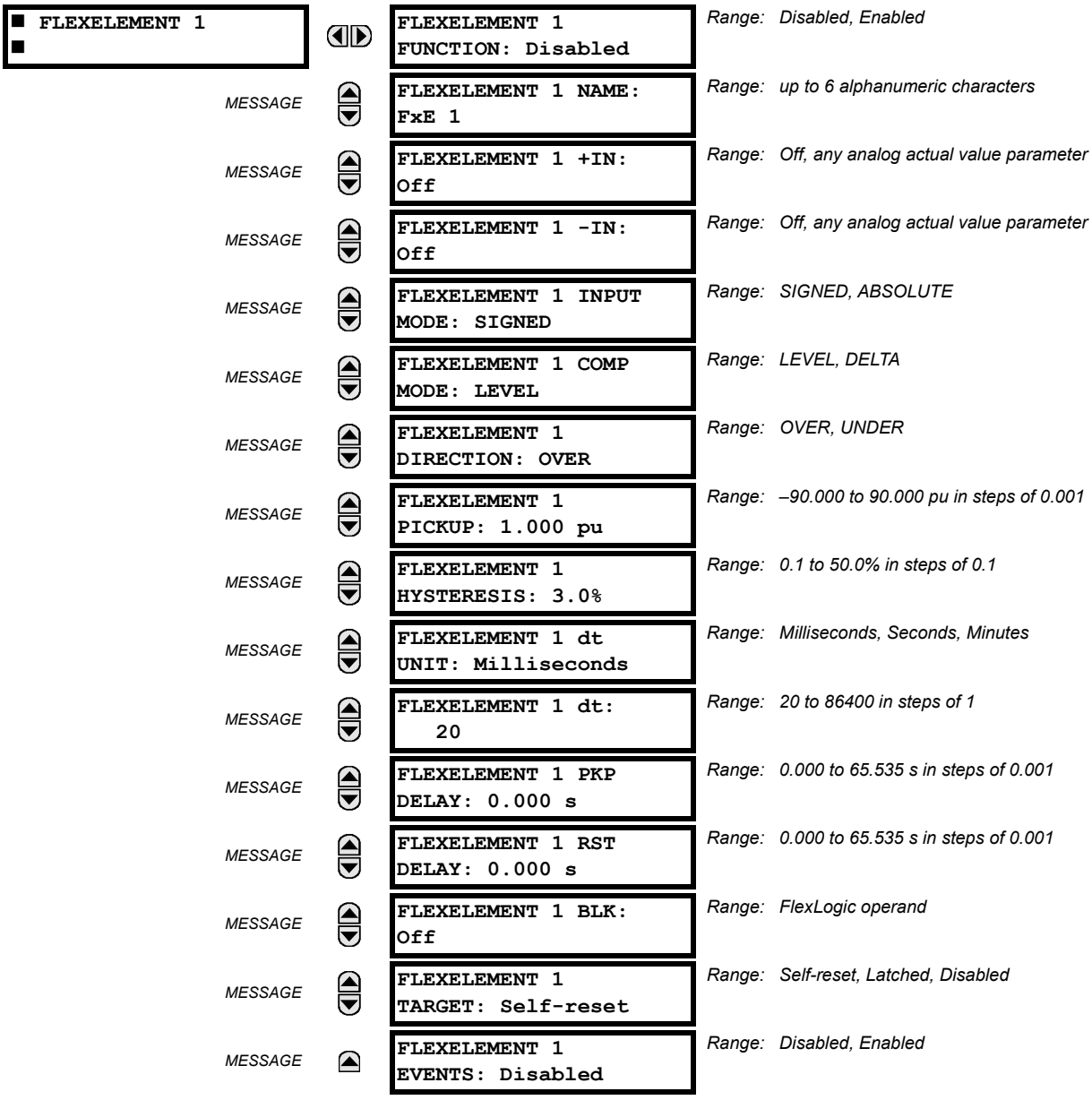
**PATH: SETTINGS ⇨⇩ FLEXLOGIC ⇨⇩ FLEXLOGIC TIMERS ⇨ FLEXLOGIC TIMER 1(32)**




There are 32 identical FlexLogic timers available. These timers can be used as operators for FlexLogic equations.

- **TIMER 1 TYPE:** This setting is used to select the time measuring unit.
- **TIMER 1 PICKUP DELAY:** Sets the time delay to pickup. If a pickup delay is not required, set this function to "0".
- **TIMER 1 DROPOUT DELAY:** Sets the time delay to dropout. If a dropout delay is not required, set this function to "0".

PATH: SETTING ⇨⇩ FLEXLOGIC ⇨⇩ FLEXELEMENTS ⇨ FLEXELEMENT 1(8)




A FlexElement is a universal comparator that can be used to monitor any analog actual value calculated by the relay or a net difference of any two analog actual values of the same type. The effective operating signal could be treated as a signed number or its absolute value could be used as per user's choice.

FlexElements run every half power cycle (every four protection passes).

The element can be programmed to respond either to a signal level or to a rate-of-change (delta) over a pre-defined period of time. The output operand is asserted when the operating signal is higher than a threshold or lower than a threshold as per user's choice.

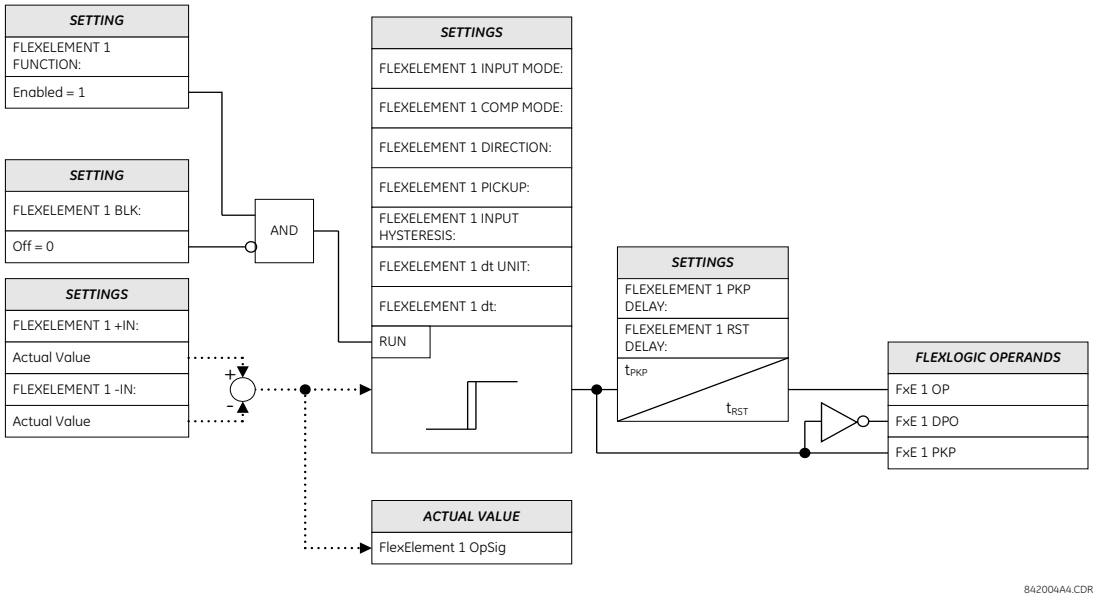



**Figure 5–58: FLEXELEMENT SCHEME LOGIC**

The **FLEXELEMENT 1 +IN** setting specifies the first (non-inverted) input to the FlexElement. Zero is assumed as the input if this setting is set to "Off". For proper operation of the element at least one input must be selected. Otherwise, the element will not assert its output operands.

This **FLEXELEMENT 1 –IN** setting specifies the second (inverted) input to the FlexElement. Zero is assumed as the input if this setting is set to "Off". For proper operation of the element at least one input must be selected. Otherwise, the element will not assert its output operands. This input should be used to invert the signal if needed for convenience, or to make the element respond to a differential signal such as for a top-bottom oil temperature differential alarm. The element will not operate if the two input signals are of different types, for example if one tries to use active power and phase angle to build the effective operating signal.

The element responds directly to the differential signal if the **FLEXELEMENT 1 INPUT MODE** setting is set to "Signed". The element responds to the absolute value of the differential signal if this setting is set to "Absolute". Sample applications for the "Absolute" setting include monitoring the angular difference between two phasors with a symmetrical limit angle in both directions, monitoring power regardless of its direction, or monitoring a trend.

The element responds directly to its operating signal – as defined by the **FLEXELEMENT 1 +IN**, **FLEXELEMENT 1 –IN** and **FLEXELEMENT 1 INPUT MODE** settings – if the **FLEXELEMENT 1 COMP MODE** setting is set to "Level". The element responds to the rate of change of its operating signal if the **FLEXELEMENT 1 COMP MODE** setting is set to "Delta". In this case the **FLEXELEMENT 1 dt UNIT** and **FLEXELEMENT 1 dt** settings specify how the rate of change is derived.

The **FLEXELEMENT 1 DIRECTION** setting enables the relay to respond to either high or low values of the operating signal. The following figure explains the application of the **FLEXELEMENT 1 DIRECTION**, **FLEXELEMENT 1 PICKUP** and **FLEXELEMENT 1 HYSTERESIS** settings.

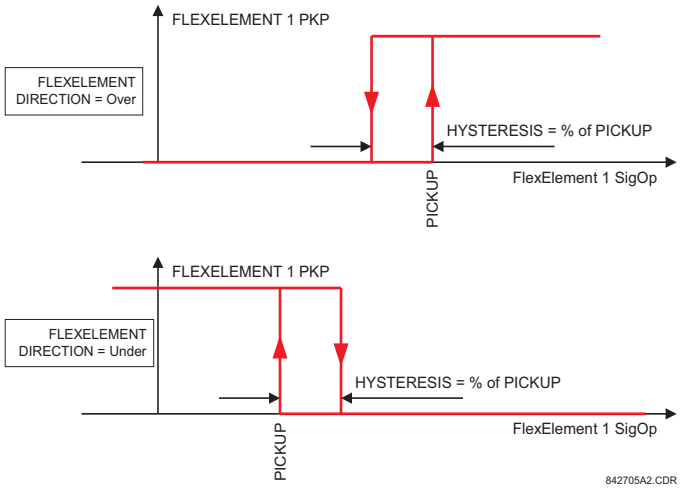



**Figure 5–59: FLEXELEMENT DIRECTION, PICKUP, AND HYSTERESIS**

In conjunction with the **FLEXELEMENT 1 INPUT MODE** setting the element could be programmed to provide two extra characteristics as shown in the figure below.

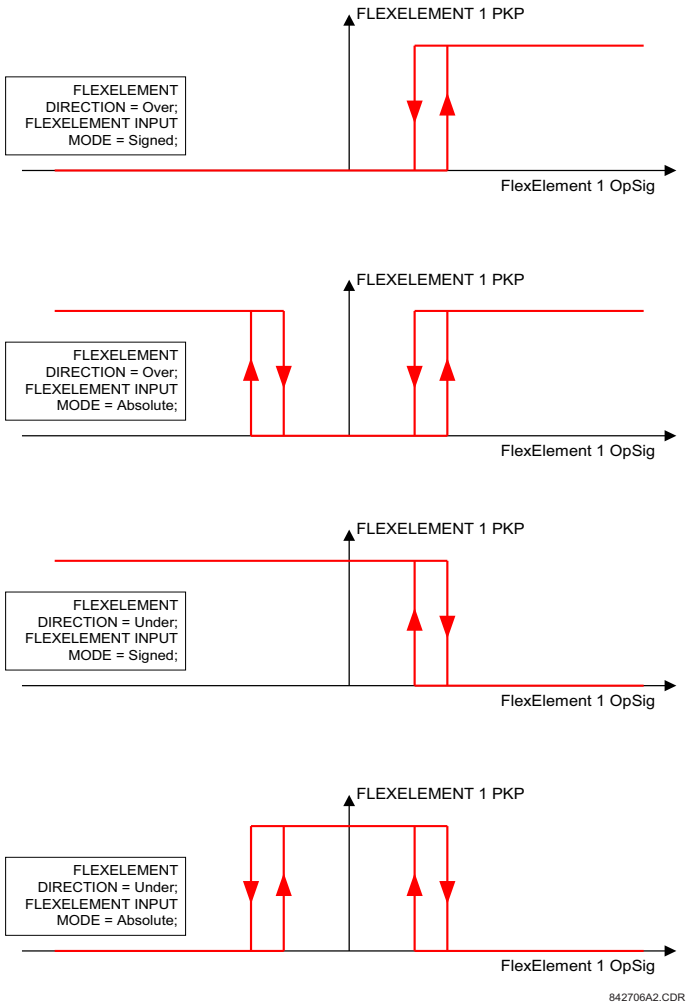



**Figure 5–60: FLEXELEMENT INPUT MODE SETTING**

The **FLEXELEMENT 1 PICKUP** setting specifies the operating threshold for the effective operating signal of the element. If set to "Over", the element picks up when the operating signal exceeds the **FLEXELEMENT 1 PICKUP** value. If set to "Under", the element picks up when the operating signal falls below the **FLEXELEMENT 1 PICKUP** value.

When using FlexElements for Voltage Elements, 1 pu is always equal to phase to ground voltage nominal secondary voltage, even if you select a phase to phase voltage as an operating quantity.

The **FLEXELEMENT 1 HYSTERESIS** setting controls the element dropout. It should be noticed that both the operating signal and the pickup threshold can be negative facilitating applications such as reverse power alarm protection. The FlexElement can be programmed to work with all analog actual values measured by the relay. The **FLEXELEMENT 1 PICKUP** setting is entered in per-unit values using the following definitions of the base units:

**Table 5–21: FLEXELEMENT BASE UNITS**

| | |
|---|---|
| 87L SIGNALS<br>(Local IA Mag, IB, and IC)<br>(Diff Curr IA Mag, IB, and IC)<br>(Terminal 1 IA Mag, IB, and IC)<br>(Terminal 2 IA Mag, IB and IC) | $I_{BASE}$ = maximum primary RMS value of the +IN and –IN inputs<br>(CT primary for source currents, and 87L source primary current for line differential currents) |
| 87L SIGNALS<br>(Op Square Curr IA, IB, and IC)<br>(Rest Square Curr IA, IB, and IC) | BASE = Squared CT secondary of the 87L source |
| BREAKER ACC ARCING AMPS<br>(Brk X Acc Arc Amp A, B, and C) | BASE = 2000 $kA^2 \times$ cycle |

**Table 5–21: FLEXELEMENT BASE UNITS**

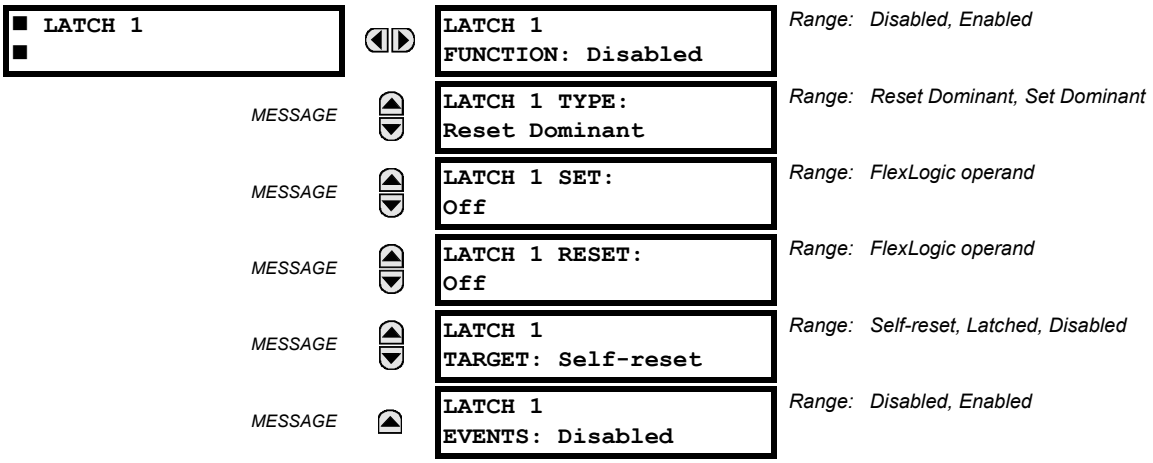
| | |
|---|---|
| BREAKER ARCING AMPS (Brk X Arc Amp A, B, and C) | BASE = 1 $kA^2 \times$ cycle |
| DCmA | BASE = maximum value of the **DCMA INPUT MAX** setting for the two transducers configured under the +IN and –IN inputs. |
| DELTA TIME | BASE = 1 µs |
| FAULT LOCATION | BASE = Line Length as specified in Fault Report |
| FREQUENCY | $f_{BASE}$ = 1 Hz |
| PHASE ANGLE | $\varphi_{BASE}$ = 360 degrees (see the UR angle referencing convention) |
| POWER FACTOR | $PF_{BASE}$ = 1.00 |
| RTDs | BASE = 100°C |
| SOURCE CURRENT | $I_{BASE}$ = maximum nominal primary RMS value of the +IN and –IN inputs |
| SOURCE POWER | $P_{BASE}$ = maximum value of $V_{BASE} \times I_{BASE}$ for the +IN and –IN inputs |
| SOURCE VOLTAGE | $V_{BASE}$ = maximum nominal primary RMS value of the +IN and –IN inputs |
| SYNCHROCHECK (Max Delta Volts) | $V_{BASE}$ = maximum primary RMS value of all the sources related to the +IN and –IN inputs |

The **FLEXELEMENT 1 HYSTERESIS** setting defines the pickup–dropout relation of the element by specifying the width of the hysteresis loop as a percentage of the pickup value as shown in the FlexElement Direction, Pickup, and Hysteresis diagram.

The **FLEXELEMENT 1 DT UNIT** setting specifies the time unit for the setting **FLEXELEMENT 1 dt**. This setting is applicable only if **FLEXELEMENT 1 COMP MODE** is set to “Delta”. The **FLEXELEMENT 1 DT** setting specifies duration of the time interval for the rate of change mode of operation. This setting is applicable only if **FLEXELEMENT 1 COMP MODE** is set to “Delta”.

This **FLEXELEMENT 1 PKP DELAY** setting specifies the pickup delay of the element. The **FLEXELEMENT 1 RST DELAY** setting specifies the reset delay of the element.

PATH: SETTINGS ⇨⇩ FLEXLOGIC ⇨⇩ NON-VOLATILE LATCHES ⇨ LATCH 1(16)




The non-volatile latches provide a permanent logical flag that is stored safely and will not reset upon reboot after the relay is powered down. Typical applications include sustaining operator commands or permanently block relay functions, such as Autorecloser, until a deliberate interface action resets the latch. The settings element operation is described below:

- **LATCH 1 TYPE**: This setting characterizes Latch 1 to be Set- or Reset-dominant.
- **LATCH 1 SET**: If asserted, the specified FlexLogic operands 'sets' Latch 1.
- **LATCH 1 RESET**: If asserted, the specified FlexLogic operand 'resets' Latch 1.

| LATCH N TYPE | LATCH N SET | LATCH N RESET | LATCH N ON | LATCH N OFF |
|---|---|---|---|---|
| Reset Dominant | ON | OFF | ON | OFF |
| | OFF | OFF | Previous State | Previous State |
| | ON | ON | OFF | ON |
| | OFF | ON | OFF | ON |
| Set Dominant | ON | OFF | ON | OFF |
| | ON | ON | ON | OFF |
| | OFF | OFF | Previous State | Previous State |
| | OFF | ON | OFF | ON |

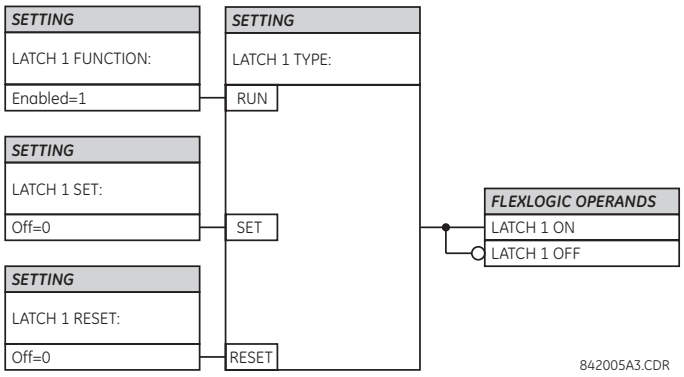


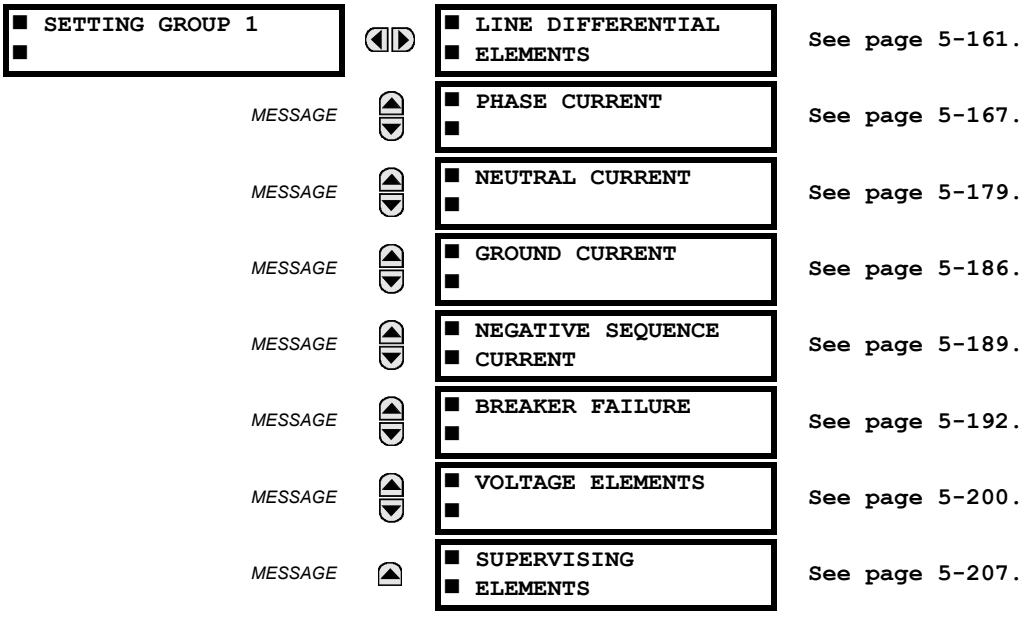

Figure 5–61: NON-VOLATILE LATCH OPERATION TABLE (N = 1 to 16) AND LOGIC

### 5.6.1 OVERVIEW

Each protection element can be assigned up to six different sets of settings according to setting group designations 1 to 6. The performance of these elements is defined by the active setting group at a given time. Multiple setting groups allow the user to conveniently change protection settings for different operating situations (for example, altered power system configuration, season of the year, etc.). The active setting group can be preset or selected via the **SETTING GROUPS** menu (see the Control Elements section later in this chapter). See also the Introduction to Elements section at the beginning of this chapter.

### 5.6.2 SETTING GROUP

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6)**



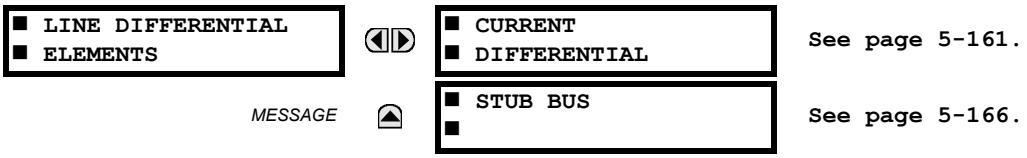

Each of the six setting group menus is identical. Setting group 1 (the default active group) automatically becomes active if no other group is active (see the Control Elements section for additional details).

If the device incorrectly switches to group 1 after power cycling, upgrade the firmware to version 7.25, 7.31, or later to correct this issue.

### 5.6.3 LINE DIFFERENTIAL ELEMENTS

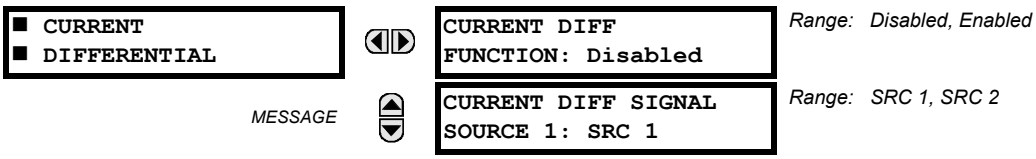
#### a) MAIN MENU

**PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ LINE DIFFERENTIAL ELEMENTS**




#### b) CURRENT DIFFERENTIAL

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ LINE DIFFERENTIAL... ⇨ CURRENT DIFFERENTIAL**



MESSAGE
CURRENT DIFF BLOCK: Off
Range: FlexLogic operand

MESSAGE
CURRENT DIFF PICKUP: 0.20 pu
Range: 0.10 to 4.00 pu in steps of 0.01

MESSAGE
CURRENT DIFF CT TAP 1: 1.00
Range: 0.20 to 5.00in steps of 0.01

MESSAGE
CURRENT DIFF CT TAP 2: 1.00
Range: 0.20 to 5.00 in steps of 0.01

MESSAGE
CURRENT DIFF RESTRAINT 1: 30%
Range: 1 to 50% in steps of 1

MESSAGE
CURRENT DIFF RESTRAINT 2: 50%
Range: 1 to 70% in steps of 1

MESSAGE
CURRENT DIFF BREAK PT: 1.0 pu
Range: 0.0 to 20.0 pu in steps of 0.1

MESSAGE
INRUSH INHIBIT MODE: Disabled
Range: Disabled, Per phase, 2-out-of-3, Average

MESSAGE
INRUSH INHIBIT LEVEL: 20% fo
Range: 1.0 to 40.0% $f_0$ in steps of 0.1

MESSAGE
CURRENT DIFF GND FUNCTION: Disabled
Range: Disabled, Enabled

MESSAGE
CURRENT DIFF GND PICKUP: 0.10 pu
Range: 0.05 to 1.00 pu in steps of 0.01

MESSAGE
CURRENT DIFF GND RESTRAINT: 25%
Range: 1 to 50% in steps of 1

MESSAGE
CURRENT DIFF GND DELAY: 0.10 s
Range: 0.00 to 5.00 s in steps of 0.01

MESSAGE
CURRENT DIFF DTT: Enabled
Range: Disabled, Enabled

MESSAGE
CURRENT DIFF KEY DTT: Off
Range: FlexLogic operand

MESSAGE
CURRENT DIFF TARGET: Self-reset
Range: Self-reset, Latched, Disabled

MESSAGE
CURRENT DIFF EVENTS: Disabled
Range: Disabled, Enabled

NOTE

See the Relay Synchronization section in the Theory of Operation chapter for information on channel failure, lost packet, CRC failure, and PFLL failure alarms.

The following settings are available for current differential protection.

- **CURRENT DIFF SIGNAL SOURCE 1**: This setting selects the first source for the current differential element local operating current. If more than one source is configured, the other source currents are scaled to the CT with the maximum primary current assigned by the CURRENT DIFF SIGNAL SOURCE 1 to CURRENT DIFF SIGNAL SOURCE 4 settings. This source is mandatory and is assigned with the SYSTEM SETUP ⇨⇩ SIGNAL SOURCES ⇨ SOURCE 1 menu.
- **CURRENT DIFF BLOCK**: This setting selects a FlexLogic operand to block the operation of the current differential element.
- **CURRENT DIFF PICKUP**: This setting is used to select current differential pickup value.

- **CURRENT DIFF CT TAP 1** and **CURRENT DIFF CT TAP 2**: These settings adapt the remote terminal 1 or 2 (communication channel 1 and 2 respectively) CT ratio to the local ratio if the CT ratios for the local and remote terminals differ. In 2-terminal, two-channel applications use the same value for both TAP 1 and TAP 2 settings, and in 3-terminals accordingly remote 1 and 2 CTs. The setting value is determined by $CT_{prim\_rem}$ / $CT_{prim\_loc}$ for local and remote terminal CTs (where $CT_{prim\_rem}$ / $CT_{prim\_loc}$ is referred to as the CT primary rated current). Ratio matching must always be performed against the remote CT with the maximum CT primary defined by the **CURRENT DIFF SIGNAL SOURCE 1** through **CURRENT DIFF SIGNAL SOURCE 4** settings. See the Current Differential Settings example in the Application of Settings chapter for additional details.

  When in-zone power transformer is present, this setting should be calculated and used by taking into account the in-zone power transformer as follows.

$$\text{CT Tap} = \frac{CT_{prim\_rem} \times V_{prim\_rem}}{CT_{prim\_loc} \times V_{prim\_loc}} \quad \text{for remote terminals 1 and 2, respecitvely} \qquad \textbf{(EQ 5.9)}$$

  In this equation, $V_{prim\_rem}$ is primary nominal voltage of the transformer winding at the remote terminal and $V_{prim\_loc}$ is primary nominal voltage of the transformer winding at the local terminal.

- **CURRENT DIFF RESTRAINT 1** and **CURRENT DIFF RESTRAINT 2**: These settings select the bias characteristic for the first and second slope, respectively.
- **CURRENT DIFF BREAK PT**: This setting is used to select an intersection point between the two slopes.
- **INRUSH INHIBIT MODE**: This setting selects the mode for blocking differential protection during magnetizing inrush conditions. Modern transformers can produce small second harmonic ratios during inrush conditions. This can result undesired tripping of the protected line. Reducing the second harmonic inhibit threshold may jeopardize dependability and speed of differential protection. When low, the second harmonic ratio causes problems in one phase only. This may be utilized as a mean to ensure security by applying cross-phase blocking rather than lowering the inrush inhibit threshold.
  - If set to “Disabled”, no inrush inhibit action is taken.
  - If set to “Per phase”, the L30 performs inrush inhibit individually in each phase.
  - If set to “2-out-of-3”, the L30 checks second harmonic level in all three phases individually. If any two phases establish an inhibiting condition, then the remaining phase is restrained automatically.
  - If set to “Average”, the L30 first calculates the average second harmonic ratio, then applies the inrush threshold to the calculated average.
- **INRUSH INHIBIT LEVEL**: This setting specifies the level of second harmonic component in the transformer magnetizing inrush current, above which the current differential element is inhibited from operating. The value of the **INRUSH INHIBIT MODE** setting must be taken into account when programming this value. This setting is typically programmed as “20% $f_0$“.
- **CURRENT DIFF GND FUNCTION**: This setting enables and disabled the 87LG neutral differential element, which may be used to detect high-resistive faults. This element uses restrained characteristics to cope with spurious zero-sequence current during system unbalance and signal distortions. The differential neutral current is calculated as the vector sum of all in-zone CT input neutral currents. The restraint current is derived as the maximum of phase currents from all terminals flowing through any individual CT, including breaker-and-a-half configurations. The 87LG neutral differential element is blocked when the phase current at any terminal is greater than 3 pu, since the phase differential element should operate for internal faults. To correctly derive the restraint quantity from the maximum through current at any terminal, it is important that the 87L phase-segregated differential pickup and slope settings are equal at all terminals. Refer to the *Applications of settings* chapter for additional details.
- **CURRENT DIFF GND PICKUP**: This setting specifies the pickup threshold for neutral current differential element.
- **CURRENT DIFF GND RESTRAINT**: This setting specifies the bias characteristic for the neutral current differential element.
- **CURRENT DIFF GND DELAY**: This setting specifies the operation delay for the neutral current differential element. Since this element is used to detect high-resistive faults where fault currents are relatively low, high-speed operation is usually not critical. This delay will provide security against spurious neutral current during switch-off transients and external fault clearing.

- **CURRENT DIFF DTT**: This setting enables and disables the sending of a DTT by the current differential element on per single-phase basis to remote devices. To allow the L30 to restart from master-master to master-slave mode (very important on three-terminal applications), **CURR DIFF DTT** must be set to “Enabled”.
- **CURRENT DIFF KEY DTT**: This setting selects an additional protection element (besides the current differential element; for example, distance element or breaker failure) which keys the DTT on a per three-phase basis.

NOTE

For the current differential element to function properly, it is imperative that all L30 devices on the protected line have exactly identical firmware revisions. For example, revision 5.62 in only compatible with 5.62, not 5.61 or 5.63.

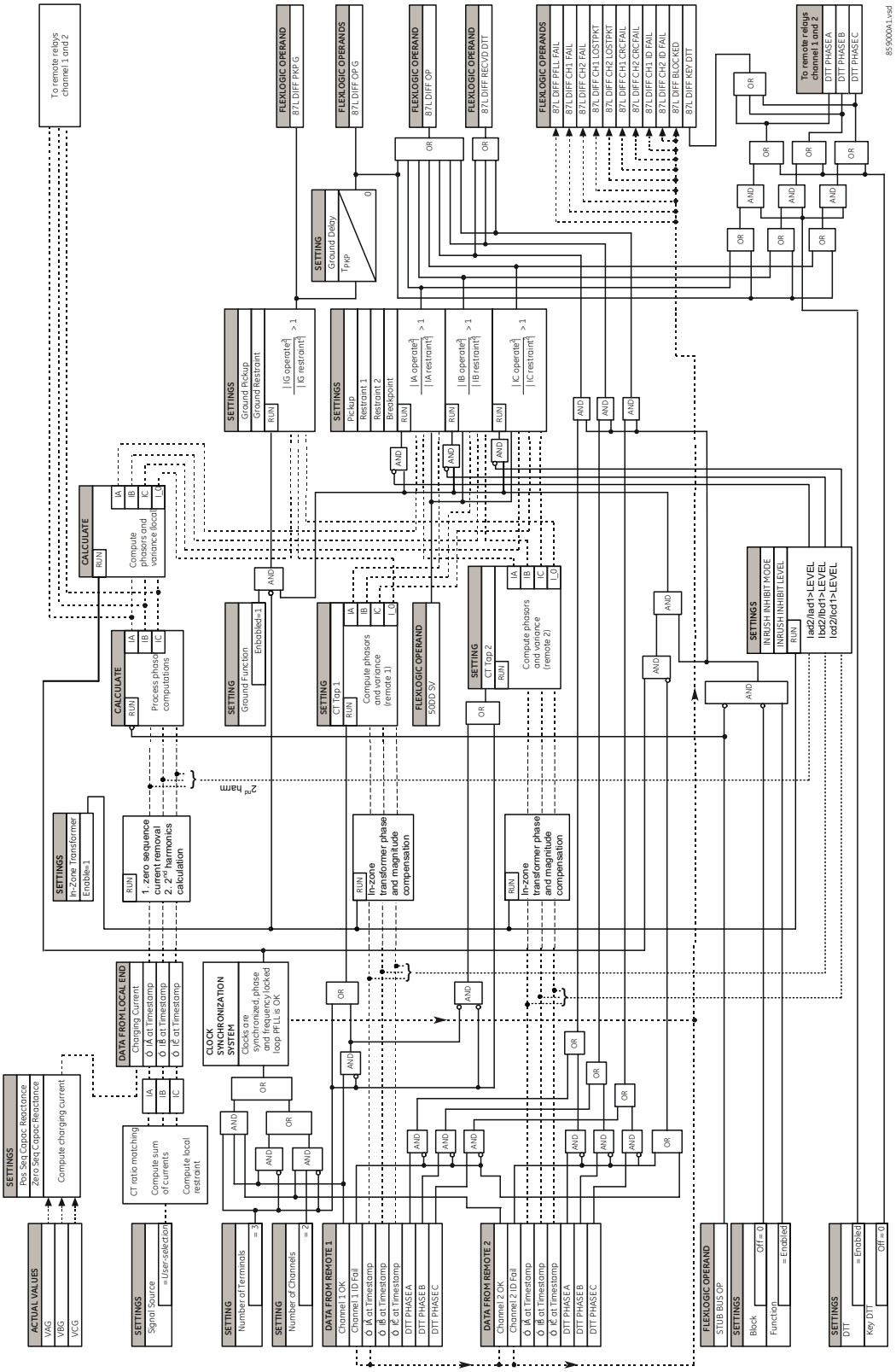
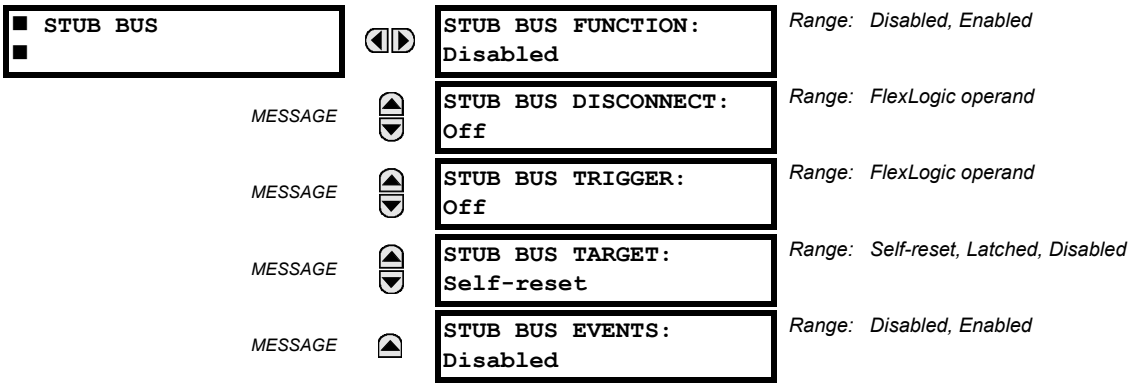



**Figure 5–62: CURRENT DIFFERENTIAL SCHEME LOGIC**

### c) STUB BUS

PATH: SETTINGS ⇨ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ LINE DIFFERENTIAL ELEMENT ⇨⇩ STUB BUS




The stub bus element protects for faults between two breakers in a breaker-and-a-half or ring bus configuration when the line disconnect switch is open. At the same time, if the line is still energized through the remote terminal(s), differential protection is still required (the line may still need to be energized because there is a tapped load on a two terminal line or because the line is a three terminal line with two of the terminals still connected). Correct operation for this condition is achieved by the local relay sending zero current values to the remote end(s) so that a local bus fault does not result in tripping the line. At the local end, the differential element is disabled and stub bus protection is provided by a user-selected overcurrent element. If there is a line fault, the remote end(s) will trip on differential but local differential function and DTT signal (if enabled) to the local end, will be blocked by the stub bus logic allowing the local breakers to remain closed.

- **STUB BUS FUNCTION:** There are three requirements for stub bus operation: the element must be enabled, an indication that the line disconnect is open, and the **STUB BUS TRIGGER** setting is set as indicated below. There are two methods of setting the stub bus trigger and thus setting up stub bus operation:

  1. If **STUB BUS TRIGGER** is “On”, the STUB BUS OPERATE operand picks up as soon as the disconnect switch opens, causing zero currents to be transmitted to remote end(s) and DTT receipt from remote end(s) to be permanently blocked. An overcurrent element, blocked by disconnect switch closed, provides protection for the local bus.
  2. An alternate method is to set **STUB BUS TRIGGER** to be the pickup of an assigned instantaneous overcurrent element. The instantaneous overcurrent element must operate quickly enough to pick up the STUB BUS OPERATE operand, disable the local differential, and send zero currents to the other terminal(s). If the bus minimum fault current is above five times the instantaneous overcurrent pickup, tests have confirmed that the STUB BUS OPERATE operand always pick up correctly for a stub bus fault and prevents tripping of the remote terminal. If minimum stub bus fault current is below this value, then method 1 should be used. Note also that correct testing of stub bus operation, when this method is used, requires sudden injection of a fault currents above five times instantaneous overcurrent pickup. The assigned current element should be mapped to appropriate output contact(s) to trip the stub bus breakers. It should be blocked unless disconnect is open. To prevent 87L tripping from remote L30 relays still protecting the line, the auxiliary contact of line disconnect switch (logic “1” when line switch is open) should be assigned to block the local 87L function by using the **CURRENT DIFF BLOCK** setting.

- **STUB BUS DISCONNECT:** Selects a FlexLogic operand to represent the open state of auxiliary contact of line disconnect switch (logic “1” when line disconnect switch is open). If necessary, simple logic representing not only line disconnect switch but also the closed state of the breakers can be created with FlexLogic and assigned to this setting.
- **STUB BUS TRIGGER:** Selects a FlexLogic operand that causes the STUB BUS OPERATE operand to pick up if the line disconnect is open. It can be set either to “On” or to an instantaneous overcurrent element (see above). If the instantaneous overcurrent used for the stub bus protection is set with a time delay, then **STUB BUS TRIGGER** should use the associated instantaneous overcurrent pickup operand. The source assigned for the current of this element must cover the stub between CTs of the associated breakers and disconnect switch.

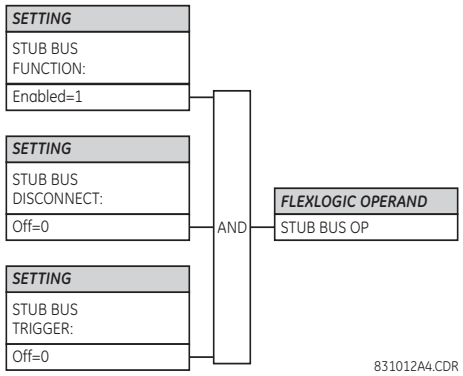



**Figure 5–63: STUB BUS SCHEME LOGIC**

## 5.6.4 PHASE CURRENT

### a) MAIN MENU

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨⇩ SETTING GROUP 1(6) ⇨ PHASE CURRENT**

| | | | |
|---|---|---|---|
| ■ PHASE CURRENT ■ | | ■ PHASE TOC 1 ■ | See page 5-173. |
| | *MESSAGE* | ■ PHASE TOC 2 ■ | See page 5-173. |
| | *MESSAGE* | ■ PHASE IOC 1 ■ | See page 5-175. |
| | *MESSAGE* | ■ PHASE IOC 2 ■ | See page 5-175. |
| | *MESSAGE* | ■ PHASE IOC 3 ■ | See page 5-175. |
| | *MESSAGE* | ■ PHASE IOC 4 ■ | See page 5-175. |
| | *MESSAGE* | ■ PHASE ■ DIRECTIONAL 1 | See page 5-176. |
| | *MESSAGE* | ■ PHASE ■ DIRECTIONAL 2 | See page 5-176. |

### b) INVERSE TIME OVERCURRENT CHARACTERISTICS

The inverse time overcurrent curves used by the time overcurrent elements are the IEEE, IEC, GE Type IAC, and $I^2t$ standard curve shapes. This allows for simplified coordination with downstream devices.

If none of these curve shapes is adequate, FlexCurves may be used to customize the inverse time curve characteristics. The definite time curve is also an option that may be appropriate if only simple protection is required.

**Table 5–22: OVERCURRENT CURVE TYPES**

| IEEE | IEC | GE TYPE IAC | OTHER |
|---|---|---|---|
| IEEE Extremely Inverse | IEC Curve A (BS142) | IAC Extremely Inverse | $I^2t$ |
| IEEE Very Inverse | IEC Curve B (BS142) | IAC Very Inverse | FlexCurves A, B, C, and D |
| IEEE Moderately Inverse | IEC Curve C (BS142) | IAC Inverse | Recloser Curves |
| | IEC Short Inverse | IAC Short Inverse | Definite Time |

A time dial multiplier setting allows selection of a multiple of the base curve shape (where the time dial multiplier = 1) with the curve shape (**CURVE**) setting. Unlike the electromechanical time dial equivalent, operate times are directly proportional to the time multiplier (**TD MULTIPLIER**) setting value. For example, all times for a multiplier of 10 are 10 times the multiplier 1 or base curve values. Setting the multiplier to zero results in an instantaneous response to all current levels above pickup.

Time overcurrent time calculations are made with an internal *energy capacity* memory variable. When this variable indicates that the energy capacity has reached 100%, a time overcurrent element will operate. If less than 100% energy capacity is accumulated in this variable and the current falls below the dropout threshold of 97 to 98% of the pickup value, the variable must be reduced. Two methods of this resetting operation are available: “Instantaneous” and “Timed”. The “Instantaneous” selection is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The “Timed” selection can be used where the relay must coordinate with electromechanical relays.

The URs calculate operate time corresponding to the values in the range of 1.03 to 20 multiples of the pickup current. Above 20 multiples of the pickup current, URs clamp the operate time to the value at a multiple of 20, resulting in the flat part of the characteristics. Reset time is calculated in the range of 0 to 0.97 multiples of the pickup current.

#### IEEE CURVES

The IEEE time overcurrent curve shapes conform to industry standards and the IEEE C37.112-1996 curve classifications for extremely, very, and moderately inverse. The IEEE curves are derived from the formulae:

$$T = TDM \times \left[ \frac{A}{\left( \frac{I}{I_{pickup}} \right)^p - 1} + B \right], \; T_{RESET} = TDM \times \left[ \frac{t_r}{1 - \left( \frac{I}{I_{pickup}} \right)^2} \right] \qquad \textbf{(EQ 5.10)}$$

where: $T$ = operate time (in seconds), $TDM$ = Multiplier setting, $I$ = input current, $I_{pickup}$ = Pickup Current setting
$A$, $B$, $p$ = constants, $T_{RESET}$ = reset time in seconds (assuming energy capacity is 100% and **RESET** is “Timed”),
$t_r$ = characteristic constant

**Table 5–23: IEEE INVERSE TIME CURVE CONSTANTS**

| IEEE CURVE SHAPE | A | B | P | $T_R$ |
|---|---|---|---|---|
| IEEE Extremely Inverse | 28.2 | 0.1217 | 2.0000 | 29.1 |
| IEEE Very Inverse | 19.61 | 0.491 | 2.0000 | 21.6 |
| IEEE Moderately Inverse | 0.0515 | 0.1140 | 0.02000 | 4.85 |

**Table 5–24: IEEE CURVE TRIP TIMES (IN SECONDS)**

| MULTIPLIER (TDM) | CURRENT ( $I$ / $I_{pickup}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
| **IEEE EXTREMELY INVERSE** | | | | | | | | | | |
| 0.5 | 11.341 | 4.761 | 1.823 | 1.001 | 0.648 | 0.464 | 0.355 | 0.285 | 0.237 | 0.203 |
| 1.0 | 22.682 | 9.522 | 3.647 | 2.002 | 1.297 | 0.927 | 0.709 | 0.569 | 0.474 | 0.407 |
| 2.0 | 45.363 | 19.043 | 7.293 | 4.003 | 2.593 | 1.855 | 1.418 | 1.139 | 0.948 | 0.813 |

**Table 5–24: IEEE CURVE TRIP TIMES (IN SECONDS)**

| MULTIPLIER (TDM) | CURRENT ( $I$ / $I_{pickup}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
| 4.0 | 90.727 | 38.087 | 14.587 | 8.007 | 5.187 | 3.710 | 2.837 | 2.277 | 1.897 | 1.626 |
| 6.0 | 136.090 | 57.130 | 21.880 | 12.010 | 7.780 | 5.564 | 4.255 | 3.416 | 2.845 | 2.439 |
| 8.0 | 181.454 | 76.174 | 29.174 | 16.014 | 10.374 | 7.419 | 5.674 | 4.555 | 3.794 | 3.252 |
| 10.0 | 226.817 | 95.217 | 36.467 | 20.017 | 12.967 | 9.274 | 7.092 | 5.693 | 4.742 | 4.065 |
| **IEEE VERY INVERSE** | | | | | | | | | | |
| 0.5 | 8.090 | 3.514 | 1.471 | 0.899 | 0.654 | 0.526 | 0.450 | 0.401 | 0.368 | 0.345 |
| 1.0 | 16.179 | 7.028 | 2.942 | 1.798 | 1.308 | 1.051 | 0.900 | 0.802 | 0.736 | 0.689 |
| 2.0 | 32.358 | 14.055 | 5.885 | 3.597 | 2.616 | 2.103 | 1.799 | 1.605 | 1.472 | 1.378 |
| 4.0 | 64.716 | 28.111 | 11.769 | 7.193 | 5.232 | 4.205 | 3.598 | 3.209 | 2.945 | 2.756 |
| 6.0 | 97.074 | 42.166 | 17.654 | 10.790 | 7.849 | 6.308 | 5.397 | 4.814 | 4.417 | 4.134 |
| 8.0 | 129.432 | 56.221 | 23.538 | 14.387 | 10.465 | 8.410 | 7.196 | 6.418 | 5.889 | 5.513 |
| 10.0 | 161.790 | 70.277 | 29.423 | 17.983 | 13.081 | 10.513 | 8.995 | 8.023 | 7.361 | 6.891 |
| **IEEE MODERATELY INVERSE** | | | | | | | | | | |
| 0.5 | 3.220 | 1.902 | 1.216 | 0.973 | 0.844 | 0.763 | 0.706 | 0.663 | 0.630 | 0.603 |
| 1.0 | 6.439 | 3.803 | 2.432 | 1.946 | 1.688 | 1.526 | 1.412 | 1.327 | 1.260 | 1.207 |
| 2.0 | 12.878 | 7.606 | 4.864 | 3.892 | 3.377 | 3.051 | 2.823 | 2.653 | 2.521 | 2.414 |
| 4.0 | 25.756 | 15.213 | 9.729 | 7.783 | 6.753 | 6.102 | 5.647 | 5.307 | 5.041 | 4.827 |
| 6.0 | 38.634 | 22.819 | 14.593 | 11.675 | 10.130 | 9.153 | 8.470 | 7.960 | 7.562 | 7.241 |
| 8.0 | 51.512 | 30.426 | 19.458 | 15.567 | 13.507 | 12.204 | 11.294 | 10.614 | 10.083 | 9.654 |
| 10.0 | 64.390 | 38.032 | 24.322 | 19.458 | 16.883 | 15.255 | 14.117 | 13.267 | 12.604 | 12.068 |

5

### IEC CURVES

For European applications, the relay offers three standard curves defined in IEC 255-4 and British standard BS142. These are defined as IEC Curve A, IEC Curve B, and IEC Curve C. The formulae for these curves are:

$$T = TDM \times \left[\frac{K}{(I/I_{pickup})^{E} - 1}\right], \; T_{RESET} = TDM \times \left[\frac{t_r}{1 - (I/I_{pickup})^{2}}\right] \quad \textbf{(EQ 5.11)}$$

where: $T$ = operate time (in seconds), $TDM$ = Multiplier setting, $I$ = input current, $I_{pickup}$ = Pickup Current setting, $K$, $E$ = constants, $t_r$ = characteristic constant, and $T_{RESET}$ = reset time in seconds (assuming energy capacity is 100% and **RESET** is "Timed")

**Table 5–25: IEC (BS) INVERSE TIME CURVE CONSTANTS**

| IEC (BS) CURVE SHAPE | K | E | $T_R$ |
|---|---|---|---|
| IEC Curve A (BS142) | 0.140 | 0.020 | 9.7 |
| IEC Curve B (BS142) | 13.500 | 1.000 | 43.2 |
| IEC Curve C (BS142) | 80.000 | 2.000 | 58.2 |
| IEC Short Inverse | 0.050 | 0.040 | 0.500 |

**Table 5–26: IEC CURVE TRIP TIMES (IN SECONDS)**

| MULTIPLIER (TDM) | CURRENT ( $I$ / $I_{pickup}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
| **IEC CURVE A** | | | | | | | | | | |
| 0.05 | 0.860 | 0.501 | 0.315 | 0.249 | 0.214 | 0.192 | 0.176 | 0.165 | 0.156 | 0.149 |
| 0.10 | 1.719 | 1.003 | 0.630 | 0.498 | 0.428 | 0.384 | 0.353 | 0.330 | 0.312 | 0.297 |
| 0.20 | 3.439 | 2.006 | 1.260 | 0.996 | 0.856 | 0.767 | 0.706 | 0.659 | 0.623 | 0.594 |
| 0.40 | 6.878 | 4.012 | 2.521 | 1.992 | 1.712 | 1.535 | 1.411 | 1.319 | 1.247 | 1.188 |
| 0.60 | 10.317 | 6.017 | 3.781 | 2.988 | 2.568 | 2.302 | 2.117 | 1.978 | 1.870 | 1.782 |
| 0.80 | 13.755 | 8.023 | 5.042 | 3.984 | 3.424 | 3.070 | 2.822 | 2.637 | 2.493 | 2.376 |

**Table 5–26: IEC CURVE TRIP TIMES (IN SECONDS)**

| MULTIPLIER (TDM) | CURRENT ( $I / I_{pickup}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
| 1.00 | 17.194 | 10.029 | 6.302 | 4.980 | 4.280 | 3.837 | 3.528 | 3.297 | 3.116 | 2.971 |
| **IEC CURVE B** | | | | | | | | | | |
| 0.05 | 1.350 | 0.675 | 0.338 | 0.225 | 0.169 | 0.135 | 0.113 | 0.096 | 0.084 | 0.075 |
| 0.10 | 2.700 | 1.350 | 0.675 | 0.450 | 0.338 | 0.270 | 0.225 | 0.193 | 0.169 | 0.150 |
| 0.20 | 5.400 | 2.700 | 1.350 | 0.900 | 0.675 | 0.540 | 0.450 | 0.386 | 0.338 | 0.300 |
| 0.40 | 10.800 | 5.400 | 2.700 | 1.800 | 1.350 | 1.080 | 0.900 | 0.771 | 0.675 | 0.600 |
| 0.60 | 16.200 | 8.100 | 4.050 | 2.700 | 2.025 | 1.620 | 1.350 | 1.157 | 1.013 | 0.900 |
| 0.80 | 21.600 | 10.800 | 5.400 | 3.600 | 2.700 | 2.160 | 1.800 | 1.543 | 1.350 | 1.200 |
| 1.00 | 27.000 | 13.500 | 6.750 | 4.500 | 3.375 | 2.700 | 2.250 | 1.929 | 1.688 | 1.500 |
| **IEC CURVE C** | | | | | | | | | | |
| 0.05 | 3.200 | 1.333 | 0.500 | 0.267 | 0.167 | 0.114 | 0.083 | 0.063 | 0.050 | 0.040 |
| 0.10 | 6.400 | 2.667 | 1.000 | 0.533 | 0.333 | 0.229 | 0.167 | 0.127 | 0.100 | 0.081 |
| 0.20 | 12.800 | 5.333 | 2.000 | 1.067 | 0.667 | 0.457 | 0.333 | 0.254 | 0.200 | 0.162 |
| 0.40 | 25.600 | 10.667 | 4.000 | 2.133 | 1.333 | 0.914 | 0.667 | 0.508 | 0.400 | 0.323 |
| 0.60 | 38.400 | 16.000 | 6.000 | 3.200 | 2.000 | 1.371 | 1.000 | 0.762 | 0.600 | 0.485 |
| 0.80 | 51.200 | 21.333 | 8.000 | 4.267 | 2.667 | 1.829 | 1.333 | 1.016 | 0.800 | 0.646 |
| 1.00 | 64.000 | 26.667 | 10.000 | 5.333 | 3.333 | 2.286 | 1.667 | 1.270 | 1.000 | 0.808 |
| **IEC SHORT TIME** | | | | | | | | | | |
| 0.05 | 0.153 | 0.089 | 0.056 | 0.044 | 0.038 | 0.034 | 0.031 | 0.029 | 0.027 | 0.026 |
| 0.10 | 0.306 | 0.178 | 0.111 | 0.088 | 0.075 | 0.067 | 0.062 | 0.058 | 0.054 | 0.052 |
| 0.20 | 0.612 | 0.356 | 0.223 | 0.175 | 0.150 | 0.135 | 0.124 | 0.115 | 0.109 | 0.104 |
| 0.40 | 1.223 | 0.711 | 0.445 | 0.351 | 0.301 | 0.269 | 0.247 | 0.231 | 0.218 | 0.207 |
| 0.60 | 1.835 | 1.067 | 0.668 | 0.526 | 0.451 | 0.404 | 0.371 | 0.346 | 0.327 | 0.311 |
| 0.80 | 2.446 | 1.423 | 0.890 | 0.702 | 0.602 | 0.538 | 0.494 | 0.461 | 0.435 | 0.415 |
| 1.00 | 3.058 | 1.778 | 1.113 | 0.877 | 0.752 | 0.673 | 0.618 | 0.576 | 0.544 | 0.518 |

5

### IAC CURVES

The curves for the General Electric type IAC relay family are derived from the formulae:

$$T = \text{TDM} \times \left( A + \frac{B}{(I/I_{pkp}) - C} + \frac{D}{((I/I_{pkp}) - C)^2} + \frac{E}{((I/I_{pkp}) - C)^3} \right), \; T_{RESET} = TDM \times \left[ \frac{t_r}{1 - (I/I_{pkp})^2} \right] \quad \textbf{(EQ 5.12)}$$

where: $T$ = operate time (in seconds), $TDM$ = Multiplier setting, $I$ = Input current, $I_{pkp}$ = Pickup Current setting, $A$ *to* $E$ = constants, $t_r$ = characteristic constant, and $T_{RESET}$ = reset time in seconds (assuming energy capacity is 100% and **RESET** is "Timed")

**Table 5–27: GE TYPE IAC INVERSE TIME CURVE CONSTANTS**

| IAC CURVE SHAPE | A | B | C | D | E | $T_R$ |
|---|---|---|---|---|---|---|
| IAC Extreme Inverse | 0.0040 | 0.6379 | 0.6200 | 1.7872 | 0.2461 | 6.008 |
| IAC Very Inverse | 0.0900 | 0.7955 | 0.1000 | –1.2885 | 7.9586 | 4.678 |
| IAC Inverse | 0.2078 | 0.8630 | 0.8000 | –0.4180 | 0.1947 | 0.990 |
| IAC Short Inverse | 0.0428 | 0.0609 | 0.6200 | –0.0010 | 0.0221 | 0.222 |

**Table 5–28: IAC CURVE TRIP TIMES**

| MULTIPLIER (TDM) | CURRENT ( $I / I_{pickup}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
| **IAC EXTREMELY INVERSE** | | | | | | | | | | |
| 0.5 | 1.699 | 0.749 | 0.303 | 0.178 | 0.123 | 0.093 | 0.074 | 0.062 | 0.053 | 0.046 |

### Table 5–28: IAC CURVE TRIP TIMES

| MULTIPLIER (TDM) | CURRENT ( $I$ / $I_{pickup}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
| 1.0 | 3.398 | 1.498 | 0.606 | 0.356 | 0.246 | 0.186 | 0.149 | 0.124 | 0.106 | 0.093 |
| 2.0 | 6.796 | 2.997 | 1.212 | 0.711 | 0.491 | 0.372 | 0.298 | 0.248 | 0.212 | 0.185 |
| 4.0 | 13.591 | 5.993 | 2.423 | 1.422 | 0.983 | 0.744 | 0.595 | 0.495 | 0.424 | 0.370 |
| 6.0 | 20.387 | 8.990 | 3.635 | 2.133 | 1.474 | 1.115 | 0.893 | 0.743 | 0.636 | 0.556 |
| 8.0 | 27.183 | 11.987 | 4.846 | 2.844 | 1.966 | 1.487 | 1.191 | 0.991 | 0.848 | 0.741 |
| 10.0 | 33.979 | 14.983 | 6.058 | 3.555 | 2.457 | 1.859 | 1.488 | 1.239 | 1.060 | 0.926 |
| **IAC VERY INVERSE** | | | | | | | | | | |
| 0.5 | 1.451 | 0.656 | 0.269 | 0.172 | 0.133 | 0.113 | 0.101 | 0.093 | 0.087 | 0.083 |
| 1.0 | 2.901 | 1.312 | 0.537 | 0.343 | 0.266 | 0.227 | 0.202 | 0.186 | 0.174 | 0.165 |
| 2.0 | 5.802 | 2.624 | 1.075 | 0.687 | 0.533 | 0.453 | 0.405 | 0.372 | 0.349 | 0.331 |
| 4.0 | 11.605 | 5.248 | 2.150 | 1.374 | 1.065 | 0.906 | 0.810 | 0.745 | 0.698 | 0.662 |
| 6.0 | 17.407 | 7.872 | 3.225 | 2.061 | 1.598 | 1.359 | 1.215 | 1.117 | 1.046 | 0.992 |
| 8.0 | 23.209 | 10.497 | 4.299 | 2.747 | 2.131 | 1.813 | 1.620 | 1.490 | 1.395 | 1.323 |
| 10.0 | 29.012 | 13.121 | 5.374 | 3.434 | 2.663 | 2.266 | 2.025 | 1.862 | 1.744 | 1.654 |
| **IAC INVERSE** | | | | | | | | | | |
| 0.5 | 0.578 | 0.375 | 0.266 | 0.221 | 0.196 | 0.180 | 0.168 | 0.160 | 0.154 | 0.148 |
| 1.0 | 1.155 | 0.749 | 0.532 | 0.443 | 0.392 | 0.360 | 0.337 | 0.320 | 0.307 | 0.297 |
| 2.0 | 2.310 | 1.499 | 1.064 | 0.885 | 0.784 | 0.719 | 0.674 | 0.640 | 0.614 | 0.594 |
| 4.0 | 4.621 | 2.997 | 2.128 | 1.770 | 1.569 | 1.439 | 1.348 | 1.280 | 1.229 | 1.188 |
| 6.0 | 6.931 | 4.496 | 3.192 | 2.656 | 2.353 | 2.158 | 2.022 | 1.921 | 1.843 | 1.781 |
| 8.0 | 9.242 | 5.995 | 4.256 | 3.541 | 3.138 | 2.878 | 2.695 | 2.561 | 2.457 | 2.375 |
| 10.0 | 11.552 | 7.494 | 5.320 | 4.426 | 3.922 | 3.597 | 3.369 | 3.201 | 3.072 | 2.969 |
| **IAC SHORT INVERSE** | | | | | | | | | | |
| 0.5 | 0.072 | 0.047 | 0.035 | 0.031 | 0.028 | 0.027 | 0.026 | 0.026 | 0.025 | 0.025 |
| 1.0 | 0.143 | 0.095 | 0.070 | 0.061 | 0.057 | 0.054 | 0.052 | 0.051 | 0.050 | 0.049 |
| 2.0 | 0.286 | 0.190 | 0.140 | 0.123 | 0.114 | 0.108 | 0.105 | 0.102 | 0.100 | 0.099 |
| 4.0 | 0.573 | 0.379 | 0.279 | 0.245 | 0.228 | 0.217 | 0.210 | 0.204 | 0.200 | 0.197 |
| 6.0 | 0.859 | 0.569 | 0.419 | 0.368 | 0.341 | 0.325 | 0.314 | 0.307 | 0.301 | 0.296 |
| 8.0 | 1.145 | 0.759 | 0.559 | 0.490 | 0.455 | 0.434 | 0.419 | 0.409 | 0.401 | 0.394 |
| 10.0 | 1.431 | 0.948 | 0.699 | 0.613 | 0.569 | 0.542 | 0.524 | 0.511 | 0.501 | 0.493 |

### I2t CURVES

The curves for the $I^2t$ are derived from the formulae:

$$T = \text{TDM} \times \left[ \frac{100}{\left( \frac{I}{I_{pickup}} \right)^2} \right], \quad T_{RESET} = \text{TDM} \times \left[ \frac{100}{\left( \frac{I}{I_{pickup}} \right)^{-2}} \right] \qquad \textbf{(EQ 5.13)}$$

where: $T$ = Operate Time (sec.); TDM = Multiplier Setting; $I$ = Input Current; $I_{pickup}$ = Pickup Current Setting; $T_{RESET}$ = Reset Time in sec. (assuming energy capacity is 100% and RESET: Timed)

### Table 5–29: $I^2T$ CURVE TRIP TIMES

| MULTIPLIER (TDM) | CURRENT ( $I$ / $I_{pickup}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
| 0.01 | 0.44 | 0.25 | 0.11 | 0.06 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 |
| 0.10 | 4.44 | 2.50 | 1.11 | 0.63 | 0.40 | 0.28 | 0.20 | 0.16 | 0.12 | 0.10 |
| 1.00 | 44.44 | 25.00 | 11.11 | 6.25 | 4.00 | 2.78 | 2.04 | 1.56 | 1.23 | 1.00 |
| 10.00 | 444.44 | 250.00 | 111.11 | 62.50 | 40.00 | 27.78 | 20.41 | 15.63 | 12.35 | 10.00 |
| 100.00 | 4444.4 | 2500.0 | 1111.1 | 625.00 | 400.00 | 277.78 | 204.08 | 156.25 | 123.46 | 100.00 |

**Table 5–29: $I^2T$ CURVE TRIP TIMES**

| MULTIPLIER (TDM) | CURRENT ( $I$ / $I_{pickup}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
| 600.00 | 26666.7 | 15000.0 | 6666.7 | 3750.0 | 2400.0 | 1666.7 | 1224.5 | 937.50 | 740.74 | 600.00 |

### FLEXCURVES

The custom FlexCurves are described in detail in the FlexCurves section of this chapter. The curve shapes for the FlexCurves are derived from the formulae:

$$T = \text{TDM} \times \left[\text{FlexCurve Time at } \left(\frac{I}{I_{pickup}}\right)\right] \quad \text{when } \left(\frac{I}{I_{pickup}}\right) \geq 1.00 \qquad \textbf{(EQ 5.14)}$$

$$T_{RESET} = \text{TDM} \times \left[\text{FlexCurve Time at } \left(\frac{I}{I_{pickup}}\right)\right] \quad \text{when } \left(\frac{I}{I_{pickup}}\right) \leq 0.98 \qquad \textbf{(EQ 5.15)}$$

where: $T$ = Operate Time (sec.), TDM = Multiplier setting
$I$ = Input Current, $I_{pickup}$ = Pickup Current setting
$T_{RESET}$ = Reset Time in seconds (assuming energy capacity is 100% and RESET: Timed)

### DEFINITE TIME CURVE

The Definite Time curve shape operates as soon as the pickup level is exceeded for a specified period of time. The base definite time curve delay is in seconds. The curve multiplier of 0.00 to 600.00 makes this delay adjustable from instantaneous to 600.00 seconds in steps of 10 ms.

$$T = \text{TDM in seconds, when } I > I_{pickup} \qquad \textbf{(EQ 5.16)}$$

$$T_{RESET} = \text{TDM in seconds} \qquad \textbf{(EQ 5.17)}$$

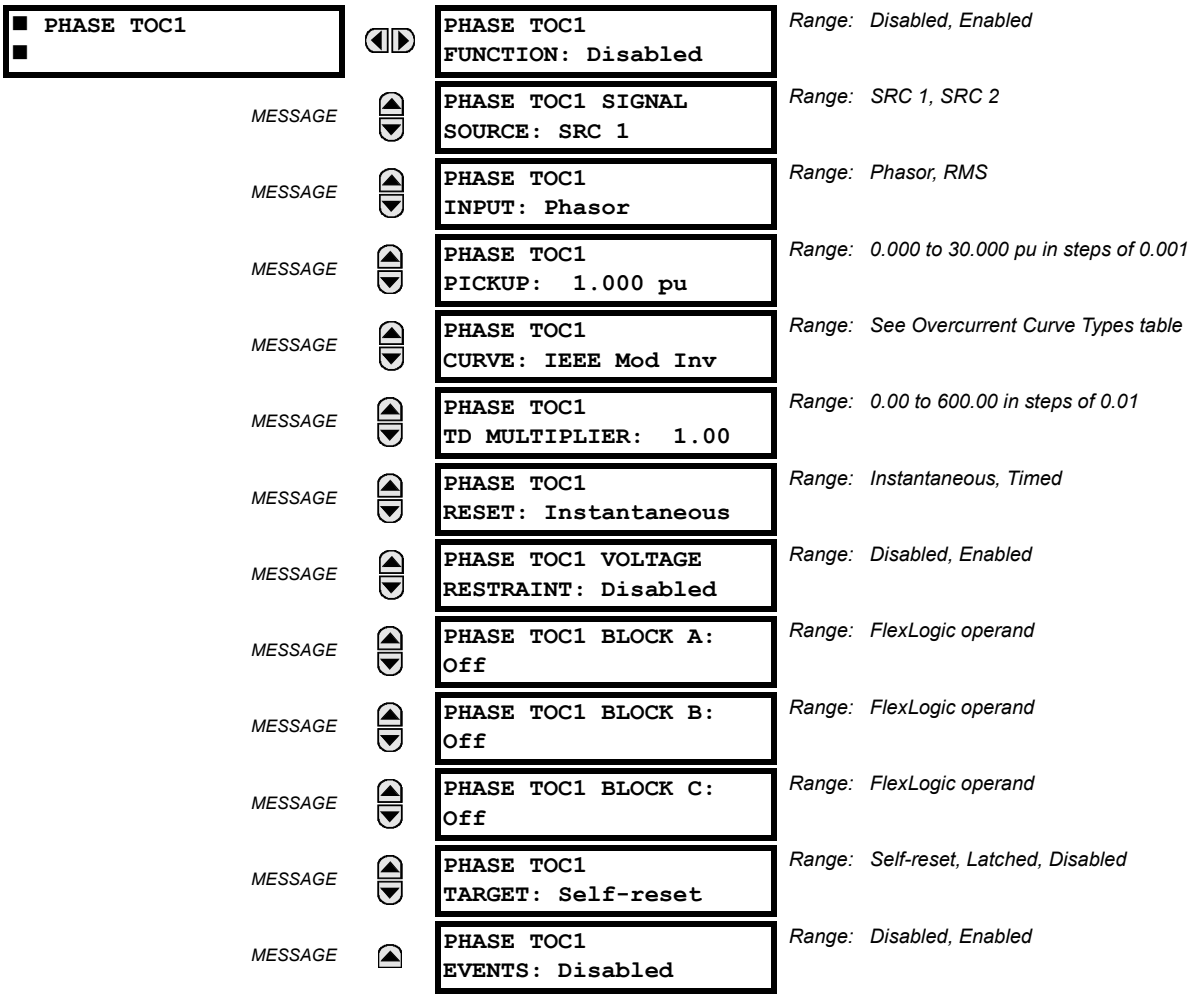
where: $T$ = Operate Time (sec.), TDM = Multiplier setting
$I$ = Input Current, $I_{pickup}$ = Pickup Current setting
$T_{RESET}$ = Reset Time in seconds (assuming energy capacity is 100% and RESET: Timed)

### RECLOSER CURVES

The L30 uses the FlexCurve feature to facilitate programming of 41 recloser curves. See the FlexCurve section in this chapter for details.

### c) PHASE TIME OVERCURRENT (ANSI 51P, IEC PTOC)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ PHASE CURRENT ⇨ PHASE TOC1(2)




The phase time overcurrent element can provide a desired time-delay operating characteristic versus the applied current or be used as a simple definite time element. The phase current input quantities may be programmed as fundamental phasor magnitude or total waveform RMS magnitude as required by the application.

Two methods of resetting operation are available: “Timed” and “Instantaneous” (see the Inverse TOC Curve Characteristics section earlier for details on curve setup, trip times, and reset operation). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to “Instantaneous” and the element is blocked, the time accumulator will be cleared immediately.

The **PHASE TOC1 PICKUP** setting can be dynamically reduced by a voltage restraint feature (when enabled). This is accomplished via the multipliers (Mvr) corresponding to the phase-phase voltages of the voltage restraint characteristic curve (see the figure below); the pickup level is calculated as ‘Mvr’ times the **PHASE TOC1 PICKUP** setting. If the voltage restraint feature is disabled, the pickup level always remains at the setting value.

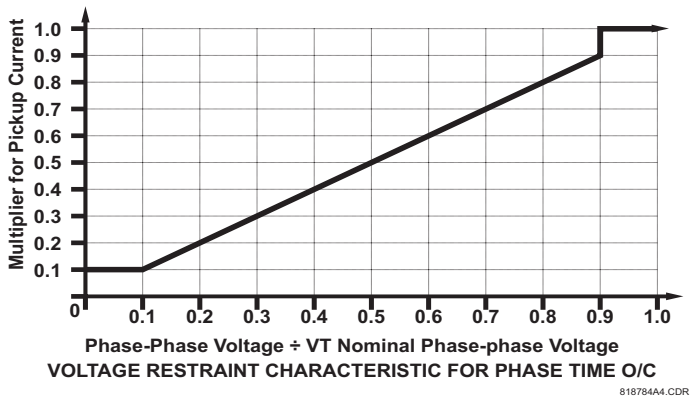



**Figure 5–64: PHASE TIME OVERCURRENT VOLTAGE RESTRAINT CHARACTERISTIC**

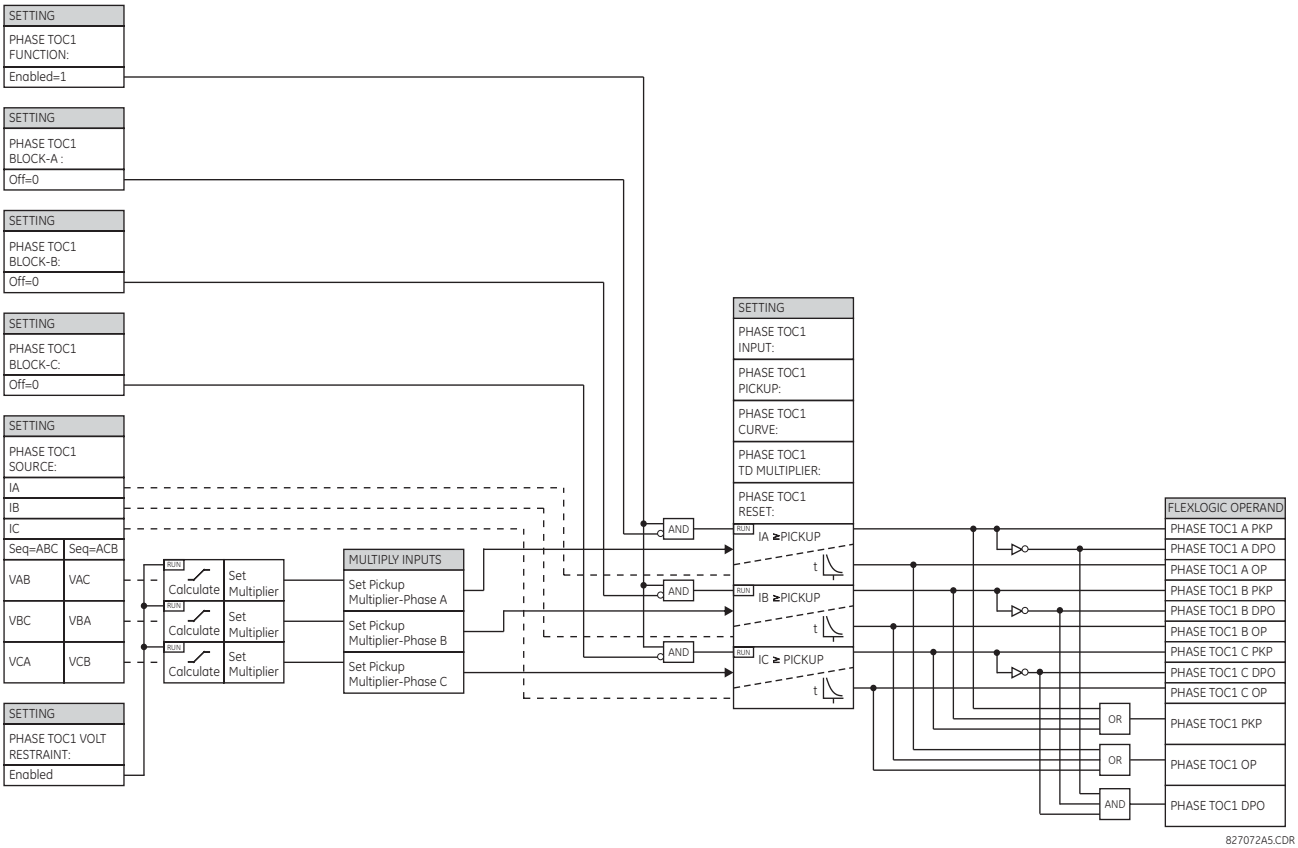



**Figure 5–65: PHASE TIME OVERCURRENT 1 SCHEME LOGIC**

### d) PHASE INSTANTANEOUS OVERCURRENT (ANSI 50P, IEC PIOC)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ PHASE CURRENT ⇨ PHASE IOC 1(4)

| | | | |
|---|---|---|---|
| ■ PHASE IOC 1 ■ | | PHASE IOC1 FUNCTION: Disabled | Range: Disabled, Enabled |
| | MESSAGE | PHASE IOC1 SIGNAL SOURCE: SRC 1 | Range: SRC 1, SRC 2 |
| | MESSAGE | PHASE IOC1 PICKUP: 1.000 pu | Range: 0.000 to 30.000 pu in steps of 0.001 |
| | MESSAGE | PHASE IOC1 PICKUP DELAY: 0.00 s | Range: 0.00 to 600.00 s in steps of 0.01 |
| | MESSAGE | PHASE IOC1 RESET DELAY: 0.00 s | Range: 0.00 to 600.00 s in steps of 0.01 |
| | MESSAGE | PHASE IOC1 BLOCK A: Off | Range: FlexLogic operand |
| | MESSAGE | PHASE IOC1 BLOCK B: Off | Range: FlexLogic operand |
| | MESSAGE | PHASE IOC1 BLOCK C: Off | Range: FlexLogic operand |
| | MESSAGE | PHASE IOC1 TARGET: Self-reset | Range: Self-reset, Latched, Disabled |
| | MESSAGE | PHASE IOC1 EVENTS: Disabled | Range: Disabled, Enabled |

The phase instantaneous overcurrent element may be used as an instantaneous element with no intentional delay or as a definite time element. The input current is the fundamental phasor magnitude.

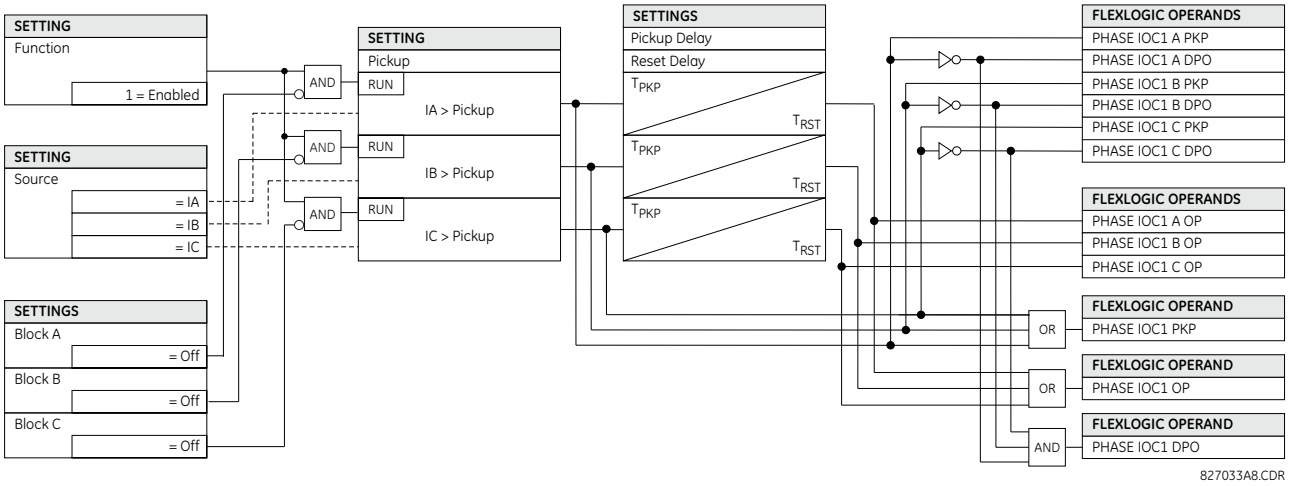
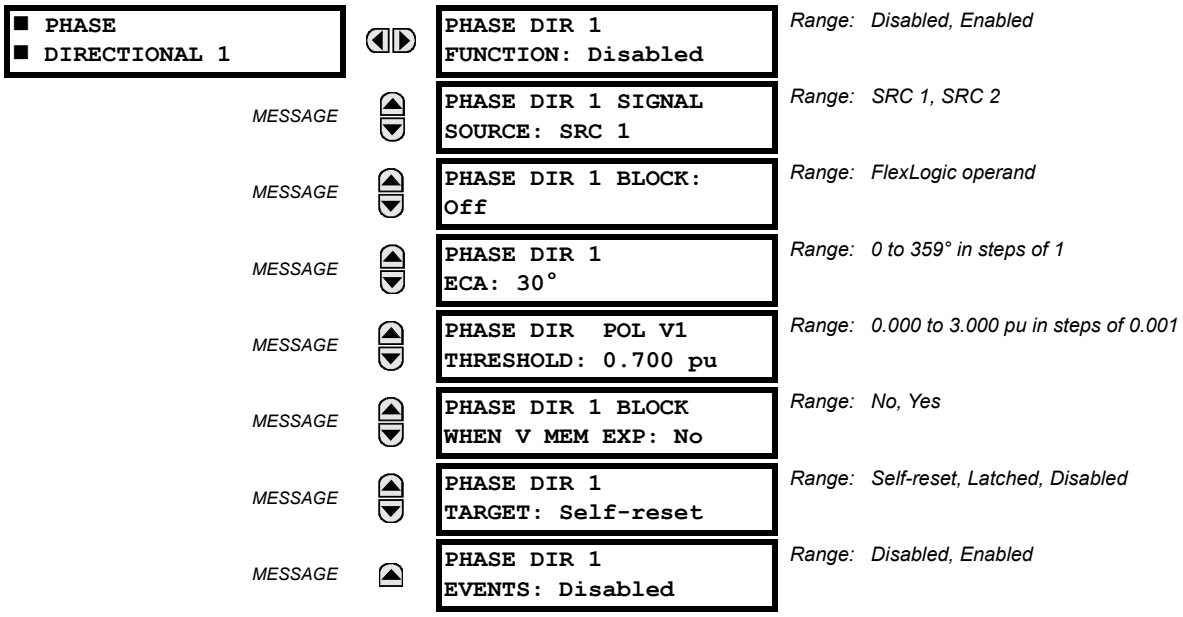



**Figure 5–66: PHASE INSTANTANEOUS OVERCURRENT 1 SCHEME LOGIC**

### e) PHASE DIRECTIONAL OVERCURRENT (ANSI 67P, IEC PDOC/PTOC)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ PHASE CURRENT ⇨ PHASE DIRECTIONAL 1(2)




5

NOTE

The TARGET setting is not user-selectable and forced to "Disabled". If Targets are required from directional elements, it can be achieved by assigning directional element output to a digital element, where targets selection can be used as required.

The phase directional elements (one for each of phases A, B, and C) determine the phase current flow direction for steady state and fault conditions and can be used to control the operation of the phase overcurrent elements via the **BLOCK** inputs of these elements.

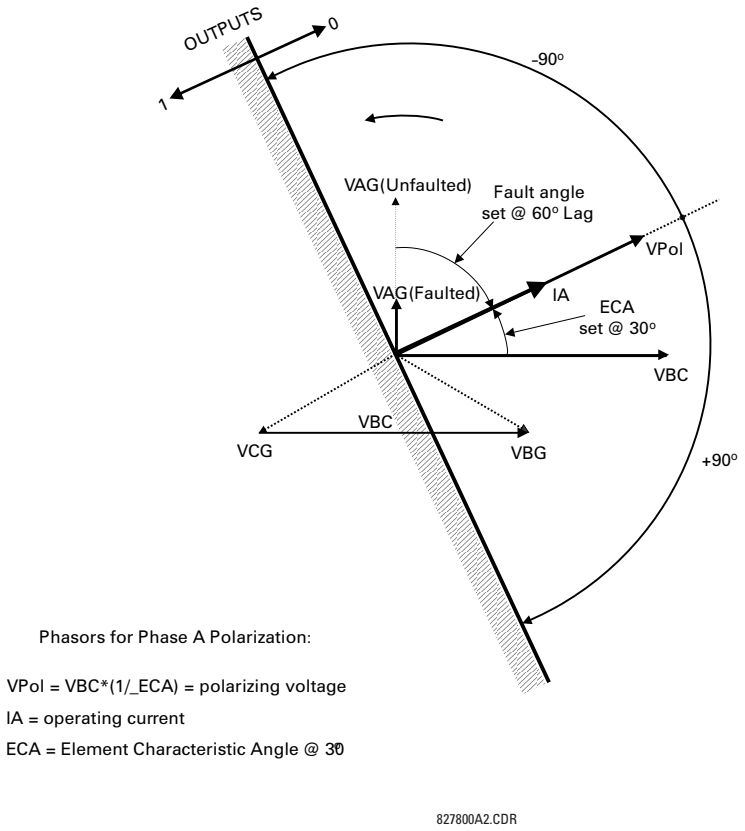



**Figure 5–67: PHASE A DIRECTIONAL POLARIZATION**

This element is intended to apply a block signal to an overcurrent element to prevent an operation when current is flowing in a particular direction. The direction of current flow is determined by measuring the phase angle between the current from the phase CTs and the line-line voltage from the VTs, based on the 90° or quadrature connection. If there is a requirement to supervise overcurrent elements for flows in opposite directions, such as can happen through a bus-tie breaker, two phase directional elements should be programmed with opposite element characteristic angle (ECA) settings.

To increase security for three phase faults very close to the VTs used to measure the polarizing voltage, a voltage memory feature is incorporated. This feature stores the polarizing voltage the moment before the voltage collapses, and uses it to determine direction. The voltage memory remains valid for one second after the voltage has collapsed.

The main component of the phase directional element is the phase angle comparator with two inputs: the operating signal (phase current) and the polarizing signal (the line voltage, shifted in the leading direction by the characteristic angle, ECA).

The following table shows the operating and polarizing signals used for phase directional control:

| PHASE | OPERATING SIGNAL | POLARIZING SIGNAL $V_{pol}$ | |
|---|---|---|---|
| | | ABC PHASE SEQUENCE | ACB PHASE SEQUENCE |
| A | angle of IA | angle of VBC × (1∠ECA) | angle of VCB × (1∠ECA) |
| B | angle of IB | angle of VCA × (1∠ECA) | angle of VAC × 1∠ECA) |
| C | angle of IC | angle of VAB × (1∠ECA) | angle of VBA × (1∠ECA) |

**MODE OF OPERATION:**

- When the function is “Disabled”, or the operating current is below 5% × CT nominal, the element output is “0”.
- When the function is “Enabled”, the operating current is above 5% × CT nominal, and the polarizing voltage is above the **PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES ⇨⇩ VOLTAGE CUT-OFF LEVEL** value, the element output is dependent on the phase angle between the operating and polarizing signals:
  - The element output is logic “0” when the operating current is within polarizing voltage ±90°.
  - For all other angles, the element output is logic “1”.
- Once the voltage memory has expired, the phase overcurrent elements under directional control can be set to block or trip on overcurrent as follows:
  - When **BLOCK WHEN V MEM EXP** is set to “Yes”, the directional element will block the operation of any phase overcurrent element under directional control when voltage memory expires.
  - When **BLOCK WHEN V MEM EXP** is set to “No”, the directional element allows tripping of phase overcurrent elements under directional control when voltage memory expires.

In all cases, directional blocking will be permitted to resume when the polarizing voltage becomes greater than the ‘polarizing voltage threshold’.

**SETTINGS:**

- **PHASE DIR 1 SIGNAL SOURCE:** This setting is used to select the source for the operating and polarizing signals. The operating current for the phase directional element is the phase current for the selected current source. The polarizing voltage is the line voltage from the phase VTs, based on the 90° or ‘quadrature’ connection and shifted in the leading direction by the element characteristic angle (ECA).
- **PHASE DIR 1 ECA:** This setting is used to select the element characteristic angle, i.e. the angle by which the polarizing voltage is shifted in the leading direction to achieve dependable operation. In the design of the UR-series elements, a block is applied to an element by asserting logic 1 at the blocking input. This element should be programmed via the ECA setting so that the output is **logic 1 for current in the non-tripping direction**.
- **PHASE DIR 1 POL V THRESHOLD:** This setting is used to establish the minimum level of voltage for which the phase angle measurement is healthy and reliable. Do not set this setting too low because the element can continue using the actual voltage already distorted by the fault instead of using healthy memory voltage—this can cause wrong directional discrimination.
- **PHASE DIR 1 BLOCK WHEN V MEM EXP:** This setting is used to select the required operation upon expiration of voltage memory. When set to "Yes", the directional element blocks the operation of any phase overcurrent element under directional control, when voltage memory expires; when set to "No", the directional element allows tripping of phase overcurrent elements under directional control.

NOTE

The phase directional element responds to the forward load current. In the case of a following reverse fault, the element needs some time – in the order of 8 ms – to establish a blocking signal. Some protection elements such as instantaneous overcurrent may respond to reverse faults before the blocking signal is established. Therefore, a coordination time of at least 10 ms must be added to all the instantaneous protection elements under the supervision of the phase directional element. If current reversal is of a concern, a longer delay – in the order of 20 ms – may be needed.

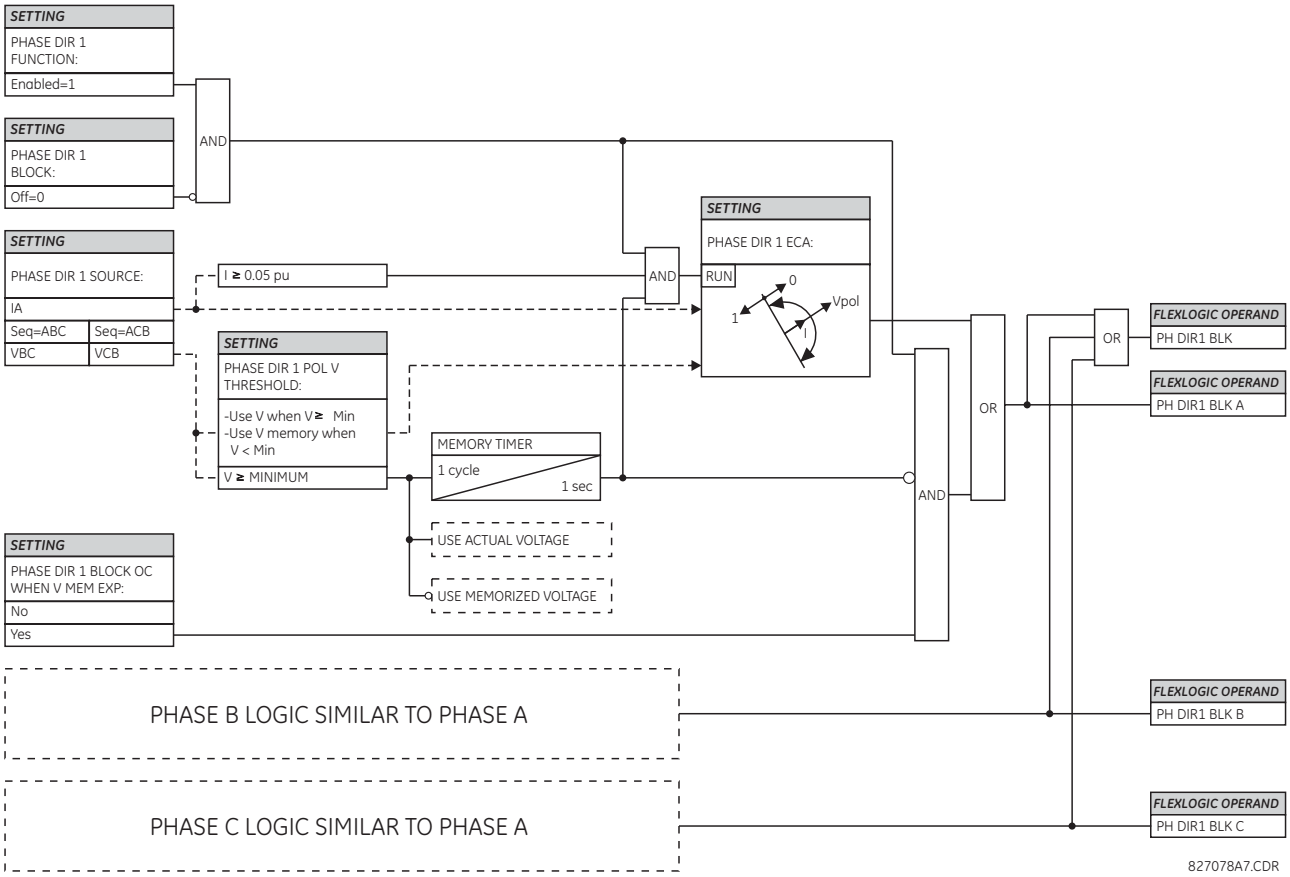
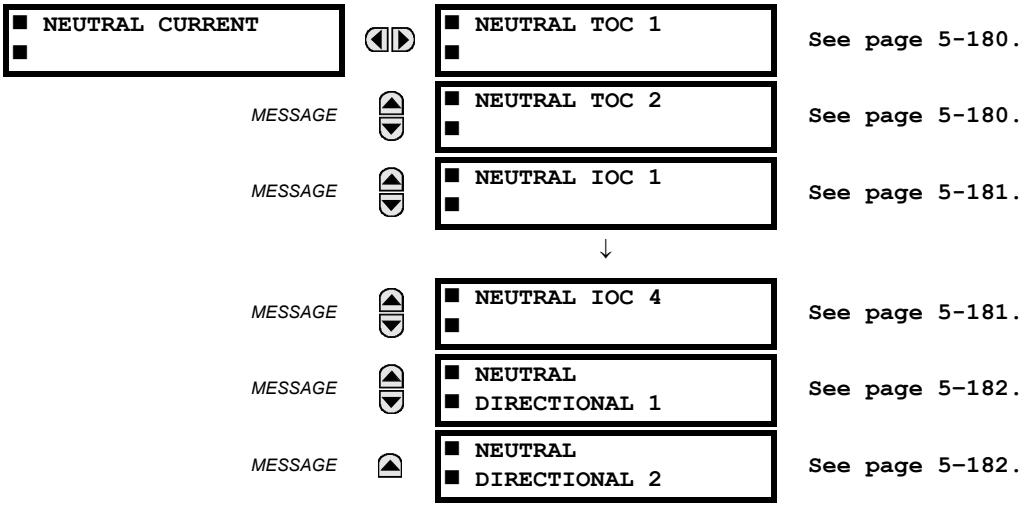



**Figure 5–68: PHASE DIRECTIONAL SCHEME LOGIC**

## 5.6.5 NEUTRAL CURRENT

### a) MAIN MENU

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨⇩ SETTING GROUP 1(6) ⇨ NEUTRAL CURRENT**



### b) NEUTRAL TIME OVERCURRENT (ANSI 51N, IEC PTOC)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEUTRAL CURRENT ⇨ NEUTRAL TOC1(2)

| | | |
|---|---|---|
| NEUTRAL TOC 1 | NEUTRAL TOC1 FUNCTION: Disabled | Range: Disabled, Enabled |
| MESSAGE | NEUTRAL TOC1 SIGNAL SOURCE: SRC 1 | Range: SRC 1, SRC 2 |
| MESSAGE | NEUTRAL TOC1 INPUT: Phasor | Range: Phasor, RMS |
| MESSAGE | NEUTRAL TOC1 PICKUP: 1.000 pu | Range: 0.000 to 30.000 pu in steps of 0.001 |
| MESSAGE | NEUTRAL TOC1 CURVE: IEEE Mod Inv | Range: See the Overcurrent Curve Types table |
| MESSAGE | NEUTRAL TOC1 TD MULTIPLIER: 1.00 | Range: 0.00 to 600.00 in steps of 0.01 |
| MESSAGE | NEUTRAL TOC1 RESET: Instantaneous | Range: Instantaneous, Timed |
| MESSAGE | NEUTRAL TOC1 BLOCK: Off | Range: FlexLogic operand |
| MESSAGE | NEUTRAL TOC1 TARGET: Self-reset | Range: Self-reset, Latched, Disabled |
| MESSAGE | NEUTRAL TOC1 EVENTS: Disabled | Range: Disabled, Enabled |

The neutral time overcurrent element can provide a desired time-delay operating characteristic versus the applied current or be used as a simple definite time element. The neutral current input value is a quantity calculated as 3I0 from the phase currents and may be programmed as fundamental phasor magnitude or total waveform RMS magnitude as required by the application.

Two methods of resetting operation are available: “Timed” and “Instantaneous” (see the Inverse TOC Curve Characteristics section for details on curve setup, trip times and reset operation). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to “Instantaneous” and the element is blocked, the time accumulator will be cleared immediately.

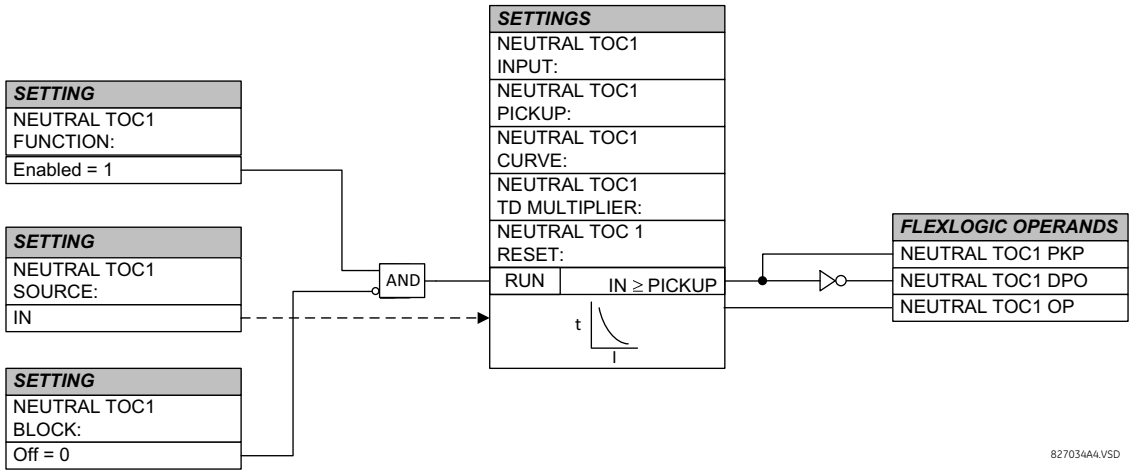



Figure 5–69: NEUTRAL TIME OVERCURRENT 1 SCHEME LOGIC

### c) NEUTRAL INSTANTANEOUS OVERCURRENT (ANSI 50N, IEC PIOC)

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL IOC1(4)**

| | | | |
|---|---|---|---|
| ■ NEUTRAL IOC 1 ■ | | NEUTRAL IOC1 FUNCTION: Disabled | *Range: Disabled, Enabled* |
| | *MESSAGE* | NEUTRAL IOC1 SIGNAL SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | NEUTRAL IOC1 PICKUP: 1.000 pu | *Range: 0.000 to 30.000 pu in steps of 0.001* |
| | *MESSAGE* | NEUTRAL IOC1 PICKUP DELAY: 0.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | NEUTRAL IOC1 RESET DELAY: 0.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | NEUTRAL IOC1 BLOCK: Off | *Range: FlexLogic operand* |
| | *MESSAGE* | NEUTRAL IOC1 TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | NEUTRAL IOC1 EVENTS: Disabled | *Range: Disabled, Enabled* |

The neutral instantaneous overcurrent element may be used as an instantaneous function with no intentional delay or as a definite time function. The element essentially responds to the magnitude of a neutral current fundamental frequency phasor calculated from the phase currents. A positive-sequence restraint is applied for better performance. A small portion (6.25%) of the positive-sequence current magnitude is subtracted from the zero-sequence current magnitude when forming the operating quantity of the element as follows:

$$I_{op} = 3 \times (|I\_0| - Kx|I\_1|) \quad \text{where } K = 1/16 \qquad \textbf{(EQ 5.18)}$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious zero-sequence currents resulting from

- System unbalances under heavy load conditions
- Transformation errors of current transformers (CTs) during double-line and three-phase faults
- Switch-off transients during double-line and three-phase faults

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on how test currents are injected into the relay, where single-phase injection is $I_{op} = 0.9375 \times I_{injected}$ and three-phase pure zero-sequence injection is $I_{op} = 3 \times I_{injected}$

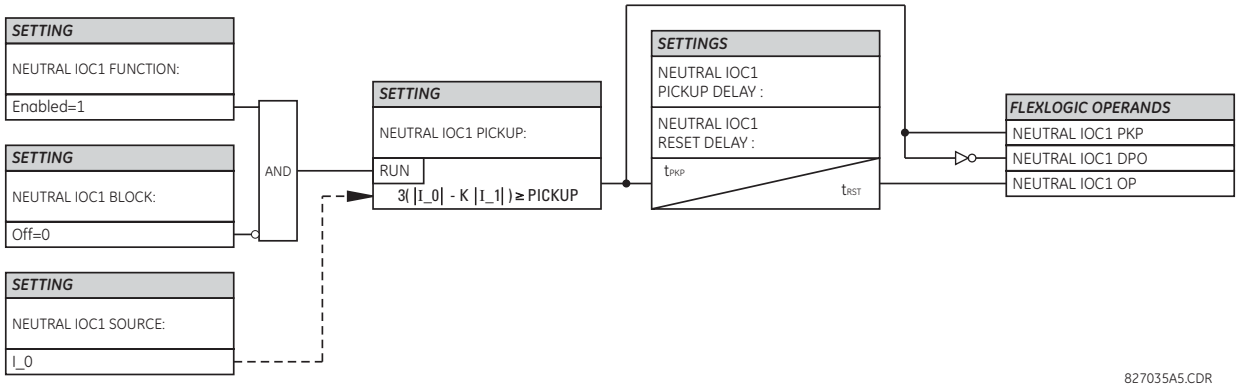



**Figure 5–70: NEUTRAL IOC1 SCHEME LOGIC**

### d) NEUTRAL DIRECTIONAL OVERCURRENT (ANSI 67N, IEC PDEF/PTOC)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL DIRECTIONAL OC1(2)

| | | | |
|---|---|---|---|
| ■ NEUTRAL<br>■ DIRECTIONAL OC1 | ◀▶ | NEUTRAL DIR OC1<br>FUNCTION: Disabled | *Range: Disabled, Enabled* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC 1<br>SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1<br>POLARIZING: Voltage | *Range: Voltage, Current, Dual, Dual-V, Dual-I* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1 POL<br>VOLT: Calculated V0 | *Range: Calculated V0, Aux. Voltage (VX)* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1 OP<br>CURR: Calculated 3I0 | *Range: Calculated 3I0, Measured IG* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1 POS-<br>SEQ RESTRAINT: 0.063 | *Range: 0.000 to 0.500 in steps of 0.001* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1<br>OFFSET: 0.00 Ω | *Range: 0.00 to 250.00 Ω in steps of 0.01* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1 FWD<br>ECA: 75° Lag | *Range: –90 to 90° in steps of 1* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1 FWD<br>LIMIT ANGLE: 90° | *Range: 40 to 90° in steps of 1* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1 FWD<br>PICKUP: 0.050 pu | *Range: 0.006 to 30.000 pu in steps of 0.001* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1 REV<br>LIMIT ANGLE: 90° | *Range: 40 to 90° in steps of 1* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1 REV<br>PICKUP: 0.050 pu | *Range: 0.006 to 30.000 pu in steps of 0.001* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1 BLK:<br>Off | *Range: FlexLogic operand* |
| *MESSAGE* | ▲▼ | NEUTRAL DIR OC1<br>TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| *MESSAGE* | ▲ | NEUTRAL DIR OC1<br>EVENTS: Disabled | *Range: Disabled, Enabled* |

The neutral directional overcurrent element provides both forward and reverse fault direction indications the NEUTRAL DIR OC1 FWD and NEUTRAL DIR OC1 REV operands, respectively. The output operand is asserted if the magnitude of the operating current is above a pickup level (overcurrent unit) and the fault direction is seen as *forward* or *reverse*, respectively (directional unit).

The **overcurrent unit** responds to the magnitude of a fundamental frequency phasor of the either the neutral current calculated from the phase currents or the ground current. There are separate pickup settings for the forward-looking and reverse-looking functions. If set to use the calculated 3I_0, the element applies a *positive-sequence restraint* for better performance: a small user-programmable portion of the positive-sequence current magnitude is subtracted from the zero-sequence current magnitude when forming the operating quantity.

$$I_{op} = 3 \times (|I\_0| - K \times |I\_1|) \quad \textbf{(EQ 5.19)}$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious zero-sequence currents resulting from:

- System unbalances under heavy load conditions.

- Transformation errors of current transformers (CTs) during double-line and three-phase faults.
- Switch-off transients during double-line and three-phase faults.

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on the way the test currents are injected into the relay (single-phase injection: $I_{op} = (1 - K) \times I_{injected}$ ; three-phase pure zero-sequence injection: $I_{op} = 3 \times I_{injected}$).

The positive-sequence restraint is removed for low currents. If the positive-sequence current is below 0.8 pu, the restraint is removed by changing the constant *K* to zero. This facilitates better response to high-resistance faults when the unbalance is very small and there is no danger of excessive CT errors as the current is low.

The **directional unit** uses the zero-sequence current (I_0) or ground current (IG) for fault direction discrimination and may be programmed to use either zero-sequence voltage ("Calculated V0" or "Measured VX"), ground current (IG), or both for polarizing. The zero-sequence current (I_0) must be greater than the **PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES ⇨⇩ CURRENT CUT-OFF LEVEL** setting value and IG must be greater than 0.05 pu to be validated as the operating quantity for directional current. The following tables define the neutral directional overcurrent element.

**Table 5–30: QUANTITIES FOR "CALCULATED 3I0" CONFIGURATION**

| DIRECTIONAL UNIT | | | | OVERCURRENT UNIT |
|---|---|---|---|---|
| POLARIZING MODE | DIRECTION | COMPARED PHASORS | | |
| Voltage | Forward | –V_0 + Z_offset × I_0 | I_0 × 1∠ECA | $I_{op} = 3 \times (\lvert I\_0\rvert - K \times \lvert I\_1\rvert)$ if $\lvert I_1\rvert > 0.8$ pu<br>$I_{op} = 3 \times (\lvert I\_0\rvert)$ if $\lvert I_1\rvert \le 0.8$ pu |
| | Reverse | –V_0 + Z_offset × I_0 | –I_0 × 1∠ECA | |
| Current | Forward | IG | I_0 | |
| | Reverse | IG | –I_0 | |
| Dual, Dual-V, Dual-I | Forward | –V_0 + Z_offset × I_0 | I_0 × 1∠ECA | |
| | | *or* | | |
| | | IG | I_0 | |
| | Reverse | –V_0 + Z_offset × I_0 | –I_0 × 1∠ECA | |
| | | *or* | | |
| | | IG | –I_0 | |

**Table 5–31: QUANTITIES FOR "MEASURED IG" CONFIGURATION**

| DIRECTIONAL UNIT | | | | OVERCURRENT UNIT |
|---|---|---|---|---|
| POLARIZING MODE | DIRECTION | COMPARED PHASORS | | |
| Voltage | Forward | –V_0 + Z_offset × IG/3 | IG × 1∠ECA | $I_{op} = \lvert IG\rvert$ |
| | Reverse | –V_0 + Z_offset × IG/3 | –IG × 1∠ECA | |

where: $V\_0 = \frac{1}{3}(VAG + VBG + VCG) =$ zero sequence voltage ,

$I\_0 = \frac{1}{3}IN = \frac{1}{3}(IA + IB + IC) =$ zero sequence current ,

ECA = element characteristic angle
IG = ground current
Z_offset is the offset impedance, for which magnitude is the OFFSET setting and angle is the FWD ECA

When **NEUTRAL DIR OC1 POL VOLT** is set to "Measured VX", one-third of this voltage is used in place of V_0. The following figure explains the usage of the voltage polarized directional unit of the element.

The figure below shows the voltage-polarized phase angle comparator characteristics for a phase A to ground fault, with:

- ECA = 90° (element characteristic angle = centerline of operating characteristic)
- FWD LA = 80° (forward limit angle = the ± angular limit with the ECA for operation)
- REV LA = 80° (reverse limit angle = the ± angular limit with the ECA for operation)

The above bias should be taken into account when using the neutral directional overcurrent element to directionalize other protection elements.

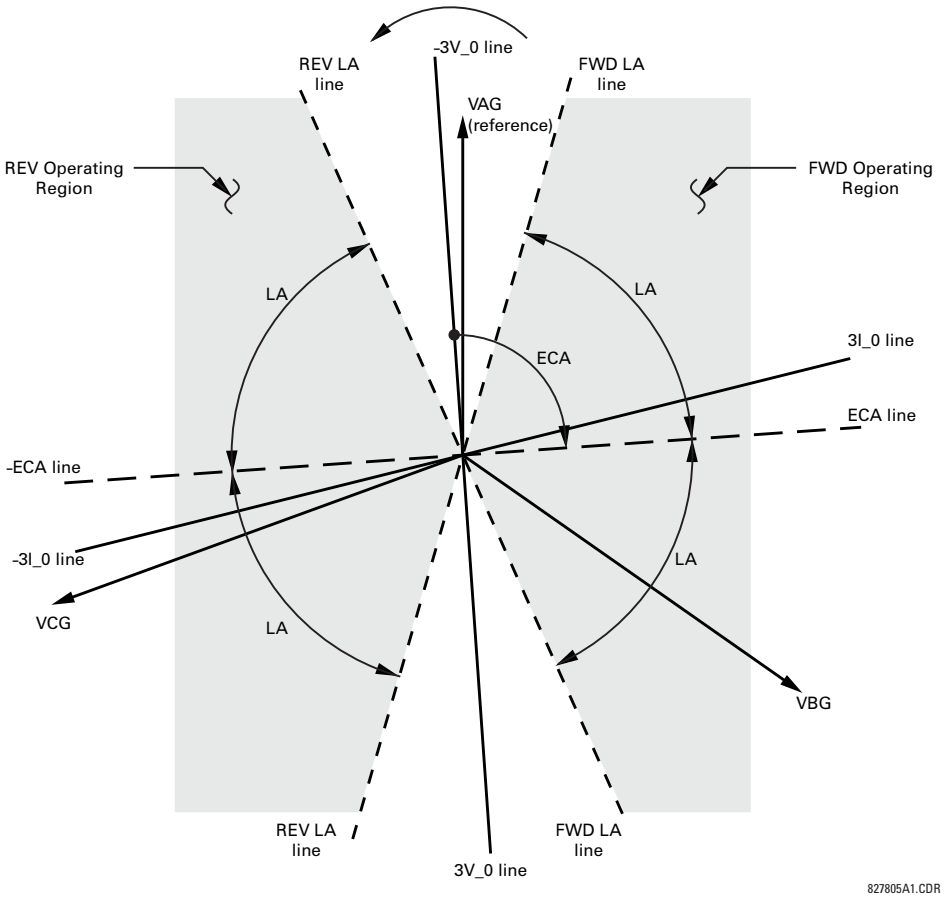



**Figure 5–71: NEUTRAL DIRECTIONAL VOLTAGE-POLARIZED CHARACTERISTICS**

- **NEUTRAL DIR OC1 POLARIZING:** This setting selects the polarizing mode for the directional unit.
  - If "Voltage" polarizing is selected, the element uses the zero-sequence voltage angle for polarization. The user can use either the zero-sequence voltage V_0 calculated from the phase voltages, or the zero-sequence voltage supplied externally as the auxiliary voltage V_X, both from the **NEUTRAL DIR OC1 SOURCE**.

    The calculated V_0 can be used as polarizing voltage only if the voltage transformers are connected in Wye. The auxiliary voltage can be used as the polarizing voltage provided **SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK ⇨⇩ AUXILIARY VT CONNECTION** is set to "Vn" and the auxiliary voltage is connected to a zero-sequence voltage source (such as broken delta connected secondary of VTs).

    The zero sequence voltage V_0 must be greater than **PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES ⇨⇩ VOLTAGE CUT-OFF LEVEL** to be validated for use as polarizing signal. Additionally, when offset impedance is applied and zero-sequence current is above 0.2 pu, compensated zero-sequence voltage -V_0 + Z_offset x I_0 has to be above 0.02 pu in order to discriminate fault direction; otherwise when zero-sequence current is less than 0.2 pu, -V_0 is then used as the polarizing signal. If the polarizing signal is invalid, neither forward nor reverse indication is given.
  - If "Current" polarizing is selected, the element uses the ground current angle connected externally and configured under **NEUTRAL OC1 SOURCE** for polarization. The ground CT must be connected between the ground and neutral point of an adequate local source of ground current. The ground current must be greater than 0.05 pu to be validated as a polarizing signal. If the polarizing signal is not valid, neither forward nor reverse indication is given. In addition, the zero-sequence current (I_0) must be greater than the **PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES ⇨⇩ CURRENT CUT-OFF LEVEL** setting value.

For a choice of current polarizing, it is recommended that the polarizing signal be analyzed to ensure that a known direction is maintained irrespective of the fault location. For example, if using an autotransformer neutral current as a polarizing source, it should be ensured that a reversal of the ground current does not occur for a high-side fault. The low-side system impedance should be assumed minimal when checking for this condition. A similar situation arises for a wye/delta/wye transformer, where current in one transformer winding neutral may reverse when faults on both sides of the transformer are considered.

– If “Dual” polarizing is selected, the element performs both directional comparisons as described. A given direction is confirmed if either voltage or current comparators indicate so. If a conflicting (simultaneous forward and reverse) indication occurs, the forward direction overrides the reverse direction.

– If "Dual-V" polarizing is selected, "Voltage" polarizing is performed and "Current" polarizing is ignored if the voltage polarizing signal is valid; otherwise "Current" polarizing is performed if the current polarizing signal is valid. If neither of them is valid, neither forward nor reverse indication is given.

– If "Dual-I" polarizing is selected, "Current" polarizing is performed and "Voltage" polarizing is ignored if the current polarizing signal is valid; otherwise "Voltage" polarizing is performed if the voltage polarizing signal is valid. If neither of them is valid, neither forward nor reverse indication is given.

- **NEUTRAL DIR OC1 POL VOLT:** Selects the polarizing voltage used by the directional unit when "Voltage," "Dual," "Dual-V," or "Dual-I" polarizing mode is set. The polarizing voltage can be programmed to be either the zero-sequence voltage calculated from the phase voltages ("Calculated V0") or supplied externally as an auxiliary voltage ("Measured VX").
- **NEUTRAL DIR OC1 OP CURR:** This setting indicates whether the 3I_0 current calculated from the phase currents, or the ground current shall be used by this protection. This setting acts as a switch between the neutral and ground modes of operation (67N and 67G). If set to “Calculated 3I0” the element uses the phase currents and applies the positive-sequence restraint; if set to “Measured IG” the element uses ground current supplied to the ground CT of the CT bank configured as **NEUTRAL DIR OC1 SOURCE**. If this setting is “Measured IG”, then the **NEUTRAL DIR OC1 POLARIZING** setting must be “Voltage”, as it is not possible to use the ground current as an operating and polarizing signal simultaneously. IG current has to be above 0.05 pu to be used as operate quantity.
- **NEUTRAL DIR OC1 POS-SEQ RESTRAINT**: This setting controls the amount of the positive-sequence restraint. Set to 0.063 for backward compatibility with firmware revision 3.40 and older. Set to zero to remove the restraint. Set higher if large system unbalances or poor CT performance are expected.
- **NEUTRAL DIR OC1 OFFSET:** This setting specifies the offset impedance used by this protection. The primary application for the offset impedance is to guarantee correct identification of fault direction on series compensated lines. In regular applications, the offset impedance ensures proper operation even if the zero-sequence voltage at the relaying point is very small. If this is the intent, the offset impedance shall not be larger than the zero-sequence impedance of the protected circuit. Practically, it shall be several times smaller. The offset impedance shall be entered in secondary ohms.
- **NEUTRAL DIR OC1 FWD ECA:** This setting defines the characteristic angle (ECA) for the forward direction in the "Voltage" polarizing mode. The "Current" polarizing mode uses a fixed ECA of 0°. The ECA in the reverse direction is the angle set for the forward direction shifted by 180°.
- **NEUTRAL DIR OC1 FWD LIMIT ANGLE:** This setting defines a symmetrical (in both directions from the ECA) limit angle for the forward direction.
- **NEUTRAL DIR OC1 FWD PICKUP:** This setting defines the pickup level for the overcurrent unit of the element in the forward direction. When selecting this setting it must be kept in mind that the design uses a ‘positive-sequence restraint’ technique for the “Calculated 3I0” mode of operation.
- **NEUTRAL DIR OC1 REV LIMIT ANGLE:** This setting defines a symmetrical (in both directions from the ECA) limit angle for the reverse direction.
- **NEUTRAL DIR OC1 REV PICKUP:** This setting defines the pickup level for the overcurrent unit of the element in the reverse direction. When selecting this setting it must be kept in mind that the design uses a *positive-sequence restraint* technique for the “Calculated 3I0” mode of operation.

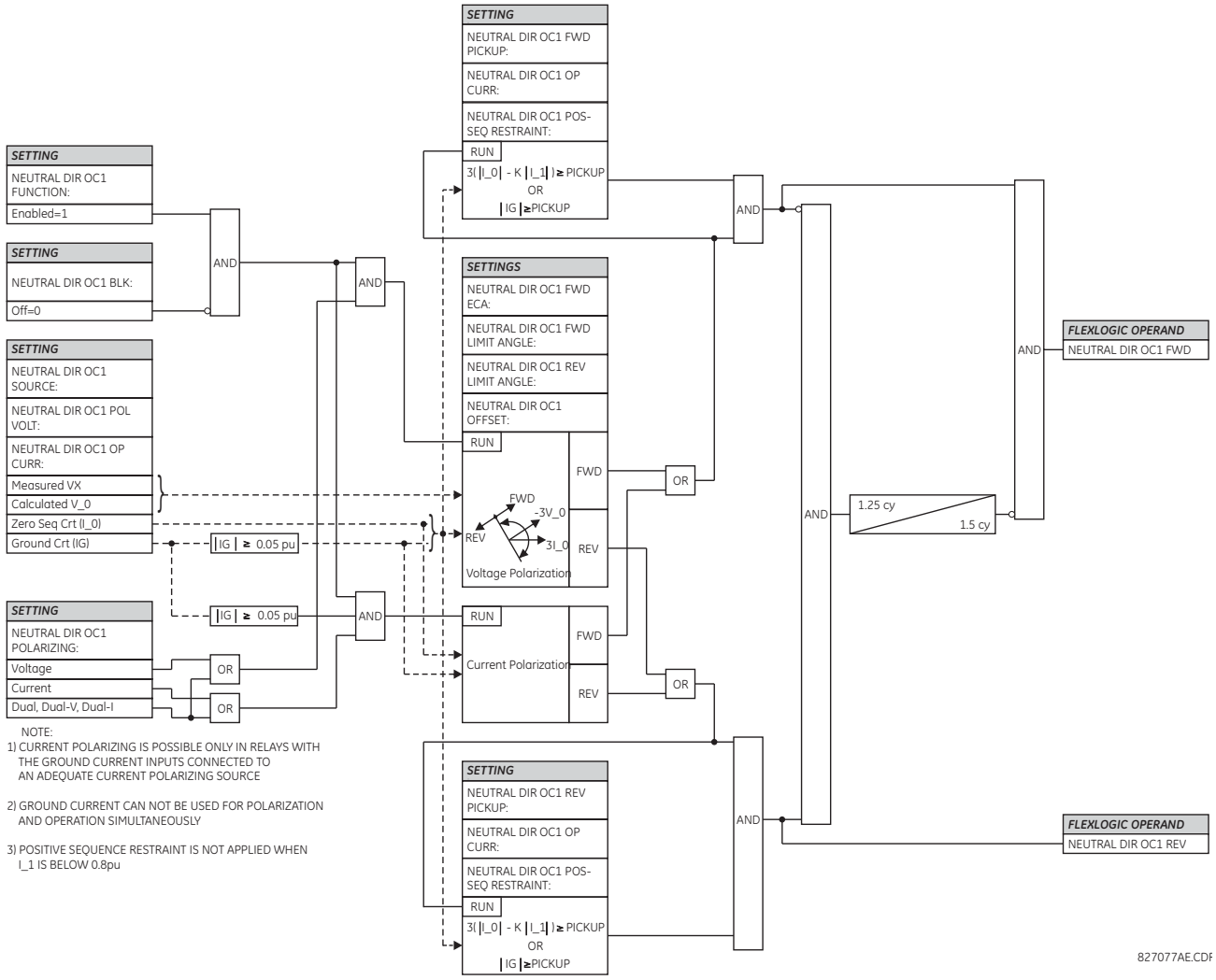
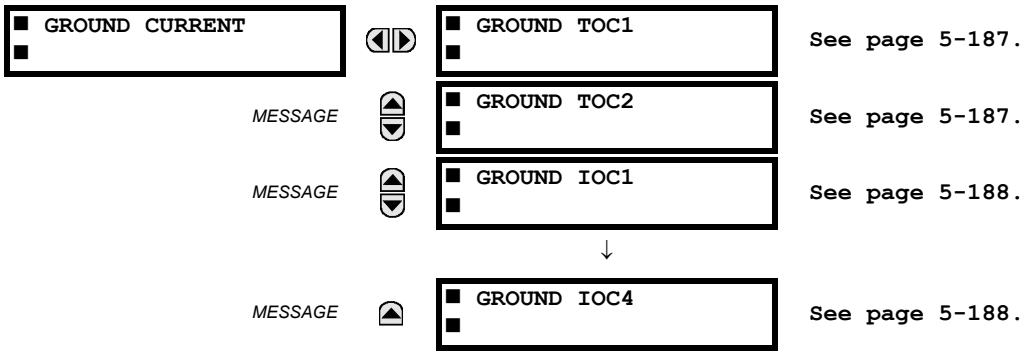



**Figure 5–72: NEUTRAL DIRECTIONAL OVERCURRENT LOGIC**

## 5.6.6 GROUND CURRENT

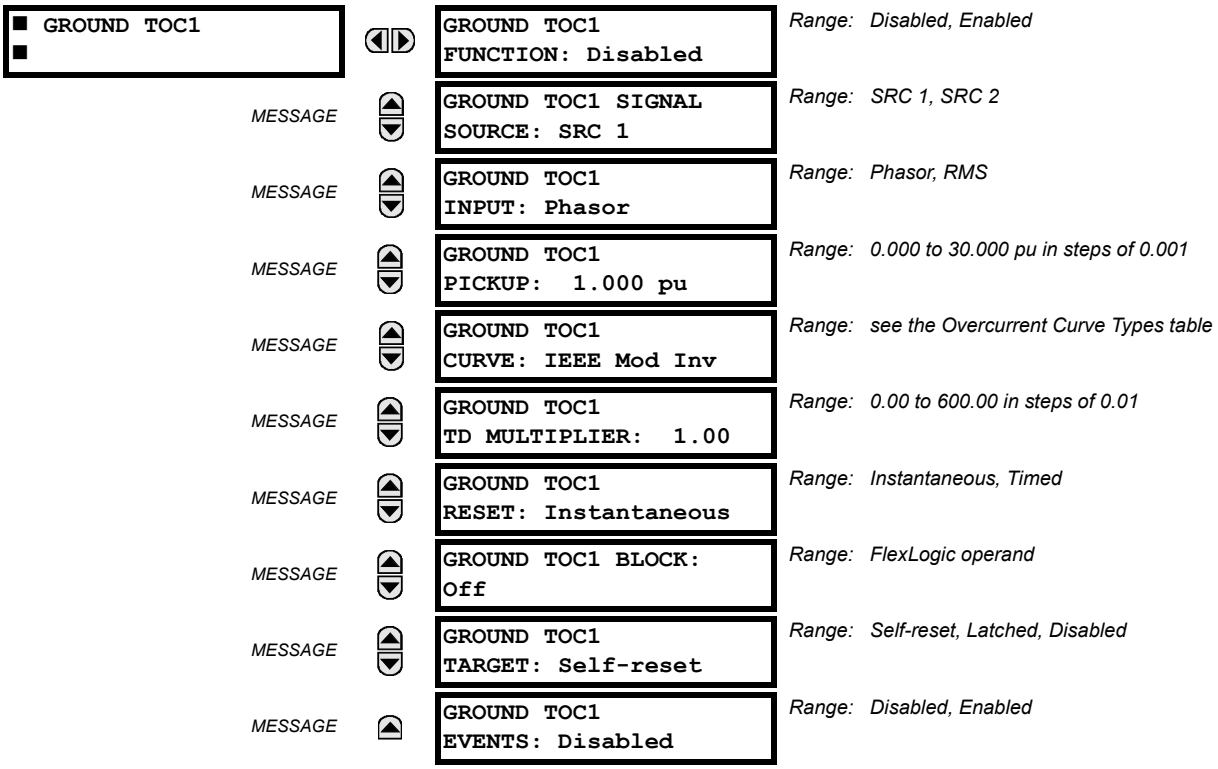
### a) MAIN MENU

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨⇩ SETTING GROUP 1(6) ⇨⇩ GROUND CURRENT**



### b) GROUND TIME OVERCURRENT (ANSI 51G, IEC PTOC)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ GROUND CURRENT ⇨ GROUND TOC1(2)




This element can provide a desired time-delay operating characteristic versus the applied current or be used as a simple definite time element. The ground current input value is the quantity measured by the ground input CT and is the fundamental phasor or RMS magnitude. Two methods of resetting operation are available: “Timed” and “Instantaneous” (see the Inverse TOC Curve Characteristics section for details). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to “Instantaneous” and the element is blocked, the time accumulator will be cleared immediately.

NOTE

These elements measure the current that is connected to the ground channel of a CT/VT module. The conversion range of a standard channel is from 0.02 to 46 times the CT rating.

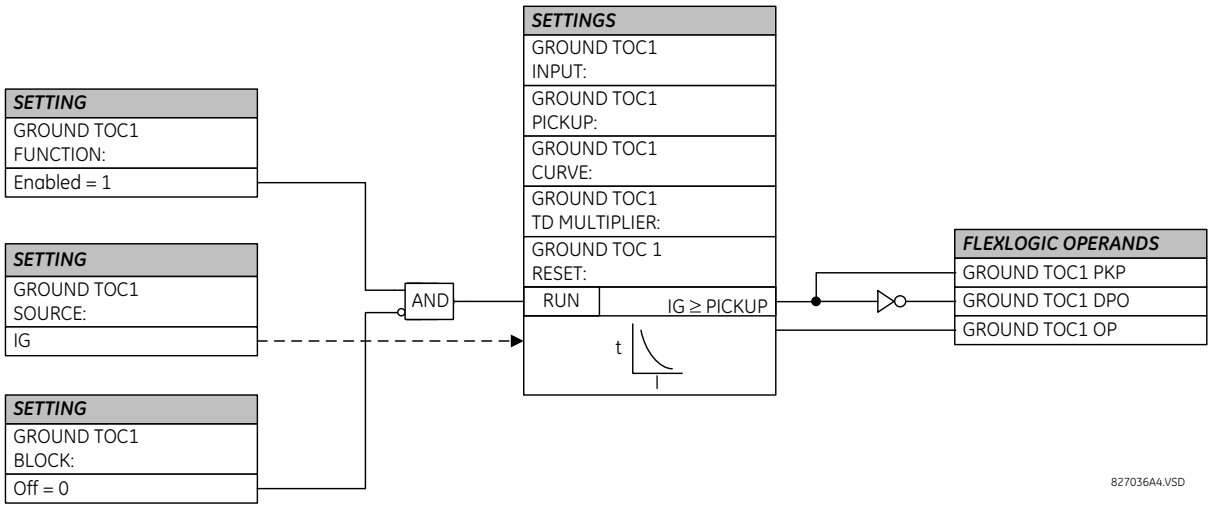



**Figure 5–73: GROUND TOC1 SCHEME LOGIC**

### c) GROUND INSTANTANEOUS OVERCURRENT (ANSI 50G, IEC PIOC)

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ GROUND CURRENT ⇨⇩ GROUND IOC1(4)**

| | | | |
|---|---|---|---|
| ■ GROUND IOC1 ■ | | GROUND IOC1 FUNCTION: Disabled | *Range: Disabled, Enabled* |
| | *MESSAGE* | GROUND IOC1 SIGNAL SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | GROUND IOC1 PICKUP: 1.000 pu | *Range: 0.000 to 30.000 pu in steps of 0.001* |
| | *MESSAGE* | GROUND IOC1 PICKUP DELAY: 0.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | GROUND IOC1 RESET DELAY: 0.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | GROUND IOC1 BLOCK: Off | *Range: FlexLogic operand* |
| | *MESSAGE* | GROUND IOC1 TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | GROUND IOC1 EVENTS: Disabled | *Range: Disabled, Enabled* |

The ground instantaneous overcurrent element may be used as an instantaneous element with no intentional delay or as a definite time element. The ground current input is the quantity measured by the ground input CT and is the fundamental phasor magnitude.

NOTE

These elements measure the current that is connected to the ground channel of a CT/VT module. The conversion range of a standard channel is from 0.02 to 46 times the CT rating.

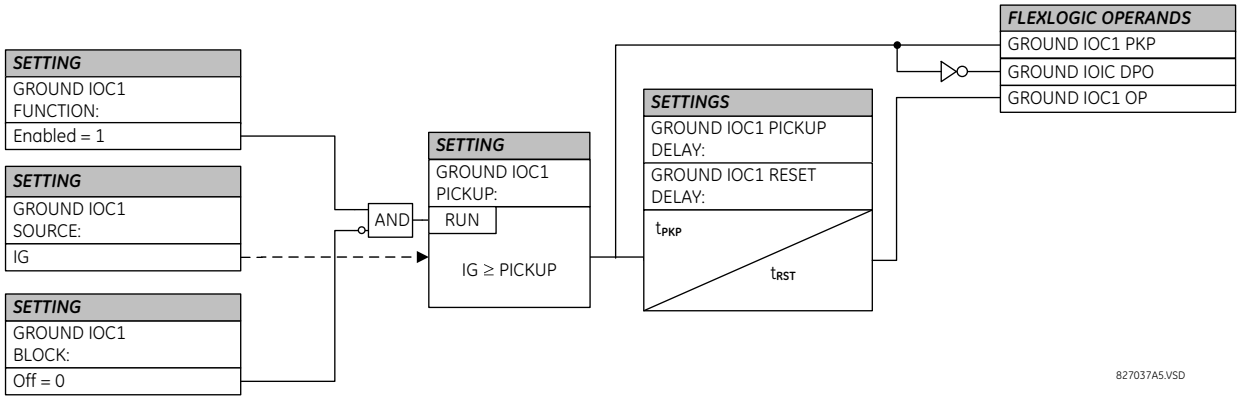



**Figure 5–74: GROUND IOC1 SCHEME LOGIC**

## 5.6.7 NEGATIVE SEQUENCE CURRENT

### a) NEGATIVE SEQUENCE TIME OVERCURRENT (ANSI 51Q, IEC PTOC)

**PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨⇩ SETTING GROUP 1(6) ⇨⇩ NEGATIVE SEQUENCE CURRENT ⇨ NEG SEQ TOC1(2)**

| | | | |
|---|---|---|---|
| ■ NEG SEQ TOC1 ■ | | NEG SEQ TOC1 FUNCTION: Disabled | *Range: Disabled, Enabled* |
| | *MESSAGE* | NEG SEQ TOC1 SIGNAL SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | NEG SEQ TOC1 PICKUP: 1.000 pu | *Range: 0.000 to 30.000 pu in steps of 0.001* |
| | *MESSAGE* | NEG SEQ TOC1 CURVE: IEEE Mod Inv | *Range: see OVERCURRENT CURVE TYPES table* |
| | *MESSAGE* | NEG SEQ TOC1 TD MULTIPLIER: 1.00 | *Range: 0.00 to 600.00 in steps of 0.01* |
| | *MESSAGE* | NEG SEQ TOC1 RESET: Instantaneous | *Range: Instantaneous, Timed* |
| | *MESSAGE* | NEG SEQ TOC1 BLOCK: Off | *Range: FlexLogic operand* |
| | *MESSAGE* | NEG SEQ TOC1 TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | NEG SEQ TOC1 EVENTS: Disabled | *Range: Disabled, Enabled* |

The negative-sequence time overcurrent element may be used to determine and clear unbalance in the system. The input for calculating negative-sequence current is the fundamental phasor value.

Two methods of resetting operation are available; “Timed” and “Instantaneous” (refer to the Inverse Time Overcurrent Characteristics sub-section for details on curve setup, trip times and reset operation). When the element is blocked, the time accumulator resets according to the reset characteristic. For example, if the element reset characteristic is set to “Instantaneous” and the element is blocked, the time accumulator is cleared immediately.

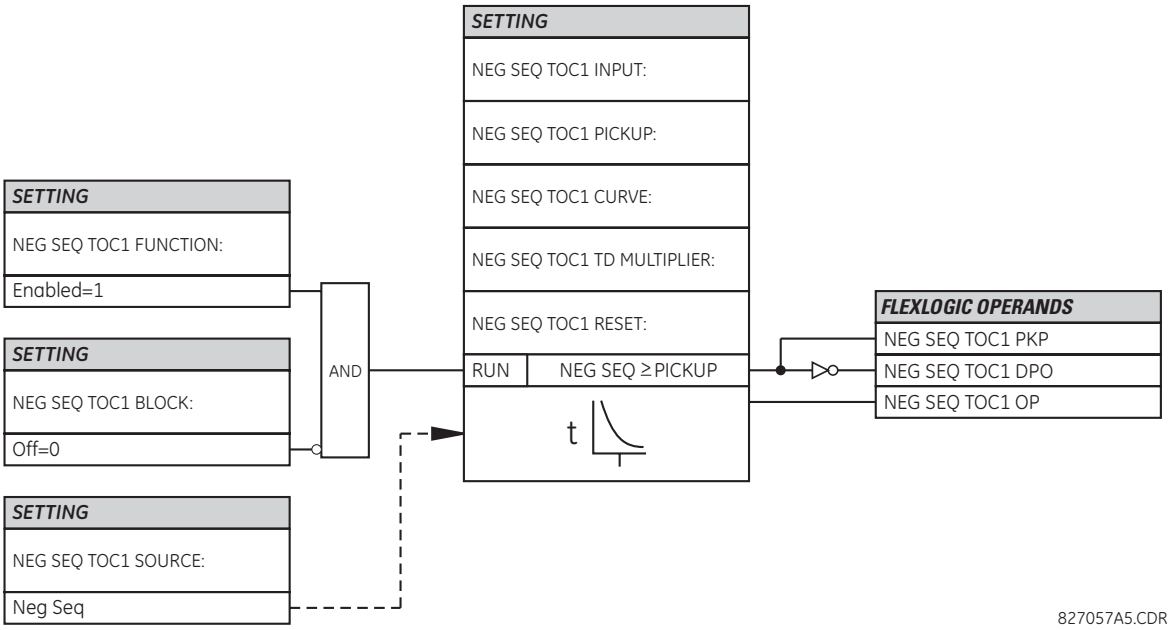



**Figure 5–75: NEGATIVE SEQUENCE TOC1 SCHEME LOGIC**

5

### b) NEGATIVE SEQUENCE INSTANTANEOUS OVERCURRENT (ANSI 50Q, IEC PIOC)

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEGATIVE SEQUENCE CURRENT ⇨⇩ NEG SEQ OC1(2)**

| | | | |
|---|---|---|---|
| ■ NEG SEQ IOC1 ■ | | NEG SEQ IOC1 FUNCTION: Disabled | *Range: Disabled, Enabled* |
| | *MESSAGE* | NEG SEQ IOC1 SIGNAL SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | NEG SEQ IOC1 PICKUP: 1.000 pu | *Range: 0.000 to 30.000 pu in steps of 0.001* |
| | *MESSAGE* | NEG SEQ IOC1 PICKUP DELAY: 0.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | NEG SEQ IOC1 RESET DELAY: 0.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | NEG SEQ IOC1 BLOCK: Off | *Range: FlexLogic operand* |
| | *MESSAGE* | NEG SEQ IOC1 TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | NEG SEQ IOC1 EVENTS: Disabled | *Range: Disabled, Enabled* |

The negative-sequence instantaneous overcurrent element may be used as an instantaneous function with no intentional delay or as a definite time function. The element responds to the negative-sequence current fundamental frequency phasor magnitude (calculated from the phase currents) and applies a positive-sequence restraint for better performance: a small portion (12.5%) of the positive-sequence current magnitude is subtracted from the negative-sequence current magnitude when forming the operating quantity:

$$I_{op} = |I\_2| - K \cdot |I\_1| \quad \text{where } K = 1/8 \qquad \textbf{(EQ 5.20)}$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious negative-sequence currents resulting from:

- system unbalances under heavy load conditions
- transformation errors of current transformers (CTs) during three-phase faults
- fault inception and switch-off transients during three-phase faults

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on the way the test currents are injected into the relay (single-phase injection: $I_{op} = 0.2917 \cdot I_{injected}$; three-phase injection, opposite rotation: $I_{op} = I_{injected}$).

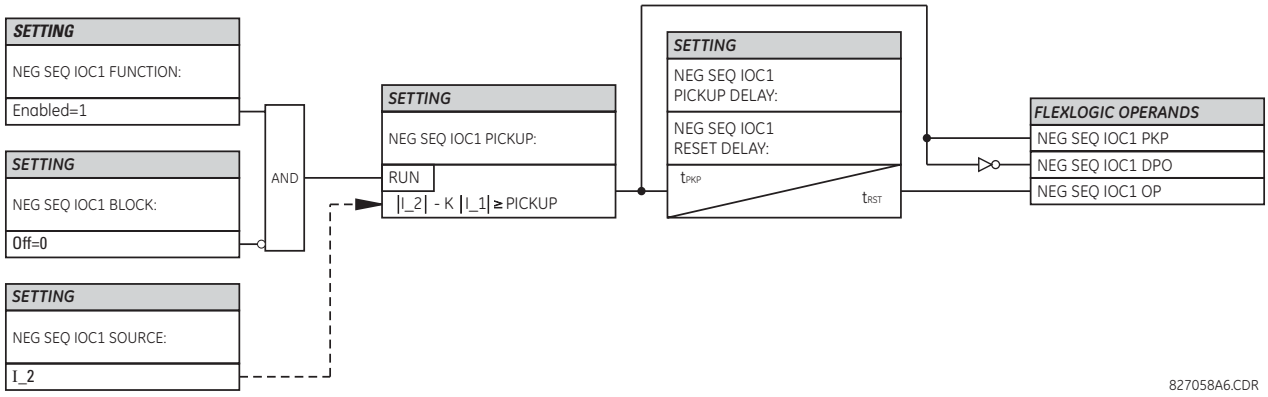
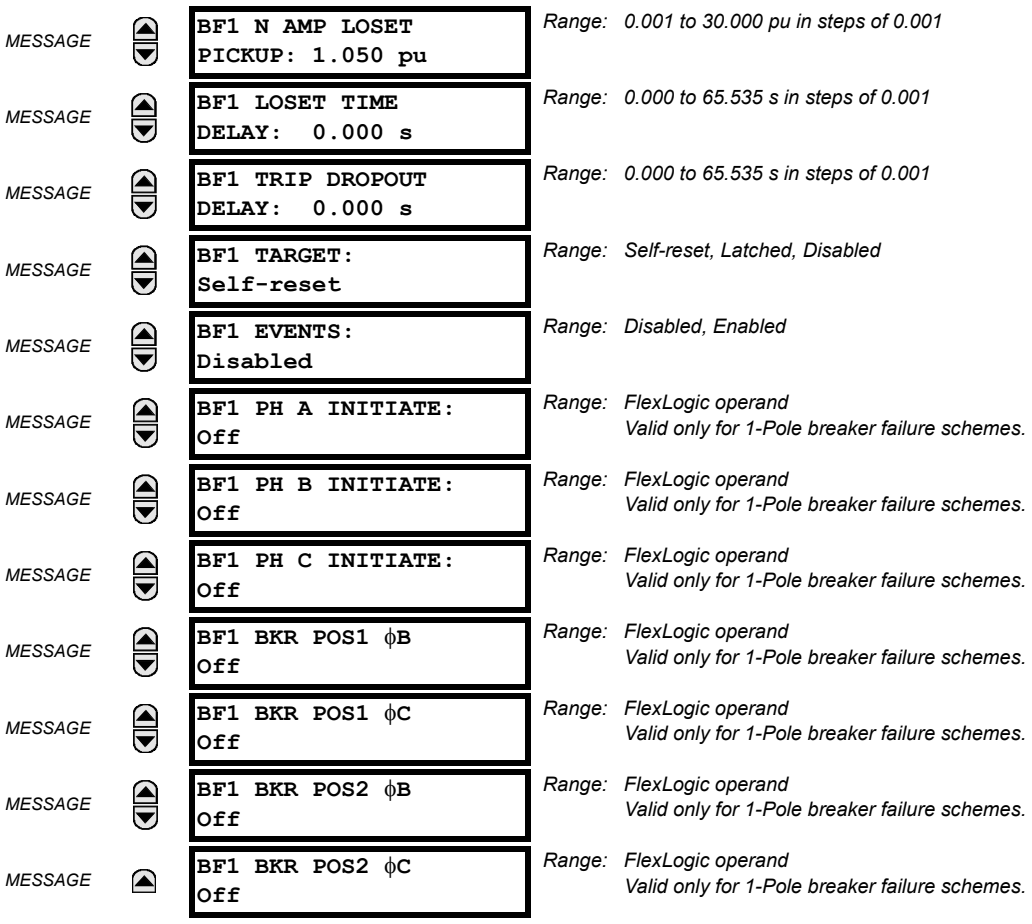



**Figure 5–76: NEGATIVE SEQUENCE IOC1 SCHEME LOGIC**

## 5.6.8 BREAKER FAILURE (ANSI 50BF)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ BREAKER FAILURE ⇨ BREAKER FAILURE 1(2)

| | | |
|---|---|---|
| | BF1 FUNCTION: Disabled | Range: Disabled, Enabled |
| MESSAGE | BF1 MODE: 3-Pole | Range: 3-Pole, 1-Pole |
| MESSAGE | BF1 SOURCE: SRC 1 | Range: SRC 1, SRC 2 |
| MESSAGE | BF1 USE AMP SUPV: Yes | Range: Yes, No |
| MESSAGE | BF1 USE SEAL-IN: Yes | Range: Yes, No |
| MESSAGE | BF1 3-POLE INITIATE: Off | Range: FlexLogic operand |
| MESSAGE | BF1 BLOCK: Off | Range: FlexLogic operand |
| MESSAGE | BF1 PH AMP SUPV PICKUP: 1.050 pu | Range: 0.001 to 30.000 pu in steps of 0.001 |
| MESSAGE | BF1 N AMP SUPV PICKUP: 1.050 pu | Range: 0.001 to 30.000 pu in steps of 0.001 |
| MESSAGE | BF1 USE TIMER 1: Yes | Range: Yes, No |
| MESSAGE | BF1 TIMER 1 PICKUP DELAY: 0.000 s | Range: 0.000 to 65.535 s in steps of 0.001 |
| MESSAGE | BF1 USE TIMER 2: Yes | Range: Yes, No |
| MESSAGE | BF1 TIMER 2 PICKUP DELAY: 0.000 s | Range: 0.000 to 65.535 s in steps of 0.001 |
| MESSAGE | BF1 USE TIMER 3: Yes | Range: Yes, No |
| MESSAGE | BF1 TIMER 3 PICKUP DELAY: 0.000 s | Range: 0.000 to 65.535 s in steps of 0.001 |
| MESSAGE | BF1 BKR POS1 ϕA/3P: Off | Range: FlexLogic operand |
| MESSAGE | BF1 BKR POS2 ϕA/3P: Off | Range: FlexLogic operand |
| MESSAGE | BF1 BREAKER TEST ON: Off | Range: FlexLogic operand |
| MESSAGE | BF1 PH AMP HISET PICKUP: 1.050 pu | Range: 0.001 to 30.000 pu in steps of 0.001 |
| MESSAGE | BF1 N AMP HISET PICKUP: 1.050 pu | Range: 0.001 to 30.000 pu in steps of 0.001 |
| MESSAGE | BF1 PH AMP LOSET PICKUP: 1.050 pu | Range: 0.001 to 30.000 pu in steps of 0.001 |




In general, a breaker failure scheme determines that a breaker signaled to trip has not cleared a fault within a definite time, so further tripping action must be performed. Tripping from the breaker failure scheme should trip all breakers, both local and remote, that can supply current to the faulted zone. Usually operation of a breaker failure element will cause clearing of a larger section of the power system than the initial trip. Because breaker failure can result in tripping a large number of breakers and this affects system safety and stability, a very high level of security is required.

Two schemes are provided: one for three-pole tripping only (identified by the name “3BF”) and one for three pole plus single-pole operation (identified by the name “1BF”). The philosophy used in these schemes is identical. The operation of a breaker failure element includes three stages: initiation, determination of a breaker failure condition, and output.

#### INITIATION STAGE

A FlexLogic operand representing the protection trip signal initially sent to the breaker must be selected to initiate the scheme. The initiating signal should be sealed-in if primary fault detection can reset before the breaker failure timers have finished timing. The seal-in is supervised by current level, so it is reset when the fault is cleared. If desired, an incomplete sequence seal-in reset can be implemented by using the initiating operand to also initiate a FlexLogic timer, set longer than any breaker failure timer, whose output operand is selected to block the breaker failure scheme.

Schemes can be initiated either directly or with current level supervision. It is particularly important in any application to decide if a current-supervised initiate is to be used. The use of a current-supervised initiate results in the breaker failure element not being initiated for a breaker that has very little or no current flowing through it, which may be the case for transformer faults. For those situations where it is required to maintain breaker fail coverage for fault levels below the **BF1 PH AMP SUPV PICKUP** or the **BF1 N AMP SUPV PICKUP** setting, a current supervised initiate should *not* be used. This feature should be utilized for those situations where coordinating margins may be reduced when high speed reclosing is used. Thus, if this choice is made, fault levels must always be above the supervision pickup levels for dependable operation of the breaker fail scheme. This can also occur in breaker-and-a-half or ring bus configurations where the first breaker closes into a fault; the protection trips and attempts to initiate breaker failure for the second breaker, which is in the process of closing, but does not yet have current flowing through it.

When the scheme is initiated, it immediately sends a trip signal to the breaker initially signaled to trip (this feature is usually described as re-trip). This reduces the possibility of widespread tripping that results from a declaration of a failed breaker.

**DETERMINATION OF A BREAKER FAILURE CONDITION**

The schemes determine a breaker failure condition via three *paths*. Each of these paths is equipped with a time delay, after which a failed breaker is declared and trip signals are sent to all breakers required to clear the zone. The delayed paths are associated with breaker failure timers 1, 2, and 3, which are intended to have delays increasing with increasing timer numbers. These delayed paths are individually enabled to allow for maximum flexibility.

Timer 1 logic (early path) is supervised by a fast-operating breaker auxiliary contact. If the breaker is still closed (as indicated by the auxiliary contact) and fault current is detected after the delay interval, an output is issued. Operation of the breaker auxiliary switch indicates that the breaker has mechanically operated. The continued presence of current indicates that the breaker has failed to interrupt the circuit.

Timer 2 logic (main path) is not supervised by a breaker auxiliary contact. If fault current is detected after the delay interval, an output is issued. This path is intended to detect a breaker that opens mechanically but fails to interrupt fault current; the logic therefore does not use a breaker auxiliary contact.

The timer 1 and 2 paths provide two levels of current supervision, high-set and low-set, that allow the supervision level to change from a current that flows before a breaker inserts an opening resistor into the faulted circuit to a lower level after resistor insertion. The high-set detector is enabled after timeout of timer 1 or 2, along with a timer that enables the low-set detector after its delay interval. The delay interval between high-set and low-set is the expected breaker opening time. Both current detectors provide a fast operating time for currents at small multiples of the pickup value. The overcurrent detectors are required to operate after the breaker failure delay interval in case current still flows through the breaker, and they are supervised by a fast reset element described as follows.

Timer 3 logic (slow path) is supervised by a breaker auxiliary contact and a control switch contact used to indicate that the breaker is in or out-of-service, disabling this path when the breaker is out-of-service for maintenance. There is no current level check in this logic as it is intended to detect low magnitude faults and it is therefore the slowest to operate.

**OUTPUT**

The outputs from the schemes are:

- FlexLogic operands that report on the operation of portions of the scheme
- FlexLogic operand used to re-trip the protected breaker
- FlexLogic operands that initiate tripping required to clear the faulted zone. The trip output can be sealed-in for an adjustable period.
- Target message indicating a failed breaker has been declared
- Illumination of the faceplate Trip LED (and the Phase A, B or C LED, if applicable)

**MAIN PATH SEQUENCE**

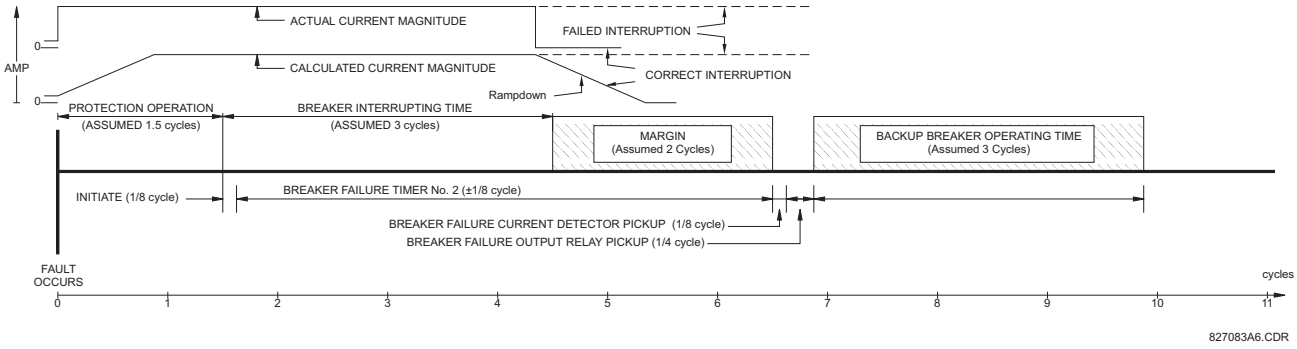



**Figure 5–77: BREAKER FAILURE MAIN PATH SEQUENCE**

The current supervision elements reset in less than 0.7 of a power cycle for any multiple of pickup current as shown below.

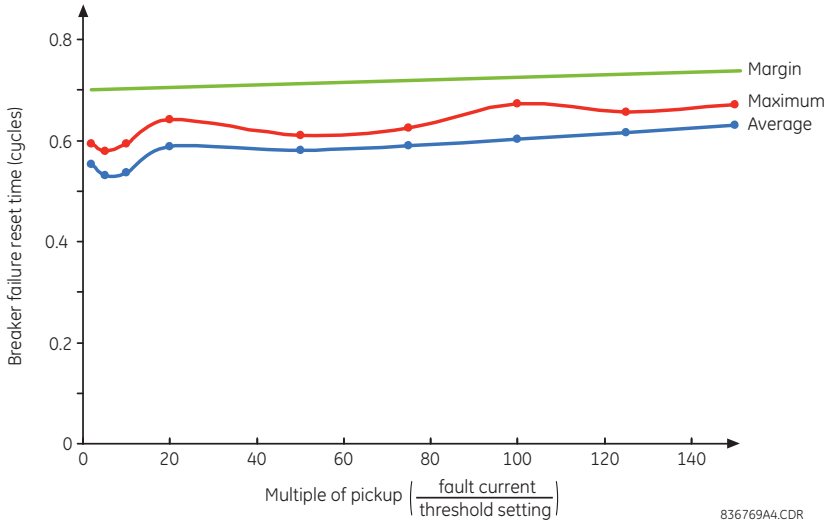



**Figure 5–78: BREAKER FAILURE OVERCURRENT SUPERVISION RESET TIME**

**SETTINGS**

- **BF1 MODE:** This setting is used to select the breaker failure operating mode: single or three pole.
- **BF1 USE AMP SUPV:** If set to "Yes", the element will only be initiated if current flowing through the breaker is above the supervision pickup level.
- **BF1 USE SEAL-IN:** If set to "Yes", the element will only be sealed-in if current flowing through the breaker is above the supervision pickup level.
- **BF1 3-POLE INITIATE:** This setting selects the FlexLogic operand that will initiate three-pole tripping of the breaker.
- **BF1 PH AMP SUPV PICKUP:** This setting is used to set the phase current initiation and seal-in supervision level. Generally this setting should detect the lowest expected fault current on the protected breaker. It can be set as low as necessary (lower than breaker resistor current or lower than load current) – high-set and low-set current supervision will guarantee correct operation.
- **BF1 N AMP SUPV PICKUP:** This setting is used to set the neutral current initiate and seal-in supervision level. Generally this setting should detect the lowest expected fault current on the protected breaker. Neutral current supervision is used only in the three phase scheme to provide increased sensitivity. This setting is valid only for three-pole tripping schemes.
- **BF1 USE TIMER 1:** If set to "Yes", the early path is operational.
- **BF1 TIMER 1 PICKUP DELAY:** Timer 1 is set to the shortest time required for breaker auxiliary contact Status-1 to open, from the time the initial trip signal is applied to the breaker trip circuit, plus a safety margin.
- **BF1 USE TIMER 2:** If set to "Yes", the main path is operational.
- **BF1 TIMER 2 PICKUP DELAY:** Timer 2 is set to the expected opening time of the breaker, plus a safety margin. This safety margin was historically intended to allow for measuring and timing errors in the breaker failure scheme equipment. In microprocessor relays this time is not significant. In L30 relays, which use a Fourier transform, the calculated current magnitude ramps-down to zero one power frequency cycle after the current is interrupted, however this lag does not need to be included in the overall margin duration due to a novel current supervision reset element, as it occurs after current interruption. As shown in the previous figure, this current supervision reset element guarantees breaker failure reset in less than 0.7 power cycles for any subsidence current and irrespective of the magnitude of the fault current.

  Note that in bulk oil circuit breakers, the interrupting time for currents less than 25% of the interrupting rating can be significantly longer than the normal interrupting time.
- **BF1 USE TIMER 3:** If set to "Yes", the Slow Path is operational.
- **BF1 TIMER 3 PICKUP DELAY:** Timer 3 is set to the same interval as timer 2, plus an increased safety margin. Because this path is intended to operate only for low level faults, the delay can be in the order of 300 to 500 ms.

- **BF1 BKR POS1 ϕA/3P:** This setting selects the FlexLogic operand that represents the protected breaker early-type auxiliary switch contact (52/a). When using the single-pole breaker failure scheme, this operand represents the protected breaker early-type auxiliary switch contact on pole A. This is normally a non-multiplied form-A contact. The contact may even be adjusted to have the shortest possible operating time.
- **BF1 BKR POS2 ϕA/3P:** This setting selects the FlexLogic operand that represents the breaker normal-type auxiliary switch contact (52/a). When using the single-pole breaker failure scheme, this operand represents the protected breaker auxiliary switch contact on pole A. This may be a multiplied contact.
- **BF1 BREAKER TEST ON:** This setting is used to select the FlexLogic operand that represents the breaker in-service/out-of-service switch set to the out-of-service position.
- **BF1 PH AMP HISET PICKUP:** This setting sets the phase current output supervision level. Generally this setting should detect the lowest expected fault current on the protected breaker, before a breaker opening resistor is inserted.
- **BF1 N AMP HISET PICKUP:** This setting sets the neutral current output supervision level. Generally this setting should detect the lowest expected fault current on the protected breaker, before a breaker opening resistor is inserted. Neutral current supervision is used only in the three pole scheme to provide increased sensitivity. *This setting is valid only for three-pole breaker failure schemes*.
- **BF1 PH AMP LOSET PICKUP:** This setting sets the phase current output supervision level. Generally this setting should detect the lowest expected fault current on the protected breaker, after a breaker opening resistor is inserted (approximately 90% of the resistor current).
- **BF1 N AMP LOSET PICKUP:** This setting sets the neutral current output supervision level. Generally this setting should detect the lowest expected fault current on the protected breaker, after a breaker opening resistor is inserted (approximately 90% of the resistor current). *This setting is valid only for three-pole breaker failure schemes*.
- **BF1 LOSET TIME DELAY:** Sets the pickup delay for current detection after opening resistor insertion.
- **BF1 TRIP DROPOUT DELAY:** This setting is used to set the period of time for which the trip output is sealed-in. This timer must be coordinated with the automatic reclosing scheme of the failed breaker, to which the breaker failure element sends a cancel reclosure signal. Reclosure of a remote breaker can also be prevented by holding a transfer trip signal on longer than the reclaim time.
- **BF1 PH A INITIATE / BF1 PH B INITIATE / BF 1 PH C INITIATE:** These settings select the FlexLogic operand to initiate phase A, B, or C single-pole tripping of the breaker and the phase A, B, or C portion of the scheme, accordingly. *This setting is only valid for single-pole breaker failure schemes*.
- **BF1 BKR POS1 ϕB / BF1 BKR POS 1 ϕC:** These settings select the FlexLogic operand to represents the protected breaker early-type auxiliary switch contact on poles B or C, accordingly. This contact is normally a non-multiplied Form-A contact. The contact may even be adjusted to have the shortest possible operating time. *This setting is valid only for single-pole breaker failure schemes*.
- **BF1 BKR POS2 ϕB:** Selects the FlexLogic operand that represents the protected breaker normal-type auxiliary switch contact on pole B (52/a). This may be a multiplied contact. *This setting is valid only for single-pole breaker failure schemes*.
- **BF1 BKR POS2 ϕC:** This setting selects the FlexLogic operand that represents the protected breaker normal-type auxiliary switch contact on pole C (52/a). This may be a multiplied contact. For single-pole operation, the scheme has the same overall general concept except that it provides re-tripping of each single pole of the protected breaker. The approach shown in the following single pole tripping diagram uses the initiating information to determine which pole is supposed to trip. The logic is segregated on a per-pole basis. The overcurrent detectors have ganged settings. *This setting is valid only for single-pole breaker failure schemes*.

  Upon operation of the breaker failure element for a single pole trip command, a three-pole trip command should be given via output operand BKR FAIL 1 TRIP OP.

## SINGLE-POLE BREAKER FAILURE, INITIATE

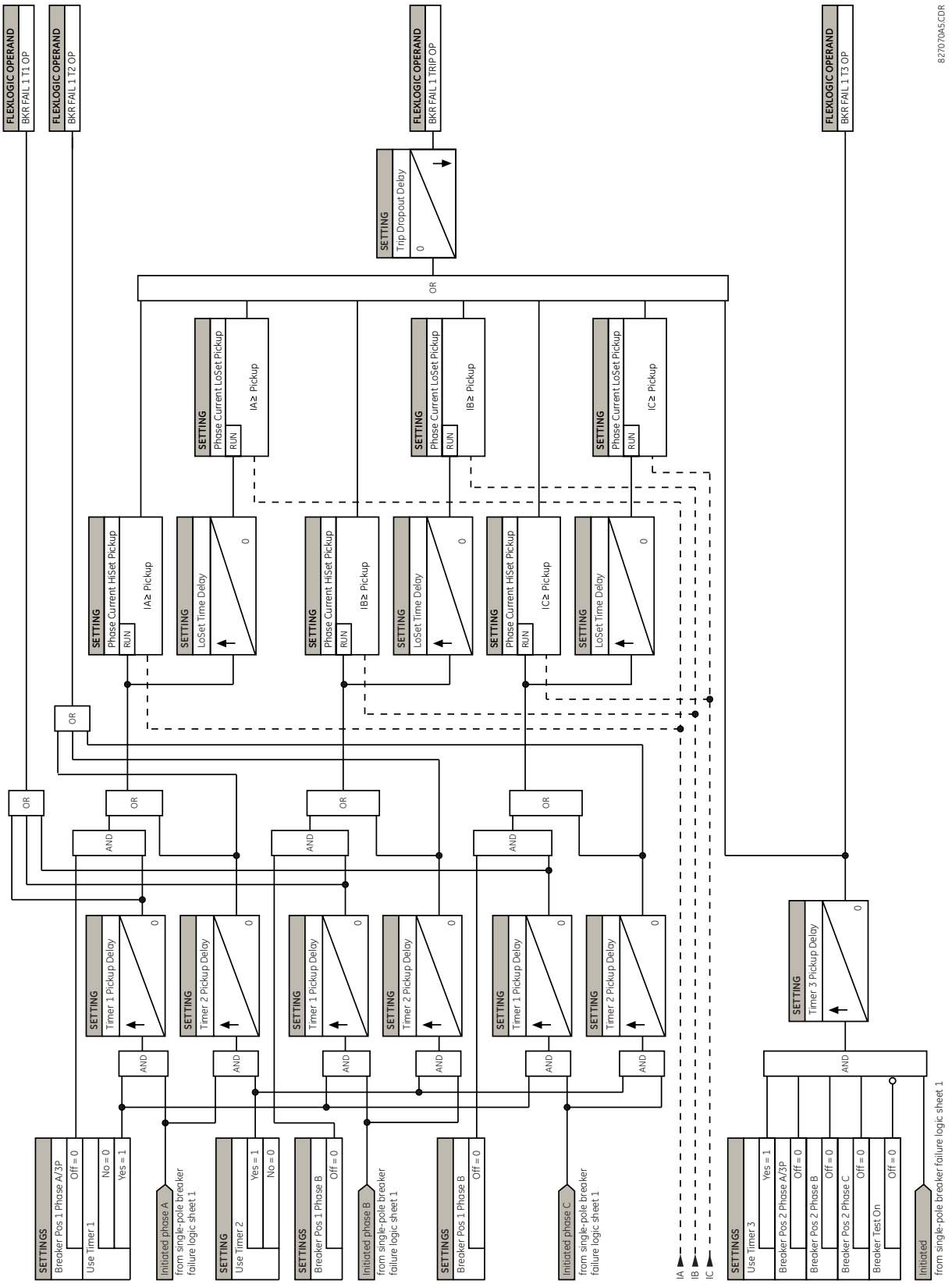



**Figure 5–79: SINGLE-POLE BREAKER FAILURE, TIMERS**

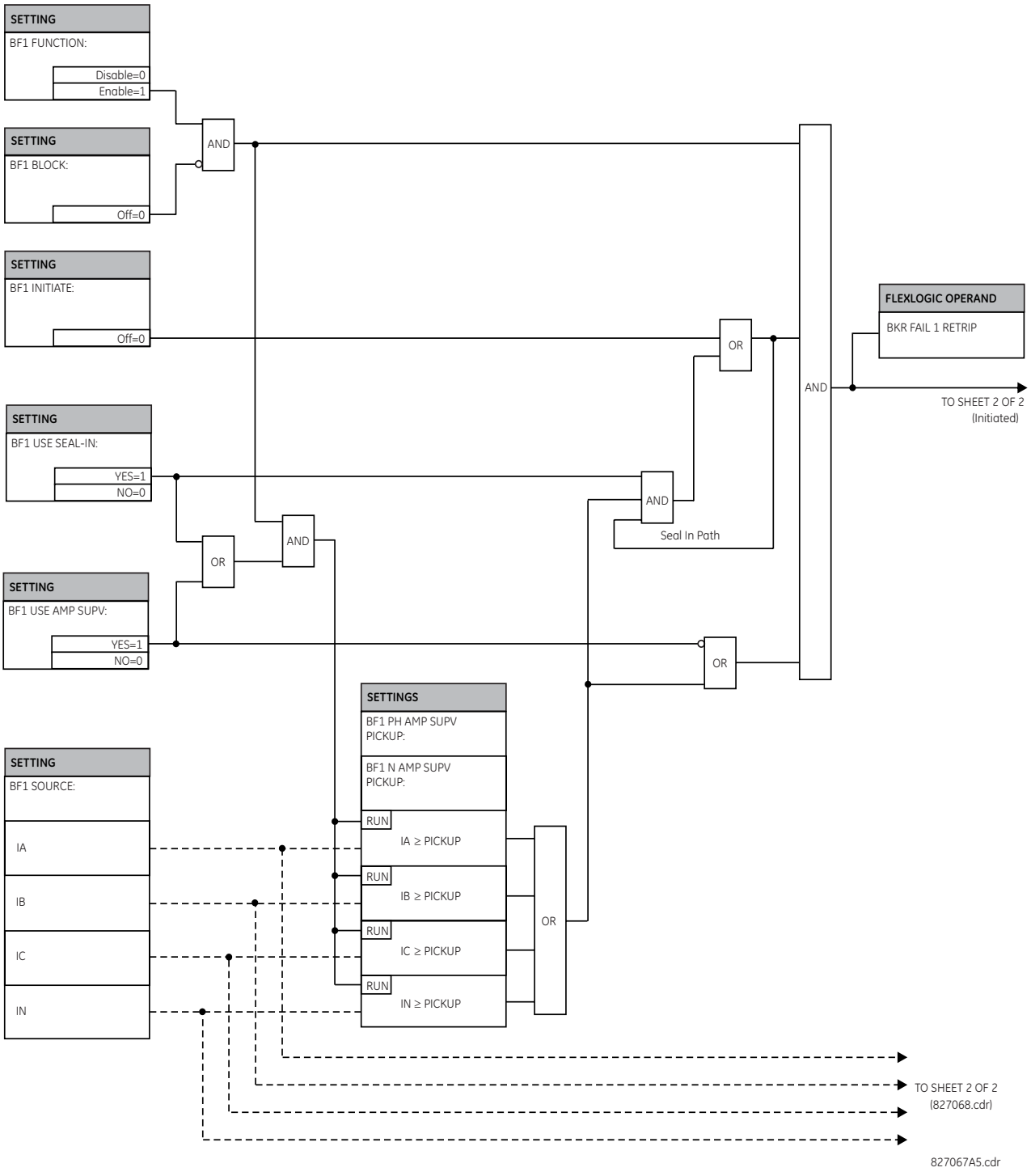



**Figure 5–80: THREE-POLE BREAKER FAILURE, INITIATE**

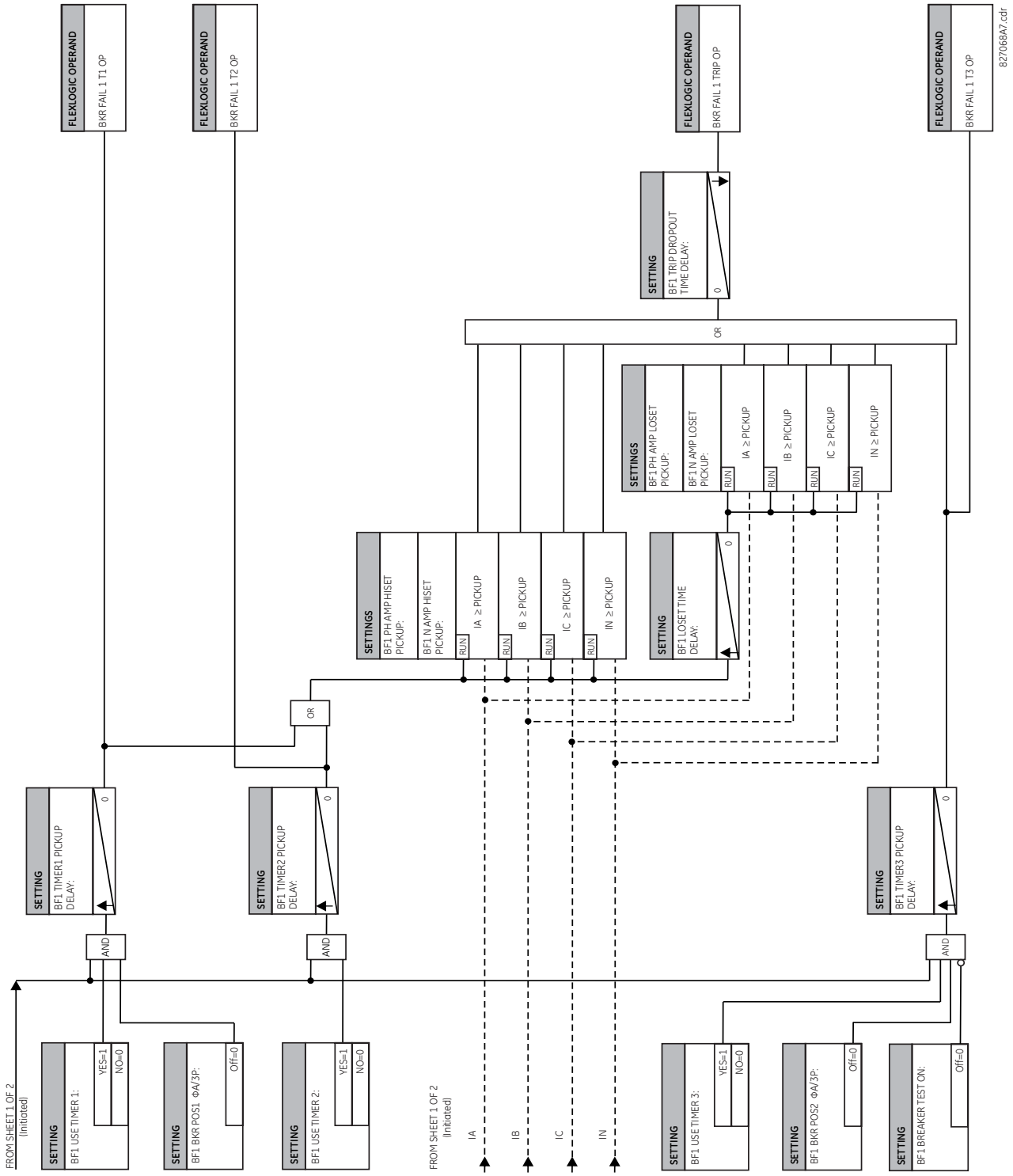
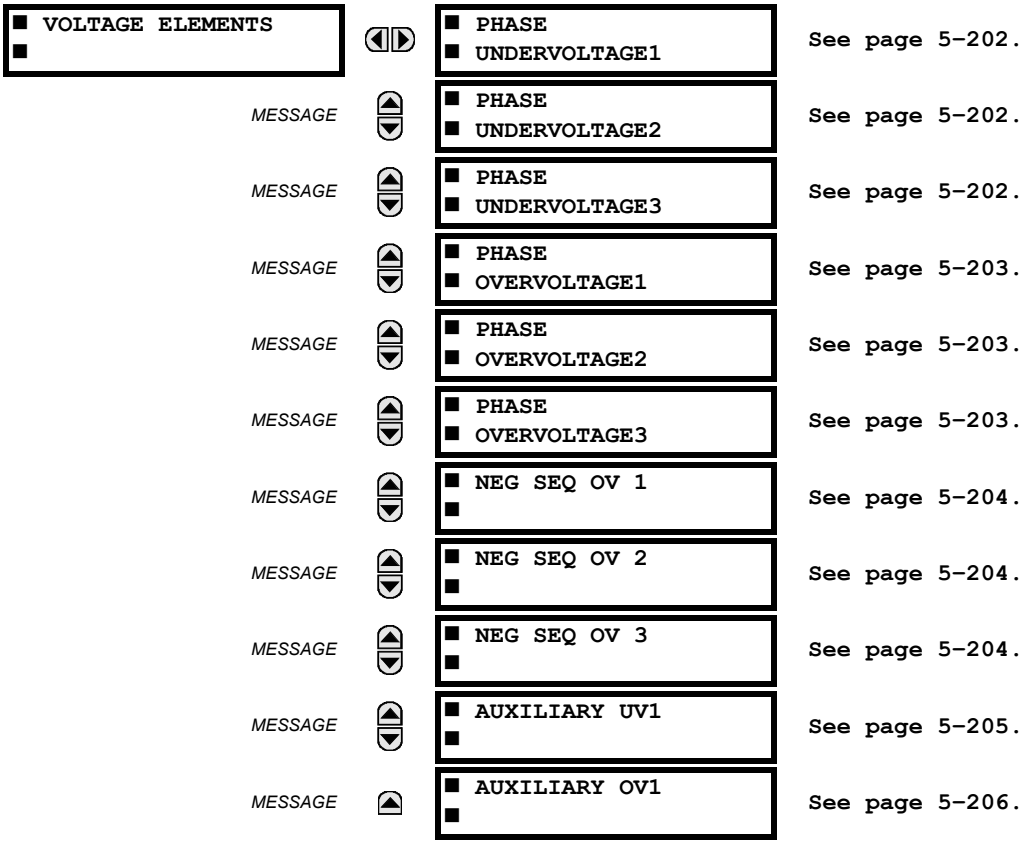



**Figure 5–81: THREE-POLE BREAKER FAILURE, TIMERS**

### a) MAIN MENU

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS




These protection elements can be used for a variety of applications such as:

- ***Undervoltage Protection:*** For voltage sensitive loads, such as induction motors, a drop in voltage increases the drawn current which may cause dangerous overheating in the motor. The undervoltage protection feature can be used to either cause a trip or generate an alarm when the voltage drops below a specified voltage setting for a specified time delay.
- ***Permissive Functions:*** The undervoltage feature may be used to block the functioning of external devices by operating an output relay when the voltage falls below the specified voltage setting. The undervoltage feature may also be used to block the functioning of other elements through the block feature of those elements.
- ***Source Transfer Schemes:*** In the event of an undervoltage, a transfer signal may be generated to transfer a load from its normal source to a standby or emergency power source.

The undervoltage elements can be programmed to have a definite time delay characteristic. The definite time curve operates when the voltage drops below the pickup level for a specified period of time. The time delay is adjustable from 0 to 600.00 seconds in steps of 0.01. The undervoltage elements can also be programmed to have an inverse time delay characteristic.

The undervoltage delay setting defines the family of curves shown below.

$$T = \frac{D}{\left(1 - \frac{V}{V_{pickup}}\right)} \quad \text{(EQ 5.21)}$$

where: $T$ = operating time
$D$ = undervoltage delay setting ($D$ = 0.00 operates instantaneously)
$V$ = secondary voltage applied to the relay
$V_{pickup}$ = pickup level

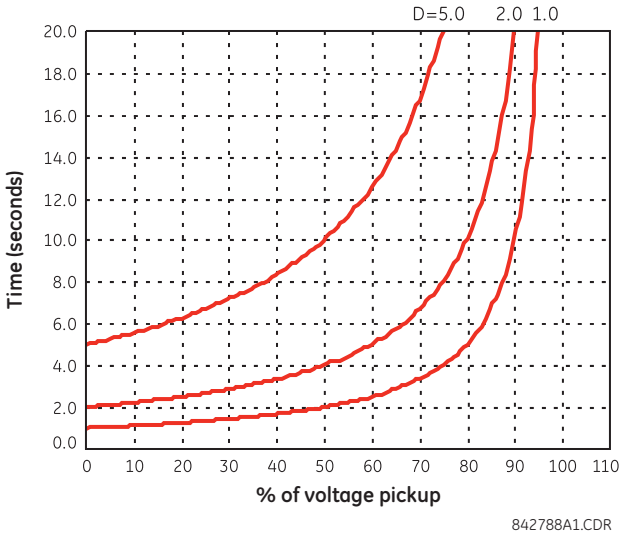



**Figure 5–82: INVERSE TIME UNDERVOLTAGE CURVES**

NOTE

At 0% of pickup, the operating time equals the **UNDERVOLTAGE DELAY** setting.

### b) PHASE UNDERVOLTAGE (ANSI 27P, IEC PTUV)

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨ PHASE UNDERVOLTAGE1(3)**

| | | | |
|---|---|---|---|
| ■ PHASE<br>■ UNDERVOLTAGE1 | | PHASE UV1<br>FUNCTION: Disabled | *Range: Disabled, Enabled* |
| | *MESSAGE* | PHASE UV1 SIGNAL<br>SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | PHASE UV1 MODE:<br>Phase to Ground | *Range: Phase to Ground, Phase to Phase* |
| | *MESSAGE* | PHASE UV1<br>PICKUP: 1.000 pu | *Range: 0.000 to 3.000 pu in steps of 0.001* |
| | *MESSAGE* | PHASE UV1<br>CURVE: Definite Time | *Range: Definite Time, Inverse Time* |
| | *MESSAGE* | PHASE UV1<br>DELAY: 1.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | PHASE UV1 MINIMUM<br>VOLTAGE: 0.100 pu | *Range: 0.000 to 3.000 pu in steps of 0.001* |
| | *MESSAGE* | PHASE UV1 BLOCK:<br>Off | *Range: FlexLogic operand* |
| | *MESSAGE* | PHASE UV1<br>TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | PHASE UV1<br>EVENTS: Disabled | *Range: Disabled, Enabled* |

This element may be used to give a desired time-delay operating characteristic versus the applied fundamental voltage (phase-to-ground or phase-to-phase for wye VT connection, or phase-to-phase for delta VT connection) or as a definite time element. The element resets instantaneously if the applied voltage exceeds the dropout voltage. The delay setting selects the minimum operating time of the phase undervoltage. The minimum voltage setting selects the operating voltage below which the element is blocked (a setting of "0" will allow a dead source to be considered a fault condition).

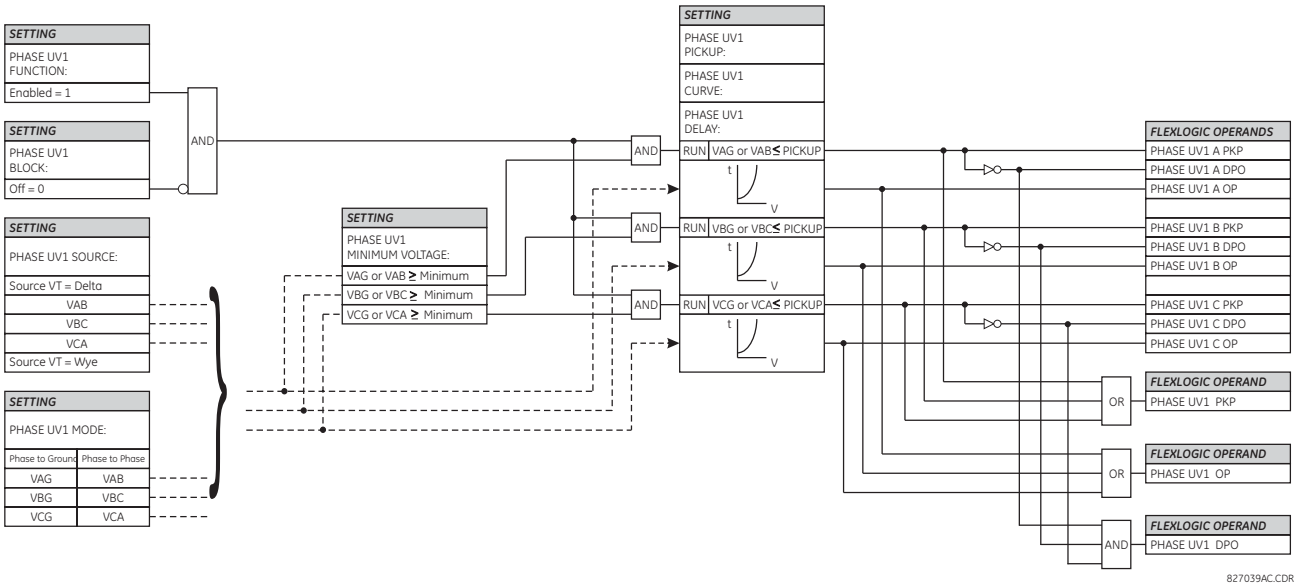



**Figure 5–83: PHASE UNDERVOLTAGE1 SCHEME LOGIC**

### c) PHASE OVERVOLTAGE (ANSI 59P, IEC PTOV)

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ PHASE OVERVOLTAGE1(3)**

| | | | |
|---|---|---|---|
| ■ PHASE<br>■ OVERVOLTAGE1 | | PHASE OV1<br>FUNCTION: Disabled | *Range: Disabled, Enabled* |
| | *MESSAGE* | PHASE OV1 SIGNAL<br>SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | PHASE OV1<br>PICKUP: 1.000 pu | *Range: 0.000 to 3.000 pu in steps of 0.001* |
| | *MESSAGE* | PHASE OV1 PICKUP<br>DELAY: 1.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | PHASE OV1 RESET<br>DELAY: 1.00 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | PHASE OV1 BLOCK:<br>Off | *Range: FlexLogic Operand* |
| | *MESSAGE* | PHASE OV1<br>TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | PHASE OV1<br>EVENTS: Disabled | *Range: Disabled, Enabled* |

There are three phase overvoltage elements available. A phase overvoltage element is used as an instantaneous element with no intentional time delay or as a definite time element. The input voltage is the phase-to-phase voltage, either measured directly from delta-connected VTs or as calculated from phase-to-ground (wye) connected VTs. The specific voltages to be used for each phase are shown below.



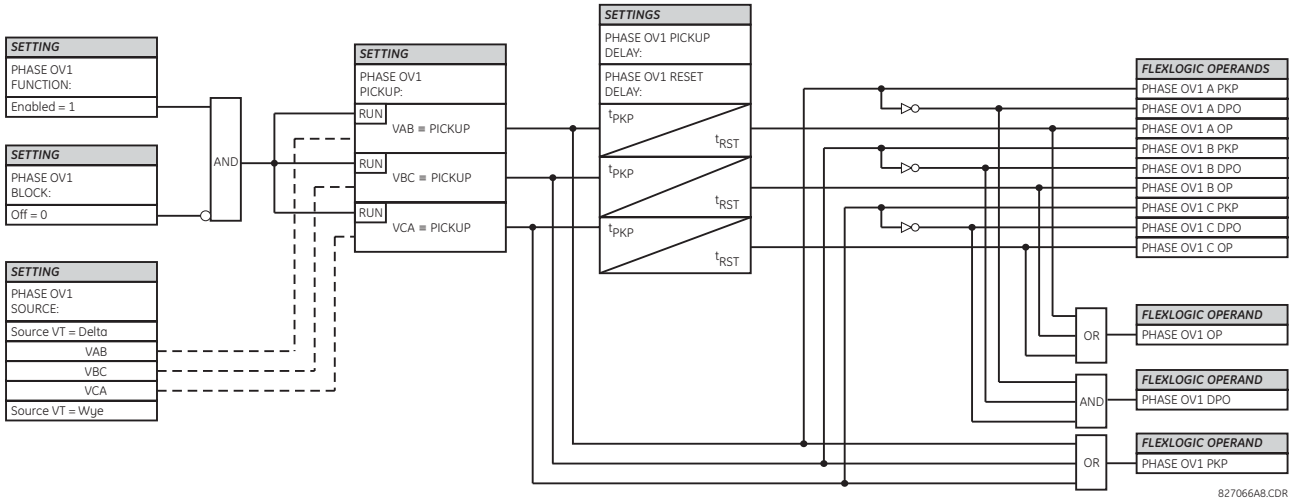



**Figure 5–84: PHASE OVERVOLTAGE SCHEME LOGIC**

NOTE

If the source VT is wye-connected, then the phase overvoltage pickup condition is $V > \sqrt{3} \times$ Pickup for $V_{AB}$, $V_{BC}$, and $V_{CA}$.

### d) NEGATIVE SEQUENCE OVERVOLTAGE (ANSI 59Q, IEC PTOV)

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ NEG SEQ OV 1(3)**

| | | | |
|---|---|---|---|
| ■ NEG SEQ OV 1 ■ | | NEG SEQ OV 1 FUNCTION: Disabled | *Range: Disabled, Enabled* |
| | *MESSAGE* | NEG SEQ OV 1 SIGNAL SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | NEG SEQ OV 1 PICKUP: 0.300 pu | *Range: 0.000 to 1.250 pu in steps of 0.001* |
| | *MESSAGE* | NEG SEQ OV 1 PICKUP DELAY: 0.50 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | NEG SEQ OV 1 RESET DELAY: 0.50 s | *Range: 0.00 to 600.00 s in steps of 0.01* |
| | *MESSAGE* | NEG SEQ OV 1 BLOCK: Off | *Range: FlexLogic operand* |
| | *MESSAGE* | NEG SEQ OV 1 TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | NEG SEQ OV 1 EVENTS: Disabled | *Range: Disabled, Enabled* |

5

There are three negative-sequence overvoltage elements available.

The negative-sequence overvoltage element may be used to detect loss of one or two phases of the source, a reversed phase sequence of voltage, or a non-symmetrical system voltage condition.

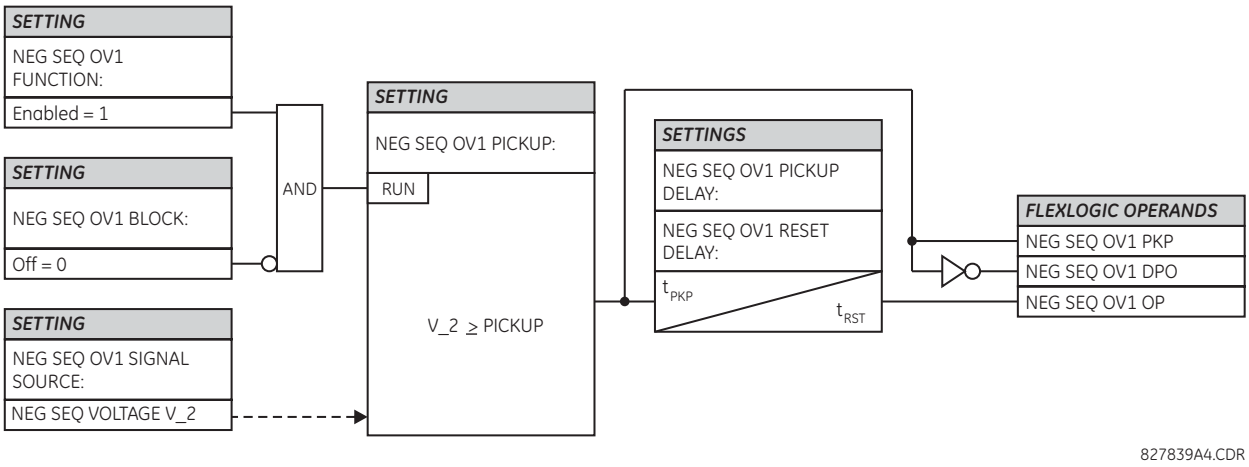



**Figure 5–85: NEGATIVE-SEQUENCE OVERVOLTAGE SCHEME LOGIC**

### e) AUXILIARY UNDERVOLTAGE (ANSI 27X, IEC PTUV)

**PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ AUXILIARY UV1**

| | | | |
|---|---|---|---|
| ■ AUXILIARY UV1 ■ | | AUX UV1 FUNCTION: Disabled | Range: Disabled, Enabled |
| | MESSAGE | AUX UV1 SIGNAL SOURCE: SRC 1 | Range: SRC 1, SRC 2 |
| | MESSAGE | AUX UV1 PICKUP: 0.700 pu | Range: 0.000 to 3.000 pu in steps of 0.001 |
| | MESSAGE | AUX UV1 CURVE: Definite Time | Range: Definite Time, Inverse Time |
| | MESSAGE | AUX UV1 DELAY: 1.00 s | Range: 0.00 to 600.00 s in steps of 0.01 |
| | MESSAGE | AUX UV1 MINIMUM VOLTAGE: 0.100 pu | Range: 0.000 to 3.000 pu in steps of 0.001 |
| | MESSAGE | AUX UV1 BLOCK: Off | Range: FlexLogic operand |
| | MESSAGE | AUX UV1 TARGET: Self-reset | Range: Self-reset, Latched, Disabled |
| | MESSAGE | AUX UV1 EVENTS: Disabled | Range: Disabled, Enabled |

The L30 contains one auxiliary undervoltage element for each VT bank. This element is intended for monitoring undervoltage conditions of the auxiliary voltage. The **AUX UV1 PICKUP** selects the voltage level at which the time undervoltage element starts timing. The nominal secondary voltage of the auxiliary voltage channel entered under **SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK X5 ⇨⇩ AUXILIARY VT X5 SECONDARY** is the per-unit base used when setting the pickup level.

The **AUX UV1 DELAY** setting selects the minimum operating time of the auxiliary undervoltage element. Both **AUX UV1 PICKUP** and **AUX UV1 DELAY** settings establish the operating curve of the undervoltage element. The auxiliary undervoltage element can be programmed to use either definite time delay or inverse time delay characteristics. The operating characteristics and equations for both definite and inverse time delay are as for the phase undervoltage element.

The element resets instantaneously. The minimum voltage setting selects the operating voltage below which the element is blocked.

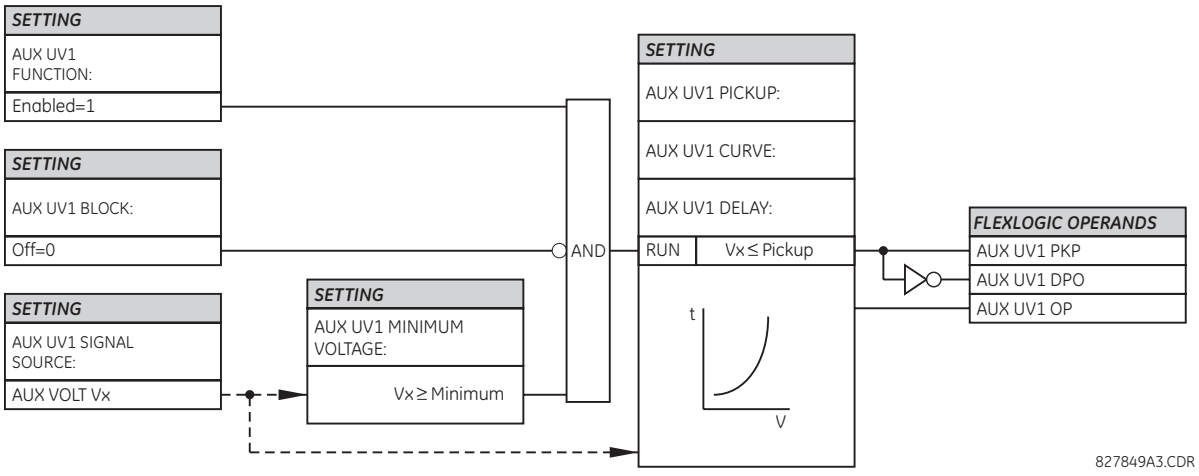



**Figure 5–86: AUXILIARY UNDERVOLTAGE SCHEME LOGIC**

### f) AUXILIARY OVERVOLTAGE (ANSI 59X, IEC PTOV)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ AUXILIARY OV1

| | | | |
|---|---|---|---|
| ■ AUXILIARY OV1 ■ | | AUX OV1 FUNCTION: Disabled | Range: Disabled, Enabled |
| | MESSAGE | AUX OV1 SIGNAL SOURCE: SRC 1 | Range: SRC 1, SRC 2 |
| | MESSAGE | AUX OV1 PICKUP: 0.300 pu | Range: 0.000 to 3.000 pu in steps of 0.001 |
| | MESSAGE | AUX OV1 PICKUP DELAY: 1.00 s | Range: 0.00 to 600.00 s in steps of 0.01 |
| | MESSAGE | AUX OV1 RESET DELAY: 1.00 s | Range: 0.00 to 600.00 s in steps of 0.01 |
| | MESSAGE | AUX OV1 BLOCK: Off | Range: FlexLogic operand |
| | MESSAGE | AUX OV1 TARGET: Self-reset | Range: Self-reset, Latched, Disabled |
| | MESSAGE | AUX OV1 EVENTS: Disabled | Range: Disabled, Enabled |

5

The L30 contains one auxiliary overvoltage element for each VT bank. This element is intended for monitoring overvoltage conditions of the auxiliary voltage. The nominal secondary voltage of the auxiliary voltage channel entered under SYSTEM SETUP ⇨ AC INPUTS ⇩⇨ VOLTAGE BANK X5 ⇩⇨ AUXILIARY VT X5 SECONDARY is the per-unit (pu) base used when setting the pickup level.

A typical application for this element is monitoring the zero-sequence voltage (3V_0) supplied from an open-corner-delta VT connection.

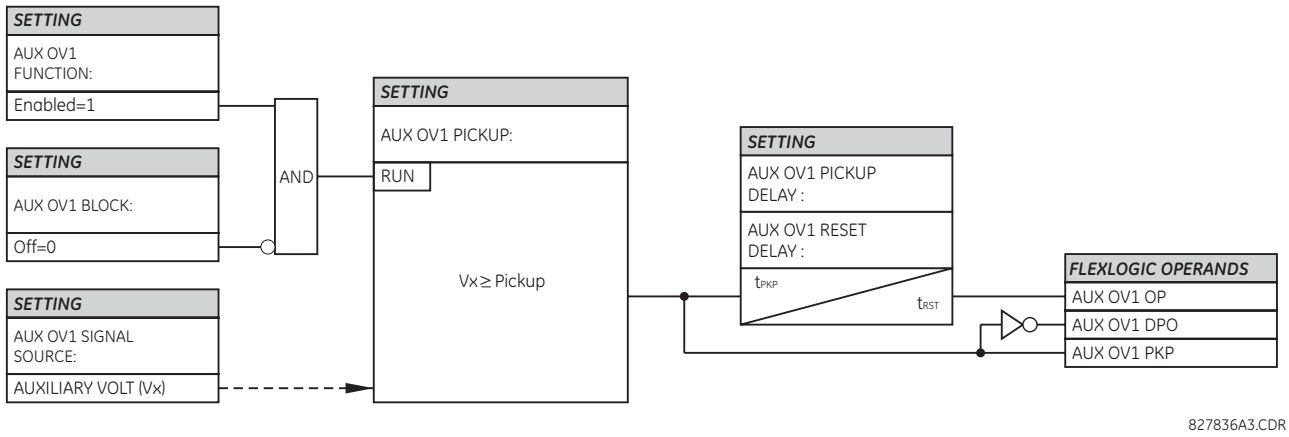



**Figure 5–87: AUXILIARY OVERVOLTAGE SCHEME LOGIC**

### a) MAIN MENU

PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨⇩ SETTING GROUP 1(6) ⇨⇩ SUPERVISING ELEMENTS

```
■ SUPERVISING
■ ELEMENTS
```

⇔

```
■ DISTURBANCE
■ DETECTOR
```

See page 5-207.

### b) DISTURBANCE DETECTOR

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨⇩ SETTING GROUP 1(6) ⇨⇩ SUPERVISING ELEMENTS ⇨ DISTURBANCE DETECTOR

```
■ DISTURBANCE
■ DETECTOR
```

⇔

```
DD
FUNCTION: Disabled
```

*Range: Disabled, Enabled*

*MESSAGE* ⇕

```
DD NON-CURRENT SUPV:
Off
```

*Range: FlexLogic operand*

*MESSAGE* ⇕

```
DD CONTROL LOGIC:
Off
```

*Range: FlexLogic operand*

*MESSAGE* ⇕

```
DD LOGIC SEAL-IN:
Off
```

*Range: FlexLogic operand*

*MESSAGE* ⇧

```
DD
EVENTS: Disabled
```

*Range: Disabled, Enabled*

The disturbance detector (50DD) element is an 87L-dedicated sensitive current disturbance detector that is used to detect any disturbance on the protected system. This detector is intended for such functions as trip output supervision and starting oscillography The disturbance detector also signals the 87L function that a disturbance (possible fault) occurred and to resize the operating window to remove the pre-fault current. It is essential to have the disturbance detector enabled for applications where the 87L operating time is critical.

If the disturbance detector is used to supervise the operation of the 87L function, it is recommended that the 87L trip element be used. The 50DD SV disturbance detector FlexLogic operand must then be assigned to an **87L TRIP SUPV** setting.

The disturbance detector function measures the magnitude of the negative-sequence current (I_2), the magnitude of the zero-sequence current (I_0), the change in negative-sequence current (ΔI_2), the change in zero-sequence current (ΔI_0), and the change in positive-sequence current (ΔI_1). The disturbance detector element uses net local current, computed as a sum of all sources configured in the current differential element, to detect system disturbances.

The adaptive level detector operates as follows:

- When the absolute level increases above 0.12 pu for I_0 or I_2, the adaptive level detector output is active and the next highest threshold level is increased 8 cycles later from 0.12 to 0.24 pu in steps of 0.02 pu. If the level exceeds 0.24 pu, the current adaptive level detector setting remains at 0.24 pu and the output remains active (as well as the disturbance detector output) when the measured value remains above the current setting.
- When the absolute level is decreasing from in range from 0.24 to 0.12 pu, the lower level is set every 8 cycles without the adaptive level detector active. Note that the 50DD output remains inactive during this change as long as the delta change is less than 0.04 pu.

The delta level detectors (ΔI) detectors are designed to pickup for the 0.04 pu change in I_1, I_2, and I_0 currents. The ΔI value is measured by comparing the present value to the value calculated 4 cycles earlier.

- **DD FUNCTION:** This setting is used to enable/disable the operation of the disturbance detector.
- **DD NON-CURRENT SUPV**: This setting is used to select a FlexLogic operand which will activate the output of the disturbance detector upon events (such as frequency or voltage change) not accompanied by a current change.
- **DD CONTROL LOGIC**: This setting is used to prevent operation of I_0 and I_2 logic of disturbance detector during conditions such as single breaker pole being open which leads to unbalanced load current in single-pole tripping schemes. Breaker auxiliary contact can be used for such scheme.

- **DD LOGIC SEAL-IN**: This setting is used to maintain disturbance detector output for such conditions as balanced three-phase fault, low level time overcurrent fault, etc. whenever the disturbance detector might reset. Output of the disturbance detector will be maintained until the chosen FlexLogic operand resets.

NOTE

The user may disable the **DD EVENTS** setting as the disturbance detector element will respond to any current disturbance on the system which may result in filling the events buffer and possible loss of valuable data.

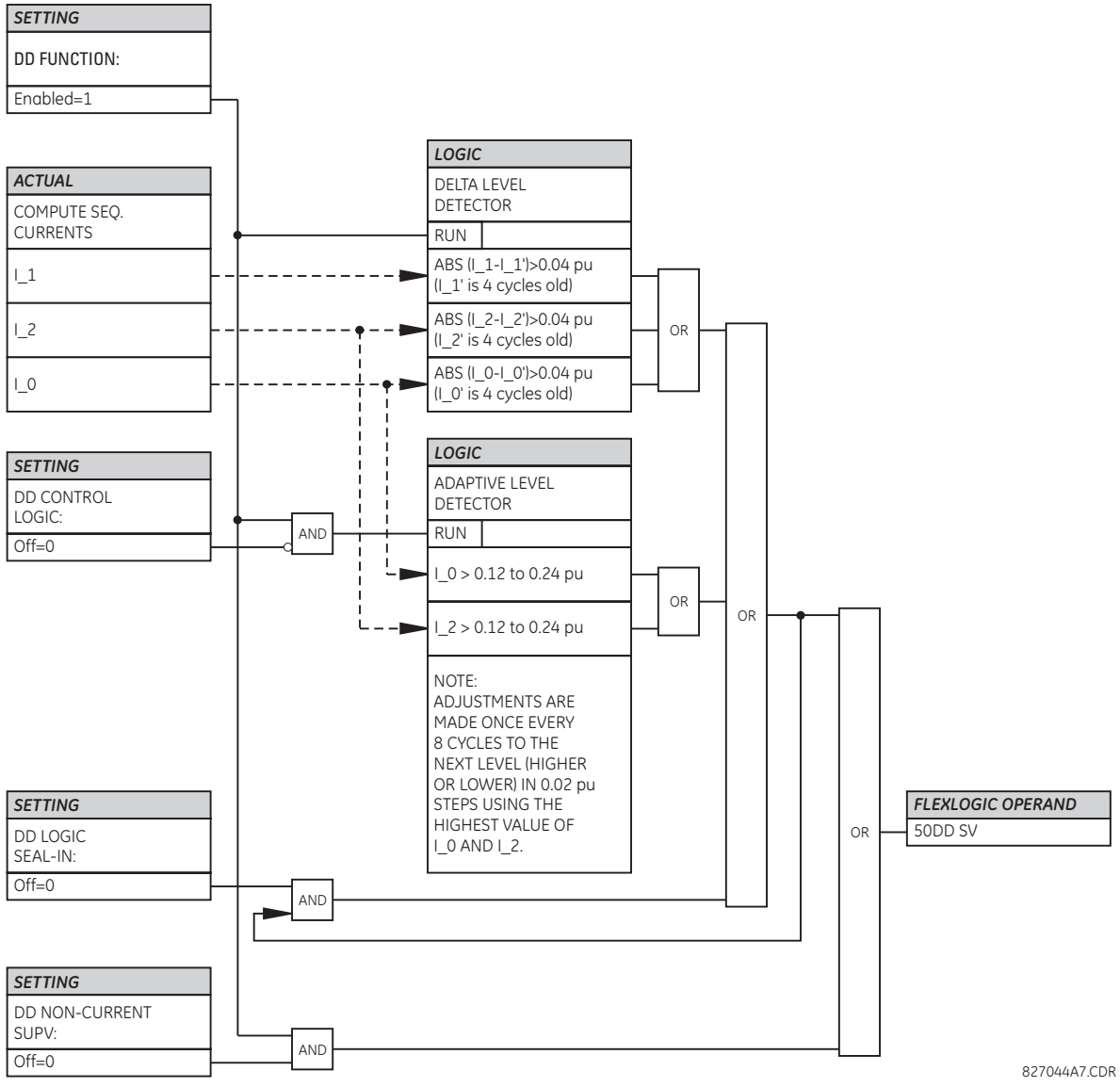


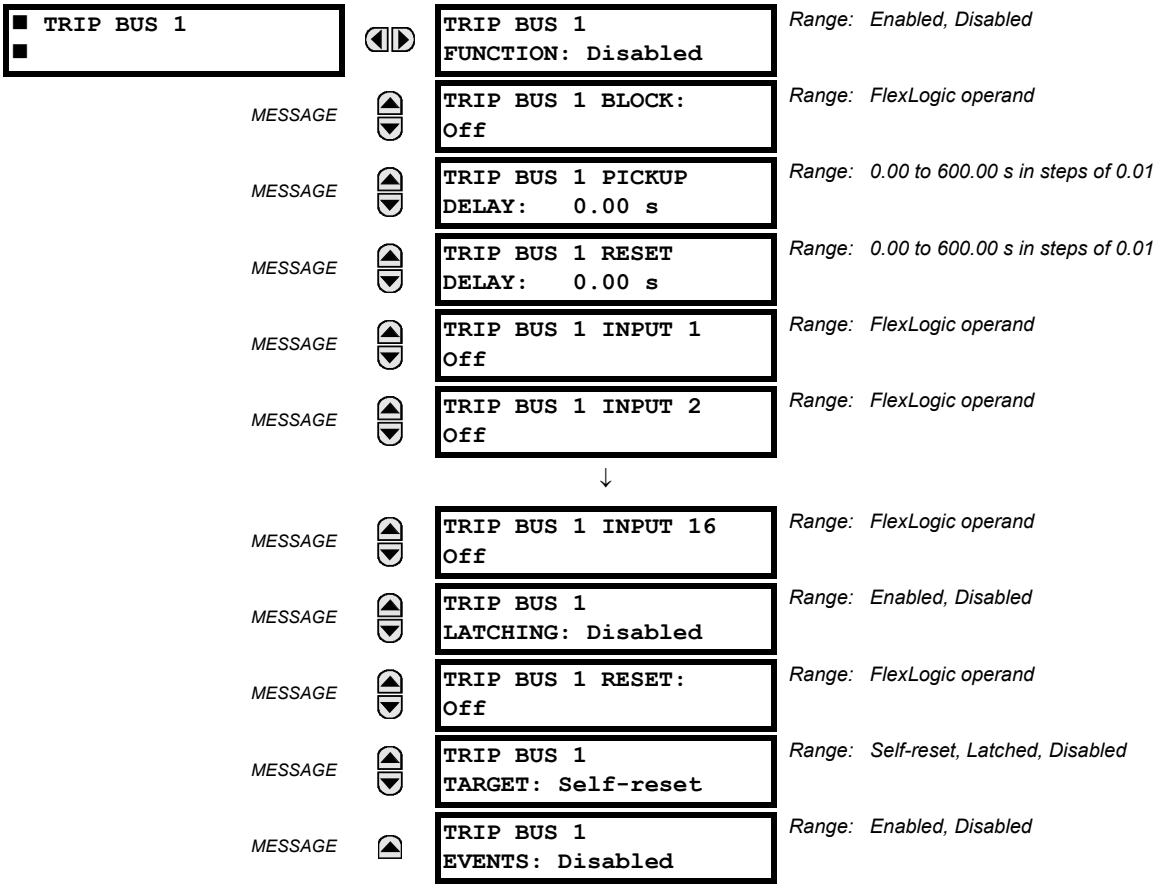

**Figure 5–88: DISTURBANCE DETECTOR SCHEME LOGIC**

### 5.7.1 OVERVIEW

Control elements are generally used for control rather than protection. See the Introduction to Elements section at the beginning of this chapter for further information.

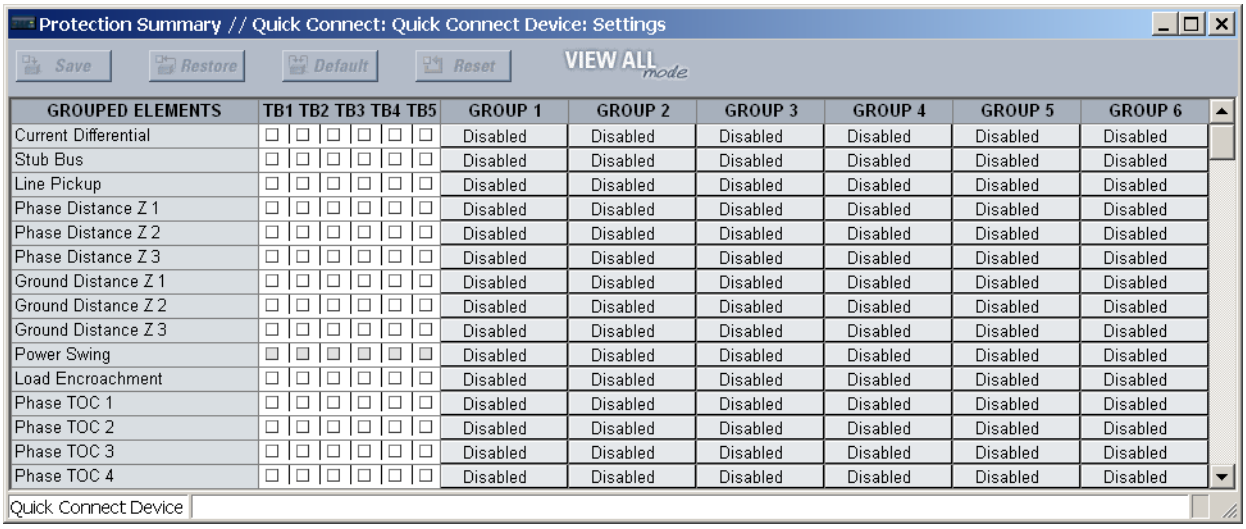
### 5.7.2 TRIP BUS

**PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨ TRIP BUS ⇨ TRIP BUS 1(6)**




The trip bus element allows aggregating outputs of protection and control elements without using FlexLogic and assigning them a simple and effective manner. Each trip bus can be assigned for either trip or alarm actions. Simple trip conditioning such as latch, delay, and seal-in delay are available.

The easiest way to assign element outputs to a trip bus is through the EnerVista UR Setup software A protection summary is displayed by navigating to a specific protection or control protection element and checking the desired bus box. Once the desired element is selected for a specific bus, a list of element operate-type operands are displayed and can be assigned to a trip bus. If more than one operate-type operand is required, it may be assigned directly from the trip bus menu.




| GROUPED ELEMENTS | TB1 | TB2 | TB3 | TB4 | TB5 | GROUP 1 | GROUP 2 | GROUP 3 | GROUP 4 | GROUP 5 | GROUP 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Current Differential | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Stub Bus | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Line Pickup | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Phase Distance Z 1 | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Phase Distance Z 2 | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Phase Distance Z 3 | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Ground Distance Z 1 | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Ground Distance Z 2 | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Ground Distance Z 3 | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Power Swing | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Load Encroachment | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Phase TOC 1 | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Phase TOC 2 | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Phase TOC 3 | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |
| Phase TOC 4 | ☐ | ☐ | ☐ | ☐ | ☐ | Disabled | Disabled | Disabled | Disabled | Disabled | Disabled |

**Figure 5–89: TRIP BUS FIELDS IN THE PROTECTION SUMMARY**

The following settings are available.

- **TRIP BUS 1 BLOCK**: The trip bus output is blocked when the operand assigned to this setting is asserted.
- **TRIP BUS 1 PICKUP DELAY**: This setting specifies a time delay to produce an output depending on how output is used.
- **TRIP BUS 1 RESET DELAY**: This setting specifies a time delay to reset an output command. The time delay should be set long enough to allow the breaker or contactor to perform a required action.
- **TRIP BUS 1 INPUT 1** to **TRIP BUS 1 INPUT 16**: These settings select a FlexLogic operand to be assigned as an input to the trip bus.
- **TRIP BUS 1 LATCHING**: This setting enables or disables latching of the trip bus output. This is typically used when lockout is required or user acknowledgement of the relay response is required.
- **TRIP BUS 1 RESET**: The trip bus output is reset when the operand assigned to this setting is asserted. Note that the RESET OP operand is pre-wired to the reset gate of the latch, As such, a reset command the front panel interface or via communications will reset the trip bus output.

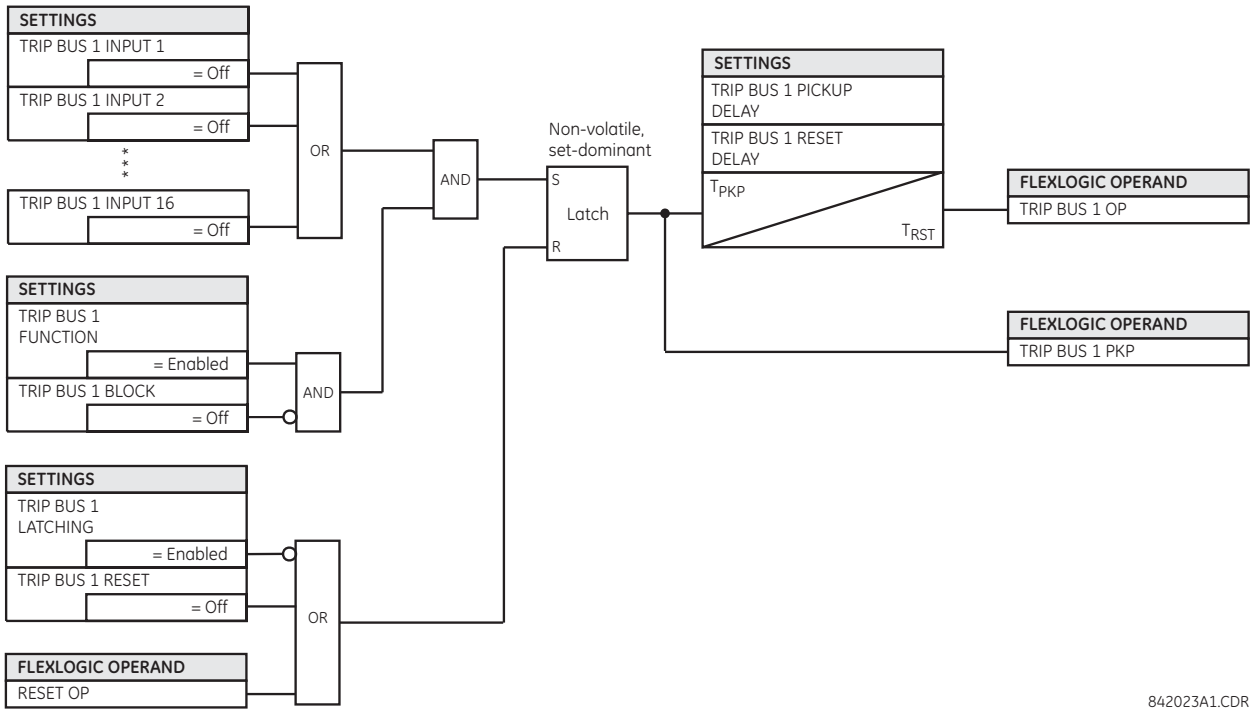



**Figure 5–90: TRIP BUS LOGIC**



## 5.7.3 SETTING GROUPS

**PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨ SETTINGS GROUPS**

| | | | |
|---|---|---|---|
| ■ SETTING GROUPS ■ | | SETTING GROUPS FUNCTION: Enabled | *Range: Disabled, Enabled* |
| | *MESSAGE* | SETTING GROUPS BLK: Off | *Range: FlexLogic operand* |
| | *MESSAGE* | GROUP 2 ACTIVATE ON: Off | *Range: FlexLogic operand* |
| | *MESSAGE* | GROUP 3 ACTIVATE ON: Off | *Range: FlexLogic operand* |
| | | ↓ | |
| | *MESSAGE* | GROUP 6 ACTIVATE ON: Off | *Range: FlexLogic operand* |
| | *MESSAGE* | GROUP 1 NAME: | *Range: up to 16 alphanumeric characters* |
| | *MESSAGE* | GROUP 2 NAME: | *Range: up to 16 alphanumeric characters* |
| | | ↓ | |
| | *MESSAGE* | GROUP 6 NAME: | *Range: up to 16 alphanumeric characters* |
| | *MESSAGE* | SETTING GROUP EVENTS: Disabled | *Range: Disabled, Enabled* |

The 61850 standard provides for the ability to monitor, edit, and change setting groups in a relay through a series of services operating on Setting Group Control Block values. There is one SGCB in LLN0 in LD1 in the UR as, at present, the other LDs do not support multiple setting groups The default value of **SETTING GROUPS** is Disabled. In order for 61850 and/or UR setting group control to function, the **SETTING GROUPS FUNCTION** must be set to Enabled.

On a setting group change, protection elements are blocked temporarily to allow the relay to re-initialize with the new settings. The duration of the block depends on relay configuration and can last up to four cycles. The actual block duration on the group switching can be verified by the PROTSUPV operand.

The active setting group in the UR is settable from either the value set via a FlexLogic operand in the UR (present practice) or a SelectActiveSG command from a 61850 Client. For both the UR and IEC 61850, the default active setting group is "1".

A 61850 SelectActiveSG command sets one of the internal Non-Volatile flags (61850 SG Level x) that represents the requested Active Setting Group shown as follows:

**Table 5–32: ACTIVE SETTING GROUP**

| SELECTACTIVESG VALUE | FLAG SET |
|---|---|
| 1 (default) | SG Level 1 |
| 2 | SG Level 2 |
| 3 | SG Level 3 |
| 4 | SG Level 4 |
| 5 | SG Level 4 |
| 6 | SG Level 6 |

On power-up or restart, the previously selected 61850 SG Level x is re-instated. Similarly, the input to the setting group control in the UR can be designed with Non-Volatile latches to achieve the same effect.



The setting groups menu controls the activation and deactivation of up to six possible groups of settings in the **GROUPED ELEMENTS** settings menu. The faceplate Settings In Use LEDs indicate which active group (with a non-flashing energized LED) is in service.

The **SETTING GROUPS BLK** setting prevents the active setting group from changing when the FlexLogic parameter is set to "On". This can be useful in applications where it is undesirable to change the settings under certain conditions, such as the breaker being open.

The **GROUP 2 ACTIVATE ON** to **GROUP 6 ACTIVATE ON** settings select a FlexLogic operand which, when set, makes the particular setting group active for use by any grouped element. A priority scheme ensures that only one group is active at a given time – the highest-numbered group that is activated by its **ACTIVATE ON** parameter takes priority over the lower-numbered groups. There is no activate on setting for group 1 (the default active group), because group 1 automatically becomes active if no other group is active.

The **SETTING GROUP 1 NAME** to **SETTING GROUP 6 NAME** settings allows the user to assign a name to each of the six settings groups. Once programmed, this name appears on the second line of the **GROUPED ELEMENTS ⇨ SETTING GROUP 1(6)** menu display.

The relay can be set up via a FlexLogic equation to receive requests to activate or de-activate a particular non-default settings group. The following FlexLogic equation (see the following figure) illustrates requests via remote communications (for example, VIRTUAL INPUT 1 ON) or from a local contact input (for example, CONTACT IP 1 ON) to initiate the use of a particular settings group, and requests from several overcurrent pickup measuring elements to inhibit the use of the particular settings group. The assigned VIRTUAL OUTPUT 1 operand is used to control the “On” state of a particular settings group.

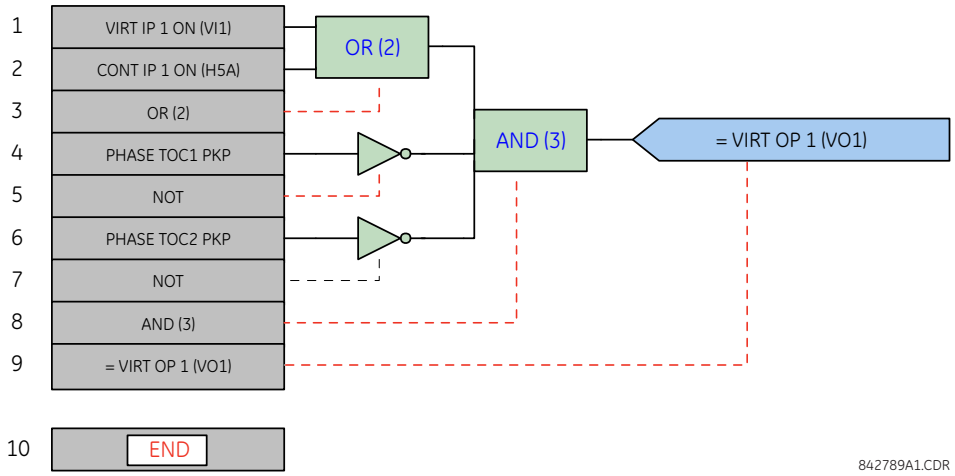
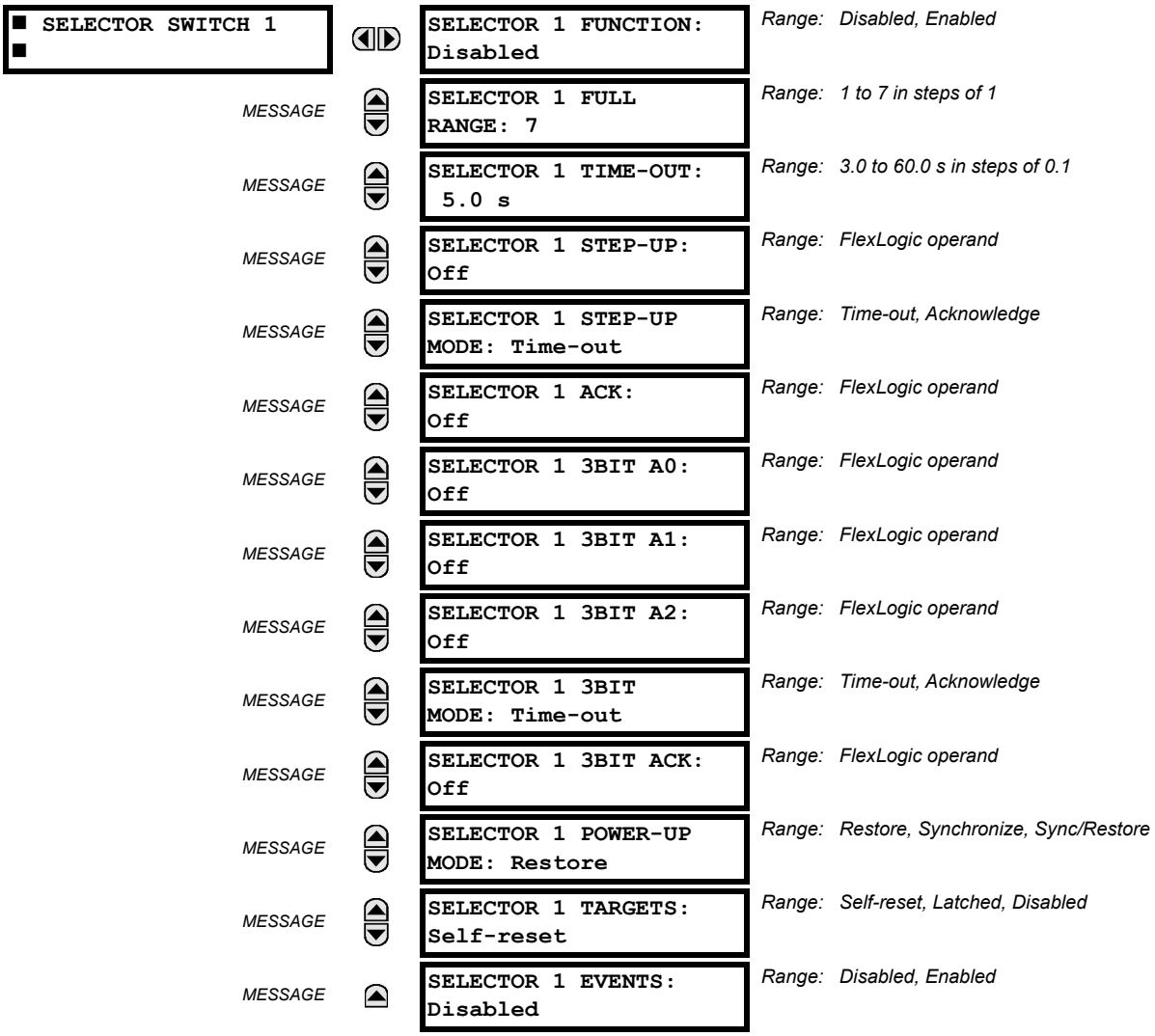



**Figure 5–91: EXAMPLE FLEXLOGIC CONTROL OF A SETTINGS GROUP**

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ SELECTOR SWITCH ⇨ SELECTOR SWITCH 1(2)




The selector switch element is intended to replace a mechanical selector switch. Typical applications include setting group control or control of multiple logic sub-circuits in user-programmable logic.

The element provides for two control inputs. The step-up control allows stepping through selector position one step at a time with each pulse of the control input, such as a user-programmable pushbutton. The three-bit control input allows setting the selector to the position defined by a three-bit word.

The element allows pre-selecting a new position without applying it. The pre-selected position gets applied either after time-out or upon acknowledgement via separate inputs (user setting). The selector position is stored in non-volatile memory. Upon power-up, either the previous position is restored or the relay synchronizes to the current three-bit word (user setting). Basic alarm functionality alerts the user under abnormal conditions; for example, the three-bit control input being out of range.

A selector switch runs every two power cycles.

- **SELECTOR 1 FULL RANGE**: This setting defines the upper position of the selector. When stepping up through available positions of the selector, the upper position wraps up to the lower position (position 1). When using a direct three-bit control word for programming the selector to a desired position, the change would take place only if the control word is within the range of 1 to the **SELECTOR FULL RANGE**. If the control word is outside the range, an alarm is established by setting the SELECTOR ALARM FlexLogic operand for three seconds.

- **SELECTOR 1 TIME-OUT:** This setting defines the time-out period for the selector. This value is used by the relay in the following two ways. When the **SELECTOR STEP-UP MODE** is "Time-out", the setting specifies the required period of inactivity of the control input after which the pre-selected position is automatically applied. When the **SELECTOR STEP-UP MODE** is "Acknowledge", the setting specifies the period of time for the acknowledging input to appear. The timer is re-started by any activity of the control input. The acknowledging input must come before the **SELECTOR 1 TIME-OUT** timer expires; otherwise, the change will not take place and an alarm will be set.
- **SELECTOR 1 STEP-UP**: This setting specifies a control input for the selector switch. The switch is shifted to a new position at each rising edge of this signal. The position changes incrementally, wrapping up from the last (**SELECTOR 1 FULL RANGE**) to the first (position 1). Consecutive pulses of this control operand must not occur faster than every 50 ms. After each rising edge of the assigned operand, the time-out timer is restarted and the **SELECTOR SWITCH 1: POS Z CHNG INITIATED** target message is displayed, where ***Z*** the pre-selected position. The message is displayed for the time specified by the **FLASH MESSAGE TIME** setting. The pre-selected position is applied after the selector times out ("Time-out" mode), or when the acknowledging signal appears before the element times out ("Acknowledge" mode). When the new position is applied, the relay displays the **SELECTOR SWITCH 1: POSITION Z IN USE** message. Typically, a user-programmable pushbutton is configured as the stepping up control input.
- **SELECTOR 1 STEP-UP MODE**: This setting defines the selector mode of operation. When set to "Time-out", the selector will change its position after a pre-defined period of inactivity at the control input. The change is automatic and does not require any explicit confirmation of the intent to change the selector's position. When set to "Acknowledge", the selector will change its position only after the intent is confirmed through a separate acknowledging signal. If the acknowledging signal does not appear within a pre-defined period of time, the selector does not accept the change and an alarm is established by setting the SELECTOR STP ALARM output FlexLogic operand for three seconds.
- **SELECTOR 1 ACK**: This setting specifies an acknowledging input for the stepping up control input. The pre-selected position is applied on the rising edge of the assigned operand. This setting is active only under "Acknowledge" mode of operation. The acknowledging signal must appear within the time defined by the **SELECTOR 1 TIME-OUT** setting after the last activity of the control input. A user-programmable pushbutton is typically configured as the acknowledging input.
- **SELECTOR 1 3BIT A0, A1, and A2**: These settings specify a three-bit control input of the selector. The three-bit control word pre-selects the position using the following encoding convention:

| A2 | A1 | A0 | POSITION |
|---|---|---|---|
| 0 | 0 | 0 | rest |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 2 |
| 0 | 1 | 1 | 3 |
| 1 | 0 | 0 | 4 |
| 1 | 0 | 1 | 5 |
| 1 | 1 | 0 | 6 |
| 1 | 1 | 1 | 7 |

  The "rest" position (0, 0, 0) does not generate an action and is intended for situations when the device generating the three-bit control word is having a problem. When **SELECTOR 1 3BIT MODE** is "Time-out", the pre-selected position is applied in **SELECTOR 1 TIME-OUT** seconds after the last activity of the three-bit input. When **SELECTOR 1 3BIT MODE** is "Acknowledge", the pre-selected position is applied on the rising edge of the **SELECTOR 1 3BIT ACK** acknowledging input.

  The stepping up control input (**SELECTOR 1 STEP-UP**) and the three-bit control inputs (**SELECTOR 1 3BIT A0** through **A2**) lock-out mutually: once the stepping up sequence is initiated, the three-bit control input is inactive; once the three-bit control sequence is initiated, the stepping up input is inactive.
- **SELECTOR 1 3BIT MODE**: This setting defines the selector mode of operation. When set to "Time-out", the selector changes its position after a pre-defined period of inactivity at the control input. The change is automatic and does not require explicit confirmation to change the selector position. When set to "Acknowledge", the selector changes its position only after confirmation via a separate acknowledging signal. If the acknowledging signal does not appear within a pre-defined period of time, the selector rejects the change and an alarm established by invoking the SELECTOR BIT ALARM FlexLogic operand for three seconds.
- **SELECTOR 1 3BIT ACK**: This setting specifies an acknowledging input for the three-bit control input. The pre-selected position is applied on the rising edge of the assigned FlexLogic operand. This setting is active only under the

"Acknowledge" mode of operation. The acknowledging signal must appear within the time defined by the **SELECTOR TIME-OUT** setting after the last activity of the three-bit control inputs. Note that the stepping up control input and three-bit control input have independent acknowledging signals (**SELECTOR 1 ACK** and **SELECTOR 1 3BIT ACK**, accordingly).

- **SELECTOR 1 POWER-UP MODE**: This setting specifies the element behavior on power up of the relay.

  When set to "Restore", the last position of the selector (stored in the non-volatile memory) is restored after powering up the relay. If the position restored from memory is out of range, position 0 (no output operand selected) is applied and an alarm is set (SELECTOR 1 PWR ALARM).

  When set to "Synchronize" selector switch acts as follows. For two power cycles, the selector applies position 0 to the switch and activates SELECTOR 1 PWR ALARM. After two power cycles expire, the selector synchronizes to the position dictated by the three-bit control input. This operation does not wait for time-out or the acknowledging input. When the synchronization attempt is unsuccessful (that is, the three-bit input is not available (0,0,0) or out of range) then the selector switch output is set to position 0 (no output operand selected) and an alarm is established (SELECTOR 1 PWR ALARM).

  The operation of "Synch/Restore" mode is similar to the "Synchronize" mode. The only difference is that after an unsuccessful synchronization attempt, the switch will attempt to restore the position stored in the relay memory. The "Synch/Restore" mode is useful for applications where the selector switch is employed to change the setting group in redundant (two relay) protection schemes.

- **SELECTOR 1 EVENTS**: If enabled, the following events are logged:

| EVENT NAME | DESCRIPTION |
|---|---|
| SELECTOR 1 POS *Z* | Selector 1 changed its position to *Z*. |
| SELECTOR 1 STP ALARM | The selector position pre-selected via the stepping up control input has not been confirmed before the time out. |
| SELECTOR 1 BIT ALARM | The selector position pre-selected via the three-bit control input has not been confirmed before the time out. |

The following figures illustrate the operation of the selector switch. In these diagrams, “T” represents a time-out setting.

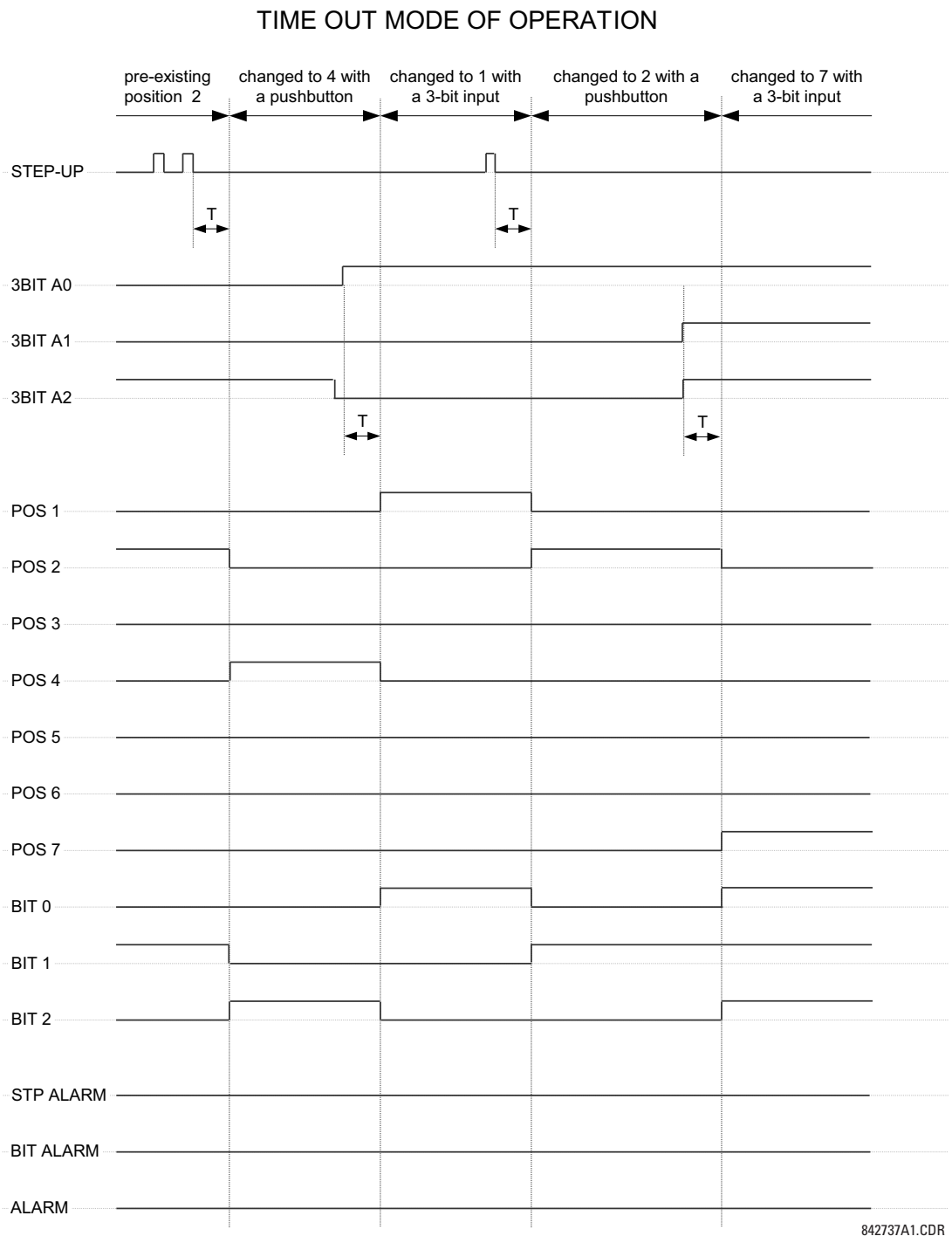



**Figure 5–92: TIME-OUT MODE**

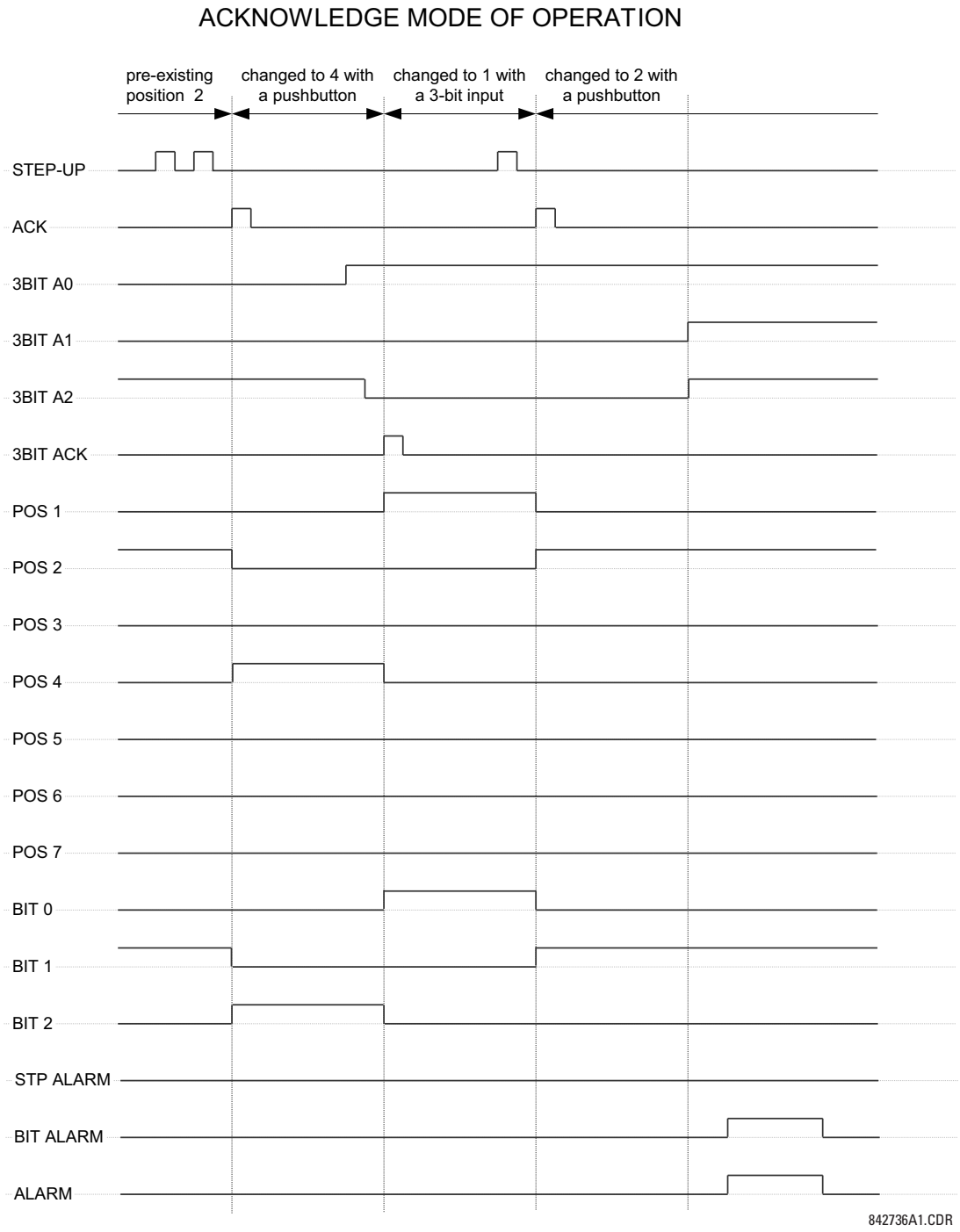



**Figure 5–93: ACKNOWLEDGE MODE**

### APPLICATION EXAMPLE

Consider an application where the selector switch is used to control setting groups 1 through 4 in the relay. The setting groups are to be controlled from both user-programmable pushbutton 1 and from an external device via contact inputs 1 through 3. The active setting group shall be available as an encoded three-bit word to the external device and SCADA via output contacts 1 through 3. The pre-selected setting group shall be applied automatically after 5 seconds of inactivity of the control inputs. When the relay powers up, it should synchronize the setting group to the three-bit control input.

Make the following changes to setting group control in the **SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨ SETTING GROUPS** menu:

**SETTING GROUPS FUNCTION:** "Enabled"
**SETTING GROUPS BLK:** "Off"
**GROUP 2 ACTIVATE ON:** "SELECTOR 1 POS 2"
**GROUP 3 ACTIVATE ON:** "SELECTOR 1 POS 3"
**GROUP 4 ACTIVATE ON:** "SELECTOR 1 POS 4"
**GROUP 5 ACTIVATE ON:** "Off"
**GROUP 6 ACTIVATE ON:** "Off"

Make the following changes to selector switch element in the **SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ SELECTOR SWITCH ⇨ SELECTOR SWITCH 1** menu to assign control to user programmable pushbutton 1 and contact inputs 1 through 3:

**SELECTOR 1 FUNCTION:** "Enabled"
**SELECTOR 1 FULL-RANGE:** "4"
**SELECTOR 1 STEP-UP MODE:** "Time-out"
**SELECTOR 1 TIME-OUT:** "5.0 s"
**SELECTOR 1 STEP-UP:** "PUSHBUTTON 1 ON"
**SELECTOR 1 ACK:** "Off"
**SELECTOR 1 3BIT A0:** "CONT IP 1 ON"
**SELECTOR 1 3BIT A1:** "CONT IP 2 ON"
**SELECTOR 1 3BIT A2:** "CONT IP 3 ON"
**SELECTOR 1 3BIT MODE:** "Time-out"
**SELECTOR 1 3BIT ACK:** "Off"
**SELECTOR 1 POWER-UP MODE:** "Synchronize"

Now, assign the contact output operation (assume the H6E module) to the selector switch element by making the following changes in the **SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS** menu:

**OUTPUT H1 OPERATE:** "SELECTOR 1 BIT 0"
**OUTPUT H2 OPERATE:** "SELECTOR 1 BIT 1"
**OUTPUT H3 OPERATE:** "SELECTOR 1 BIT 2"

Finally, assign configure user-programmable pushbutton 1 by making the following changes in the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE PUSHBUTTONS ⇨ USER PUSHBUTTON 1** menu:

**PUSHBUTTON 1 FUNCTION:** "Self-reset"
**PUSHBUTTON 1 DROP-OUT TIME:** "0.10 s"

The logic for the selector switch is shown below:

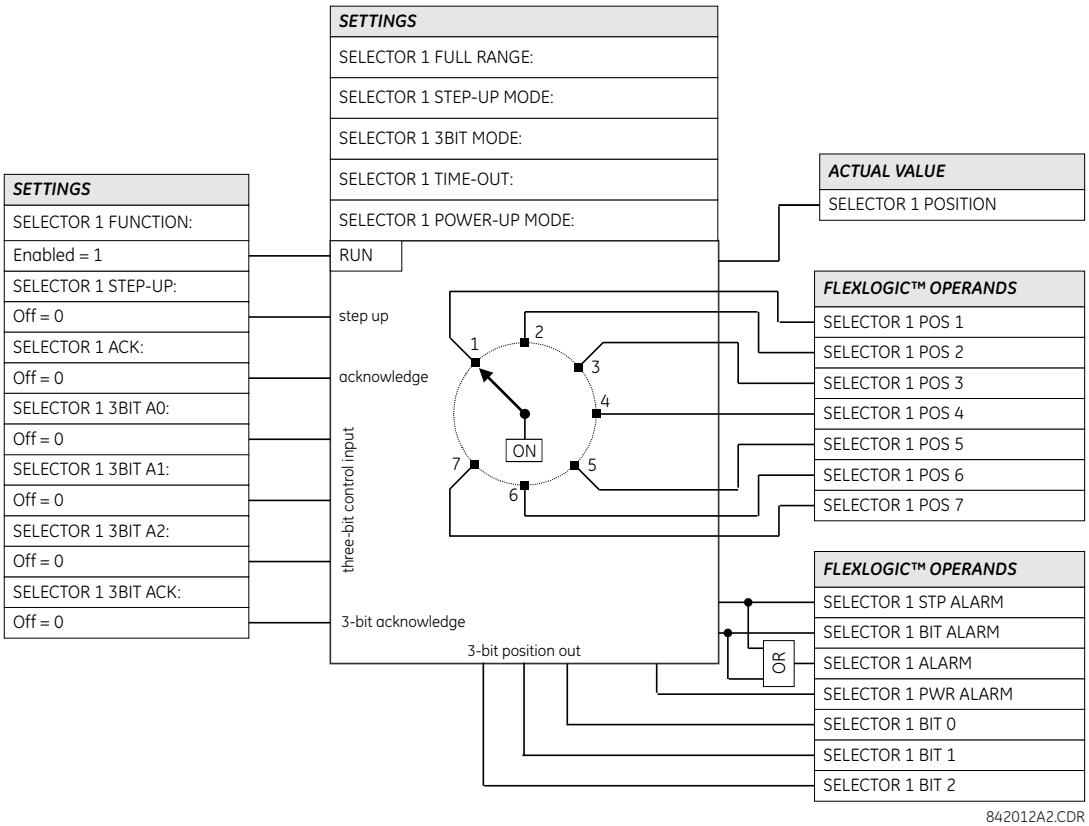
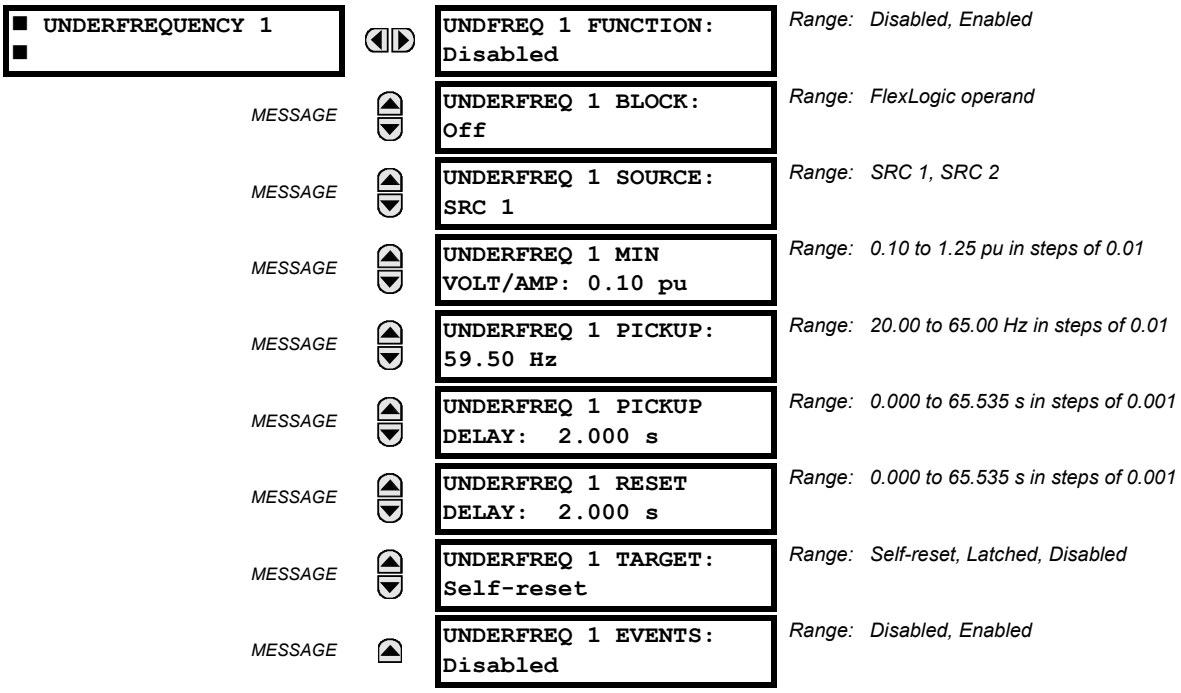



**Figure 5–94: SELECTOR SWITCH LOGIC**

## 5.7.5 UNDERFREQUENCY (ANSI 81U)

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ UNDERFREQUENCY ⇨ UNDERFREQUENCY 1(6)




There are six identical underfrequency elements, numbered from 1 through 6.

The steady-state frequency of a power system is a certain indicator of the existing balance between the generated power and the load. Whenever this balance is disrupted through the loss of an important generating unit or the isolation of part of the system from the rest of the system, the effect will be a reduction in frequency. If the control systems of the system generators do not respond fast enough, the system may collapse. A reliable method to quickly restore the balance between load and generation is to automatically disconnect selected loads, based on the actual system frequency. This technique, called “load-shedding”, maintains system integrity and minimize widespread outages. After the frequency returns to normal, the load may be automatically or manually restored.

The **UNDERFREQ 1 SOURCE** setting is used to select the source for the signal to be measured. The element first checks for a live phase voltage available from the selected source. If voltage is not available, the element attempts to use a phase current. If neither voltage nor current is available, the element will not operate, as it will not measure a parameter below the minimum voltage/current setting.

The **UNDERFREQ 1 MIN VOLT/AMP** setting selects the minimum per unit voltage or current level required to allow the underfrequency element to operate. This threshold is used to prevent an incorrect operation because there is no signal to measure.

This **UNDERFREQ 1 PICKUP** setting is used to select the level at which the underfrequency element is to pickup. For example, if the system frequency is 60 Hz and the load shedding is required at 59.5 Hz, the setting will be 59.50 Hz.

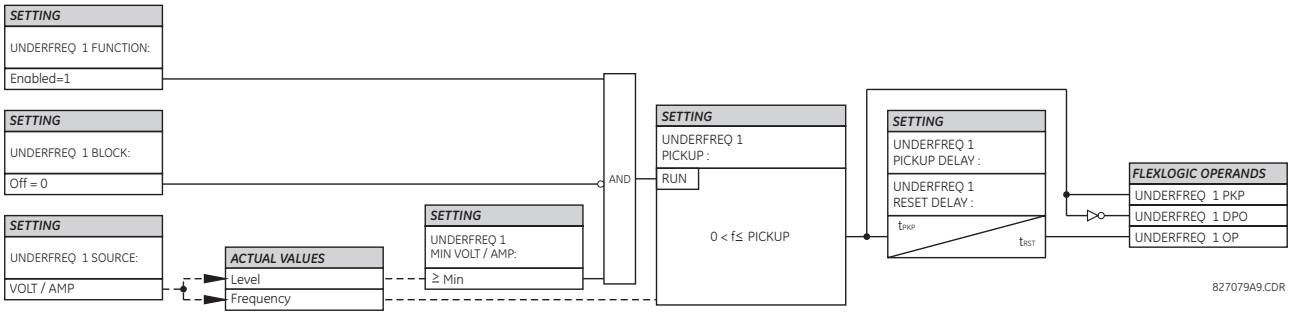



**Figure 5–95: UNDERFREQUENCY SCHEME LOGIC**

### 5.7.6 SYNCHROCHECK (ANSI 25)

**PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ SYNCHROCHECK ⇨ SYNCHROCHECK 1(4)**

| | | | |
|---|---|---|---|
| ■ SYNCHROCHECK 1 ■ | | SYNCHK1 FUNCTION: Disabled | *Range: Disabled, Enabled* |
| | *MESSAGE* | SYNCHK1 BLOCK: Off | *Range: FlexLogic operand* |
| | *MESSAGE* | SYNCHK1 V1 SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | SYNCHK1 V2 SOURCE: SRC 2 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | SYNCHK1 MAX VOLT DIFF: 10000 V | *Range: 0 to 400000 V in steps of 1* |
| | *MESSAGE* | SYNCHK1 MAX ANGLE DIFF: 30 | *Range: 0 to 100° in steps of 1* |
| | *MESSAGE* | SYNCHK1 MAX FREQ DIFF: 1.00 Hz | *Range: 0.00 to 2.00 Hz in steps of 0.01* |
| | *MESSAGE* | SYNCHK1 MAX FREQ HYSTERESIS: 0.06 Hz | *Range: 0.00 to 0.10 Hz in steps of 0.01* |
| | *MESSAGE* | SYNCHK1 DEAD SOURCE SELECT: LV1 and DV2 | *Range: None, LV1 and DV2, DV1 and LV2, DV1 or DV2, DV1 Xor DV2, DV1 and DV2* |
| | *MESSAGE* | SYNCHK1 DEAD V1 MAX VOLT: 0.30 pu | *Range: 0.00 to 1.25 pu in steps of 0.01* |
| | *MESSAGE* | SYNCHK1 DEAD V2 MAX VOLT: 0.30 pu | *Range: 0.00 to 1.25 pu in steps of 0.01* |
| | *MESSAGE* | SYNCHK1 LIVE V1 MIN VOLT: 0.70 pu | *Range: 0.00 to 1.25 pu in steps of 0.01* |
| | *MESSAGE* | SYNCHK1 LIVE V2 MIN VOLT: 0.70 pu | *Range: 0.00 to 1.25 pu in steps of 0.01* |
| | *MESSAGE* | SYNCHK1 TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | SYNCHK1 EVENTS: Disabled | *Range: Disabled, Enabled* |

There are four identical synchrocheck elements available, numbered 1 to 4.

The synchronism check function is intended for supervising the paralleling of two parts of a system which are to be joined by the closure of a circuit breaker. The synchrocheck elements are typically used at locations where the two parts of the system are interconnected through at least one other point in the system.

Synchrocheck verifies that the voltages (V1 and V2) on the two sides of the supervised circuit breaker are within set limits of magnitude, angle and frequency differences. The time that the two voltages remain within the admissible angle difference is determined by the setting of the phase angle difference $\Delta\Phi$ and the frequency difference $\Delta$F (slip frequency). It can be defined as the time it would take the voltage phasor V1 or V2 to traverse an angle equal to $2 \times \Delta\Phi$ at a frequency equal to the frequency difference $\Delta$F. This time can be calculated by:

$$T = \frac{1}{\frac{360^\circ}{2 \times \Delta\Phi} \times \Delta F} \quad \text{(EQ 5.22)}$$

where: $\Delta\Phi$ = phase angle difference in degrees; $\Delta$F = frequency difference in Hz.

If one or both sources are de-energized, the synchrocheck programming can allow for closing of the circuit breaker using undervoltage control to by-pass the synchrocheck measurements (dead source function).

- **SYNCHK1 V1 SOURCE**: This setting selects the source for voltage V1 (see NOTES below).
- **SYNCHK1 V2 SOURCE**: This setting selects the source for voltage V2, which must not be the same as used for the V1 (see NOTES below).
- **SYNCHK1 MAX VOLT DIFF**: This setting selects the maximum primary voltage difference in volts between the two sources. A primary voltage magnitude difference between the two input voltages below this value is within the permissible limit for synchronism.
- **SYNCHK1 MAX ANGLE DIFF:** This setting selects the maximum angular difference in degrees between the two sources. An angular difference between the two input voltage phasors below this value is within the permissible limit for synchronism.
- **SYNCHK1 MAX FREQ DIFF:** This setting selects the maximum frequency difference in 'Hz' between the two sources. A frequency difference between the two input voltage systems below this value is within the permissible limit for synchronism.
- **SYNCHK1 MAX FREQ HYSTERESIS**: This setting specifies the required hysteresis for the maximum frequency difference condition. The condition becomes satisfied when the frequency difference becomes lower than **SYNCHK1 MAX FREQ DIFF**. Once the Synchrocheck element has operated, the frequency difference must increase above the **SYNCHK1 MAX FREQ DIFF + SYNCHK1 MAX FREQ HYSTERESIS** sum to drop out (assuming the other two conditions, voltage and angle, remain satisfied).
- **SYNCHK1 DEAD SOURCE SELECT:** This setting selects the combination of dead and live sources that will by-pass synchronism check function and permit the breaker to be closed when one or both of the two voltages (V1 or/and V2) are below the maximum voltage threshold. A dead or live source is declared by monitoring the voltage level. Six options are available:

  | | |
  |---|---|
  | None: | Dead Source function is disabled |
  | LV1 and DV2: | Live V1 and Dead V2 |
  | DV1 and LV2: | Dead V1 and Live V2 |
  | DV1 or DV2: | Dead V1 or Dead V2 |
  | DV1 Xor DV2: | Dead V1 exclusive-or Dead V2 (one source is Dead and the other is Live) |
  | DV1 and DV2: | Dead V1 and Dead V2 |

- **SYNCHK1 DEAD V1 MAX VOLT:** This setting establishes a maximum voltage magnitude for V1 in 1 'pu'. Below this magnitude, the V1 voltage input used for synchrocheck will be considered "Dead" or de-energized.
- **SYNCHK1 DEAD V2 MAX VOLT**: This setting establishes a maximum voltage magnitude for V2 in 'pu'. Below this magnitude, the V2 voltage input used for synchrocheck will be considered "Dead" or de-energized.
- **SYNCHK1 LIVE V1 MIN VOLT**: This setting establishes a minimum voltage magnitude for V1 in 'pu'. Above this magnitude, the V1 voltage input used for synchrocheck will be considered "Live" or energized.
- **SYNCHK1 LIVE V2 MIN VOLT**: This setting establishes a minimum voltage magnitude for V2 in 'pu'. Above this magnitude, the V2 voltage input used for synchrocheck will be considered "Live" or energized.

**NOTES ON THE SYNCHROCHECK FUNCTION:**

1. The selected sources for synchrocheck inputs V1 and V2 (which must not be the same source) may include both a three-phase and an auxiliary voltage. The relay will automatically select the specific voltages to be used by the synchrocheck element in accordance with the following table.

| NO. | V1 OR V2 (SOURCE Y) | V2 OR V1 (SOURCE Z) | AUTO-SELECTED COMBINATION | | AUTO-SELECTED VOLTAGE |
|---|---|---|---|---|---|
| | | | SOURCE Y | SOURCE Z | |
| 1 | Phase VTs and Auxiliary VT | Phase VTs and Auxiliary VT | Phase | Phase | VAB |
| 2 | Phase VTs and Auxiliary VT | Phase VT | Phase | Phase | VAB |
| 3 | Phase VT | Phase VT | Phase | Phase | VAB |
| 4 | Phase VT and Auxiliary VT | Auxiliary VT | Phase | Auxiliary | V auxiliary (as set for Source z) |
| 5 | Auxiliary VT | Auxiliary VT | Auxiliary | Auxiliary | V auxiliary (as set for selected sources) |

The voltages V1 and V2 will be matched automatically so that the corresponding voltages from the two sources will be used to measure conditions. A phase to phase voltage will be used if available in both sources; if one or both of the Sources have only an auxiliary voltage, this voltage will be used. For example, if an auxiliary voltage is programmed to VAG, the synchrocheck element will automatically select VAG from the other source. If the comparison is required on a specific voltage, the user can externally connect that specific voltage to auxiliary voltage terminals and then use this "Auxiliary Voltage" to check the synchronism conditions.

If using a single CT/VT module with both phase voltages and an auxiliary voltage, ensure that only the auxiliary voltage is programmed in one of the sources to be used for synchrocheck.

NOTE

Exception: Synchronism cannot be checked between Delta connected phase VTs and a Wye connected auxiliary voltage.

2. The relay measures frequency and Volts/Hz from an input on a given source with priorities as established by the configuration of input channels to the source. The relay will use the phase channel of a three-phase set of voltages if programmed as part of that source. The relay will use the auxiliary voltage channel only if that channel is programmed as part of the Source and a three-phase set is not.

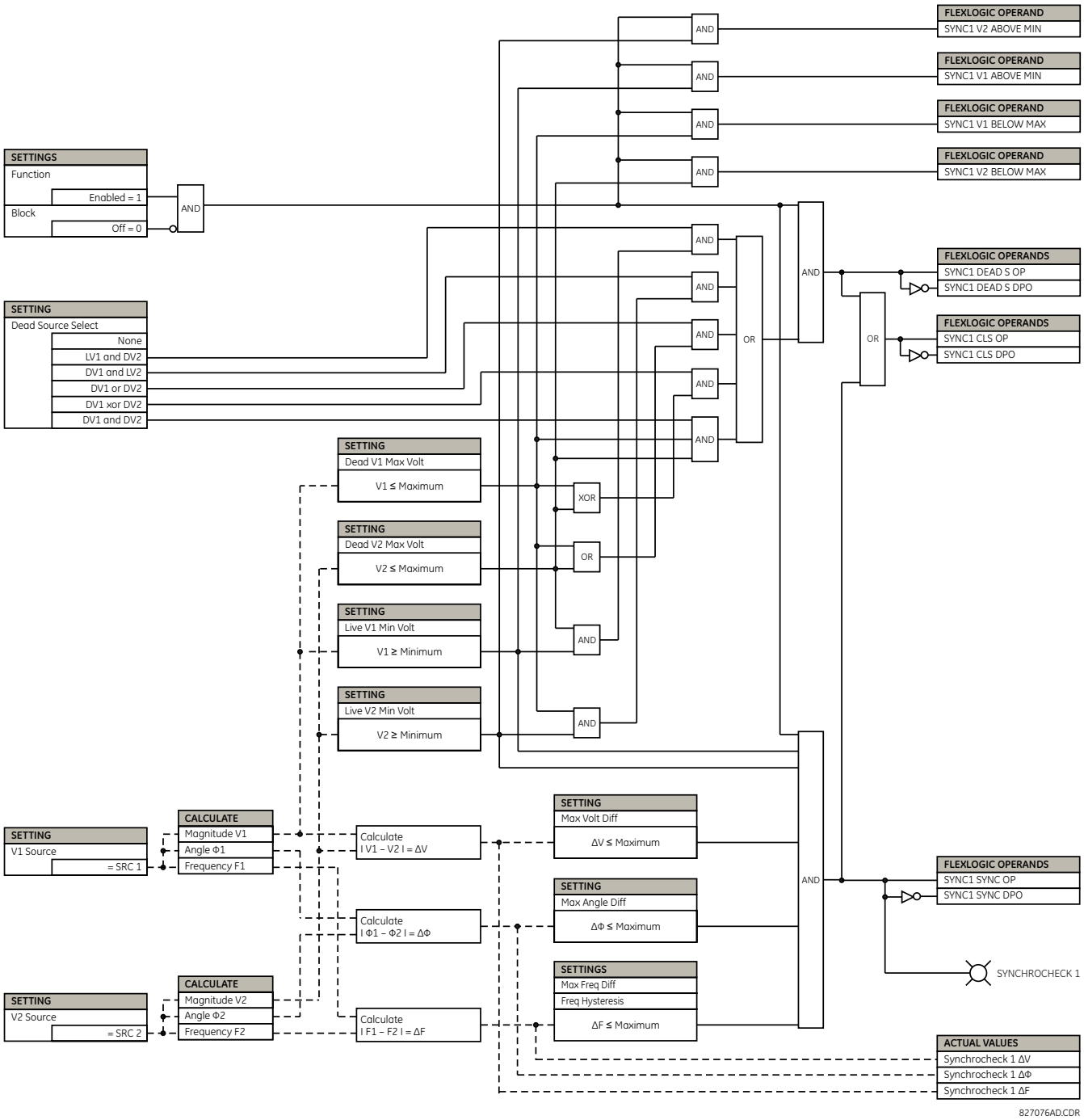
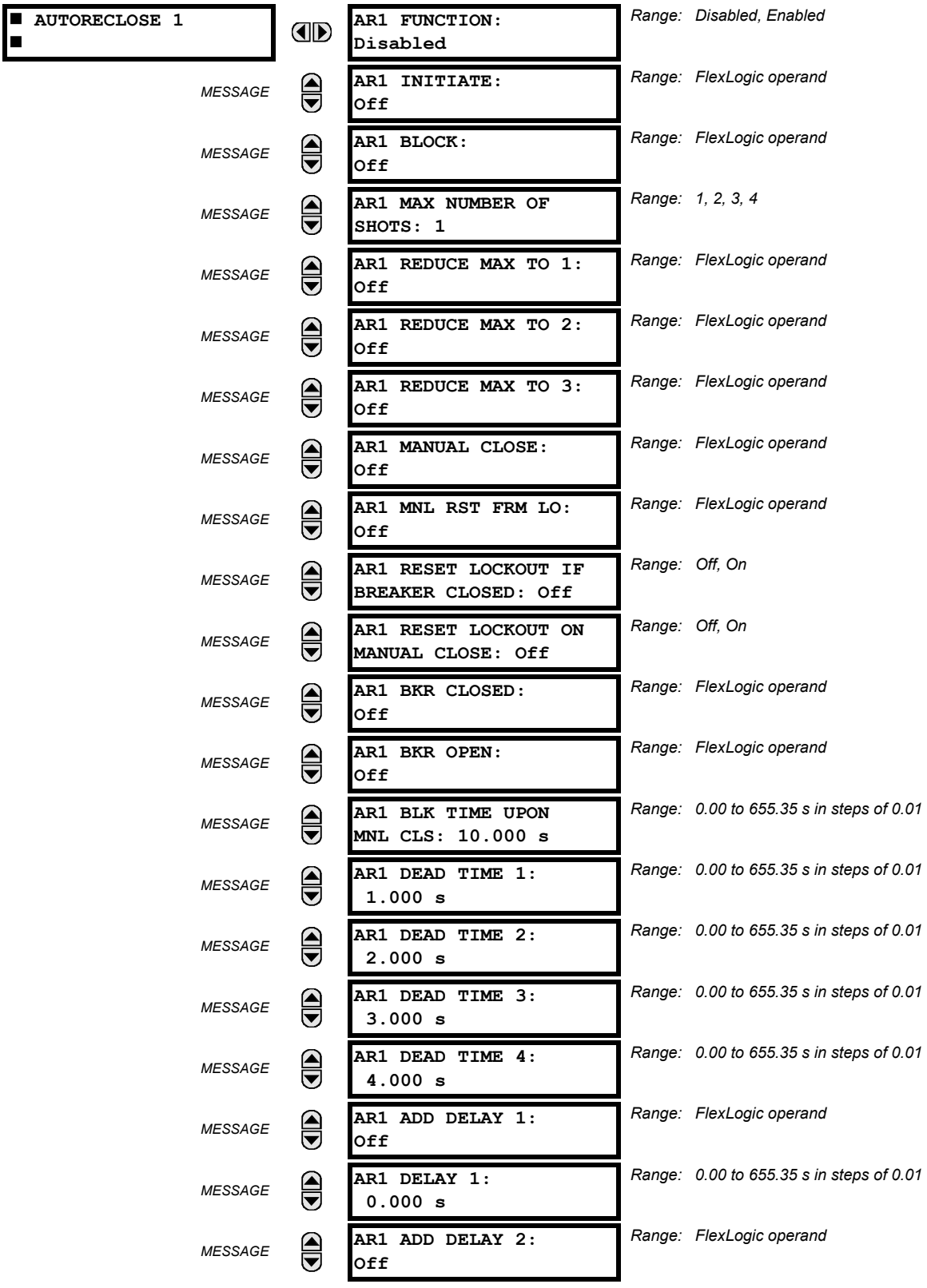
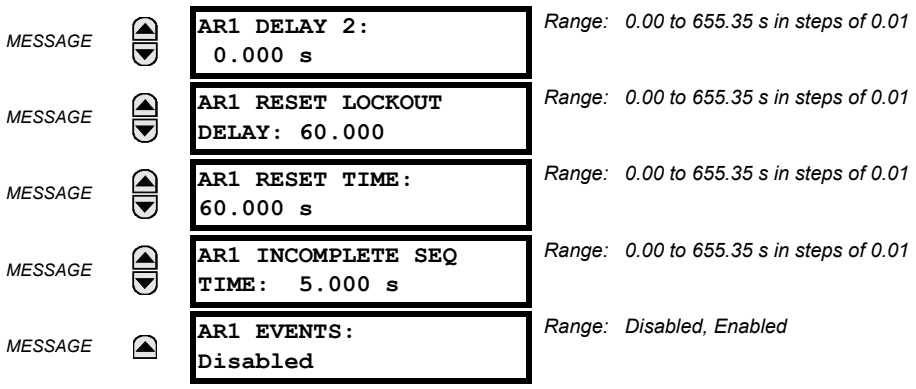



**Figure 5–96: SYNCHROCHECK SCHEME LOGIC**

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ AUTORECLOSE ⇨ AUTORECLOSE 1(2)






The maximum number of autoreclosure elements available is equal to the number of installed CT banks.

The autoreclosure feature is intended for use with transmission and distribution lines, in three-pole tripping schemes for single breaker applications. Up to four selectable reclosures 'shots' are possible prior to locking out. Each shot has an independently settable dead time. The protection settings can be changed between shots if so desired, using FlexLogic. Logic inputs are available for disabling or blocking the scheme.

Faceplate panel LEDs indicate the state of the autoreclose scheme as follows:

- Reclose Enabled: The scheme is enabled and may reclose if initiated.
- Reclose Disabled: The scheme is disabled.
- Reclose In Progress: An autoreclosure has been initiated but the breaker has not yet been signaled to close.
- Reclose Locked Out: The scheme has generated the maximum number of breaker closures allowed and, as the fault persists, will not close the breaker again; known as 'Lockout'. The scheme may also be sent in 'Lockout' when the incomplete sequence timer times out or when a block signal occurs while in 'reclose in progress'. The scheme must be reset from Lockout in order to perform reclose for further faults.

The reclosure scheme is considered *enabled* when all of the following conditions are true:

- The **AR1 FUNCTION** is set to "Enabled".
- The scheme is not in the 'Lockout' state.
- The 'Block' input is not asserted.
- The **AR1 BLK TIME UPON MNL CLS** timer is not active.

The autoreclose scheme is initiated by a trip signal from any selected protection feature operand. The scheme is initiated provided the circuit breaker is in the closed state before protection operation.

The reclose-in-progress (RIP) is set when a reclosing cycle begins following a reclose initiate signal. Once the cycle is successfully initiated, the RIP signal will seal-in and the scheme will continue through its sequence until one of the following conditions is satisfied:

- The close signal is issued when the dead timer times out, or
- The scheme goes to lockout.

While RIP is active, the scheme checks that the breaker is open and the shot number is below the limit, and then begins measuring the dead time.

Each of the four possible shots has an independently settable dead time. Two additional timers can be used to increase the initial set dead times 1 to 4 by a delay equal to **AR1 DELAY 1** or **AR1 DELAY 2** or the sum of these two delays depending on the selected settings. This offers enhanced setting flexibility using FlexLogic operands to turn the two additional timers "on" and "off". These operands may possibly include AR1 SHOT CNT =n, SETTING GROUP ACT 1, etc. The autoreclose provides up to maximum 4 selectable shots. Maximum number of shots can be dynamically modified through the settings **AR1 REDUCE MAX TO 1 (2, 3)**, using the appropriate FlexLogic operand.

Scheme lockout blocks all phases of the reclosing cycle, preventing automatic reclosure, if any of the following occurs:

- The maximum shot number was reached.
- A 'Block' input is in effect (for instance; Breaker Failure, bus differential protection operated, etc.).

- The ‘Incomplete Sequence’ timer times out.

The recloser will be latched in the Lockout state until a ‘reset from lockout’ signal is asserted, either from a manual close of the breaker or from a manual reset command (local or remote). The reset from lockout can be accomplished by operator command, by manually closing the breaker, or whenever the breaker has been closed and stays closed for a preset time.

After the dead time elapses, the scheme issues the close signal. The close signal is latched until the breaker closes or the scheme goes to Lockout.

A reset timer output resets the recloser following a successful reclosure sequence. The reset time is based on the breaker ‘reclaim time’ which is the minimum time required between successive reclose sequences.

**SETTINGS:**

- **AR1 INITIATE:** Selects the FlexLogic operand that initiates the scheme, typically the trip signal from protection.
- **AR1 BLOCK:** Selects the FlexLogic operand that blocks the autoreclosure initiate (it could be from the breaker failure, bus differential protection, etc.).
- **AR1 MAX NUMBER OF SHOTS:** Specifies the number of reclosures that can be attempted before reclosure goes to “Lockout” because the fault is permanent.
- **AR1 REDUCE MAX TO 1(3):** Selects the FlexLogic operand that changes the maximum number of shots from the initial setting to 1, 2, or 3, respectively.
- **AR1 MANUAL CLOSE:** Selects the logic input set when the breaker is manually closed.
- **AR1 MNL RST FRM LO:** Selects the FlexLogic operand that resets the autoreclosure from Lockout condition. Typically this is a manual reset from lockout, local or remote.
- **AR1 RESET LOCKOUT IF BREAKER CLOSED:** This setting allows the autoreclose scheme to reset from Lockout if the breaker has been manually closed and stays closed for a preset time. In order for this setting to be effective, the next setting (**AR1 RESET LOCKOUT ON MANUAL CLOSE**) should be disabled.
- **AR1 RESET LOCKOUT ON MANUAL CLOSE:** This setting allows the autoreclose scheme to reset from Lockout when the breaker is manually closed regardless if the breaker remains closed or not. This setting overrides the previous setting (**AR1 RESET LOCKOUT IF BREAKER CLOSED**).
- **AR1 BLK TIME UPON MNL CLS:** The autoreclose scheme can be disabled for a programmable time delay after the associated circuit breaker is manually closed. This prevents reclosing onto a fault after a manual close. This delay must be longer than the slowest expected trip from any protection not blocked after manual closing. If no overcurrent trips occur after a manual close and this time expires, the autoreclose scheme is enabled.
- **AR1 DEAD TIME 1 to AR1 DEAD TIME 4:** These are the intentional delays before first, second, third, and fourth breaker automatic reclosures (1st, 2nd, and 3rd shots), respectively, and should be set longer than the estimated deionizing time following a three pole trip.
- **AR1 ADD DELAY 1:** This setting selects the FlexLogic operand that introduces an additional delay (Delay 1) to the initial set Dead Time (1 to 4). When this setting is “Off”, Delay 1 is by-passed.
- **AR1 DELAY 1:** This setting establishes the extent of the additional dead time Delay 1.
- **AR1 ADD DELAY 2:** This setting selects the FlexLogic operand that introduces an additional delay (Delay 2) to the initial set Dead Time (1 to 4). When this setting is “Off”, Delay 2 is by-passed.
- **AR1 DELAY 2:** This setting establishes the extent of the additional dead time Delay 2.
- **AR1 RESET LOCKOUT DELAY:** This setting establishes how long the breaker should stay closed after a manual close command, in order for the autorecloser to reset from Lockout.
- **AR1 RESET TIME**: A reset timer output resets the recloser following a successful reclosure sequence. The setting is based on the breaker ‘reclaim time’ which is the minimum time required between successive reclose sequences.
- **AR1 INCOMPLETE SEQ TIME**: This timer defines the maximum time interval allowed for a single reclose shot. It is started whenever a reclosure is initiated and is active when the scheme is in the ‘reclose-in-progress’ state. If all conditions allowing a breaker closure are not satisfied when this time expires, the scheme goes to “Lockout”.

NOTE

This timer must be set to a delay less than the reset timer.

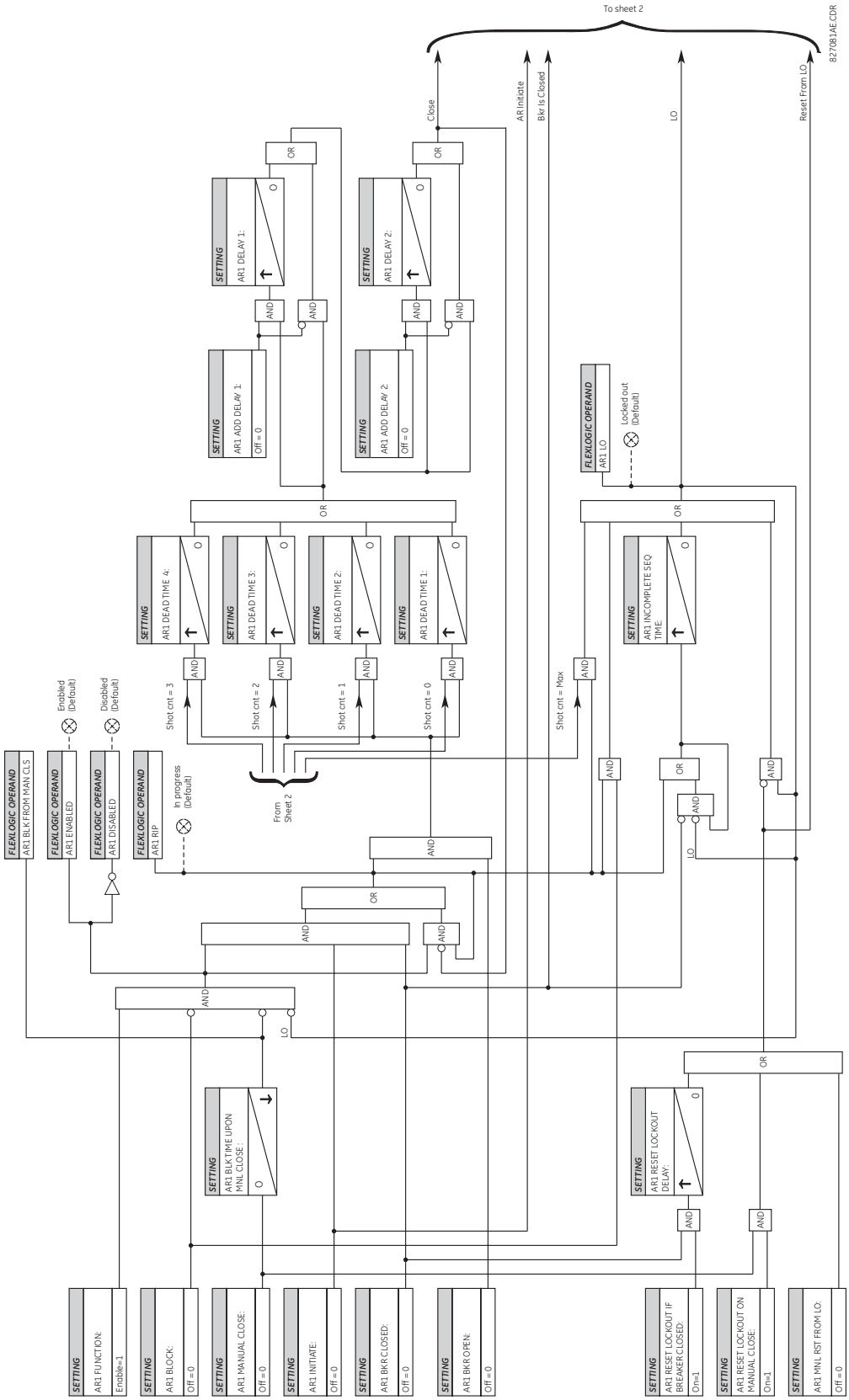



**Figure 5–97: AUTORECLOSURE SCHEME LOGIC (Sheet 1 of 2)**

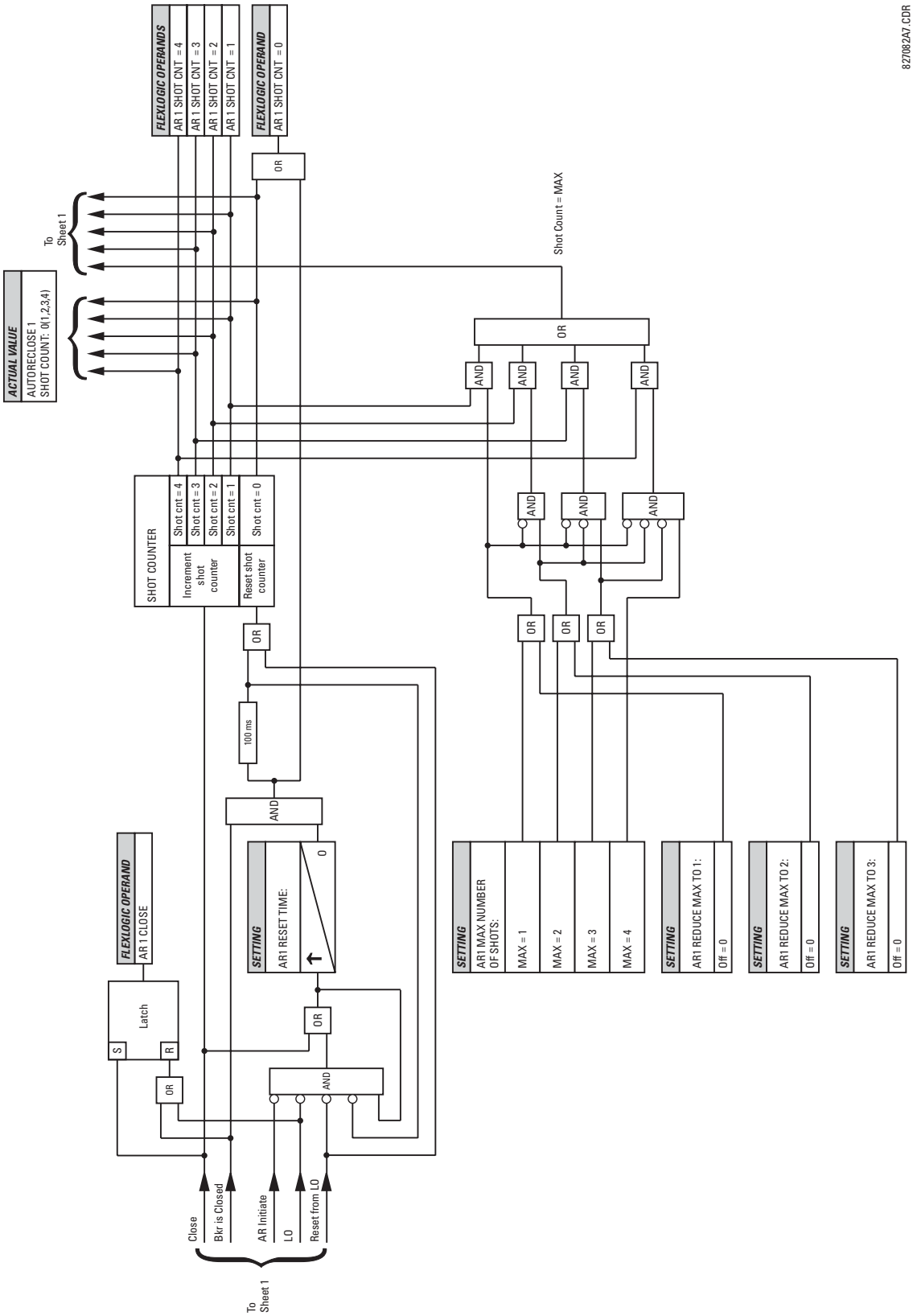



**Figure 5–98: AUTORECLOSURE SCHEME LOGIC (Sheet 2 of 2)**

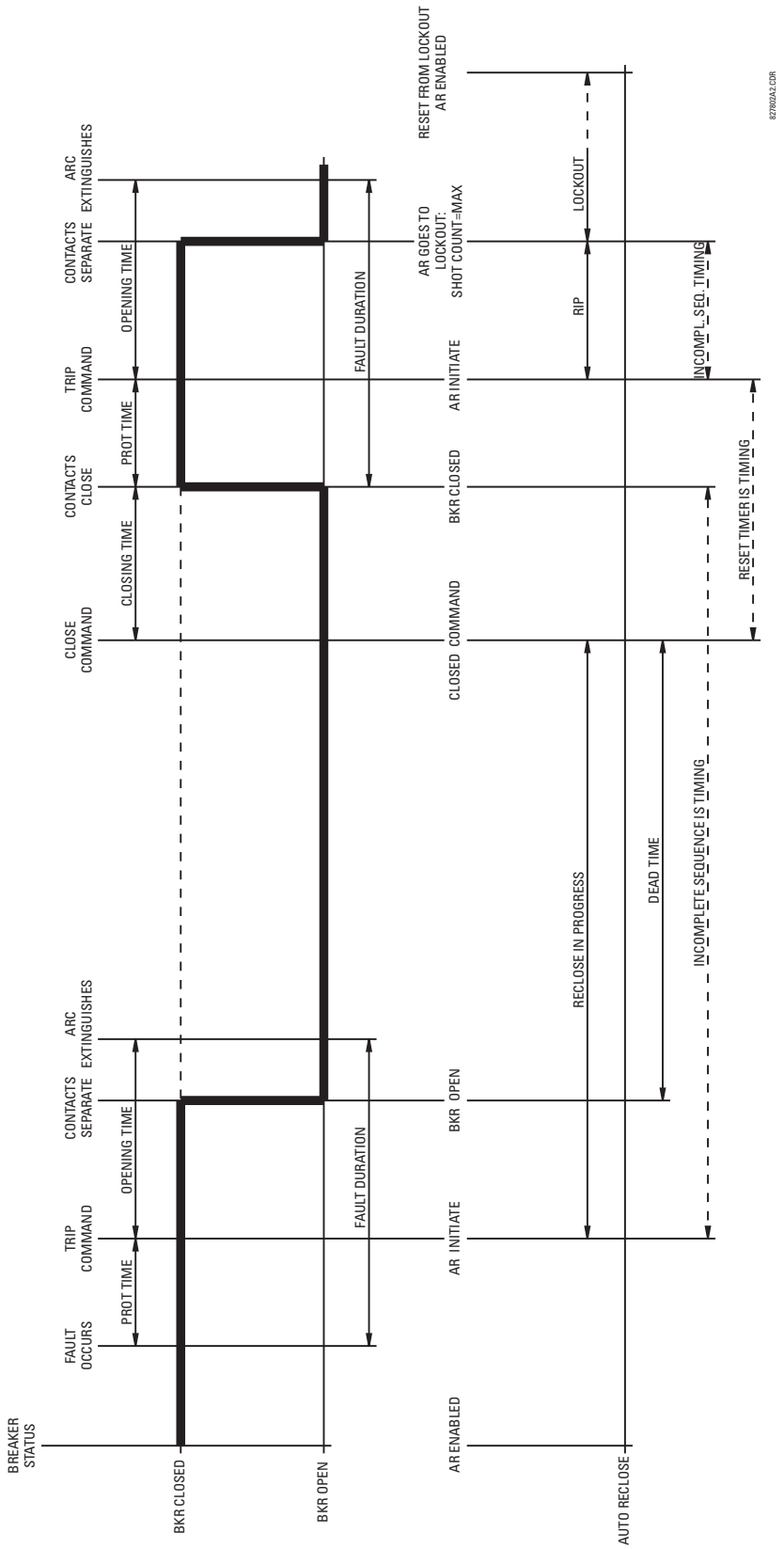
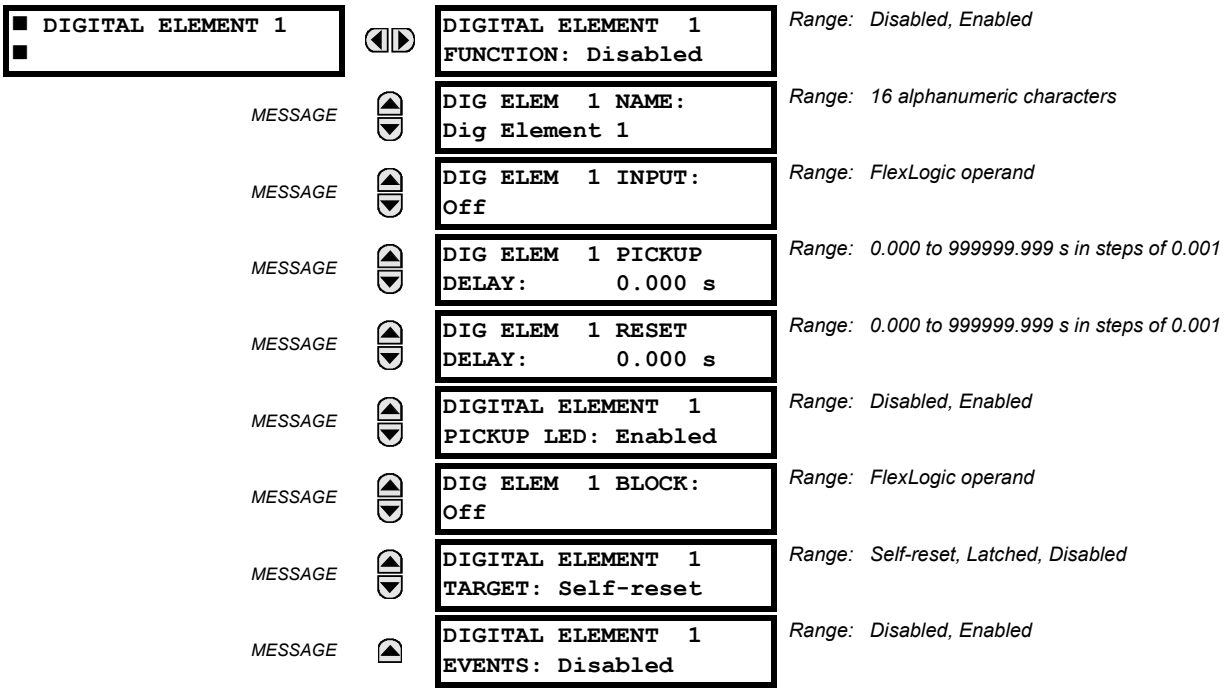



**Figure 5–99: SINGLE SHOT AUTORECLOSING SEQUENCE - PERMANENT FAULT**

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ DIGITAL ELEMENTS ⇨ DIGITAL ELEMENT 1(48)




NOTE

Digital elements run once per power system cycle.

As such they can easily fail to react to an input signal or a block signal with a duration less than one power system cycle. This also means that digital element output can react up to one power system cycle later than the pickup and reset delay settings indicate.

Do not use digital elements with transient signals, such as communications commands. Do not use digital elements where random delays of up to one cycle cannot be tolerated, such as in high speed protection.

There are 48 identical digital elements available, numbered 1 to 48. A digital element can monitor any FlexLogic operand and present a target message and/or enable events recording depending on the output operand state. The digital element settings include a name which will be referenced in any target message, a blocking input from any selected FlexLogic operand, and a timer for pickup and reset delays for the output operand.

- **DIGITAL ELEMENT 1 INPUT:** Selects a FlexLogic operand to be monitored by the digital element.
- **DIGITAL ELEMENT 1 PICKUP DELAY:** Sets the required time delay from element pickup to element operation. If a pickup delay is not required, set to "0". To avoid nuisance alarms, set the delay greater than the operating time of the breaker.
- **DIGITAL ELEMENT 1 RESET DELAY:** Sets the time delay to reset. If a reset delay is not required, set to “0”.
- **DIGITAL ELEMENT 1 PICKUP LED**: This setting enables or disabled the digital element pickup LED. When set to “Disabled”, the operation of the pickup LED is blocked.

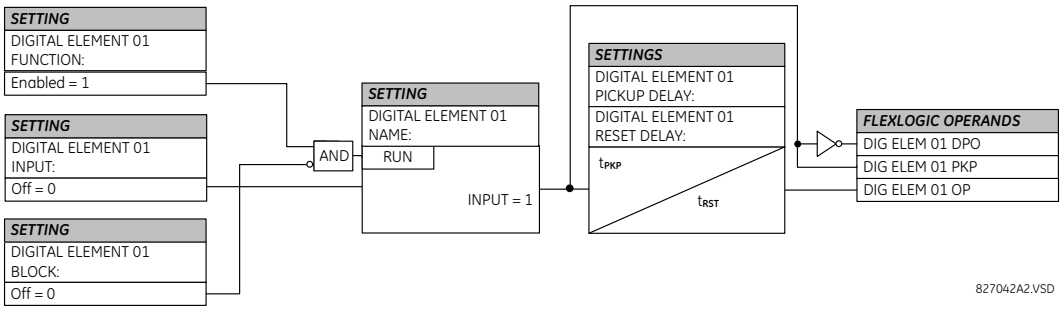



**Figure 5–100: DIGITAL ELEMENT SCHEME LOGIC**

**CIRCUIT MONITORING APPLICATIONS:**

Some versions of the digital input modules include an active voltage monitor circuit connected across form-A contacts. The voltage monitor circuit limits the trickle current through the output circuit (see technical specifications for form-A).

As long as the current through the voltage monitor is above a threshold (see technical specifications for form-A), the "Cont Op 1 VOn" FlexLogic operand will be set (for contact input 1 – corresponding operands exist for each contact output). If the output circuit has a high resistance or the DC current is interrupted, the trickle current will drop below the threshold and the "Cont Op 1 VOff" FlexLogic operand will be set. Consequently, the state of these operands can be used as indicators of the integrity of the circuits in which form-A contacts are inserted.

**EXAMPLE 1: BREAKER TRIP CIRCUIT INTEGRITY MONITORING**

In many applications it is desired to monitor the breaker trip circuit integrity so problems can be detected before a trip operation is required. The circuit is considered to be healthy when the voltage monitor connected across the trip output contact detects a low level of current, well below the operating current of the breaker trip coil. If the circuit presents a high resistance, the trickle current will fall below the monitor threshold and an alarm would be declared.

In most breaker control circuits, the trip coil is connected in series with a breaker auxiliary contact which is open when the breaker is open (see diagram below). To prevent unwanted alarms in this situation, the trip circuit monitoring logic must include the breaker position.

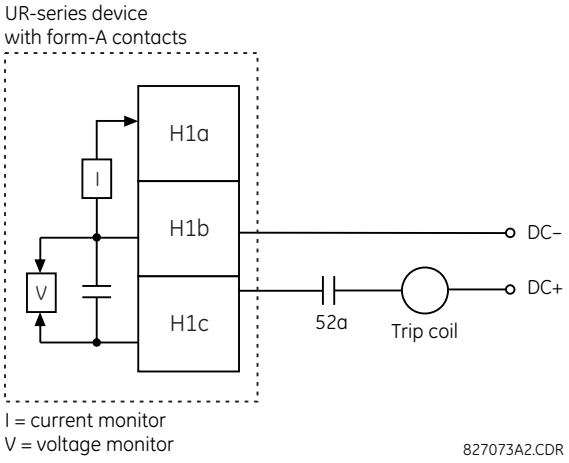
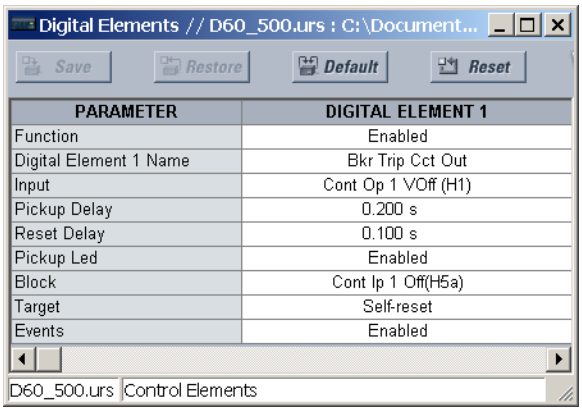


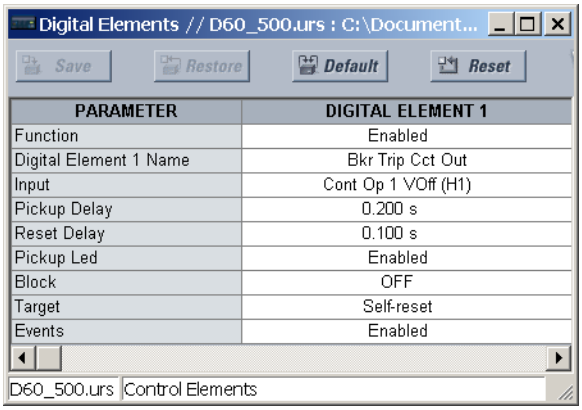

**Figure 5–101: TRIP CIRCUIT EXAMPLE 1**

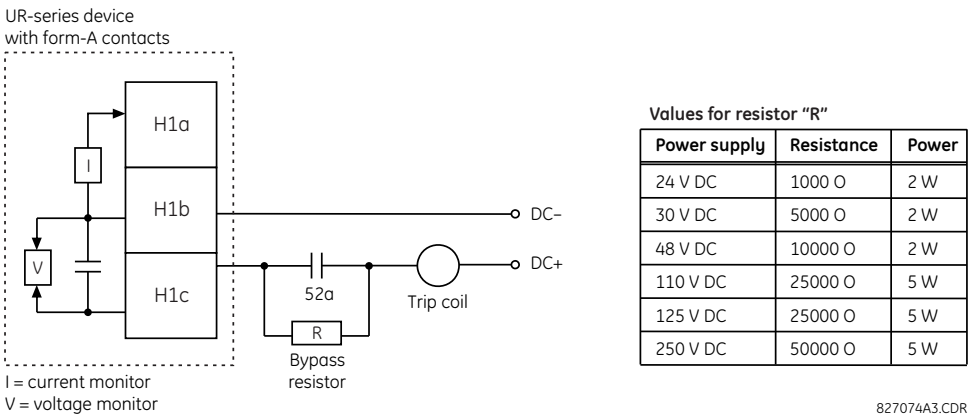
Assume the output contact H1 is a trip contact. Using the contact output settings, this output will be given an ID name; for example, “Cont Op 1". Assume a 52a breaker auxiliary contact is connected to contact input H5a to monitor breaker status. Using the contact input settings, this input will be given an ID name, for example, “Cont Ip 1", and will be set “On” when the breaker is closed. The settings to use digital element 1 to monitor the breaker trip circuit are indicated below (EnerVista UR Setup example shown):




**EXAMPLE 2: BREAKER TRIP CIRCUIT INTEGRITY MONITORING**

If it is required to monitor the trip circuit continuously, independent of the breaker position (open or closed), a method to maintain the monitoring current flow through the trip circuit when the breaker is open must be provided (as shown in the figure below). This can be achieved by connecting a suitable resistor (see figure below) across the auxiliary contact in the trip circuit. In this case, it is not required to supervise the monitoring circuit with the breaker position – the **BLOCK** setting is selected to “Off”. In this case, the settings are as follows (EnerVista UR Setup example shown).




Values for resistor “R”

| Power supply | Resistance | Power |
|---|---|---|
| 24 V DC | 1000 Ω | 2 W |
| 30 V DC | 5000 Ω | 2 W |
| 48 V DC | 10000 Ω | 2 W |
| 110 V DC | 25000 Ω | 5 W |
| 125 V DC | 25000 Ω | 5 W |
| 250 V DC | 50000 Ω | 5 W |

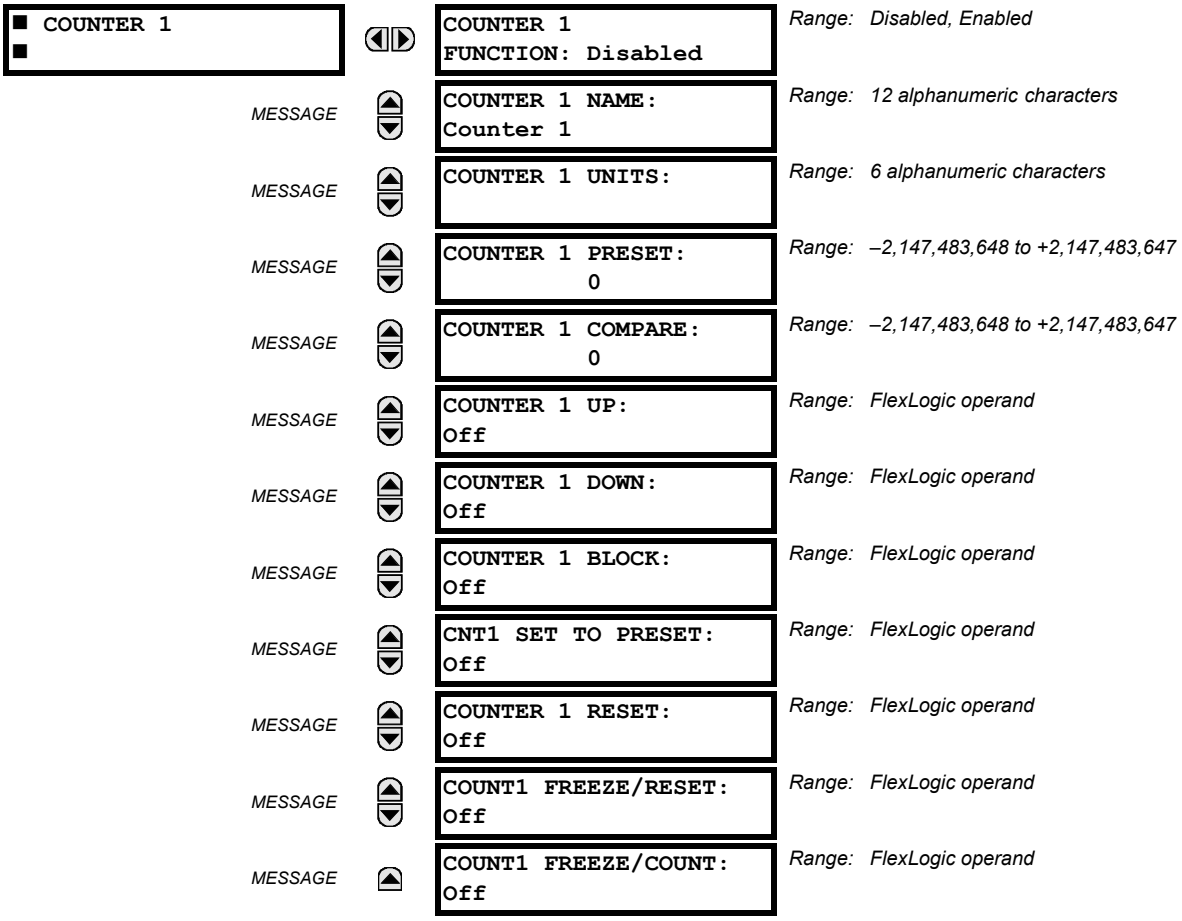
**Figure 5–102: TRIP CIRCUIT EXAMPLE 2**

NOTE

The wiring connection for two examples above is applicable to both form-A contacts with voltage monitoring and solid-state contact with voltage monitoring.

## 5.7.9 DIGITAL COUNTERS

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ DIGITAL COUNTERS ⇨ COUNTER 1(8)




There are eight identical digital counters, numbered from 1 to 8. A digital counter counts the number of state transitions from Logic 0 to Logic 1. The counter is used to count operations such as the pickups of an element, the changes of state of an external contact (e.g. breaker auxiliary switch), or pulses from a watt-hour meter.

- **COUNTER 1 UNITS:** Assigns a label to identify the unit of measure pertaining to the digital transitions to be counted. The units label will appear in the corresponding actual values status.
- **COUNTER 1 PRESET:** Sets the count to a required preset value before counting operations begin, as in the case where a substitute relay is to be installed in place of an in-service relay, or while the counter is running.
- **COUNTER 1 COMPARE:** Sets the value to which the accumulated count value is compared. Three FlexLogic output operands are provided to indicate if the present value is 'more than (HI)', 'equal to (EQL)', or 'less than (LO)' the set value.
- **COUNTER 1 UP:** Selects the FlexLogic operand for incrementing the counter. If an enabled UP input is received when the accumulated value is at the limit of +2,147,483,647 counts, the counter will rollover to –2,147,483,648.
- **COUNTER 1 DOWN:** Selects the FlexLogic operand for decrementing the counter. If an enabled DOWN input is received when the accumulated value is at the limit of –2,147,483,648 counts, the counter will rollover to +2,147,483,647.
- **COUNTER 1 BLOCK:** Selects the FlexLogic operand for blocking the counting operation. All counter operands are blocked.

- **CNT1 SET TO PRESET:** Selects the FlexLogic operand used to set the count to the preset value. The counter will be set to the preset value in the following situations:
  1. When the counter is enabled and the **CNT1 SET TO PRESET** operand has the value 1 (when the counter is enabled and **CNT1 SET TO PRESET** operand is 0, the counter will be set to 0).
  2. When the counter is running and the **CNT1 SET TO PRESET** operand changes the state from 0 to 1 (**CNT1 SET TO PRESET** changing from 1 to 0 while the counter is running has no effect on the count).
  3. When a reset or reset/freeze command is sent to the counter and the **CNT1 SET TO PRESET** operand has the value 1 (when a reset or reset/freeze command is sent to the counter and the **CNT1 SET TO PRESET** operand has the value 0, the counter will be set to 0).
- **COUNTER 1 RESET:** Selects the FlexLogic operand for setting the count to either "0" or the preset value depending on the state of the **CNT1 SET TO PRESET** operand.
- **COUNTER 1 FREEZE/RESET:** Selects the FlexLogic operand for capturing (freezing) the accumulated count value into a separate register with the date and time of the operation, and resetting the count to "0".
- **COUNTER 1 FREEZE/COUNT:** Selects the FlexLogic operand for capturing (freezing) the accumulated count value into a separate register with the date and time of the operation, and continuing counting. The present accumulated value and captured frozen value with the associated date/time stamp are available as actual values. If control power is interrupted, the accumulated and frozen values are saved into non-volatile memory during the power down operation.

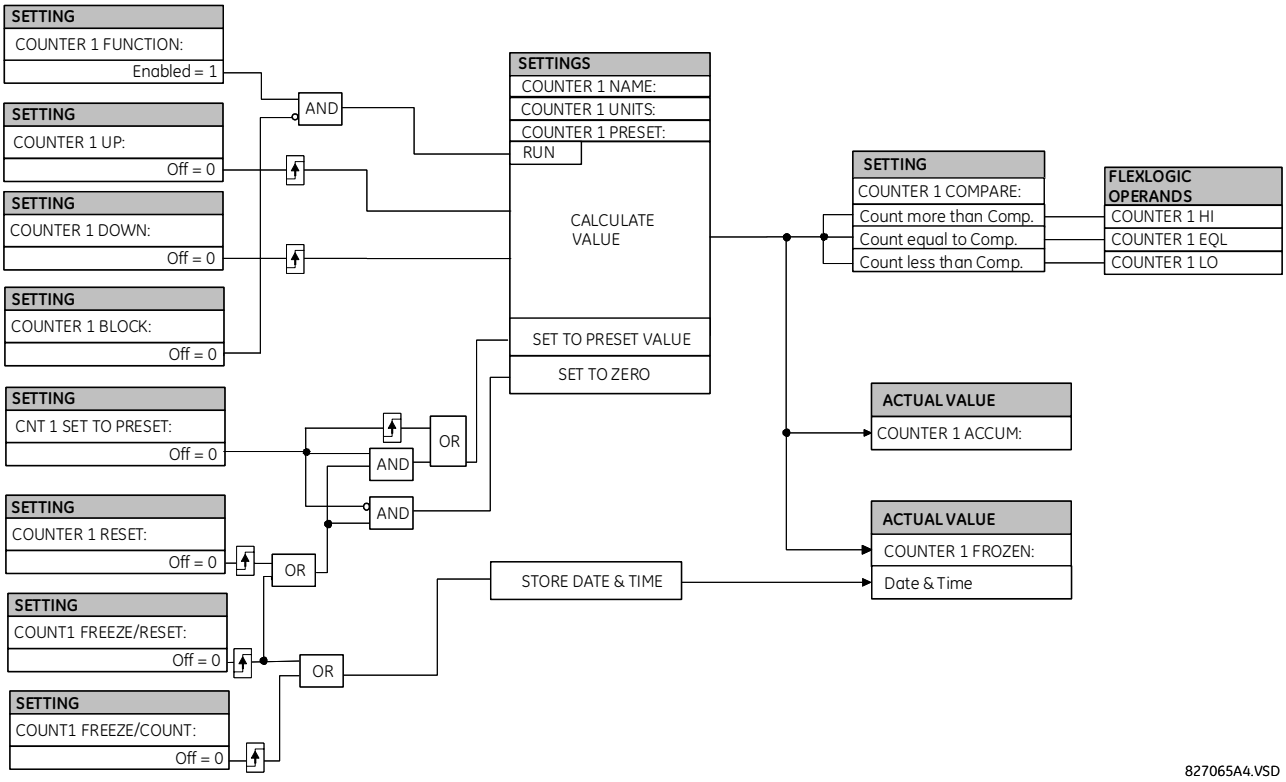



**Figure 5–103: DIGITAL COUNTER SCHEME LOGIC**

### a) MAIN MENU

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS

| | | | |
|---|---|---|---|
| ■ MONITORING<br>■ ELEMENTS | ◀▶ | ■ BREAKER 1<br>■ ARCING CURRENT | See page 5–236. |
| | MESSAGE ▲▼ | ■ BREAKER 2<br>■ ARCING CURRENT | See page 5–236. |
| | MESSAGE ▲▼ | ■ CT FAILURE<br>■ DETECTOR 1 | See page 5–239. |
| | MESSAGE ▲▼ | ■ CT FAILURE<br>■ DETECTOR 2 | See page 5–239. |
| | MESSAGE ▲▼ | ■ VT FUSE FAILURE 1<br>■ | See page 5–240. |
| | MESSAGE ▲▼ | ■ VT FUSE FAILURE 2<br>■ | See page 5–240. |
| | MESSAGE ▲▼ | ■ BROKEN CONDUCTOR 1<br>■ | See page 5–242. |
| | MESSAGE ▲▼ | ■ BROKEN CONDUCTOR 2<br>■ | See page 5–242. |
| | MESSAGE ▲ | ■ THERMAL OVERLOAD<br>■ PROTECTION | See page 5–244. |

### b) BREAKER ARCING CURRENT

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨ BREAKER 1(2) ARCING CURRENT

| | | | |
|---|---|---|---|
| ■ BREAKER 1<br>■ ARCING CURRENT | ◀▶ | BKR 1 ARC AMP<br>FUNCTION: Disabled | *Range: Disabled, Enabled* |
| | MESSAGE ▲▼ | BKR 1 ARC AMP<br>SOURCE: SRC 1 | *Range: SRC 1, SRC 2* |
| | MESSAGE ▲▼ | BKR 1 ARC AMP INT-A:<br>Off | *Range: FlexLogic operand* |
| | MESSAGE ▲▼ | BKR 1 ARC AMP INT-B:<br>Off | *Range: FlexLogic operand* |
| | MESSAGE ▲▼ | BKR 1 ARC AMP INT-C:<br>Off | *Range: FlexLogic operand* |
| | MESSAGE ▲▼ | BKR 1 ARC AMP<br>DELAY: 0.000 s | *Range: 0.000 to 65.535 s in steps of 0.001* |
| | MESSAGE ▲▼ | BKR 1 ARC AMP LIMIT:<br>1000 kA2-cyc | *Range: 0 to 50000 kA$^2$-cycle in steps of 1* |
| | MESSAGE ▲▼ | BKR 1 ARC AMP BLOCK:<br>Off | *Range: FlexLogic operand* |
| | MESSAGE ▲▼ | BKR 1 ARC AMP<br>TARGET: Self-reset | *Range: Self-reset, Latched, Disabled* |
| | MESSAGE ▲ | BKR 1 ARC AMP<br>EVENTS: Disabled | *Range: Disabled, Enabled* |

There is one breaker arcing current element available per CT bank, with a minimum of two elements. This element calculates an estimate of the per-phase wear on the breaker contacts by measuring and integrating the current squared passing through the breaker contacts as an arc. These per-phase values are added to accumulated totals for each phase and compared to a programmed threshold value. When the threshold is exceeded in any phase, the relay can set an output operand to "1". The accumulated value for each phase can be displayed as an actual value.

The operation of the scheme is shown in the following logic diagram. The same output operand that is selected to operate the output relay used to trip the breaker, indicating a tripping sequence has begun, is used to initiate this feature. A time delay is introduced between initiation and the starting of integration to prevent integration of current flow through the breaker before the contacts have parted. This interval includes the operating time of the output relay, any other auxiliary relays and the breaker mechanism. For maximum measurement accuracy, the interval between change-of-state of the operand (from 0 to 1) and contact separation should be measured for the specific installation. Integration of the measured current continues for 100 ms, which is expected to include the total arcing period.

The feature is programmed to perform fault duration calculations. Fault duration is defined as a time between operation of the disturbance detector occurring before initiation of this feature, and reset of an internal low-set overcurrent function. Correction is implemented to account for a non-zero reset time of the overcurrent function.

Breaker arcing currents and fault duration values are available under the **ACTUAL VALUES** ⇨⇩ **RECORDS** ⇨⇩ **MAINTENANCE** ⇨ **BREAKER 1(2)** menus.

- **BKR 1 ARC AMP INT-A(C):** Select the same output operands that are configured to operate the output relays used to trip the breaker. In three-pole tripping applications, the same operand should be configured to initiate arcing current calculations for poles A, B and C of the breaker. In single-pole tripping applications, per-pole tripping operands should be configured to initiate the calculations for the poles that are actually tripped.
- **BKR 1 ARC AMP DELAY:** This setting is used to program the delay interval between the time the tripping sequence is initiated and the time the breaker contacts are expected to part, starting the integration of the measured current.
- **BKR 1 ARC AMP LIMIT:** Selects the threshold value above which the output operand is set.

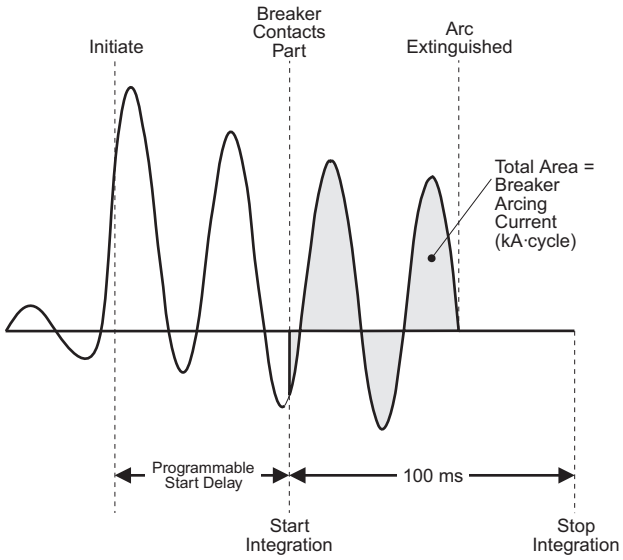



**Figure 5–104: ARCING CURRENT MEASUREMENT**

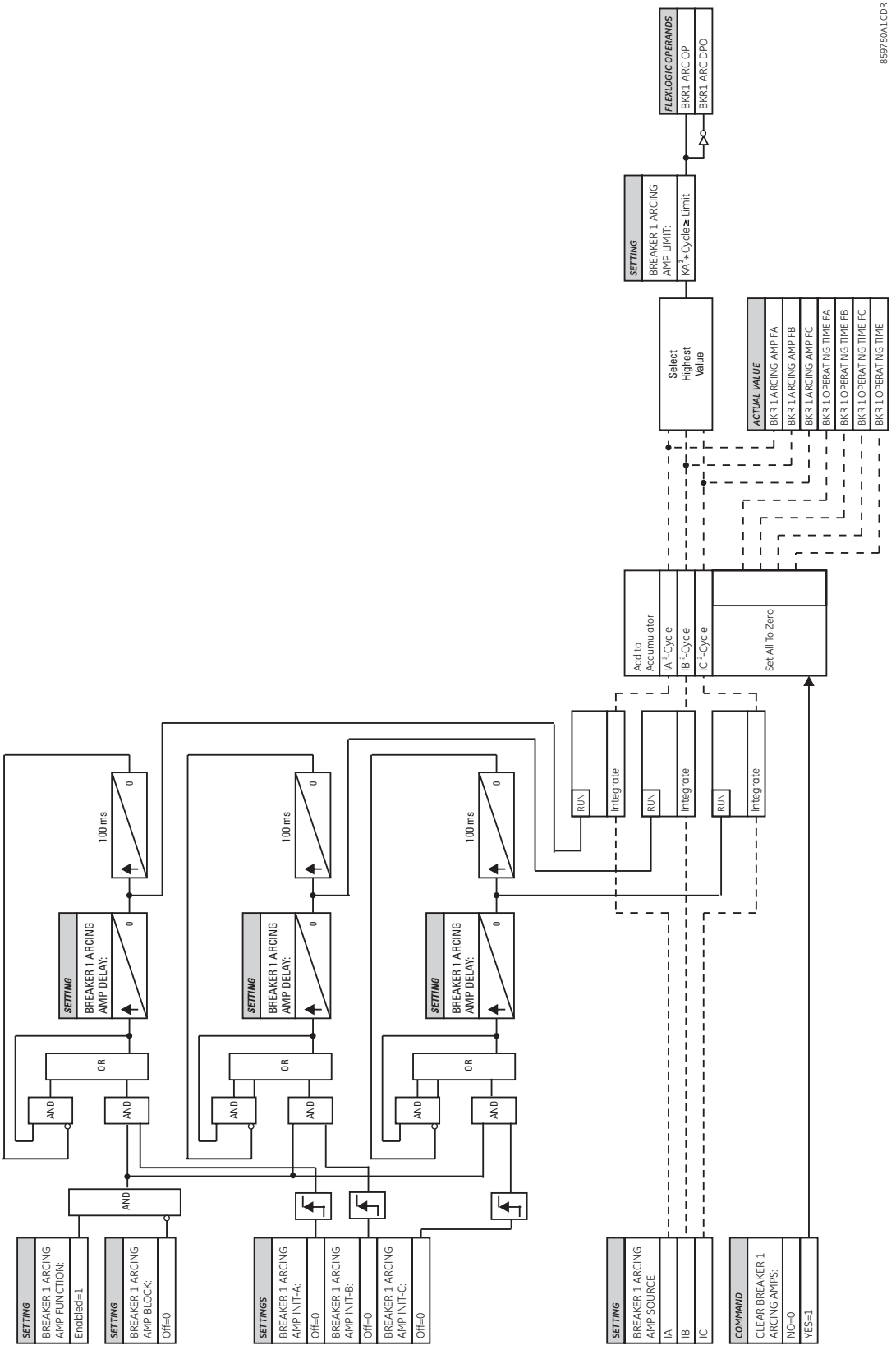



**Figure 5–105: BREAKER ARCING CURRENT SCHEME LOGIC**

### c) CT FAILURE DETECTOR

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ CT FAILURE DETECTOR 1(2)

| | | | |
|---|---|---|---|
| ■ CT FAILURE<br>■ DETECTOR 1 | | CT FAIL 1 FUNCTION:<br>Disabled | *Range: Disabled, Enabled* |
| | *MESSAGE* | CT FAIL 1 BLOCK:<br>Off | *Range: FlexLogic operand* |
| | *MESSAGE* | CT FAIL 1 3I0 INP 1:<br>SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | CT FAIL 1 3I0 INP 1<br>PKP: 0.2 pu | *Range: 0.0 to 2.0 pu in steps of 0.1* |
| | *MESSAGE* | CT FAIL 1 3I0 INP 2:<br>SRC 2 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | CT FAIL 1 3I0 INP 2<br>PKP: 0.2 pu | *Range: 0.0 to 2.0 pu in steps of 0.1* |
| | *MESSAGE* | CT FAIL 1 3V0 INPUT:<br>SRC 1 | *Range: SRC 1, SRC 2* |
| | *MESSAGE* | CT FAIL 1 3V0 INPUT<br>PKP: 0.20 pu | *Range: 0.00 to 2.00 pu in steps of 0.01* |
| | *MESSAGE* | CT FAIL 1 PICKUP<br>DELAY: 1.000 s | *Range: 0.000 to 65.535 s in steps of 0.001* |
| | *MESSAGE* | CT FAIL 1 TARGET:<br>Self-reset | *Range: Self-reset, Latched, Disabled* |
| | *MESSAGE* | CT FAIL 1 EVENTS:<br>Disabled | *Range: Disabled, Enabled* |

The CT failure function is designed to detect problems with system current transformers used to supply current to the relay. This logic detects the presence of a zero-sequence current at the supervised source of current without a simultaneous zero-sequence current at another source, zero-sequence voltage, or some protection element condition.

The CT failure logic (see below) is based on the presence of the zero-sequence current in the supervised CT source and the absence of one of three or all of the three following conditions.

1. Zero-sequence current at different source current (may be different set of CTs or different CT core of the same CT).
2. Zero-sequence voltage at the assigned source.
3. Appropriate protection element or remote signal.

The CT failure settings are described below.

- **CT FAIL 1 FUNCTION:** This setting enables or disables operation of the CT failure element.
- **CT FAIL 1 BLOCK:** This setting selects a FlexLogic operand to block operation of the element during some condition (for example, an open pole in process of the single pole tripping-reclosing) when CT fail should be blocked. Local signals or remote signals representing operation of some remote current protection elements via communication channels can also be chosen.
- **CT FAIL 1 3I0 INPUT 1:** This setting selects the current source for input 1. The most critical protection element should also be assigned to the same source.
- **CT FAIL 1 3I0 INPUT 1 PICKUP:** This setting selects the 3I_0 pickup value for input 1 (the main supervised CT source).
- **CT FAIL 1 3I0 INPUT 2**: This setting selects the current source for input 2. Input 2 should use a different set of CTs or a different CT core of the same CT. If 3I_0 does not exist at source 2, then a CT failure is declared.
- **CT FAIL 1 3I0 INPUT 2 PICKUP**: This setting selects the 3I_0 pickup value for input 2 (different CT input) of the relay.

- **CT FAIL 1 3V0 INPUT:** This setting selects the voltage source.
- **CT FAIL 1 3V0 INPUT PICKUP:** This setting specifies the pickup value for the 3V_0 source.
- **CT FAIL 1 PICKUP DELAY:** This setting specifies the pickup delay of the CT failure element.

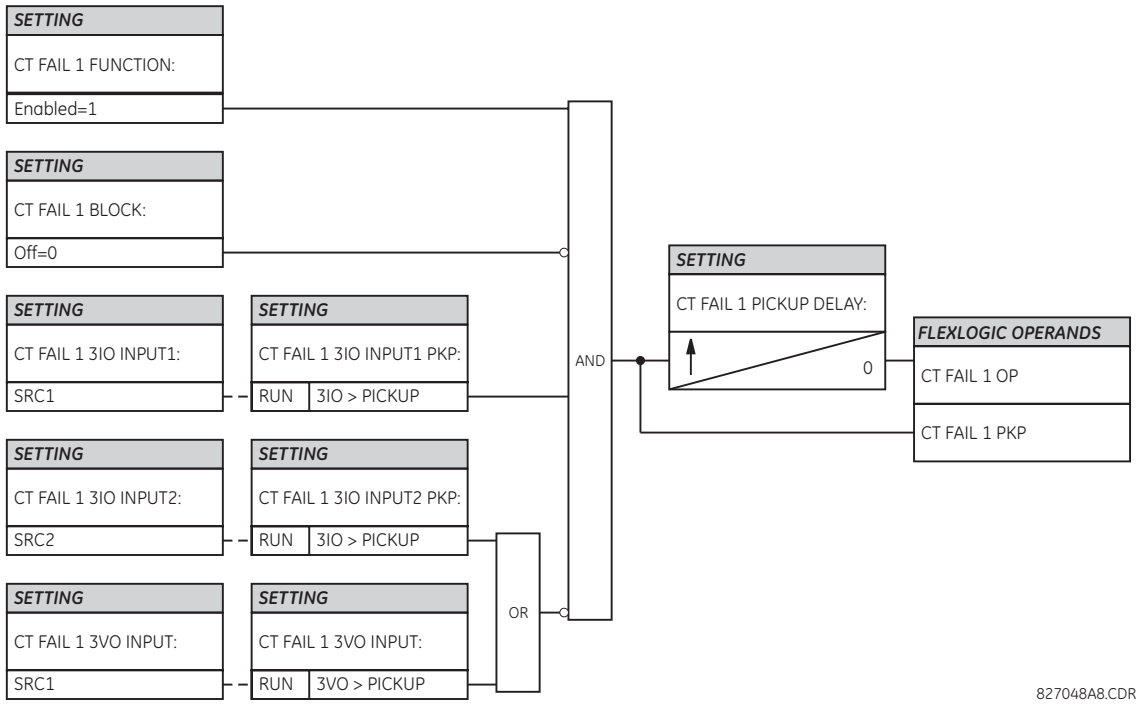
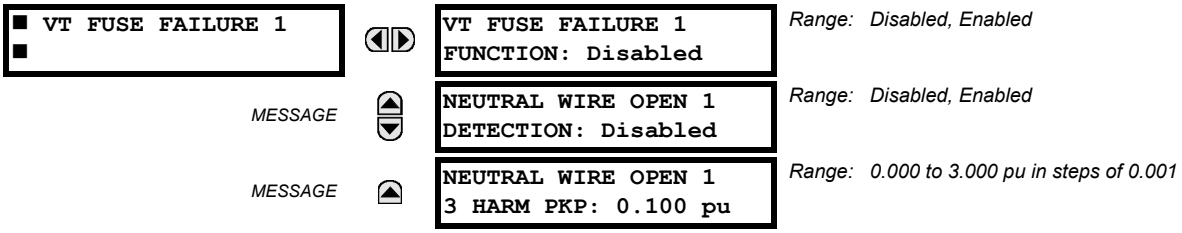



**Figure 5–106: CT FAILURE DETECTOR SCHEME LOGIC**

### d) VT FUSE FAILURE

**PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ VT FUSE FAILURE 1(2)**




Every signal source includes a fuse failure scheme. A signal source must have a three-phase VT bank and a three-phase CT bank assigned to it, in order for the fuse failure scheme to operate.

The VT fuse failure detector can be used to raise an alarm and/or block elements that may operate incorrectly for a full or partial loss of AC potential caused by one or more blown fuses. Some elements that might be blocked (via the BLOCK input) are distance, voltage restrained overcurrent, and directional current.

There are two classes of fuse failure that occur:

- Class A: loss of one or two phases.
- Class B: loss of all three phases.

Different means of detection are required for each class. An indication of class A failures is a significant level of negative-sequence voltage, whereas an indication of class B failures is when positive sequence current is present and there is an insignificant amount of positive sequence voltage. Also rapid decrease in the phase voltages magnitude from a healthy

voltage level without disturbance in current can indicate a VT fuse fail conditions. These noted indications of fuse failure can also be present when faults are present on the system, so a means of detecting faults and inhibiting fuse failure declarations during these events is provided.

Once the fuse failure condition is declared, it is sealed-in until the cause that generated it disappears.

An additional condition is introduced to inhibit a fuse failure declaration when the monitored circuit is de-energized; positive-sequence voltage and current are both below threshold levels.

The **VT FUSE FAILURE 1 FUNCTION** setting enables and disables the fuse failure feature for Source 1 VT Fuse Fail.

The **VT NEU WIRE OPEN 1 FUNCTION** setting enables and disables the VT neutral wire open detection function. When the VT is connected in Delta, do not enabled this function because there is no neutral wire for Delta connected VT.

The **VT NEU WIRE OPEN 1 3 HRAM PKP** setting specifies the pickup level of 3rd harmonic of 3V0 signal for the **VT NEU WIRE OPEN** detection logic to pick up.

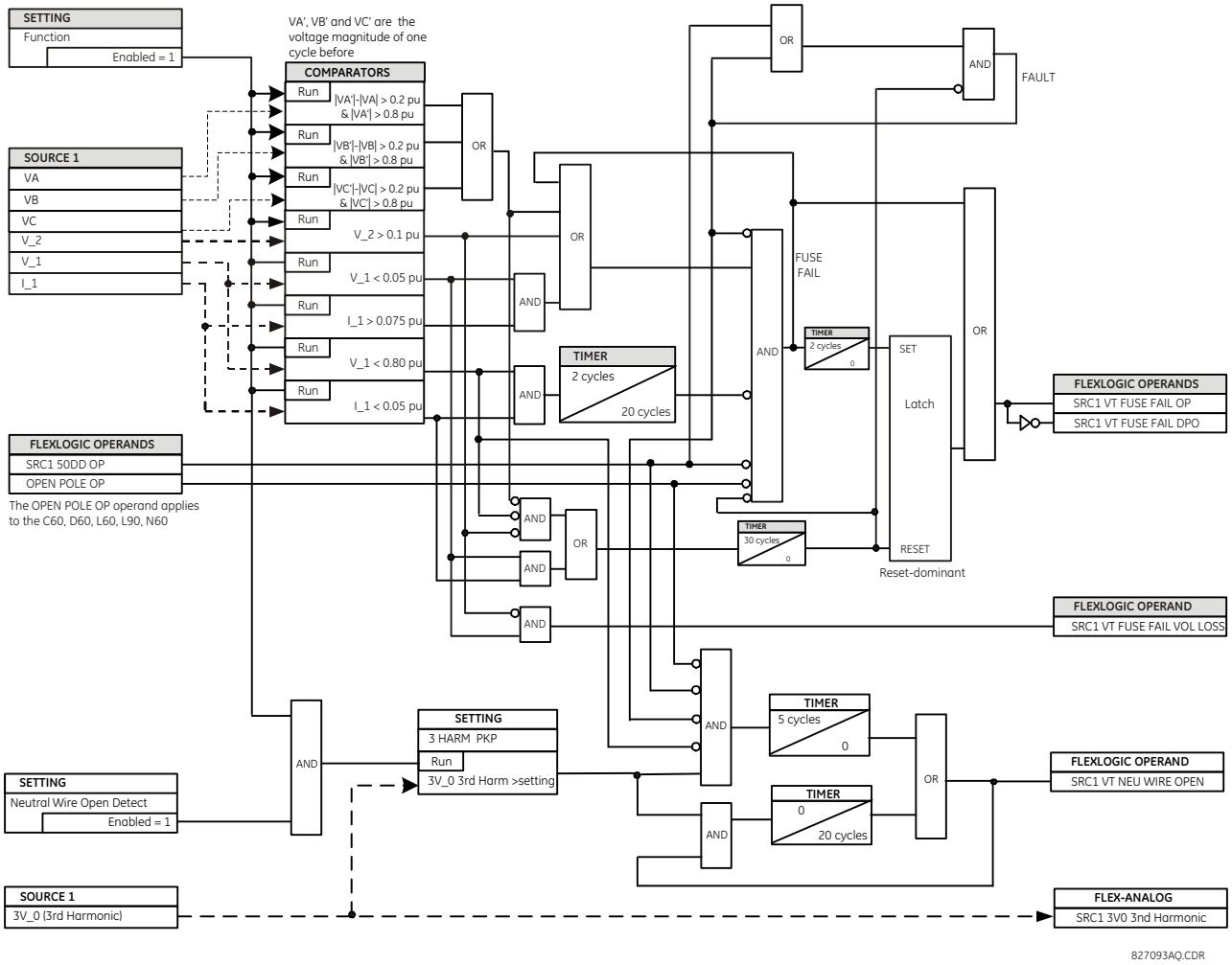
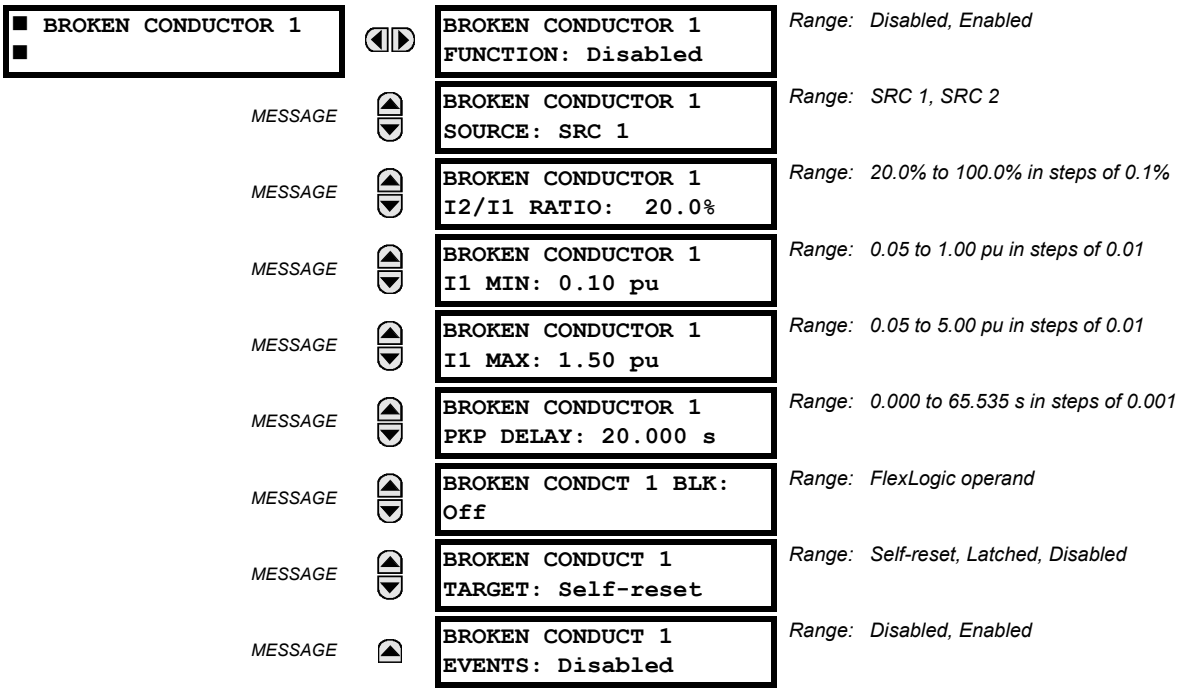



**Figure 5–107: VT FUSE FAIL SCHEME LOGIC**

Base voltage for this element is **PHASE VT SECONDARY** setting in the case of WYE VTs and (**PHASE VT SECONDARY**)/ $\sqrt{3}$ in case of DELTA VTs.

### e) BROKEN CONDUCTOR DETECTION

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ BROKEN CONDUCTOR 1(2)




The broken conductor function will detect a transmission line broken conductor condition or a single-pole breaker malfunction condition through checking the phase current input signals and the I_2 / I_1 ratio. The intention of this function is to detect a single-phase broken conductor only. As such two-phase or three-phase broken conductors cannot be detected.

To distinguish between single-phase disappearance and system disturbance in all three phases (such as load change, switching, etc.), the broken conductor element monitors the change in all three phase currents at the present instance and at four cycles previous. It also monitors changes in the I_2 / I_1 ratio, I_1 minimum, and I_1 maximum.

The broken conductor function should not be used to respond to fault transients and single-pole tripping/reclosing conditions. Therefore, the time delay should be programmed to a sufficient length to ensure coordination with the breaker dead time of the recloser function.

- **BROKEN CONDUCTOR 1 FUNCTION**: This setting enables and disables the broken conductor function.
- **BROKEN CONDUCTOR 1 SOURCE**: This setting selects a signal source used to provide three-phase current inputs to this function.
- **BROKEN CONDUCTOR 1 I2/I1 RATIO**: This setting specifies the ratio of negative-sequence current to positive-sequence current. When one phase conductor is broken, the I_2 / I_1 ratio with a balanced remaining two phases is 50%. So normally this setting should be set below 50% (for example, to 30%).
- **BROKEN CONDUCTOR 1 I1 MIN**: This setting specifies the minimum positive-sequence current supervision level. Ensure this setting is programmed to a sufficient level to prevent I_2 / I_1 from erratic pickup due to a low I_1 signal. However, this setting should not be set too high, since the broken conductor condition cannot be detected under light load conditions when I_1 is less than the value specified by this setting.
- **BROKEN CONDUCTOR 1 I1 MAX**: This setting specifies the maximum I_1 level allowed for the broken conductor function to operate. When I_1 exceeds this setting, this it is considered a fault. This broken conductor function should not respond to any fault conditions, so normally this setting is programmed to less than the maximum load current.
- **BROKEN CONDUCTOR 1 PKP DELAY**: This setting specifies the pickup time delay for this function to operate after assertion of the broken conductor pickup FlexLogic operand.

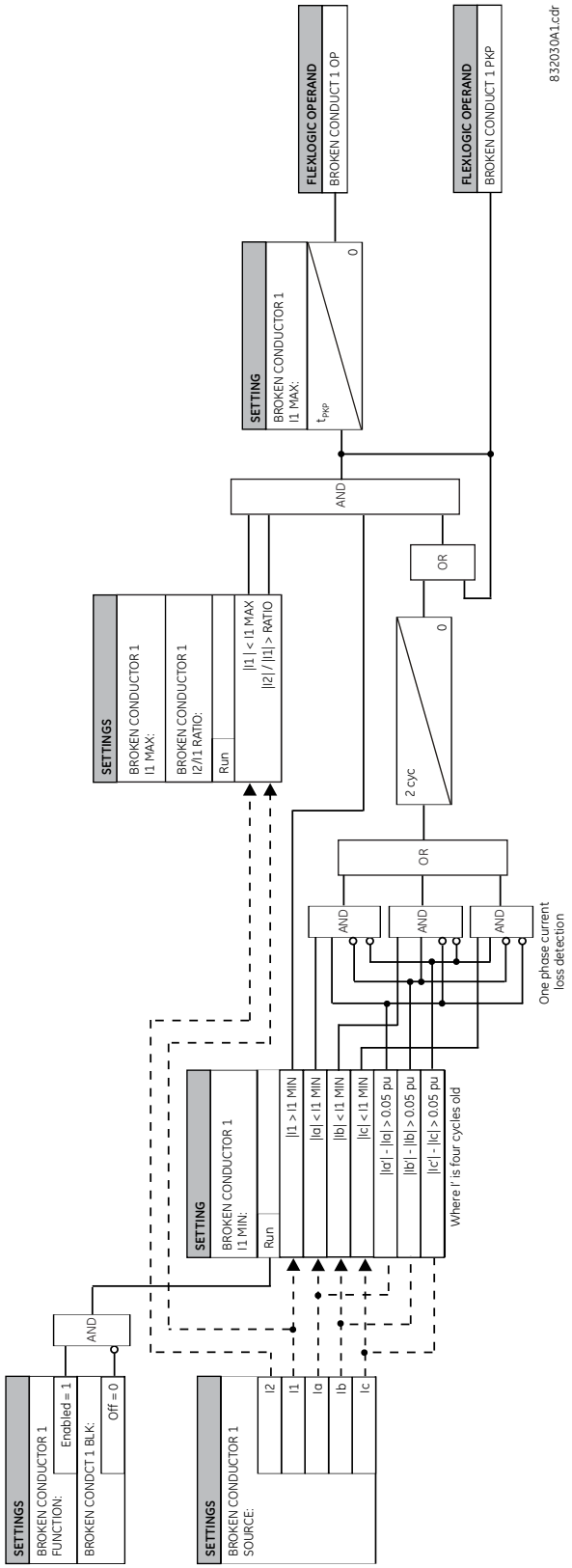



**Figure 5–108: BROKEN CONDUCTOR DETECTION LOGIC**

### f) THERMAL OVERLOAD PROTECTION (ANSI 49)

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ THERMAL OVERLOAD PROTECTION ⇨ THERMAL PROTECTION 1(2)

| | | | |
|---|---|---|---|
| ■ THERMAL<br>■ PROTECTION 1 | | THERMAL PROTECTION 1<br>FUNCTION: Disabled | Range: Disabled, Enabled |
| | MESSAGE | THERMAL PROTECTION 1<br>SOURCE: SRC1 | Range: SRC 1, SRC 2 |
| | MESSAGE | THERMAL PROTECTION 1<br>BASE CURR: 0.80 pu | Range: 0.20 to 3.00 pu in steps of 0.01 |
| | MESSAGE | THERMAL PROTECTION 1<br>k FACTOR: 1.10 | Range: 1.00 to 1.20 in steps of 0.05 |
| | MESSAGE | THERM PROT 1 TRIP<br>TIME CONST: 45 min | Range: 0 to 1000 minutes in steps of 1 |
| | MESSAGE | THERM PROT 1 RESET<br>TIME CONST: 45 min | Range: 0 to 1000 minutes in steps of 1 |
| | MESSAGE | THERM PROT 1 MINIM<br>RESET TIME: 20 min | Range: 0 to 1000 minutes in steps of 1 |
| | MESSAGE | THERM PROT 1 RESET:<br>Off | Range: FlexLogic operand |
| | MESSAGE | THERM PROT 1 BLOCK:<br>Off | Range: FlexLogic operand |
| | MESSAGE | THERMAL PROTECTION 1<br>TARGET: Self-reset | Range: Self-reset, Latched, Disabled |
| | MESSAGE | THERMAL PROTECTION 1<br>EVENTS: Disabled | Range: Disabled, Enabled |

The thermal overload protection element corresponds to the IEC 255-8 standard and is used to detect thermal overload conditions in protected power system elements. Choosing an appropriate time constant element can be used to protect different elements of the power system. The cold curve characteristic is applied when the estimated $I_p$ current is less than 10% of the base current. If $I_p$ current is greater or equal than 10% than the base current, then the hot curve characteristic is applied. $I_p$ current is estimated with a fixed time constant for both cooling and heating that reaches to the final value in two seconds on a step change (either step up or step down) signal.

The IEC255-8 cold curve is defined as follows:

$$t_{op} = \tau_{op} \times \ln\left(\frac{I^2}{I^2 - (kI_B)^2}\right) \quad \textbf{(EQ 5.23)}$$

The IEC255-8 hot curve is defined as follows:

$$t_{op} = \tau_{op} \times \ln\left(\frac{I^2 - I_p^2}{I^2 - (kI_B)^2}\right) \quad \textbf{(EQ 5.24)}$$

In the above equations,

- $t_{op}$ = time to operate
- $\tau_{op}$ = thermal protection trip time constant
- $I$ = measured overload RMS current
- $I_p$ = measured load RMS current before overload occurs
- $k$= IEC 255-8 k-factor applied to $I_B$, defining maximum permissible current above nominal current

- $I_B$ = protected element base (nominal) current

To ensure element accuracy for high overcurrent conditions, the maximum value of I/(k x $I_B$) is limited to 8, even when realistically it is exceeding this value.

The reset time of the thermal overload protection element is also time delayed using following formula:

$$t_{rst} = \tau_{rst} \times \ln\left(\frac{(kI_B)^2}{\left|I^2 - (kI_B)^2\right|}\right) + T_{min} \quad \textbf{(EQ 5.25)}$$

In the above equation,

- $\tau_{rst}$ = thermal protection trip time constant
- $T_{min}$ is a minimum reset time setting

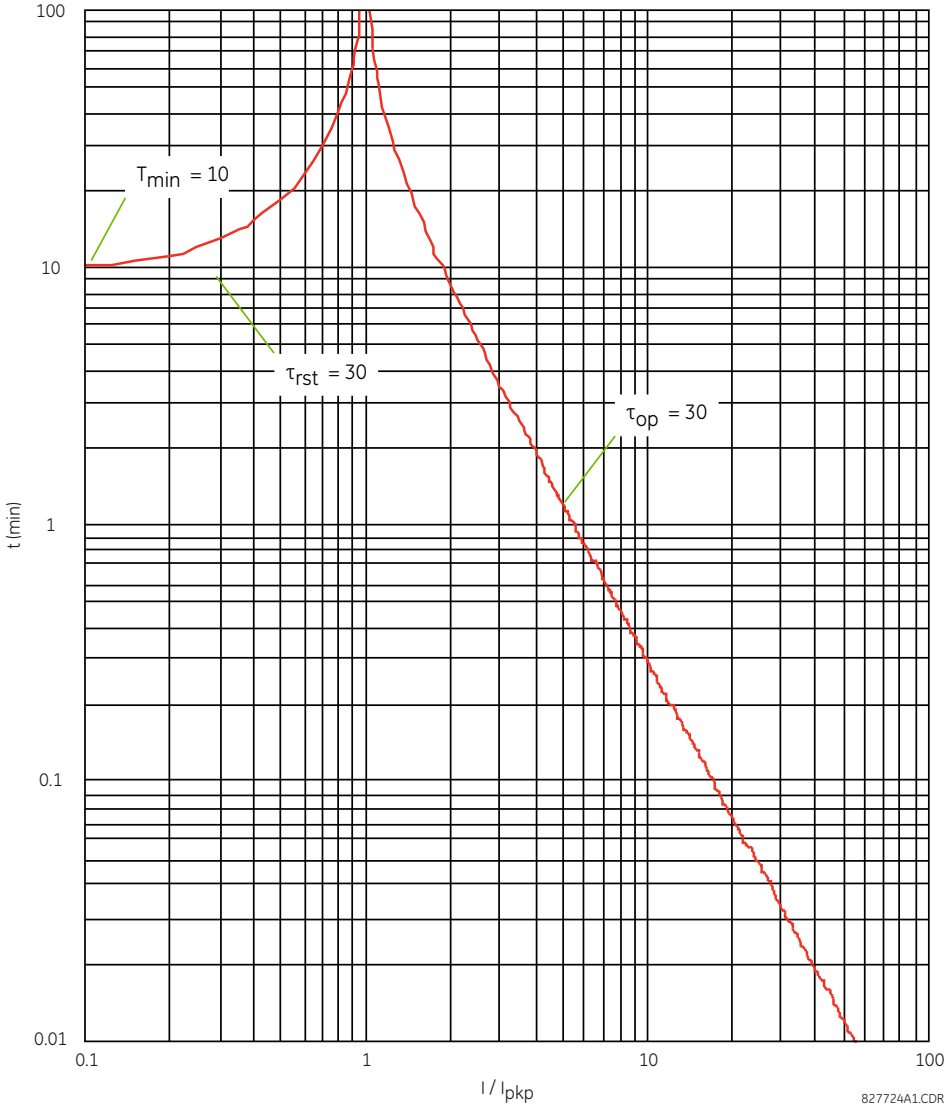



**Figure 5–109: IEC 255-8 SAMPLE OPERATE AND RESET CURVES**

The thermal overload protection element estimates accumulated thermal energy *E* using the following equations calculated each power cycle. When current is greater than the pickup level, $I_n > k \times I_B$, element starts increasing the thermal energy:

$$E_n = E_{n-1} + \frac{\Delta t}{t_{op(In)}} \quad \text{(EQ 5.26)}$$

When current is less than the dropout level, $I_n > 0.97 \times k \times I_B$, the element starts decreasing the thermal energy:

$$E_n = E_{n-1} - \frac{\Delta t}{t_{rst(In)}} \quad \text{(EQ 5.27)}$$

In the above equations,

- $\Delta t$ is the power cycle duration
- $n$ is the power cycle index
- $t_{op(In)}$ is the trip time calculated at index $n$ as per the IEC255-8 cold curve or hot curve equations
- $t_{rst(In)}$ is the reset time calculated at index $n$ as per the reset time equation
- $I_n$ is the measured overload RMS current at index $n$
- $E_n$ is the accumulated energy at index $n$
- $E_{n-1}$ is the accumulated energy at index $n - 1$

The thermal overload protection element removes the THERMAL PROT 1 OP output operand when $E < 0.05$. In case of emergency, the thermal memory and THERMAL PROT 1 OP output operand can be reset using **THERM PROT 1 RESET** setting. All calculations are performed per phase. If the accumulated energy reaches value 1 in any phase, the thermal overload protection element operates and only resets when energy is less than 0.05 in all three phases.

5

**Table 5–33: TYPICAL TIME CONSTANTS**

| PROTECTED EQUIPMENT | TIME CONSTANT | MINIMUM RESET TIME |
|---|---|---|
| Capacitor bank | 10 minutes | 30 minutes |
| Overhead line | 10 minutes | 20 minutes |
| Air-core reactor | 40 minutes | 30 minutes |
| Busbar | 60 minutes | 20 minutes |
| Underground cable | 20 to 60 minutes | 60 minutes |

The logic for the thermal overload protection element is shown below.

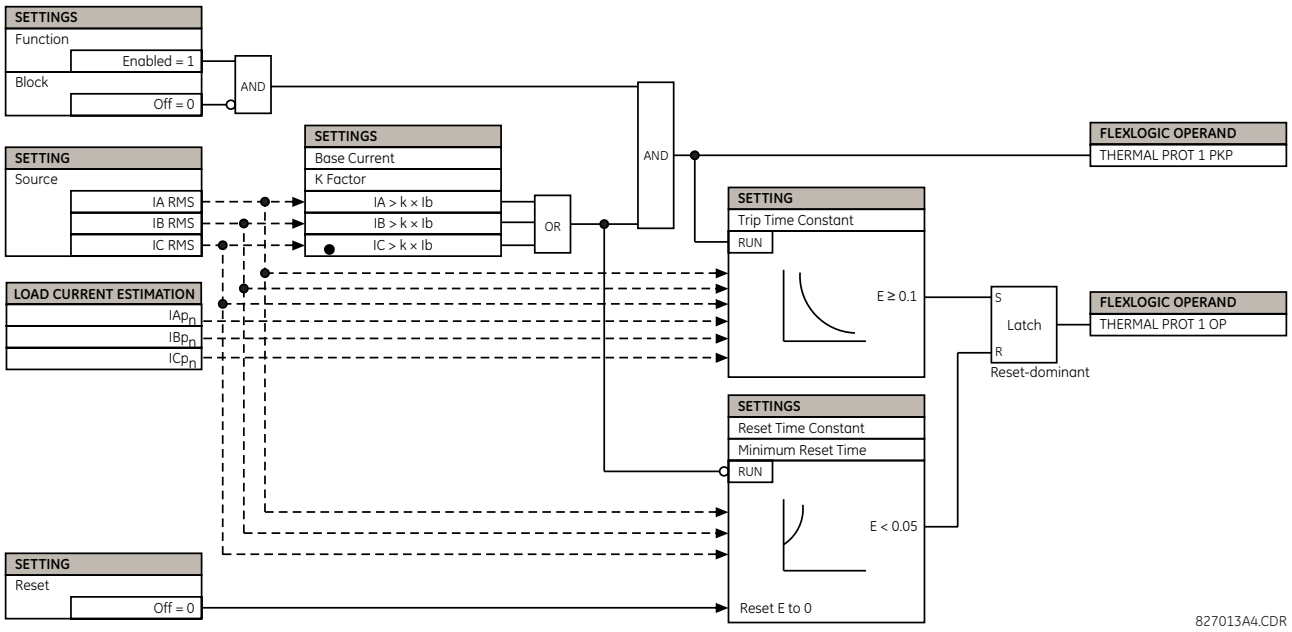
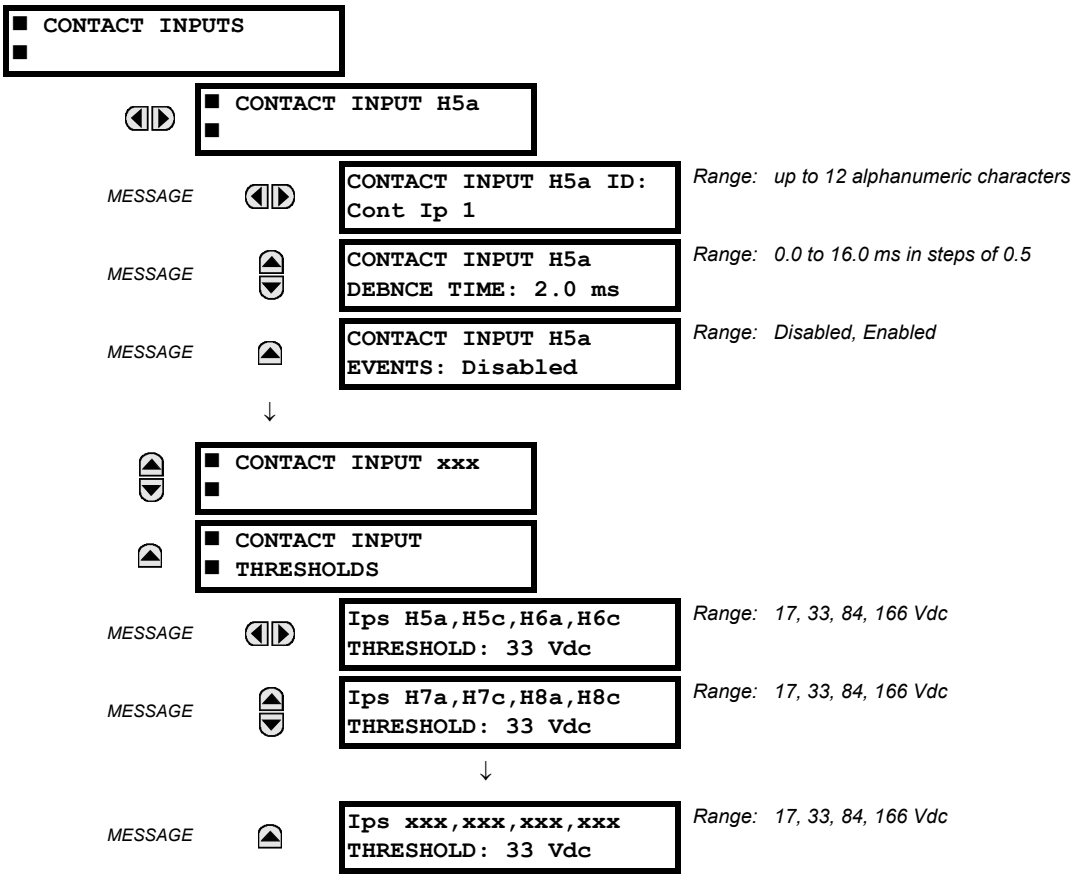



**Figure 5–110: THERMAL OVERLOAD PROTECTION SCHEME LOGIC**

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨ CONTACT INPUTS




The contact inputs menu contains configuration settings for each contact input as well as voltage thresholds for each group of four contact inputs. Upon startup, the relay processor determines (from an assessment of the installed modules) which contact inputs are available and then display settings for only those inputs.

An alphanumeric ID may be assigned to a contact input for diagnostic, setting, and event recording purposes. The CONTACT IP X On" (Logic 1) FlexLogic operand corresponds to contact input "X" being closed, while CONTACT IP X Off corresponds to contact input "X" being open. The **CONTACT INPUT DEBNCE TIME** defines the time required for the contact to overcome 'contact bouncing' conditions. As this time differs for different contact types and manufacturers, set it as a maximum contact debounce time (per manufacturer specifications) plus some margin to ensure proper operation. If **CONTACT INPUT EVENTS** is set to "Enabled", every change in the contact input state will trigger an event.

A raw status is scanned for all Contact Inputs synchronously at the constant rate of 0.5 ms as shown in the figure below. The DC input voltage is compared to a user-settable threshold. A new contact input state must be maintained for a user-settable debounce time in order for the L30 to validate the new contact state. In the figure below, the debounce time is set at 2.5 ms; thus the 6th sample in a row validates the change of state (mark no. 1 in the diagram). Once validated (debounced), the contact input asserts a corresponding FlexLogic operand and logs an event as per user setting.

A time stamp of the first sample in the sequence that validates the new state is used when logging the change of the contact input into the Event Recorder (mark no. 2 in the diagram).

Protection and control elements, as well as FlexLogic equations and timers, are executed eight times in a power system cycle. The protection pass duration is controlled by the frequency tracking mechanism. The FlexLogic operand reflecting the debounced state of the contact is updated at the protection pass following the validation (marks no. 3 and 4 on the figure below). The update is performed at the beginning of the protection pass so all protection and control functions, as well as FlexLogic equations, are fed with the updated states of the contact inputs.

The FlexLogic operand response time to the contact input change is equal to the debounce time setting plus up to one protection pass (variable and depending on system frequency if frequency tracking enabled). If the change of state occurs just after a protection pass, the recognition is delayed until the subsequent protection pass; that is, by the entire duration of the protection pass. If the change occurs just prior to a protection pass, the state is recognized immediately. Statistically a delay of half the protection pass is expected. Owing to the 0.5 ms scan rate, the time resolution for the input contact is below 1msec.

For example, 8 protection passes per cycle on a 60 Hz system correspond to a protection pass every 2.1 ms. With a contact debounce time setting of 3.0 ms, the FlexLogic operand-assert time limits are: 3.0 + 0.0 = 3.0 ms and 3.0 + 2.1 = 5.1 ms. These time limits depend on how soon the protection pass runs after the debouncing time.

Regardless of the contact debounce time setting, the contact input event is time-stamped with a 1 μs accuracy using the time of the first scan corresponding to the new state (mark no. 2 below). Therefore, the time stamp reflects a change in the DC voltage across the contact input terminals that was not accidental as it was subsequently validated using the debounce timer. Keep in mind that the associated FlexLogic operand is asserted/de-asserted later, after validating the change.

The debounce algorithm is symmetrical: the same procedure and debounce time are used to filter the LOW-HIGH (marks no.1, 2, 3, and 4 in the figure below) and HIGH-LOW (marks no. 5, 6, 7, and 8 below) transitions.

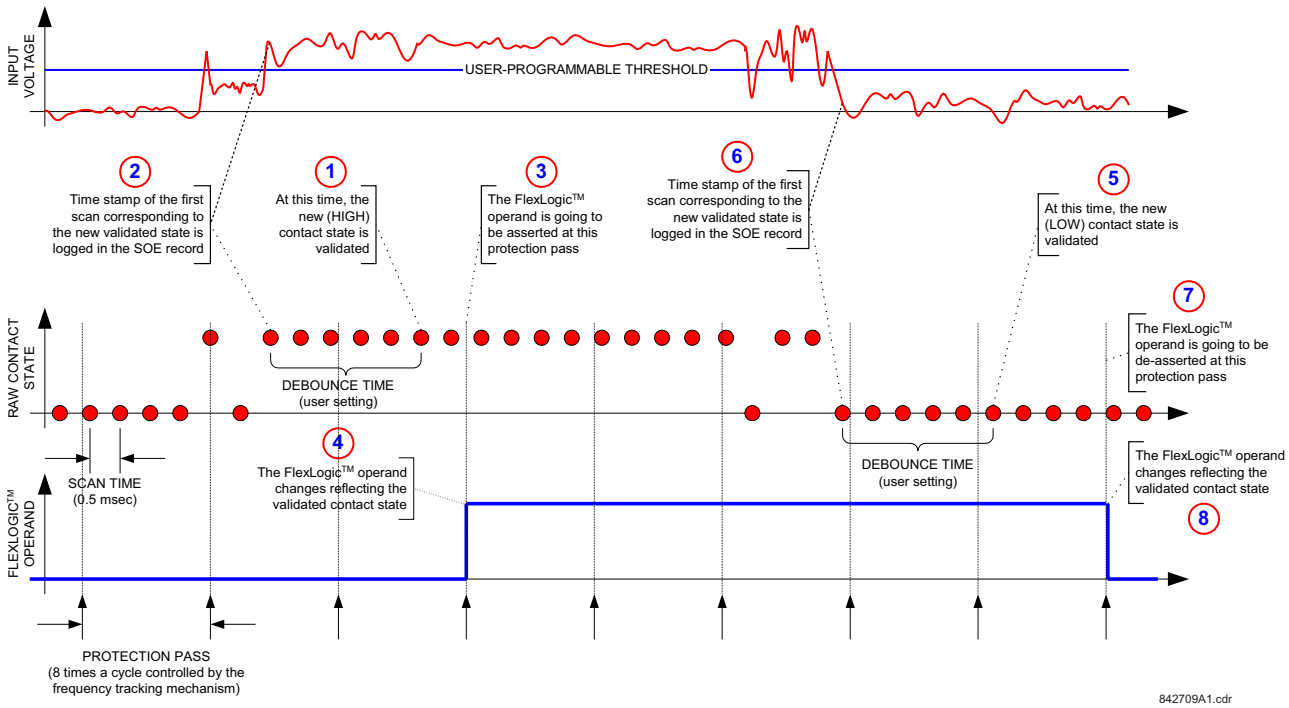



**Figure 5–111: INPUT CONTACT DEBOUNCING MECHANISM AND TIME-STAMPING SAMPLE TIMING**

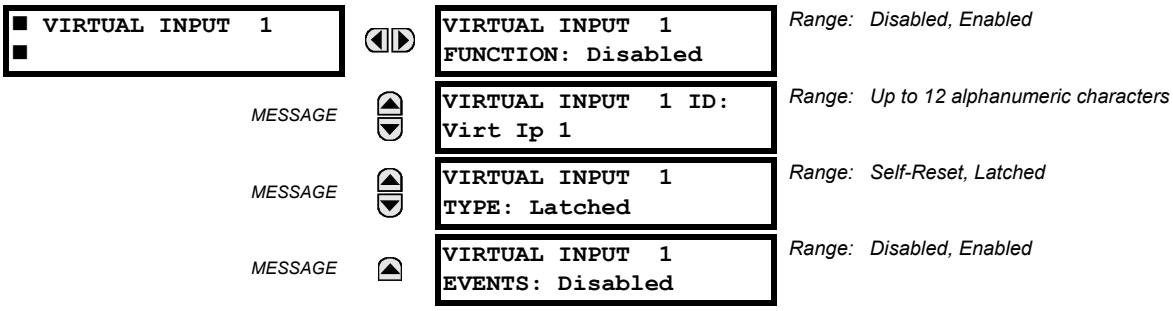
Contact inputs are isolated in groups of four to allow connection of wet contacts from different voltage sources for each group. The **CONTACT INPUT THRESHOLDS** determine the minimum voltage required to detect a closed contact input. This value should be selected according to the following criteria: 17 for 24 V sources, 33 for 48 V sources, 84 for 110 to 125 V sources and 166 for 250 V sources.

For example, to use contact input H5a as a status input from the breaker 52b contact to seal-in the trip relay and record it in the Event Records menu, make the following settings changes:

**CONTACT INPUT H5A ID:** "Breaker Closed (52b)"
**CONTACT INPUT H5A EVENTS:** "Enabled"

Note that the 52b contact is closed when the breaker is open and open when the breaker is closed.

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ VIRTUAL INPUTS ⇨ VIRTUAL INPUT 1(64)




There are 64 virtual inputs that can be individually programmed to respond to input signals from the keypad (via the COMMANDS menu) and communications protocols. All virtual input operands are defaulted to "Off" (logic 0) unless the appropriate input signal is received.

If the **VIRTUAL INPUT x FUNCTION** is to "Disabled", the input will be forced to off (logic 0) regardless of any attempt to alter the input. If set to "Enabled", the input operates as shown on the logic diagram and generates output FlexLogic operands in response to received input signals and the applied settings.

There are two types of operation: self-reset and latched. If **VIRTUAL INPUT x TYPE** is "Self-Reset", when the input signal transits from off to on, the output operand will be set to on for only one evaluation of the FlexLogic equations and then return to off. If set to "Latched", the virtual input sets the state of the output operand to the same state as the most recent received input.

NOTE

The self-reset operating mode generates the output operand for a single evaluation of the FlexLogic equations. If the operand is to be used anywhere other than internally in a FlexLogic equation, it will likely have to be lengthened in time. A FlexLogic timer with a delayed reset can perform this function.

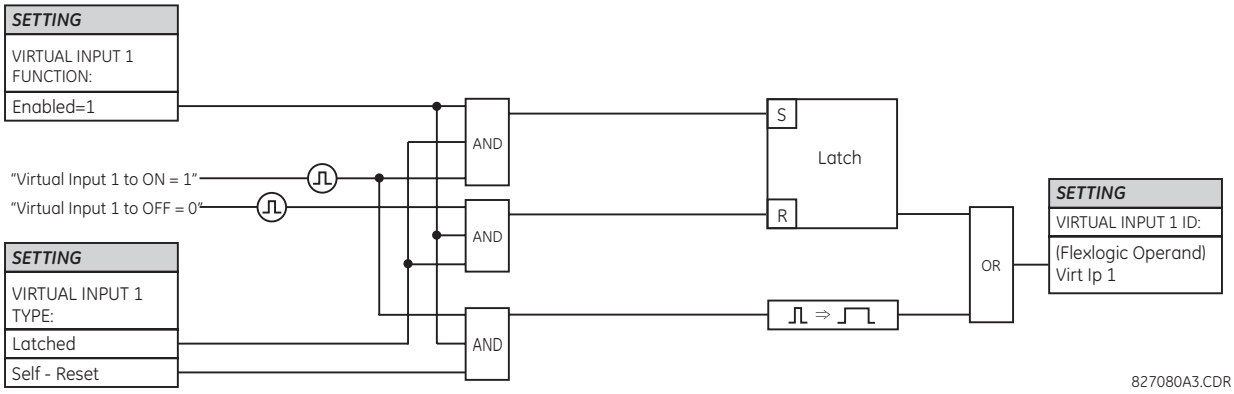



**Figure 5–112: VIRTUAL INPUTS SCHEME LOGIC**

### a) DIGITAL OUTPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS ⇨ CONTACT OUTPUT H1(H64)

| | | | |
|---|---|---|---|
| ■ CONTACT OUTPUT H1 ■ | | CONTACT OUTPUT H1 ID<br>Cont Op 1 | *Range: Up to 12 alphanumeric characters* |
| | *MESSAGE* | OUTPUT H1 OPERATE:<br>Off | *Range: FlexLogic operand* |
| | *MESSAGE* | OUTPUT H1 SEAL-IN:<br>Off | *Range: FlexLogic operand* |
| | *MESSAGE* | CONTACT OUTPUT H1<br>EVENTS: Enabled | *Range: Disabled, Enabled* |

Upon startup of the relay, the main processor determines from an assessment of the modules installed in the chassis which contact outputs are available and presents the settings for only these outputs. Where the contact input is non-latching, the settings are as shown.

An ID may be assigned to each contact output. The signal that can **OPERATE** a contact output may be any FlexLogic operand (virtual output, element state, contact input, or virtual input). An additional FlexLogic operand may be used to **SEAL-IN** the relay. Any change of state of a contact output can be logged as an Event if programmed to do so.

For example, the trip circuit current is monitored by providing a current threshold detector in series with some Form-A contacts (see the trip circuit example in the Digital Elements section). The monitor sets a flag (see the specifications for Form-A). The name of the FlexLogic operand set by the monitor, consists of the output relay designation, followed by the name of the flag; for example, CONT OP 1 ION.

In most breaker control circuits, the trip coil is connected in series with a breaker auxiliary contact used to interrupt current flow after the breaker has tripped, to prevent damage to the less robust initiating contact. This can be done by monitoring an auxiliary contact on the breaker which opens when the breaker has tripped, but this scheme is subject to incorrect operation caused by differences in timing between breaker auxiliary contact change-of-state and interruption of current in the trip circuit. The most dependable protection of the initiating contact is provided by directly measuring current in the tripping circuit, and using this parameter to control resetting of the initiating relay. This scheme is often called *trip seal-in*.

This can be realized using the CONT OP 1 ION FlexLogic operand to seal-in the contact output as follows:

**CONTACT OUTPUT H1 ID:** "Cont Op 1"
**OUTPUT H1 OPERATE:** *any suitable FlexLogic operand*
**OUTPUT H1 SEAL-IN:** "Cont Op 1 IOn"
**CONTACT OUTPUT H1 EVENTS:** "Enabled"

**Figure 5–113: CONTACT INPUT/OUTPUT MODULE TYPE 6A CONTACT 1 LOGIC**

### b) LATCHING OUTPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS ⇨ CONTACT OUTPUT H1a

| | | | |
|---|---|---|---|
| ■ CONTACT OUTPUT H1a ■ | | OUTPUT H1a ID<br>L-Cont Op 1 | *Range: Up to 12 alphanumeric characters* |

MESSAGE
OUTPUT H1a OPERATE:
Off
Range: FlexLogic operand

MESSAGE
OUTPUT H1a RESET:
Off
Range: FlexLogic operand

MESSAGE
OUTPUT H1a TYPE:
Operate-dominant
Range: Operate-dominant, Reset-dominant

MESSAGE
OUTPUT H1a EVENTS:
Disabled
Range: Disabled, Enabled

The latching output contacts are mechanically bi-stable and controlled by two separate (open and close) coils. As such they retain their position even if the relay is not powered up. The relay recognizes all latching output contact cards and populates the setting menu accordingly. On power up, the relay reads positions of the latching contacts from the hardware before executing any other functions of the relay (such as protection and control features or FlexLogic).

The latching output modules, either as a part of the relay or as individual modules, are shipped from the factory with all latching contacts opened. It is highly recommended to double-check the programming and positions of the latching contacts when replacing a module.

Since the relay asserts the output contact and reads back its position, it is possible to incorporate self-monitoring capabilities for the latching outputs. If any latching outputs exhibits a discrepancy, the **LATCHING OUTPUT ERROR** self-test error is declared. The error is signaled by the LATCHING OUT ERROR FlexLogic operand, event, and target message.

- **OUTPUT H1a OPERATE**: This setting specifies a FlexLogic operand to operate the 'close coil' of the contact. The relay will seal-in this input to safely close the contact. Once the contact is closed and the **RESET** input is logic 0 (off), any activity of the **OPERATE** input, such as subsequent chattering, will not have any effect. With both the **OPERATE** and **RESET** inputs active (logic 1), the response of the latching contact is specified by the **OUTPUT H1A TYPE** setting.
- **OUTPUT H1a RESET**: This setting specifies a FlexLogic operand to operate the 'trip coil' of the contact. The relay will seal-in this input to safely open the contact. Once the contact is opened and the **OPERATE** input is logic 0 (off), any activity of the **RESET** input, such as subsequent chattering, will not have any effect. With both the **OPERATE** and **RESET** inputs active (logic 1), the response of the latching contact is specified by the **OUTPUT H1A TYPE** setting.
- **OUTPUT H1a TYPE**: This setting specifies the contact response under conflicting control inputs; that is, when both the **OPERATE** and **RESET** signals are applied. With both control inputs applied simultaneously, the contact will close if set to "Operate-dominant" and will open if set to "Reset-dominant".

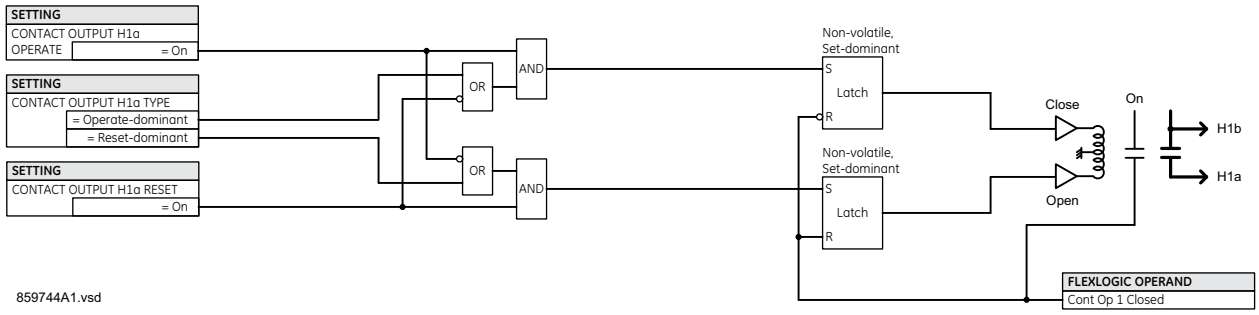



**Figure 5–114: CONTACT INPUT/OUTPUT MODULE TYPE 4L CONTACT 1 LOGIC**

**Application Example 1:**

A latching output contact H1a is to be controlled from two user-programmable pushbuttons (buttons number 1 and 2). The following settings should be applied.

Program the Latching Outputs by making the following changes in the **SETTINGS** ⇨⇩ **INPUTS/OUTPUTS** ⇨⇩ **CONTACT OUTPUTS** ⇨ **CONTACT OUTPUT H1a** menu (assuming an H4L module):

**OUTPUT H1a OPERATE:** "PUSHBUTTON 1 ON"
**OUTPUT H1a RESET:** "PUSHBUTTON 2 ON"

Program the pushbuttons by making the following changes in the PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE PUSHBUTTONS ⇨⇩ USER PUSHBUTTON 1 and USER PUSHBUTTON 2 menus:

**PUSHBUTTON 1 FUNCTION:** "Self-reset"
**PUSHBTN 1 DROP-OUT TIME:** "0.00 s"

**PUSHBUTTON 2 FUNCTION:** "Self-reset"
**PUSHBTN 2 DROP-OUT TIME:** "0.00 s"

**Application Example 2:**

A relay, having two latching contacts H1a and H1c, is to be programmed. The H1a contact is to be a Type-a contact, while the H1c contact is to be a Type-b contact (Type-a means closed after exercising the operate input; Type-b means closed after exercising the reset input). The relay is to be controlled from virtual outputs: VO1 to operate and VO2 to reset.

Program the Latching Outputs by making the following changes in the SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS ⇨ CONTACT OUTPUT H1a and CONTACT OUTPUT H1c menus (assuming an H4L module):

**OUTPUT H1a OPERATE:** "VO1"
**OUTPUT H1a RESET:** "VO2"

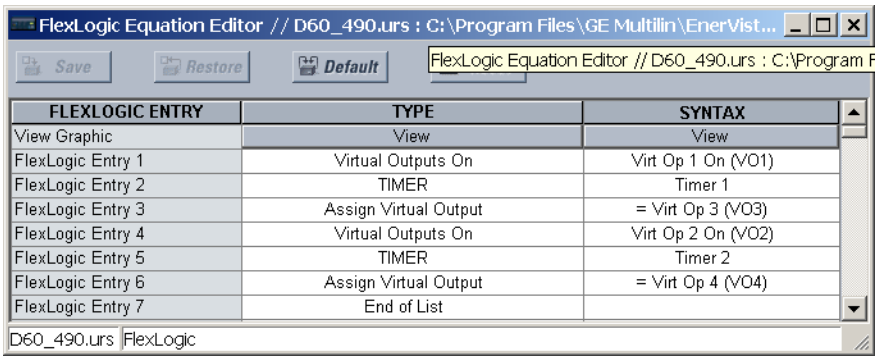
**OUTPUT H1c OPERATE:** "VO2"
**OUTPUT H1c RESET:** "VO1"

Since the two physical contacts in this example are mechanically separated and have individual control inputs, they will not operate at exactly the same time. A discrepancy in the range of a fraction of a maximum operating time may occur. Therefore, a pair of contacts programmed to be a multi-contact relay will not guarantee any specific sequence of operation (such as make before break). If required, the sequence of operation must be programmed explicitly by delaying some of the control inputs as shown in the next application example.

**Application Example 3:**

A make before break functionality must be added to the preceding example. An overlap of 20 ms is required to implement this functionality as described below:

Write the following FlexLogic equation (EnerVista UR Setup example shown):




| FLEXLOGIC ENTRY | TYPE | SYNTAX |
|---|---|---|
| View Graphic | View | View |
| FlexLogic Entry 1 | Virtual Outputs On | Virt Op 1 On (VO1) |
| FlexLogic Entry 2 | TIMER | Timer 1 |
| FlexLogic Entry 3 | Assign Virtual Output | = Virt Op 3 (VO3) |
| FlexLogic Entry 4 | Virtual Outputs On | Virt Op 2 On (VO2) |
| FlexLogic Entry 5 | TIMER | Timer 2 |
| FlexLogic Entry 6 | Assign Virtual Output | = Virt Op 4 (VO4) |
| FlexLogic Entry 7 | End of List | |

Both timers (Timer 1 and Timer 2) should be set to 20 ms pickup and 0 ms dropout.

Program the Latching Outputs by making the following changes in the SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS ⇨ CONTACT OUTPUT H1a and CONTACT OUTPUT H1c menus (assuming an H4L module):

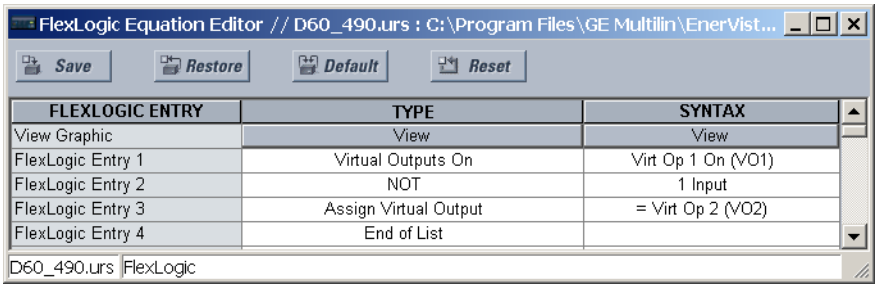
**OUTPUT H1a OPERATE:** "VO1"
**OUTPUT H1a RESET:** "VO4"

**OUTPUT H1c OPERATE:** "VO2"
**OUTPUT H1c RESET:** "VO3"

**Application Example 4:**

A latching contact H1a is to be controlled from a single virtual output VO1. The contact should stay closed as long as VO1 is high, and should stay opened when VO1 is low. Program the relay as follows.

Write the following FlexLogic equation (EnerVista UR Setup example shown):

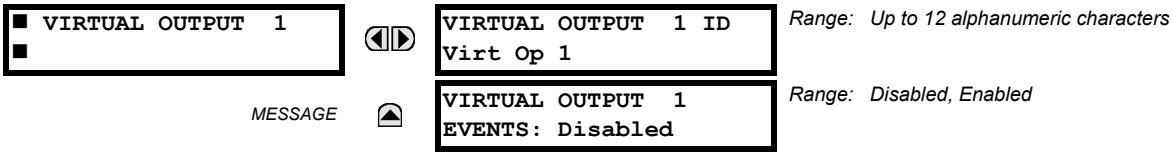



Program the Latching Outputs by making the following changes in the **SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS ⇨ CONTACT OUTPUT H1a** menu (assuming an H4L module):

**OUTPUT H1a OPERATE:** "VO1"
**OUTPUT H1a RESET:** "VO2"

## 5.8.4 VIRTUAL OUTPUTS

**PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ VIRTUAL OUTPUTS ⇨ VIRTUAL OUTPUT 1(96)**




There are 96 virtual outputs that may be assigned via FlexLogic. If not assigned, the output will be forced to 'OFF' (Logic 0). An ID may be assigned to each virtual output. Virtual outputs are resolved in each pass through the evaluation of the FlexLogic equations. Any change of state of a virtual output can be logged as an event if programmed to do so.

For example, if Virtual Output 1 is the trip signal from FlexLogic and the trip relay is used to signal events, the settings would be programmed as follows:

**VIRTUAL OUTPUT 1 ID:** "Trip"
**VIRTUAL OUTPUT 1 EVENTS:** "Disabled"

## 5.8.5 REMOTE DEVICES

### a) REMOTE INPUTS AND OUTPUTS OVERVIEW

Remote inputs and outputs provide a means of exchanging digital state information between Ethernet-networked devices. The IEC 61850 GSSE (Generic Substation State Event) and GOOSE (Generic Object Oriented Substation Event) standards are used.

The sharing of digital point state information between GSSE/GOOSE equipped relays is essentially an extension to FlexLogic, allowing distributed FlexLogic by making operands available to/from devices on a common communications network. In addition to digital point states, GSSE/GOOSE messages identify the originator of the message and provide other information required by the communication specification. All devices listen to network messages and capture data only from messages that have originated in selected devices.

IEC 61850 GSSE messages are compatible with UCA GOOSE messages and contain a fixed set of digital points. IEC 61850 GOOSE messages can, in general, contain any configurable data items. When used by the remote input/output feature, IEC 61850 GOOSE messages contain the same data as GSSE messages.

Both GSSE and GOOSE messages are designed to be short, reliable, and high priority. GOOSE messages have additional advantages over GSSE messages due to their support of VLAN (virtual LAN) and Ethernet priority tagging functionality. The GSSE message structure contains space for 128 bit pairs representing digital point state information. The IEC 61850 specification provides 32 "DNA" bit pairs that represent the state of two pre-defined events and 30 user-defined events. All remaining bit pairs are "UserSt" bit pairs, which are status bits representing user-definable events. The L30 implementation provides 32 of the 96 available UserSt bit pairs.

The IEC 61850 specification includes features that are used to cope with the loss of communication between transmitting and receiving devices. Each transmitting device will send a GSSE/GOOSE message upon a successful power-up, when the state of any included point changes, or after a specified interval (the *default update* time) if a change-of-state has not occurred. The transmitting device also sends a 'hold time' which is set greater than four times the programmed default time required by the receiving device.

Receiving devices are constantly monitoring the communications network for messages they require, as recognized by the identification of the originating device carried in the message. Messages received from remote devices include the message *time allowed to live*. The receiving relay sets a timer assigned to the originating device to this time interval, and if it has not received another message from this device at time-out, the remote device is declared to be non-communicating, so it will use the programmed default state for all points from that specific remote device. If a message is received from a remote device before the *time allowed to live* expires, all points for that device are updated to the states contained in the message and the hold timer is restarted. The status of a remote device, where "Offline" indicates non-communicating, can be displayed.

The remote input/output facility provides for 32 remote inputs and 64 remote outputs.

### b) DIRECT MESSAGES

Direct messages are used only between L30 relays connected directly using type 7 or type 2 digital communication cards. These messages are transmitted every one-half of the power frequency cycle (10 ms for 50 Hz and 8.33 ms for 60 Hz) This facility is of particular value for pilot schemes and transfer tripping. Direct messaging is available on both single channel and dual channel communications modules. The inputs and outputs on communications channel 1 are numbered 1-1 through 1-8, and the inputs and outputs on communications channel 2 are numbered 2-1 through 2-8.

NOTE

Settings associated with direct messages are automatically presented in accordance with the number of channels provided in the communications module in a specific relay.

5

### c) LOCAL DEVICES: DEVICE ID FOR TRANSMITTING GSSE MESSAGES

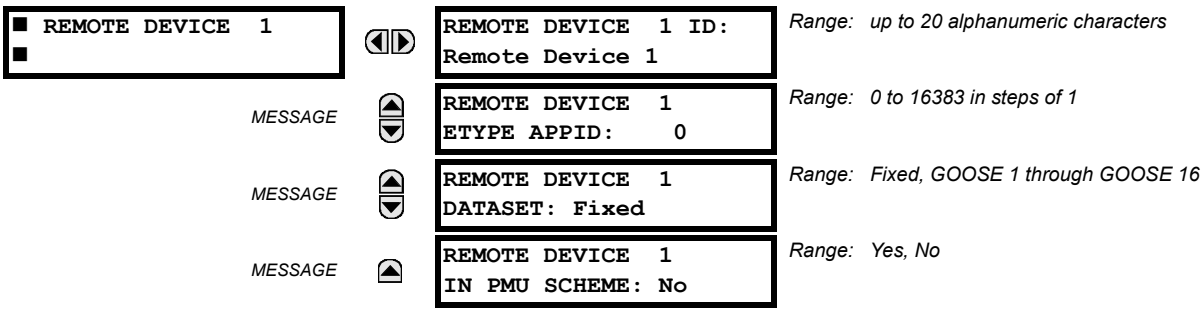
In a L30 relay, the device ID that represents the IEC 61850 GOOSE application ID (GoID) name string sent as part of each GOOSE message is programmed in the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨ TRANSMISSION ⇨⇩ FIXED GOOSE ⇨⇩ GOOSE ID** setting.

Likewise, the device ID that represents the IEC 61850 GSSE application ID name string sent as part of each GSSE message is programmed in the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨ TRANSMISSION ⇨⇩ GSSE ⇨⇩ GSSE ID** setting.

In L30 releases previous to 5.0x, these name strings were represented by the **RELAY NAME** setting.

### d) REMOTE DEVICES: ID OF DEVICE FOR RECEIVING GSSE/GOOSE MESSAGES

**PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE DEVICES ⇨ REMOTE DEVICE 1(16)**




Remote devices are available for setting purposes. A receiving relay must be programmed to capture messages from only those originating remote devices of interest. This setting is used to select specific remote devices by entering (bottom row) the exact identification (ID) assigned to those devices.

The **REMOTE DEVICE 1 ETYPE APPID** setting is only used with GOOSE messages; they are not applicable to GSSE messages. This setting identifies the Ethernet application identification in the GOOSE message. It should match the corresponding settings on the sending device.

The **REMOTE DEVICE 1 DATASET** setting provides for the choice of the L30 fixed (DNA/UserSt) dataset (that is, containing DNA and UserSt bit pairs), or one of the configurable datasets.

Note that the dataset for the received data items must be made up of existing items in an existing logical node. For this reason, logical node GGIO3 is instantiated to hold the incoming data items. GGIO3 is not necessary to make use of the received data. The remote input data item mapping takes care of the mapping of the inputs to remote input FlexLogic operands. However, GGIO3 data can be read by IEC 61850 clients.

### 5.8.6 REMOTE INPUTS

**PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE INPUTS ⇨ REMOTE INPUT 1(32)**

```
■ REMOTE INPUT 1
■
```

```
REMOTE INPUT  1 ID:
Rem Ip  1
```
*Range: up to 12 alphanumeric characters*

*MESSAGE*

```
REMOTE IN  1 DEVICE:
Remote Device  1
```
*Range: Remote Device 1 to Remote device 16*

*MESSAGE*

```
REMOTE IN  1 ITEM:
 None
```
*Range: None, DNA-1 to DNA-32, UserSt-1 to UserSt-32, Config Item 1 to Config Item 32*

*MESSAGE*

```
REMOTE IN  1 DEFAULT
STATE: Off
```
*Range: On, Off, Latest/On, Latest/Off*

*MESSAGE*

```
REMOTE IN  1
EVENTS: Disabled
```
*Range: Disabled, Enabled*

Remote Inputs that create FlexLogic operands at the receiving relay are extracted from GSSE/GOOSE messages originating in remote devices. Each remote input can be selected from a list consisting of: DNA-1 through DNA-32, UserSt-1 through UserSt-32, and Dataset Item 1 through Dataset Item 32. The function of DNA inputs is defined in the IEC 61850 specification and is presented in the IEC 61850 DNA Assignments table in the Remote Outputs section. The function of UserSt inputs is defined by the user selection of the FlexLogic operand whose state is represented in the GSSE/GOOSE message. A user must program a DNA point from the appropriate FlexLogic operand.

Remote input 1 must be programmed to replicate the logic state of a specific signal from a specific remote device for local use. This programming is performed via the three settings shown above.

The **REMOTE INPUT 1 ID** setting allows the user to assign descriptive text to the remote input. The **REMOTE IN 1 DEVICE** setting selects the remote device which originates the required signal, as previously assigned to the remote device via the setting **REMOTE DEVICE (16) ID** (see the Remote Devices section). The **REMOTE IN 1 ITEM** setting selects the specific bits of the GSSE/GOOSE message required.

The **REMOTE IN 1 DEFAULT STATE** setting selects the logic state for this point if the local relay has just completed startup or the remote device sending the point is declared to be non-communicating. The following choices are available:

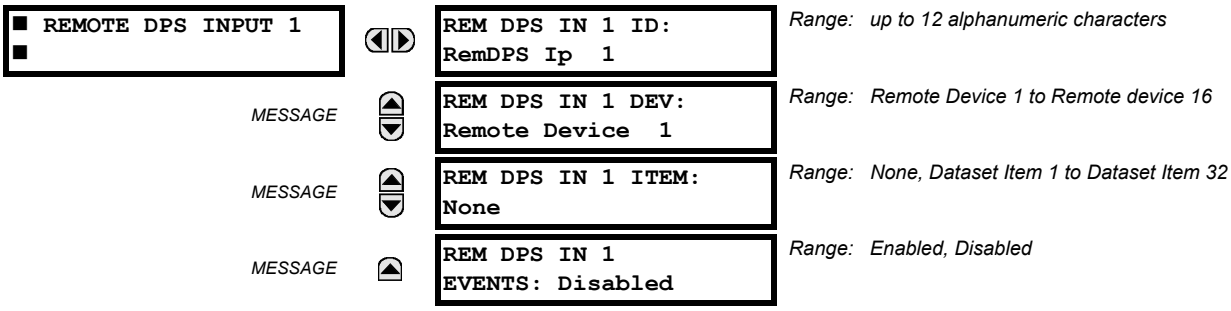
- Setting **REMOTE IN 1 DEFAULT STATE** to “On” value defaults the input to logic 1.
- Setting **REMOTE IN 1 DEFAULT STATE** to “Off” value defaults the input to logic 0.
- Setting **REMOTE IN 1 DEFAULT STATE** to “Latest/On” freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to logic 1. When communication resumes, the input becomes fully operational.
- Setting **REMOTE IN 1 DEFAULT STATE** to “Latest/Off” freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to logic 0. When communication resumes, the input becomes fully operational.

NOTE

For additional information on GSSE/GOOOSE messaging, see the Remote Devices section in this chapter.

## 5.8.7 REMOTE DOUBLE-POINT STATUS INPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE DPS INPUTS ⇨ REMOTE DPS INPUT 1(5)




Remote double-point status inputs are extracted from GOOSE messages originating in the remote device. Each remote double point status input must be programmed to replicate the logic state of a specific signal from a specific remote device for local use. This functionality is accomplished with the five remote double-point status input settings.

- **REM DPS IN 1 ID**: This setting assigns descriptive text to the remote double-point status input.
- **REM DPS IN 1 DEV**: This setting selects a remote device ID to indicate the origin of a GOOSE message. The range is selected from the remote device IDs specified in the Remote Devices section.
- **REM DPS IN 1 ITEM**: This setting specifies the required bits of the GOOSE message.

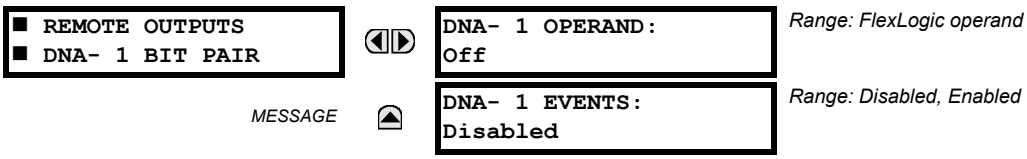
The configurable GOOSE dataset items must be changed to accept a double-point status item from a GOOSE dataset (changes are made in the SETTINGS ⇨⇩ COMMUNICATION ⇨⇩ IEC 61850 PROTOCOL ⇨⇩ GSSE/GOOSE CONFIGURATION ⇨⇩ RECEPTION ⇨⇩ CONFIGURABLE GOOSE ⇨ CONFIGURABLE GOOSE 1(16) ⇨ CONFIG GSE 1 DATASET ITEMS menus). Dataset items configured to receive any of "GGIO3.ST.IndPos1.stV" to "GGIO3.ST.IndPos5.stV" will accept double-point status information that will be decoded by the remote double-point status inputs configured to this dataset item.

The remote double point status is recovered from the received IEC 61850 dataset and is available as through the RemDPS Ip 1 BAD, RemDPS Ip 1 INTERM, RemDPS Ip 1 OFF, and RemDPS Ip 1 ON FlexLogic operands. These operands can then be used in breaker or disconnect control schemes.

## 5.8.8 REMOTE OUTPUTS

### a) DNA BIT PAIRS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE OUTPUTS DNA BIT PAIRS ⇨ REMOTE OUTPUTS DNA- 1(32) BIT PAIR



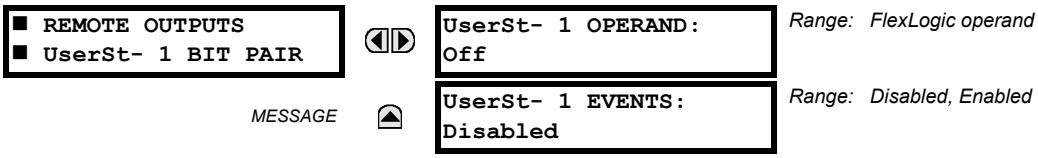

Remote outputs (1 to 32) are FlexLogic operands inserted into GSSE/GOOSE messages that are transmitted to remote devices on a LAN. Each digital point in the message must be programmed to carry the state of a specific FlexLogic operand. The above operand setting represents a specific DNA function (as shown in the following table) to be transmitted.

**Table 5–34: IEC 61850 DNA ASSIGNMENTS**

| DNA | IEC 61850 DEFINITION | FLEXLOGIC OPERAND |
|---|---|---|
| 1 | Test | IEC 61850 TEST MODE |
| 2 | ConfRev | IEC 61850 CONF REV |

### b) USERST BIT PAIRS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE OUTPUTS UserSt BIT PAIRS ⇨ REMOTE OUTPUTS UserSt- 1(32) BIT PAIR




Remote outputs 1 to 32 originate as GSSE/GOOSE messages to be transmitted to remote devices. Each digital point in the message must be programmed to carry the state of a specific FlexLogic operand. The setting above is used to select the operand which represents a specific UserSt function (as selected by the user) to be transmitted.

NOTE For more information on GSSE/GOOSE messaging, see the Remote Inputs/Outputs Overview in the *Remote Devices* section.

## 5.8.9 DIRECT INPUTS AND OUTPUTS

### a) DESCRIPTION

The relay provides eight direct inputs conveyed on communications channel 1 (numbered 1-1 through 1-8) and eight direct inputs conveyed on communications channel 2 (on three-terminal systems only, numbered 2-1 through 2-8). The user must program the remote relay connected to channels 1 and 2 of the local relay by assigning the desired FlexLogic operand to be sent via the selected communications channel.

This relay allows the user to create distributed protection and control schemes via dedicated communications channels. Some examples are directional comparison pilot schemes and transfer tripping. It should be noted that failures of communications channels will affect direct input/output functionality. The 87L function must be enabled to utilize the direct inputs.

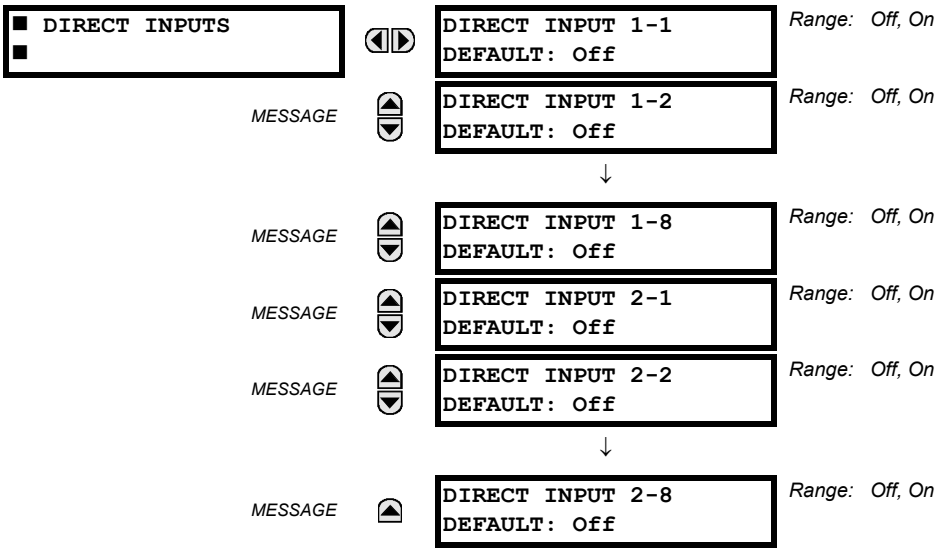
Direct input and output FlexLogic operands to be used at the local relay are assigned as follows:

- Direct input/output 1-1 through direct input/output 1-8 for communications channel 1.
- Direct input/output 2-1 through direct input/output 2-8 for communications channel 2 (three-terminal systems only).

NOTE On the two-terminal, two channel system (redundant channel), direct outputs 1-1 to 1-8 are send over both channels simultaneously and are received separately as direct inputs 1-1 to 1-8 at channel 1 and direct inputs 2-1 to 2-8 at channel 2. Therefore, to take advantage of redundancy, the respective operands from channel 1 and 2 can be ORed with FlexLogic or mapped separately.

### b) DIRECT INPUTS

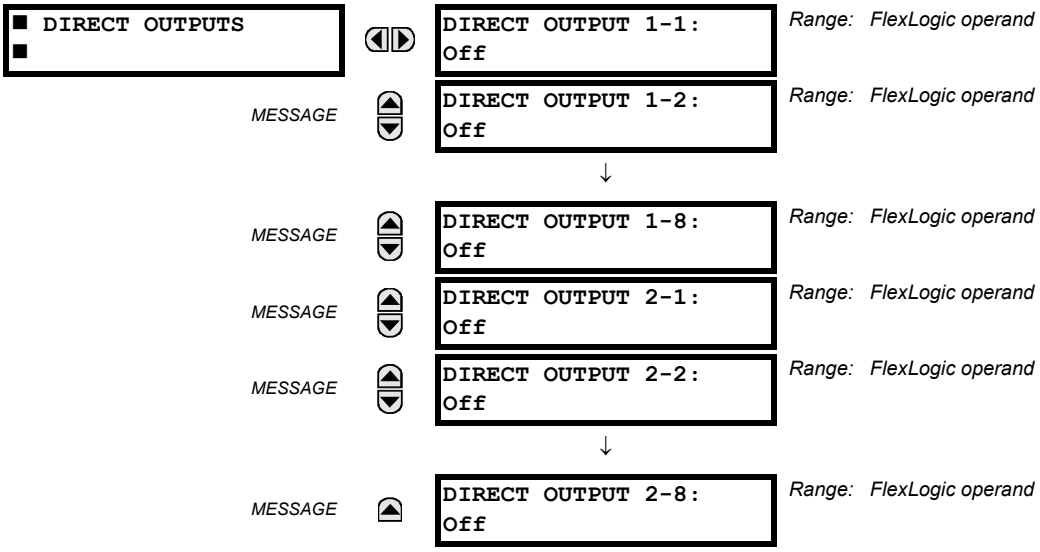
PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ DIRECT ⇨ DIRECT INPUTS



The **DIRECT INPUT 1-1(8) DEFAULT** setting selects the logic state of this particular bit used for this point if the local relay has just completed startup or the local communications channel is declared to have failed. Setting **DIRECT INPUT 1-1(8) DEFAULT** to "On" means that the corresponding local FlexLogic operand (DIRECT I/P 1-1(8)) will have logic state "1" on relay startup or during communications channel failure. When the channel is restored, the operand logic state reflects the actual state of the corresponding remote direct output.

### c) DIRECT OUTPUTS

**PATH: SETTINGS ⇩ INPUTS/OUTPUTS ⇨⇩ DIRECT ⇨⇩ DIRECT OUTPUTS**




The relay provides eight direct outputs that are conveyed on communications channel 1 (numbered 1-1 through 1-8) and eight direct outputs that are conveyed on communications channel 2 (numbered 2-1 through 2-8). Each digital point in the message must be programmed to carry the state of a specific FlexLogic operand. The setting above is used to select the operand which represents a specific function (as selected by the user) to be transmitted.

NOTE

Direct outputs 2-1 to 2-8 are only functional on three-terminal systems.

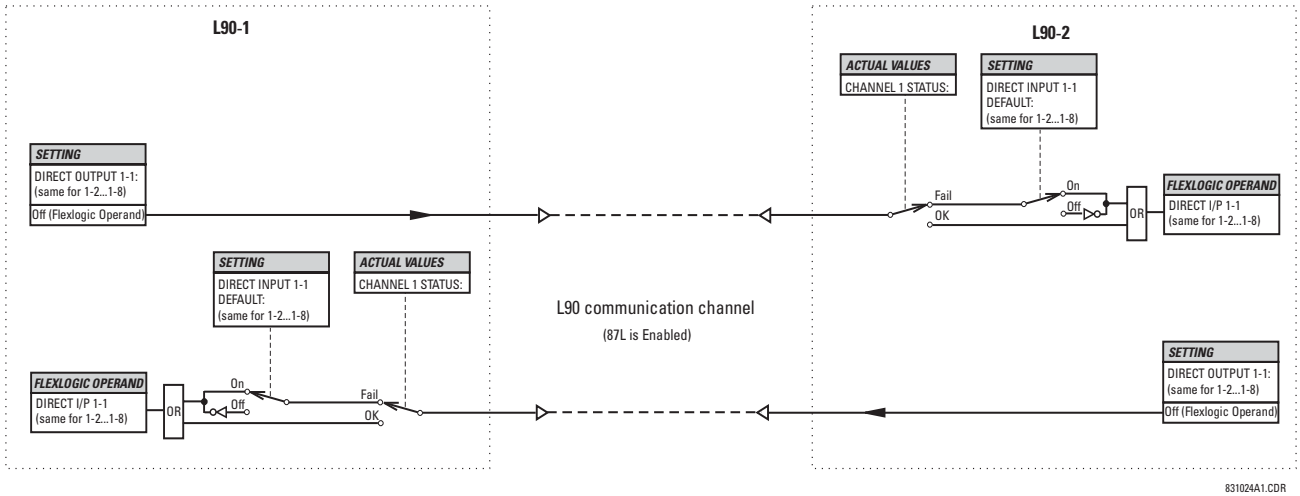
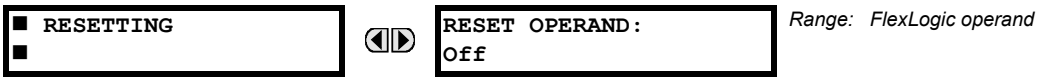



Figure 5–115: DIRECT INPUTS/OUTPUTS LOGIC

### 5.8.10 RESETTING

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ RESETTING



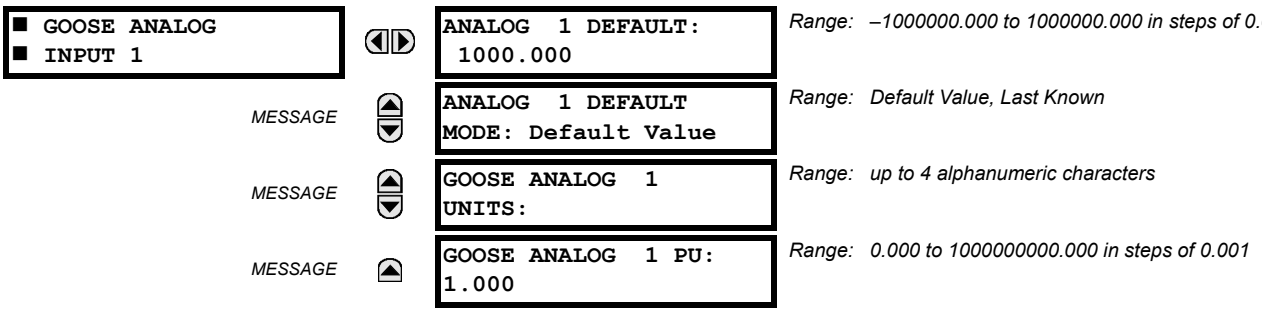

*Range: FlexLogic operand*

Some events can be programmed to latch the faceplate LED event indicators, target message, and/or graphical panel annunciator windows. Once set, the latching mechanism holds all of the latched indicators or messages in the set state after the initiating condition has cleared until a RESET command is received to return these latches (not including FlexLogic latches) to the reset state where the initiating condition has cleared. The RESET command can be sent from the faceplate Reset button, a remote device via a communications channel, or any selected operand.

The three sources of RESET commands each activates the RESET OP FlexLogic operand. Each individual source of a RESET command also creates its individual operand RESET OP (PUSHBUTTON), RESET OP (COMMS), or RESET OP (OPERAND) to identify the source of the command. Each of these three operands generates an event in the event record when activated. The setting shown above selects the operand that activates the RESET OP (OPERAND) operand.

### 5.8.11 IEC 61850 GOOSE ANALOGS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ IEC 61850 GOOSE ANALOGS ⇨⇩ GOOSE ANALOG INPUT 1(32)




*Range: –1000000.000 to 1000000.000 in steps of 0.001*

*Range: Default Value, Last Known*

*Range: up to 4 alphanumeric characters*

*Range: 0.000 to 1000000000.000 in steps of 0.001*

The IEC 61850 GOOSE analog inputs feature allows the transmission of analog values between any two UR-series devices. The following settings are available for each GOOSE analog input.

- **ANALOG 1 DEFAULT**: This setting specifies the value of the GOOSE analog input when the sending device is offline and the **ANALOG 1 DEFAULT MODE** is set to "Default Value".This setting is stored as an IEEE 754 / IEC 60559 floating point number. Because of the large range of this setting, not all possible values can be stored. Some values may be rounded to the closest possible floating point number.
- **ANALOG 1 DEFAULT MODE**: When the sending device is offline and this setting is "Last Known", the value of the GOOSE analog input remains at the last received value. When the sending device is offline and this setting value is "Default Value", then the value of the GOOSE analog input is defined by the **ANALOG 1 DEFAULT** setting.
- **GOOSE ANALOG 1 UNITS**: This setting specifies a four-character alphanumeric string that can is used in the actual values display of the corresponding GOOSE analog input value.

  GOOSE Analogs are floating-point values, with no units. The GOOSE UNIT and PU base settings allow the user to configure GOOSE Analog, so that it can be used in a FlexElement.

  GOOSE Analogs that represent current, voltage, power, frequency, angles, or power factor can be used in a FlexElement. The following text must be used in the UNITS setting, to represent these types of analogs: A, V, W, var, VA, Hz, deg, and no text (blank setting) for power factor.

  GOOSE Analogs can be compared to other GOOSE Analogs with any character string or no string.
- **GOOSE ANALOG 1PU**: This setting specifies the per-unit base factor when using the GOOSE analog input FlexAnalog values in other L30 features, such as FlexElements. The base factor is applied to the GOOSE analog input FlexAnalog quantity to normalize it to a per-unit quantity. The base units are described in the following table.

  The per-unit base setting represents thousands, not single units. For example, a PU base of 1.000 is actually 1000 and a PU base of 0.001 is 1.

When using GOOSE Analogs and PU base in FlexElements, the largest value that can be displayed in the FlexElement actual values is 2,140,000.000.

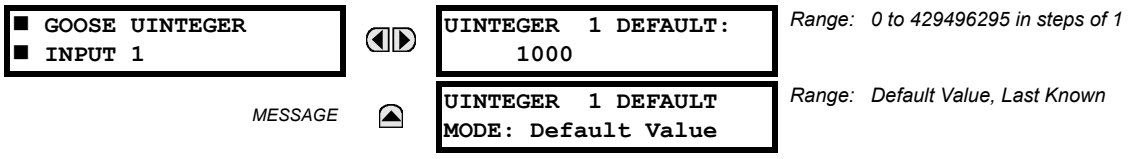
**Table 5–35: GOOSE ANALOG INPUT BASE UNITS**

| ELEMENT | BASE UNITS |
|---|---|
| 87L SIGNALS<br>(Local IA Mag, IB, and IC)<br>(Diff Curr IA Mag, IB, and IC)<br>(Terminal 1 IA Mag, IB, and IC)<br>(Terminal 2 IA Mag, IB and IC) | $I_{BASE}$ = maximum primary RMS value of the +IN and –IN inputs<br>(CT primary for source currents, and 87L source primary current for line differential currents) |
| 87L SIGNALS<br>(Op Square Curr IA, IB, and IC)<br>(Rest Square Curr IA, IB, and IC) | BASE = Squared CT secondary of the 87L source |
| BREAKER ARCING AMPS<br>(Brk X Arc Amp A, B, and C) | BASE = 2000 $kA^2 \times$ cycle |
| dcmA | BASE = maximum value of the **DCMA INPUT MAX** setting for the two transducers configured under the +IN and –IN inputs. |
| FREQUENCY | $f_{BASE}$ = 1 Hz |
| PHASE ANGLE | $\varphi_{BASE}$ = 360 degrees (see the UR angle referencing convention) |
| POWER FACTOR | $PF_{BASE}$ = 1.00 |
| RTDs | BASE = 100°C |
| SOURCE CURRENT | $I_{BASE}$ = maximum nominal primary RMS value of the +IN and –IN inputs |
| SOURCE POWER | $P_{BASE}$ = maximum value of $V_{BASE} \times I_{BASE}$ for the +IN and –IN inputs |
| SOURCE VOLTAGE | $V_{BASE}$ = maximum nominal primary RMS value of the +IN and –IN inputs |
| SYNCHROCHECK<br>(Max Delta Volts) | $V_{BASE}$ = maximum primary RMS value of all the sources related to the +IN and –IN inputs |

The GOOSE analog input FlexAnalog values are available for use in other L30 functions that use FlexAnalog values.

## 5.8.12 IEC 61850 GOOSE INTEGERS

**PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ IEC 61850 GOOSE UINTEGERS ⇨⇩ GOOSE UINTEGER INPUT 1(16)**




*Range: 0 to 429496295 in steps of 1*

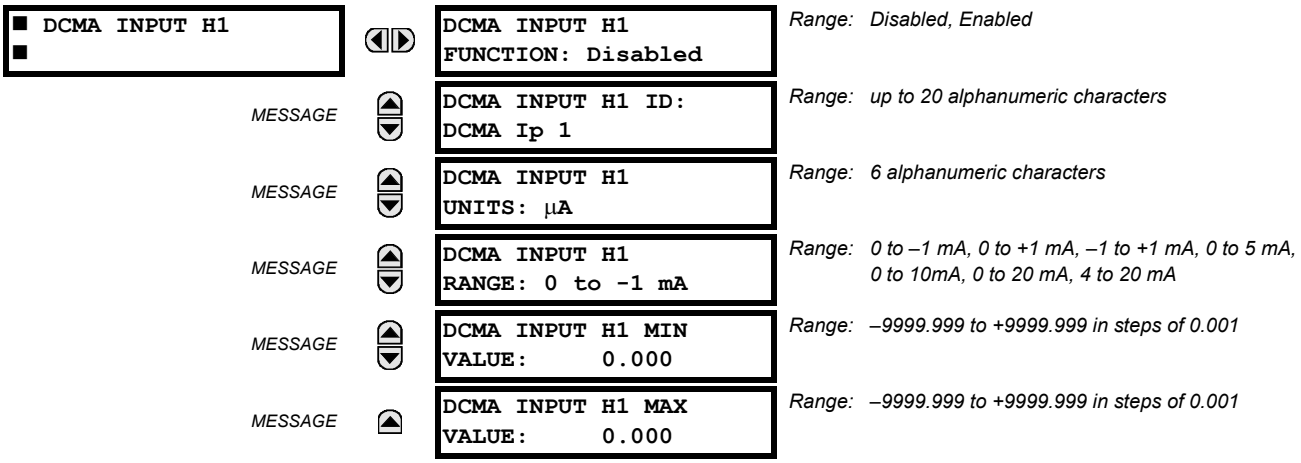
*Range: Default Value, Last Known*

The IEC 61850 GOOSE uinteger inputs feature allows the transmission of FlexInteger values between any two UR-series devices. The following settings are available for each GOOSE uinteger input.

- **UINTEGER 1 DEFAULT**: This setting specifies the value of the GOOSE uinteger input when the sending device is offline and the **UINTEGER 1 DEFAULT MODE** is set to "Default Value".This setting is stored as a 32-bit unsigned integer number.
- **UINTEGER 1 DEFAULT MODE**: When the sending device is offline and this setting is "Last Known", the value of the GOOSE uinteger input remains at the last received value. When the sending device is offline and this setting value is "Default Value", then the value of the GOOSE uinteger input is defined by the **UINTEGER 1 DEFAULT** setting.

The GOOSE integer input FlexInteger values are available for use in other L30 functions that use FlexInteger values.

PATH: SETTINGS ⇨⇩ TRANSDUCER I/O ⇨⇩ DCMA INPUTS ⇨ DCMA INPUT H1(U8)




Hardware and software is provided to receive signals from external transducers and convert these signals into a digital format for use as required. The relay will accept inputs in the range of –1 to +20 mA DC, suitable for use with most common transducer output ranges; all inputs are assumed to be linear over the complete range. Specific hardware details are contained in chapter 3.

Before the DCmA input signal can be used, the value of the signal measured by the relay must be converted to the range and quantity of the external transducer primary input parameter, such as DC voltage or temperature. The relay simplifies this process by internally scaling the output from the external transducer and displaying the actual primary parameter.

DCmA input channels are arranged in a manner similar to CT and VT channels. The user configures individual channels with the settings shown here.

The channels are arranged in sub-modules of two channels, numbered from 1 through 8 from top to bottom. On power-up, the relay will automatically generate configuration settings for every channel, based on the order code, in the same general manner that is used for CTs and VTs. Each channel is assigned a slot letter followed by the row number, 1 through 8 inclusive, which is used as the channel number. The relay generates an actual value for each available input channel.

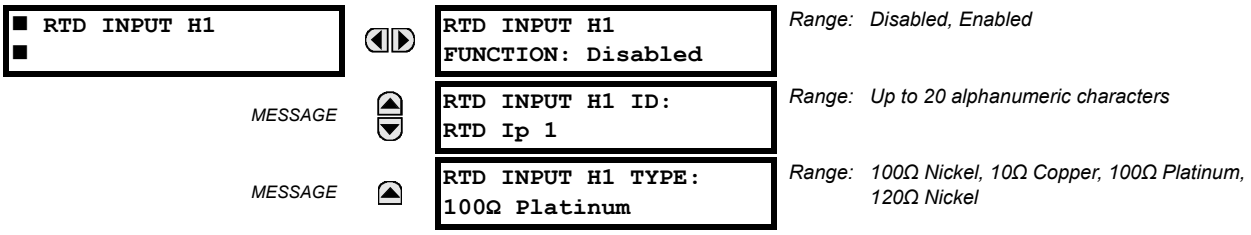
Settings are automatically generated for every channel available in the specific relay as shown above for the first channel of a type 5F transducer module installed in slot H.

The function of the channel may be either “Enabled” or “Disabled”. If “Disabled”, no actual values are created for the channel. An alphanumeric “ID” is assigned to each channel; this ID will be included in the channel actual value, along with the programmed units associated with the parameter measured by the transducer, such as volts, °C, megawatts, etc. This ID is also used to reference the channel as the input parameter to features designed to measure this type of parameter. The **DCMA INPUT H1 RANGE** setting specifies the mA DC range of the transducer connected to the input channel.

The **DCMA INPUT H1 MIN VALUE** and **DCMA INPUT H1 MAX VALUE** settings are used to program the span of the transducer in primary units. For example, a temperature transducer might have a span from 0 to 250°C; in this case the **DCMA INPUT H1 MIN VALUE** value is “0” and the **DCMA INPUT H1 MAX VALUE** value is “250”. Another example would be a watts transducer with a span from –20 to +180 MW; in this case the **DCMA INPUT H1 MIN VALUE** value would be “–20” and the **DCMA INPUT H1 MAX VALUE** value “180”. Intermediate values between the min and max values are scaled linearly.

## 5.9.2 RTD INPUTS

**PATH: SETTINGS ⇨⇩ TRANSDUCER I/O ⇨⇩ RTD INPUTS ⇨ RTD INPUT H1(U8)**




Hardware and software is provided to receive signals from external resistance temperature detectors and convert these signals into a digital format for use as required. These channels are intended to be connected to any of the RTD types in common use. Specific hardware details are contained in chapter 3.

RTD input channels are arranged in a manner similar to CT and VT channels. The user configures individual channels with the settings shown here.

The channels are arranged in sub-modules of two channels, numbered from 1 through 8 from top to bottom. On power-up, the relay will automatically generate configuration settings for every channel, based on the order code, in the same general manner that is used for CTs and VTs. Each channel is assigned a slot letter followed by the row number, 1 through 8 inclusive, which is used as the channel number. The relay generates an actual value for each available input channel.

Settings are automatically generated for every channel available in the specific relay as shown above for the first channel of a type 5C transducer module installed in the first available slot.

The function of the channel may be either “Enabled” or “Disabled”. If “Disabled”, there will not be an actual value created for the channel. An alphanumeric ID is assigned to the channel; this ID will be included in the channel actual values. It is also used to reference the channel as the input parameter to features designed to measure this type of parameter. Selecting the type of RTD connected to the channel configures the channel.

Actions based on RTD overtemperature, such as trips or alarms, are done in conjunction with the FlexElements feature. In FlexElements, the operate level is scaled to a base of 100°C. For example, a trip level of 150°C is achieved by setting the operate level at 1.5 pu. FlexElement operands are available to FlexLogic for further interlocking or to operate an output contact directly.

Refer to the following table for reference temperature values for each RTD type.

**Table 5–36: RTD TEMPERATURE VS. RESISTANCE**

| TEMPERATURE | | RESISTANCE (IN OHMS) | | | |
|---|---|---|---|---|---|
| °C | °F | 100 Ω PT (DIN 43760) | 120 Ω NI | 100 Ω NI | 10 Ω CU |
| –50 | –58 | 80.31 | 86.17 | 71.81 | 7.10 |
| –40 | –40 | 84.27 | 92.76 | 77.30 | 7.49 |
| –30 | –22 | 88.22 | 99.41 | 82.84 | 7.88 |
| –20 | –4 | 92.16 | 106.15 | 88.45 | 8.26 |
| –10 | 14 | 96.09 | 113.00 | 94.17 | 8.65 |
| 0 | 32 | 100.00 | 120.00 | 100.00 | 9.04 |
| 10 | 50 | 103.90 | 127.17 | 105.97 | 9.42 |
| 20 | 68 | 107.79 | 134.52 | 112.10 | 9.81 |
| 30 | 86 | 111.67 | 142.06 | 118.38 | 10.19 |
| 40 | 104 | 115.54 | 149.79 | 124.82 | 10.58 |
| 50 | 122 | 119.39 | 157.74 | 131.45 | 10.97 |
| 60 | 140 | 123.24 | 165.90 | 138.25 | 11.35 |
| 70 | 158 | 127.07 | 174.25 | 145.20 | 11.74 |
| 80 | 176 | 130.89 | 182.84 | 152.37 | 12.12 |
| 90 | 194 | 134.70 | 191.64 | 159.70 | 12.51 |
| 100 | 212 | 138.50 | 200.64 | 167.20 | 12.90 |
| 110 | 230 | 142.29 | 209.85 | 174.87 | 13.28 |
| 120 | 248 | 146.06 | 219.29 | 182.75 | 13.67 |
| 130 | 266 | 149.82 | 228.96 | 190.80 | 14.06 |
| 140 | 284 | 153.58 | 238.85 | 199.04 | 14.44 |
| 150 | 302 | 157.32 | 248.95 | 207.45 | 14.83 |
| 160 | 320 | 161.04 | 259.30 | 216.08 | 15.22 |
| 170 | 338 | 164.76 | 269.91 | 224.92 | 15.61 |
| 180 | 356 | 168.47 | 280.77 | 233.97 | 16.00 |
| 190 | 374 | 172.46 | 291.96 | 243.30 | 16.39 |
| 200 | 392 | 175.84 | 303.46 | 252.88 | 16.78 |
| 210 | 410 | 179.51 | 315.31 | 262.76 | 17.17 |
| 220 | 428 | 183.17 | 327.54 | 272.94 | 17.56 |
| 230 | 446 | 186.82 | 340.14 | 283.45 | 17.95 |
| 240 | 464 | 190.45 | 353.14 | 294.28 | 18.34 |
| 250 | 482 | 194.08 | 366.53 | 305.44 | 18.73 |

PATH: SETTINGS ⇨⇩ TRANSDUCER I/O ⇨⇩ DCMA OUTPUTS ⇨ DCMA OUTPUT H1(U8)

```
■ DCMA OUTPUT H1
■
```

```
DCMA OUTPUT H1
SOURCE: Off
```

*Range: Off, any analog actual value parameter*

MESSAGE

```
DCMA OUTPUT H1
RANGE: -1 to 1 mA
```

*Range: –1 to 1 mA, 0 to 1 mA, 4 to 20 mA*

MESSAGE

```
DCMA OUTPUT H1
MIN VAL: 0.000 pu
```

*Range: –90.000 to 90.000 pu in steps of 0.001*

MESSAGE

```
DCMA OUTPUT H1
MAX VAL: 1.000 pu
```

*Range: –90.000 to 90.000 pu in steps of 0.001*

Hardware and software is provided to generate DCmA signals that allow interfacing with external equipment. Specific hardware details are contained in chapter 3. The DCmA output channels are arranged in a manner similar to transducer input or CT and VT channels. The user configures individual channels with the settings shown below.

The channels are arranged in sub-modules of two channels, numbered 1 through 8 from top to bottom. On power-up, the relay automatically generates configuration settings for every channel, based on the order code, in the same manner used for CTs and VTs. Each channel is assigned a slot letter followed by the row number, 1 through 8 inclusive, which is used as the channel number.

Both the output range and a signal driving a given output are user-programmable via the following settings menu (an example for channel M5 is shown).

5

The relay checks the driving signal ($x$ in equations below) for the minimum and maximum limits, and subsequently re-scales so the limits defined as **MIN VAL** and **MAX VAL** match the output range of the hardware defined as **RANGE**. The following equation is applied:

$$I_{out} = \begin{cases} I_{min} & \text{if } x < \textbf{MIN VAL} \\ I_{max} & \text{if } x > \textbf{MAX VAL} \\ k(x - \textbf{MIN VAL}) + I_{min} & \text{otherwise} \end{cases} \quad \textbf{(EQ 5.28)}$$

where: $x$ is a driving signal specified by the **SOURCE** setting
$I_{min}$ and $I_{max}$ are defined by the **RANGE** setting
$k$ is a scaling constant calculated as:

$$k = \frac{I_{max} - I_{min}}{\textbf{MAX VAL} - \textbf{MIN VAL}} \quad \textbf{(EQ 5.29)}$$

The feature is intentionally inhibited if the **MAX VAL** and **MIN VAL** settings are entered incorrectly, e.g. when **MAX VAL** – **MIN VAL** < 0.1 pu. The resulting characteristic is illustrated in the following figure.

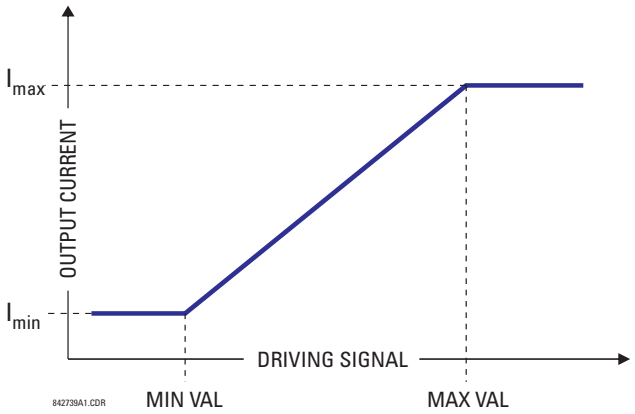



**Figure 5–116: DCMA OUTPUT CHARACTERISTIC**

The DCmA output settings are described below.

- **DCMA OUTPUT H1 SOURCE**: This setting specifies an internal analog value to drive the analog output. Actual values (FlexAnalog parameters) such as power, current amplitude, voltage amplitude, power factor, etc. can be configured as sources driving DCmA outputs. Refer to Appendix A for a complete list of FlexAnalog parameters.
- **DCMA OUTPUT H1 RANGE**: This setting allows selection of the output range. Each DCmA channel may be set independently to work with different ranges. The three most commonly used output ranges are available.
- **DCMA OUTPUT H1 MIN VAL**: This setting allows setting the minimum limit for the signal that drives the output. This setting is used to control the mapping between an internal analog value and the output current. The setting is entered in per-unit values. The base units are defined in the same manner as the FlexElement base units.
- **DCMA OUTPUT H1 MAX VAL**: This setting allows setting the maximum limit for the signal that drives the output. This setting is used to control the mapping between an internal analog value and the output current. The setting is entered in per-unit values. The base units are defined in the same manner as the FlexElement base units.

NOTE

The **DCMA OUTPUT H1 MIN VAL** and **DCMA OUTPUT H1 MAX VAL** settings are ignored for power factor base units (i.e. if the **DCMA OUTPUT H1 SOURCE** is set to FlexAnalog value based on power factor measurement).

Three application examples are described below.

**EXAMPLE: POWER MONITORING**

A three phase active power on a 13.8 kV system measured via UR-series relay source 1 is to be monitored by the DCmA H1 output of the range of –1 to 1 mA. The following settings are applied on the relay: CT ratio = 1200:5, VT secondary 115, VT connection is delta, and VT ratio = 120. The nominal current is 800 A primary and the nominal power factor is 0.90. The power is to be monitored in both importing and exporting directions and allow for 20% overload compared to the nominal.

The nominal three-phase power is:

$$P = \sqrt{3} \times 13.8 \text{ kV} \times 0.8 \text{ kA} \times 0.9 = 17.21 \text{ MW} \quad \textbf{(EQ 5.30)}$$

The three-phase power with 20% overload margin is:

$$P_{max} = 1.2 \times 17.21 \text{ MW} = 20.65 \text{ MW} \quad \textbf{(EQ 5.31)}$$

The base unit for power (refer to the FlexElements section in this chapter for additional details) is:

$$P_{BASE} = 115 \text{ V} \times 120 \times 1.2 \text{ kA} = 16.56 \text{ MW} \quad \textbf{(EQ 5.32)}$$

The minimum and maximum power values to be monitored (in pu) are:

$$\text{minimum power} = \frac{-20.65 \text{ MW}}{16.56 \text{ MW}} = -1.247 \text{ pu}, \quad \text{maximum power} = \frac{20.65 \text{ MW}}{16.56 \text{ MW}} = 1.247 \text{ pu} \quad \textbf{(EQ 5.33)}$$

The following settings should be entered:

**DCMA OUTPUT H1 SOURCE**: "SRC 1 P"
**DCMA OUTPUT H1 RANGE**: "–1 to 1 mA"
**DCMA OUTPUT H1 MIN VAL**: "–1.247 pu"
**DCMA OUTPUT H1 MAX VAL**: "1.247 pu"

With the above settings, the output will represent the power with the scale of 1 mA per 20.65 MW. The worst-case error for this application can be calculated by superimposing the following two sources of error:

- ±0.5% of the full scale for the analog output module, or $\pm 0.005 \times (1 - (-1)) \times 20.65 \text{ MW} = \pm 0.207 \text{ MW}$
- ±1% of reading error for the active power at power factor of 0.9

For example at the reading of 20 MW, the worst-case error is 0.01 × 20 MW + 0.207 MW = 0.407 MW.

**EXAMPLE: CURRENT MONITORING**

The phase A current (true RMS value) is to be monitored via the H2 current output working with the range from 4 to 20 mA. The CT ratio is 5000:5 and the maximum load current is 4200 A. The current should be monitored from 0 A upwards, allowing for 50% overload.

The phase current with the 50% overload margin is:

$$I_{max} = 1.5 \times 4.2 \text{ kA} = 6.3 \text{ kA} \quad \textbf{(EQ 5.34)}$$

The base unit for current (refer to the FlexElements section in this chapter for additional details) is:

$$I_{BASE} = 5 \text{ kA} \quad \textbf{(EQ 5.35)}$$

The minimum and maximum power values to be monitored (in pu) are:

$$\text{minimum current} = \frac{0 \text{ kA}}{5 \text{ kA}} = 0 \text{ pu}, \quad \text{maximum current} = \frac{6.3 \text{ kA}}{5 \text{ kA}} = 1.26 \text{ pu} \quad \textbf{(EQ 5.36)}$$

The following settings should be entered:

**DCMA OUTPUT H2 SOURCE**: "SRC 1 Ia RMS"
**DCMA OUTPUT H2 RANGE**: "4 to 20 mA"
**DCMA OUTPUT H2 MIN VAL**: "0.000 pu"
**DCMA OUTPUT H2 MAX VAL**: "1.260 pu"

The worst-case error for this application could be calculated by superimposing the following two sources of error:

- ±0.5% of the full scale for the analog output module, or $\pm 0.005 \times (20 - 4) \times 6.3 \text{ kA} = \pm 0.504 \text{ kA}$
- ±0.25% of reading or ±0.1% of rated (whichever is greater) for currents between 0.1 and 2.0 of nominal

For example, at the reading of 4.2 kA, the worst-case error is max(0.0025 × 4.2 kA, 0.001 × 5 kA) + 0.504 kA = 0.515 kA.

**EXAMPLE: VOLTAGE MONITORING**

A positive-sequence voltage on a 400 kV system measured via source 2 is to be monitored by the DCmA H3 output with a range of 0 to 1 mA. The VT secondary setting is 66.4 V, the VT ratio setting is 6024, and the VT connection setting is "Delta". The voltage should be monitored in the range from 70% to 110% of nominal.

The minimum and maximum positive-sequence voltages to be monitored are:

$$V_{min} = 0.7 \times \frac{400 \text{ kV}}{\sqrt{3}} = 161.66 \text{ kV}, \quad V_{max} = 1.1 \times \frac{400 \text{ kV}}{\sqrt{3}} = 254.03 \text{ kV} \quad \textbf{(EQ 5.37)}$$

The base unit for voltage (refer to the FlexElements section in this chapter for additional details) is:

$$V_{BASE} = 0.0664 \text{ kV} \times 6024 = 400 \text{ kV} \quad \textbf{(EQ 5.38)}$$

The minimum and maximum voltage values to be monitored (in pu) are:

$$\text{minimum voltage} = \frac{161.66 \text{ kV}}{400 \text{ kV}} = 0.404 \text{ pu}, \quad \text{maximum voltage} = \frac{254.03 \text{ kV}}{400 \text{ kV}} = 0.635 \text{ pu} \quad \textbf{(EQ 5.39)}$$

The following settings should be entered:

**DCMA OUTPUT H3 SOURCE**: "SRC 2 V_1 mag"
**DCMA OUTPUT H3 RANGE**: "0 to 1 mA"
**DCMA OUTPUT H3 MIN VAL**: "0.404 pu"
**DCMA OUTPUT H3 MAX VAL**: "0.635 pu"

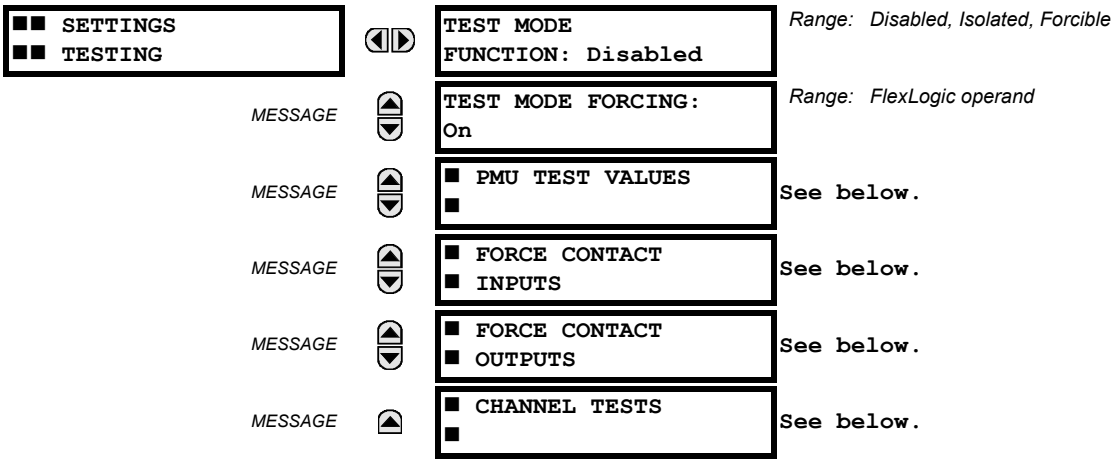
The limit settings differ from the expected 0.7 pu and 1.1 pu because the relay calculates the positive-sequence quantities scaled to the phase-to-ground voltages, even if the VTs are connected in "Delta" (see the Metering Conventions section in chapter 6), while at the same time the VT nominal voltage is 1 pu for the settings. Consequently the settings required in this example differ from naturally expected by the factor of $\sqrt{3}$.

The worst-case error for this application could be calculated by superimposing the following two sources of error:

- ±0.5% of the full scale for the analog output module, or $\pm 0.005 \times (1 - 0) \times 254.03 \text{ kV} = \pm 1.27 \text{ kV}$
- ±0.5% of reading

For example, under nominal conditions, the positive-sequence reads 230.94 kV and the worst-case error is 0.005 x 230.94 kV + 1.27 kV = 2.42 kV.

PATH: SETTINGS ⇨⇩ TESTING




The L30 provides a test facility to verify the functionality of contact inputs and outputs, some communication functions and the phasor measurement unit (where applicable), using simulated conditions. The test mode is indicated on the relay faceplate by a Test Mode LED indicator.

The test mode may be in any of three states: disabled, isolated, or forcible.

In the "Disabled" mode, L30 operation is normal and all test features are disabled.

In the "Isolated" mode, the L30 is prevented from performing certain control actions, including tripping via contact outputs. All relay contact outputs, including latching outputs, are disabled. Channel tests and phasor measurement unit tests remain usable on applicable UR-series models.

In the "Forcible" mode, the operand selected by the **TEST MODE FORCING** setting controls the relay inputs and outputs. If the test mode is forcible, and the operand assigned to the **TEST MODE FORCING** setting is "Off", the L30 inputs and outputs operate normally. If the test mode is forcible, and the operand assigned to the **TEST MODE FORCING** setting is "On", the L30 contact inputs and outputs are forced to the values specified in the following sections. Forcing may be controlled by manually changing the operand selected by the **TEST MODE FORCING** setting between on and off, or by selecting a user-programmable pushbutton, contact input, or communication-based input operand. Channel tests and phasor measurement unit tests remain usable on applicable UR-series models.

NOTE

Communications based inputs and outputs remain fully operational in test mode. If a control action is programmed using direct inputs and outputs or remote inputs and outputs, then the test procedure must take this into account.

When in "Forcible" mode, the operand selected by the **TEST MODE FORCING** setting dictates further response of the L30 to testing conditions. To force contact inputs and outputs through relay settings, set **TEST MODE FORCING** to "On". To force contact inputs and outputs through a user-programmable condition, such as FlexLogic operand (pushbutton, contact input, communication-based input, or a combination of these), set **TEST MODE FORCING** to the desired operand. The contact input or output is forced when the selected operand assumes a logic 1 state.

The L30 remains fully operational in test mode, allowing for various testing procedures. In particular, the protection and control elements, FlexLogic, and communication-based inputs and outputs function normally.

The only difference between the normal operation and the test mode is the behavior of the input and output contacts. The contact inputs can be forced to report as open or closed or remain fully operational, whereas the contact outputs can be forced to open, close, freeze, or remain fully operational. The response of the contact input and output contacts to the test mode is programmed individually for each input and output using the force contact inputs and force contact outputs test functions described in the following sections.

The test mode state is indicated on the relay faceplate by a combination of the Test Mode LED indicator, the In-Service LED indicator, and by the critical fail relay, as shown in the following table.

**Table 5–37: TEST MODE OPERATION**

| TEST MODE FUNCTION | TEST MODE FORCING OPERAND | IN-SERVICE LED | TEST MODE LED | CRITICAL FAIL RELAY | INPUT AND OUTPUT BEHAVIOR |
|---|---|---|---|---|---|
| Disabled | No effect | Unaffected | Off | Unaffected | Contact outputs and inputs are under normal operation. Channel tests and PMU tests not operational (where applicable). |
| Isolated | No effect | Off | On | De-energized | Contact outputs are disabled and contact inputs are operational. Channel tests and PMU tests are also operational (where applicable). |
| Forcible | On (logic 1) | Off | Flashing | De-energized | Contact inputs and outputs are controlled by the force contact input and force contact output functions. Channel tests and PMU tests are operational (where applicable). |
| | Off (logic 0) | Off | Flashing | De-energized | Contact outputs and inputs are under normal operation. Channel tests and PMU tests are also operational (where applicable). |

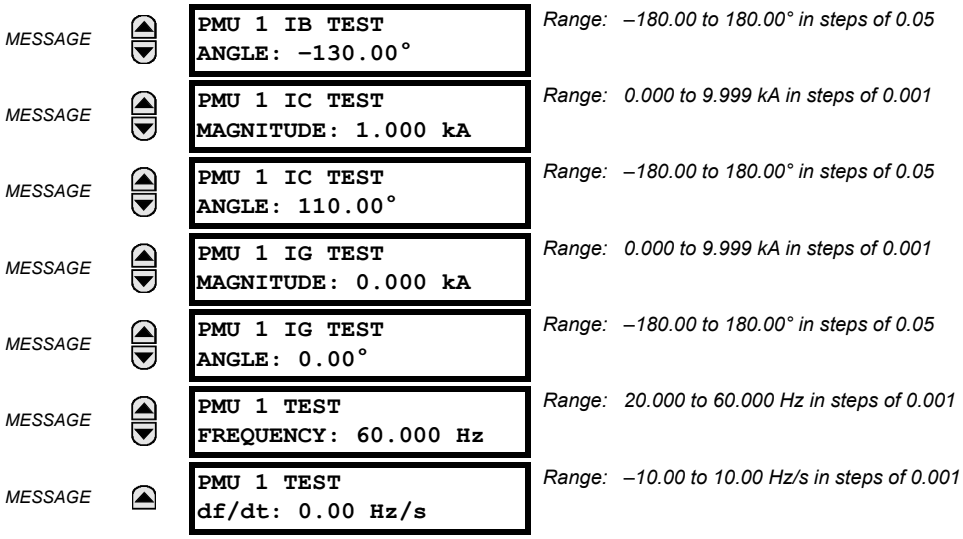
The **TEST MODE FUNCTION** setting can only be changed by a direct user command. Following a restart, power up, settings upload, or firmware upgrade, the test mode will remain at the last programmed value. This allows a L30 that has been placed in isolated mode to remain isolated during testing and maintenance activities. On restart, the **TEST MODE FORCING** setting and the force contact input and force contact output settings all revert to their default states.

## 5.10.2 PHASOR MEASUREMENT UNIT TEST VALUES



**PATH: SETTINGS ⇨⇩ TESTING ⇨⇩ PMU TEST VALUES ⇨ PMU 1 TEST VALUES**

| | | | |
|---|---|---|---|
| ■ PMU 1<br>■ TEST VALUES | | PMU 1 TEST<br>FUNCTION: Disabled | *Range: Enabled, Disabled* |
| | *MESSAGE* | PMU 1 VA TEST<br>MAGNITUDE: 500.00 kV | *Range: 0.00 to 700.00 kV in steps of 0.01* |
| | *MESSAGE* | PMU 1 VA TEST<br>ANGLE: 0.00° | *Range: –180.00 to 180.00° in steps of 0.05* |
| | *MESSAGE* | PMU 1 VB TEST<br>MAGNITUDE: 500.00 kV | *Range: 0.00 to 700.00 kV in steps of 0.01* |
| | *MESSAGE* | PMU 1 VB TEST<br>ANGLE: –120.00° | *Range: –180.00 to 180.00° in steps of 0.05* |
| | *MESSAGE* | PMU 1 VC TEST<br>MAGNITUDE: 500.00 kV | *Range: 0.00 to 700.00 kV in steps of 0.01* |
| | *MESSAGE* | PMU 1 VC TEST<br>ANGLE: 120.00° | *Range: –180.00 to 180.00° in steps of 0.05* |
| | *MESSAGE* | PMU 1 VX TEST<br>MAGNITUDE: 500.00 kV | *Range: 0.00 to 700.00 kV in steps of 0.01* |
| | *MESSAGE* | PMU 1 VX TEST<br>ANGLE: 0.00° | *Range: –180.00 to 180.00° in steps of 0.05* |
| | *MESSAGE* | PMU 1 IA TEST<br>MAGNITUDE: 1.000 kA | *Range: 0.000 to 9.999 kA in steps of 0.001* |
| | *MESSAGE* | PMU 1 IA TEST<br>ANGLE: –10.00° | *Range: –180.00 to 180.00° in steps of 0.05* |
| | *MESSAGE* | PMU 1 IB TEST<br>MAGNITUDE: 1.000 kA | *Range: 0.000 to 9.999 kA in steps of 0.001* |




The relay must be in test mode to use the PMU test mode. That is, the **TESTING ⇨ TEST MODE FUNCTION** setting must be enabled and the **TESTING ⇨⇩ TEST MODE INITIATE** initiating signal must be "On".

During the PMU test mode, the physical channels (VA, VB, VC, VX, IA, IB, IC, and IG), frequency, and rate of change of frequency are substituted with user values, while the symmetrical components are calculated from the physical channels. The test values are not explicitly marked in the outgoing data frames. When required, it is recommended to use the user-programmable digital channels to signal the IEEE C37.118 client that test values are being sent in place of the real measurements.

The UR Synchrophasor Implementation defines a test mode which sends a pre-defined set of Synchrophasors out over the communication channel when the test mode function setting is enabled. In test mode, the following actions take place:

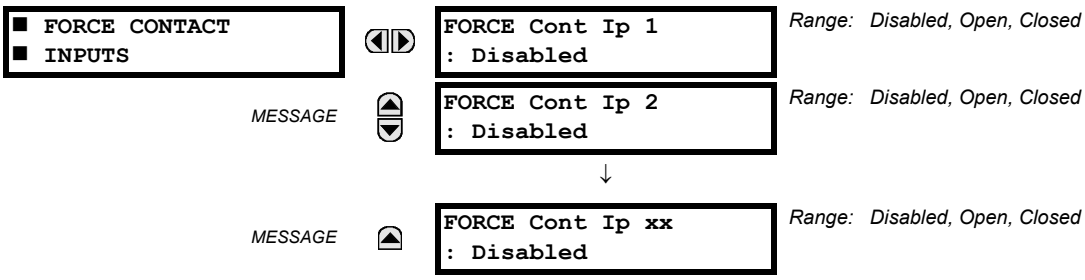
a. The Data Invalid / Test Mode bit (bit 15 in the STAT word) is set.

b. The Sim bit in all output datasets is set.



### 5.10.3 FORCE CONTACT INPUTS

**PATH: SETTINGS ⇨⇩ TESTING ⇨⇩ FORCE CONTACT INPUTS**



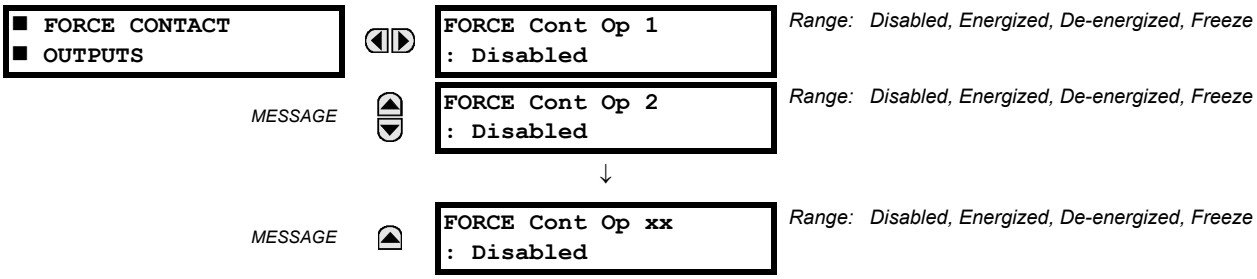

The relay contact inputs can be pre-programmed to respond to the test mode in the following ways:

- If set to "Disabled", the input remains fully operational. It is controlled by the voltage across its input terminals and can be turned on and off by external circuitry. This value should be selected if a given input must be operational during the test. This includes, for example, an input initiating the test, or being a part of a user pre-programmed test sequence.
- If set to "Open", the input is forced to report as opened (Logic 0) for the entire duration of the test mode regardless of the voltage across the input terminals.
- If set to "Closed", the input is forced to report as closed (Logic 1) for the entire duration of the test mode regardless of the voltage across the input terminals.

The force contact inputs feature provides a method of performing checks on the function of all contact inputs. Once enabled, the relay is placed into test mode, allowing this feature to override the normal function of contact inputs. The Test Mode LED will be on, indicating that the relay is in test mode. The state of each contact input may be programmed as "Disabled", "Open", or "Closed". All contact input operations return to normal when all settings for this feature are disabled.

### 5.10.4 FORCE CONTACT OUTPUTS

**PATH: SETTINGS ⇨⇩ TESTING ⇨⇩ FORCE CONTACT OUTPUTS**




The relay contact outputs can be pre-programmed to respond to the test mode.

If set to "Disabled", the contact output remains fully operational. If operates when its control operand is logic 1 and will resets when its control operand is logic 0. If set to "Energized", the output will close and remain closed for the entire duration of the test mode, regardless of the status of the operand configured to control the output contact. If set to "De-energized", the output will open and remain opened for the entire duration of the test mode regardless of the status of the operand configured to control the output contact. If set to "Freeze", the output retains its position from before entering the test mode, regardless of the status of the operand configured to control the output contact.

These settings are applied two ways. First, external circuits may be tested by energizing or de-energizing contacts. Second, by controlling the output contact state, relay logic may be tested and undesirable effects on external circuits avoided.

**Example 1: Initiating test mode through user-programmable pushbutton 1**

For example, the test mode can be initiated from user-programmable pushbutton 1. The pushbutton will be programmed as "Latched" (pushbutton pressed to initiate the test, and pressed again to terminate the test). During the test, contact input 1 should remain operational, contact inputs 2 and 3 should open, and contact input 4 should close. Also, contact output 1 should freeze, contact output 2 should open, contact output 3 should close, and contact output 4 should remain fully operational. The required settings are shown below.

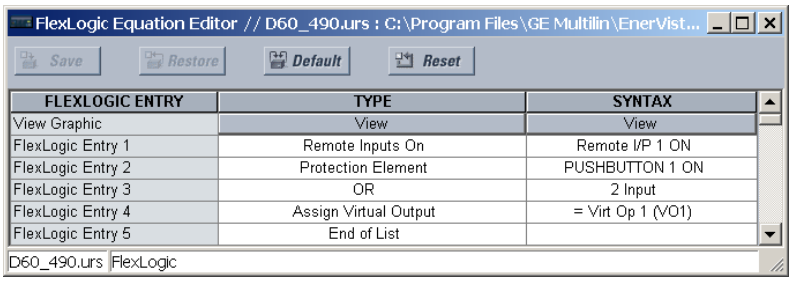
To enable user-programmable pushbutton 1 to initiate the test mode, make the following changes in the **SETTINGS ⇨⇩ TESTING ⇨ TEST MODE** menu: **TEST MODE FUNCTION:** enabled and **TEST MODE INITIATE:** "PUSHBUTTON 1 ON"

Make the following changes to configure the contact inputs and outputs. In the **SETTINGS ⇨⇩ TESTING ⇨⇩ FORCE CONTACT INPUTS** and **FORCE CONTACT OUTPUTS** menus, set:

**FORCE Cont Ip 1:** "Disabled", **FORCE Cont Ip 2:** "Open", **FORCE Cont Ip 3:** "Open", and **FORCE Cont Ip 4:** "Closed"
**FORCE Cont Op 1:** "Freeze", **FORCE Cont Op 2:** "De-energized", **FORCE Cont Op 3:** "Energized", and **FORCE Cont Op 4:** "Disabled"

**Example 2: Initiating a test from user-programmable pushbutton 1 or through remote input 1**

In this example, the test can be initiated locally from user-programmable pushbutton 1 or remotely through remote input 1. Both the pushbutton and the remote input will be programmed as "Latched". Write the following FlexLogic equation:

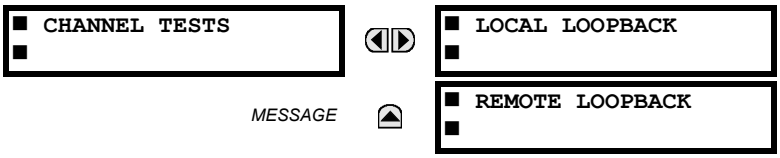


Set the user-programmable pushbutton as latching by changing **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE PUSHBUTTONS ⇨ USER PUSHBUTTON 1 ⇨ PUSHBUTTON 1 FUNCTION** to "Latched". To enable either pushbutton 1 or remote input 1 to initiate the Test mode, make the following changes in the **SETTINGS ⇨⇩ TESTING ⇨ TEST MODE** menu:

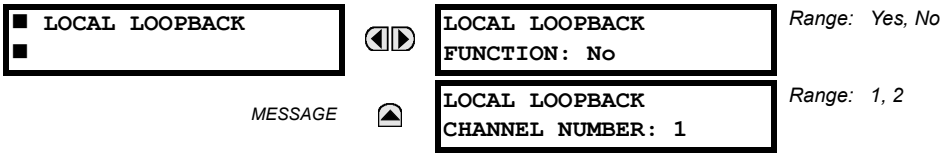
**TEST MODE FUNCTION:** enabled and **TEST MODE INITIATE:** "VO1"

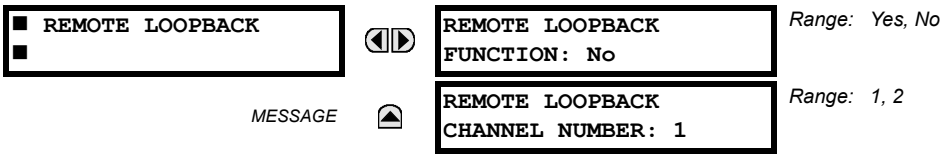
## 5.10.5 CHANNEL TESTS

**PATH: SETTINGS ⇨⇩ TESTING ⇨⇩ CHANNEL TESTS**

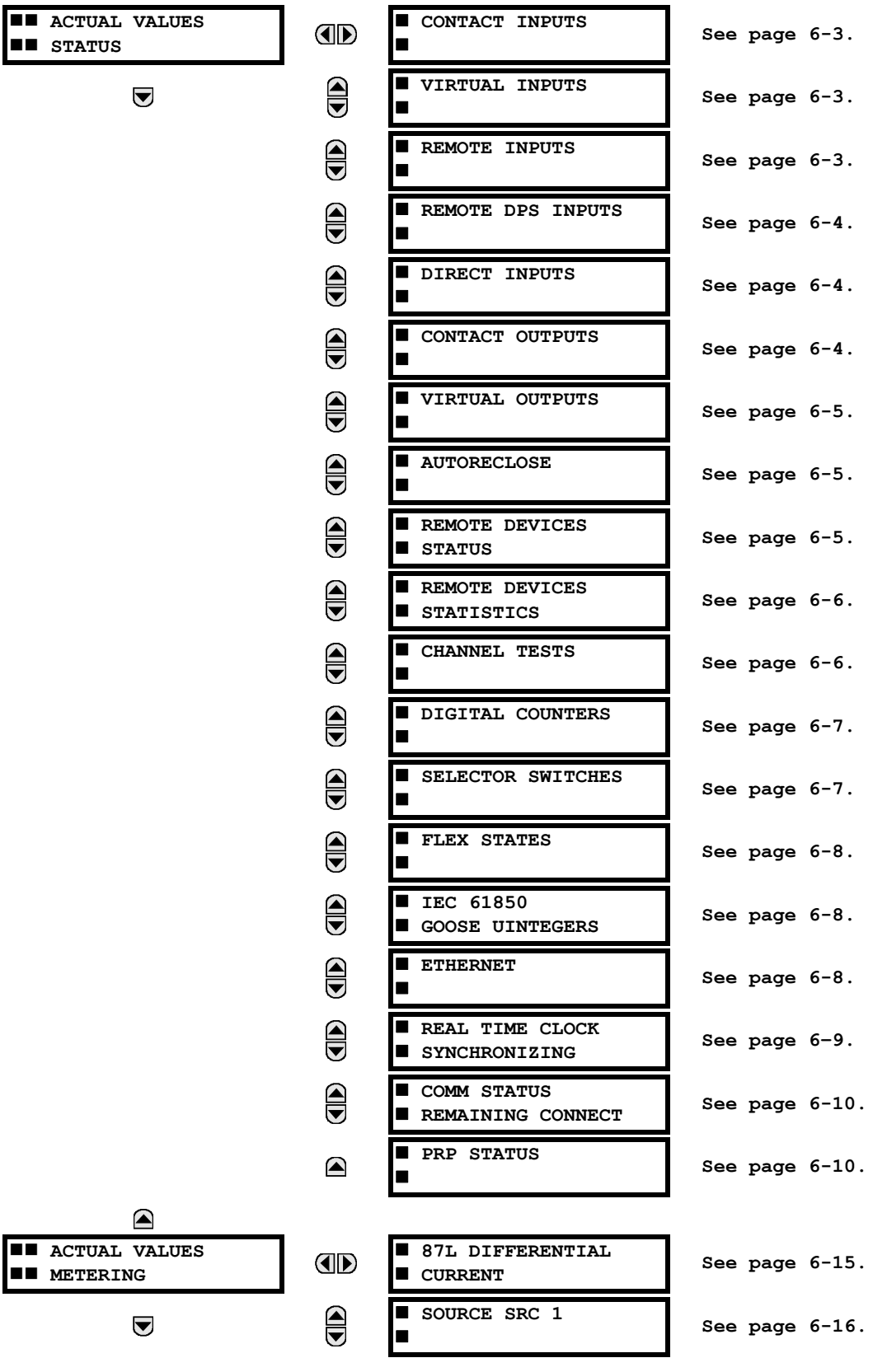


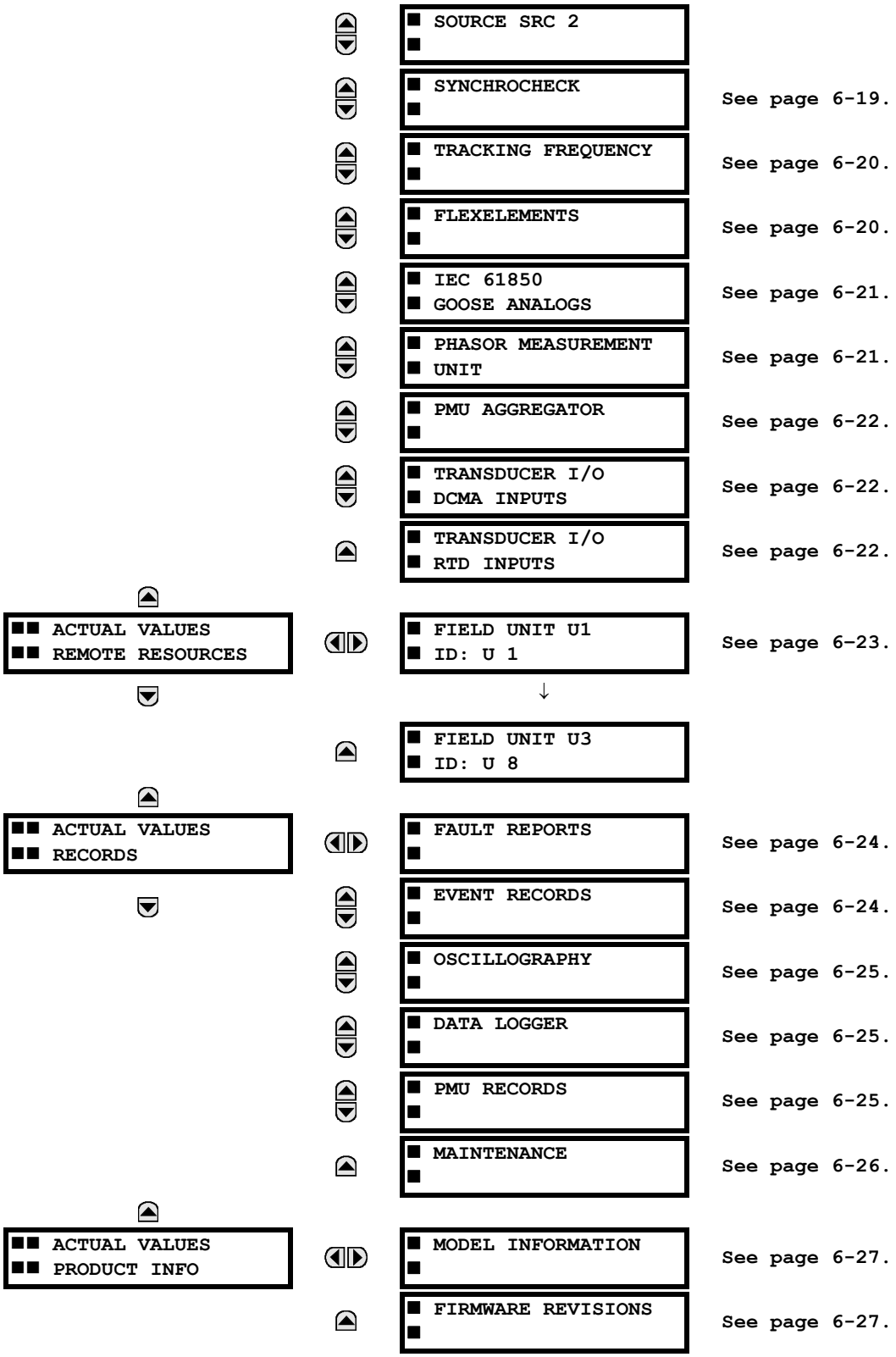

This function performs checking of the communications established by both relays.




See the Commissioning chapter for a detailed description of using the channel tests.


ACTUAL VALUES
STATUS
CONTACT INPUTS
See page 6-3.
VIRTUAL INPUTS
See page 6-3.
REMOTE INPUTS
See page 6-3.
REMOTE DPS INPUTS
See page 6-4.
DIRECT INPUTS
See page 6-4.
CONTACT OUTPUTS
See page 6-4.
VIRTUAL OUTPUTS
See page 6-5.
AUTORECLOSE
See page 6-5.
REMOTE DEVICES STATUS
See page 6-5.
REMOTE DEVICES STATISTICS
See page 6-6.
CHANNEL TESTS
See page 6-6.
DIGITAL COUNTERS
See page 6-7.
SELECTOR SWITCHES
See page 6-7.
FLEX STATES
See page 6-8.
IEC 61850 GOOSE UINTEGERS
See page 6-8.
ETHERNET
See page 6-8.
REAL TIME CLOCK SYNCHRONIZING
See page 6-9.
COMM STATUS REMAINING CONNECT
See page 6-10.
PRP STATUS
See page 6-10.
ACTUAL VALUES
METERING
87L DIFFERENTIAL CURRENT
See page 6-15.
SOURCE SRC 1
See page 6-16.



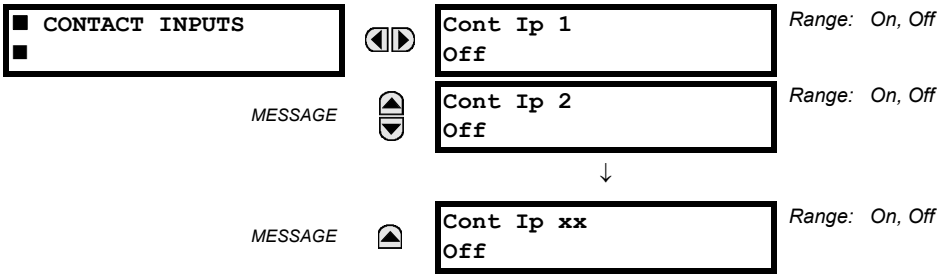

See page 6-19.
See page 6-20.
See page 6-20.
See page 6-21.
See page 6-21.
See page 6-22.
See page 6-22.
See page 6-22.
See page 6-23.
See page 6-24.
See page 6-24.
See page 6-25.
See page 6-25.
See page 6-25.
See page 6-26.
See page 6-27.
See page 6-27.

NOTE

For status reporting, 'On' represents Logic 1 and 'Off' represents Logic 0.

### 6.2.1 CONTACT INPUTS

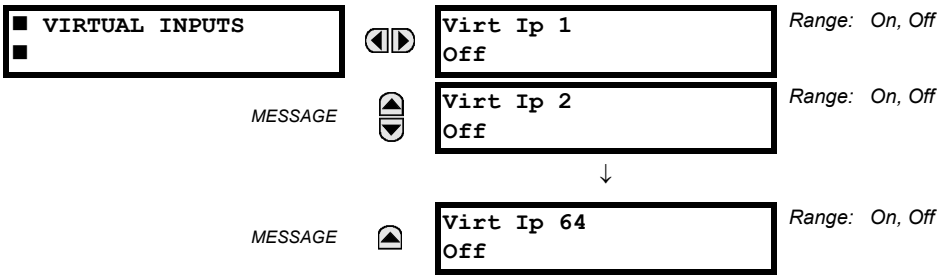
PATH: ACTUAL VALUES ⇨ STATUS ⇨ CONTACT INPUTS




The present status of the contact inputs is shown here. The first line of a message display indicates the ID of the contact input. For example, 'Cont Ip 1' refers to the contact input in terms of the default name-array index. The second line of the display indicates the logic state of the contact input.

### 6.2.2 VIRTUAL INPUTS

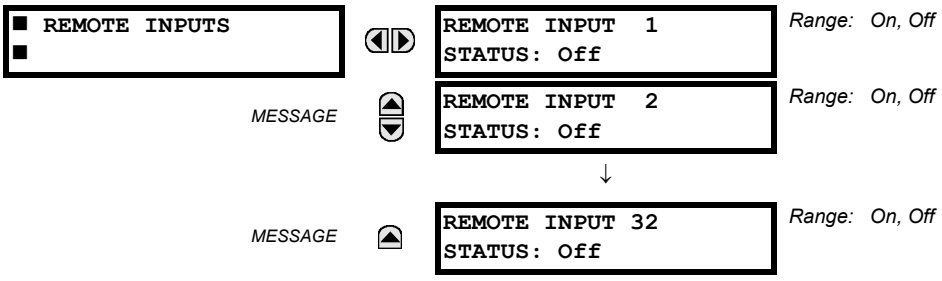
PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ VIRTUAL INPUTS




The present status of the 64 virtual inputs is shown here. The first line of a message display indicates the ID of the virtual input. For example, 'Virt Ip 1' refers to the virtual input in terms of the default name. The second line of the display indicates the logic state of the virtual input.

### 6.2.3 REMOTE INPUTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ REMOTE INPUTS

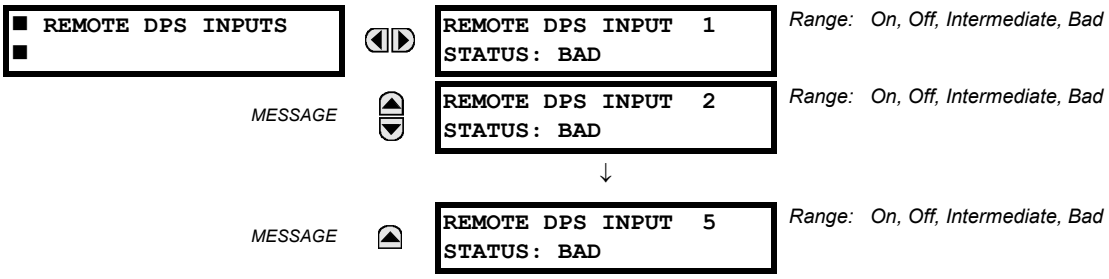



The present state of the 32 remote inputs is shown here.

The state displayed will be that of the remote point unless the remote device has been established to be "Offline" in which case the value shown is the programmed default state for the remote input.

### 6.2.4 REMOTE DOUBLE-POINT STATUS INPUTS

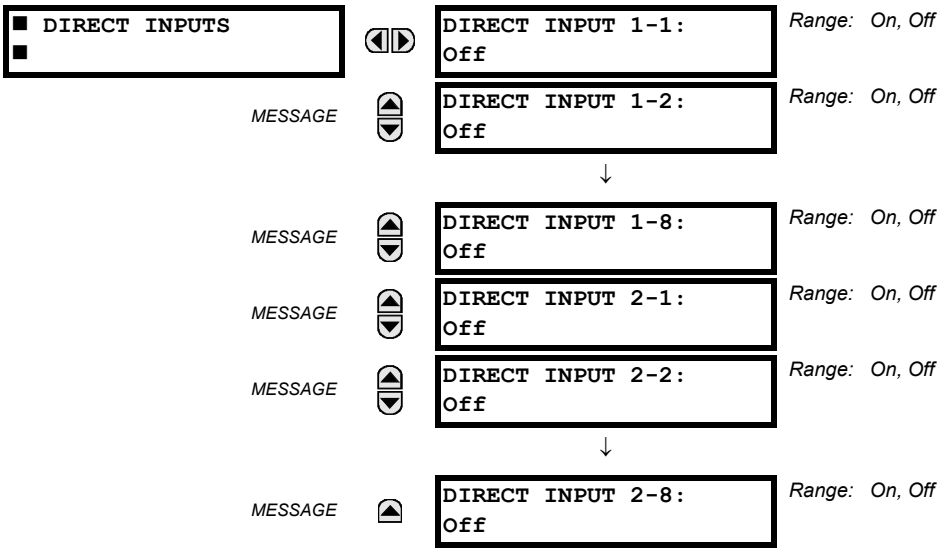
PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ REMOTE DPS INPUTS




The present state of the remote double-point status inputs is shown here. The actual values indicate if the remote double-point status inputs are in the on (close), off (open), intermediate, or bad state.

### 6.2.5 DIRECT INPUTS

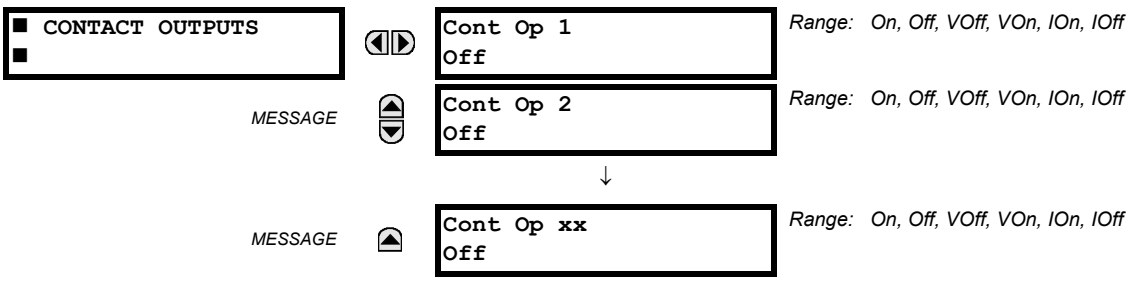
PATH: ACTUAL VALUES ⇩ STATUS ⇨⇩ DIRECT INPUTS




The present state of the direct inputs from communications channels 1 and 2 are shown here. The state displayed will be that of the remote point unless channel 1 or 2 has been declared to have "failed", in which case the value shown is the programmed default state defined in the SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ DIRECT ⇨ DIRECT INPUTS menu.

### 6.2.6 CONTACT OUTPUTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ CONTACT OUTPUTS



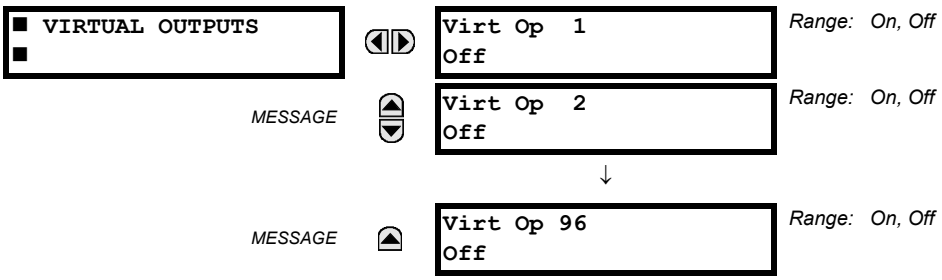
The present state of the contact outputs is shown here. The first line of a message display indicates the ID of the contact output. For example, 'Cont Op 1' refers to the contact output in terms of the default name-array index. The second line of the display indicates the logic state of the contact output.

NOTE

For form-A contact outputs, the state of the voltage and current detectors is displayed as Off, VOff, IOff, On, IOn, and VOn. For form-C contact outputs, the state is displayed as Off or On.

### 6.2.7 VIRTUAL OUTPUTS

**PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ VIRTUAL OUTPUTS**




The present state of up to 96 virtual outputs is shown here. The first line of a message display indicates the ID of the virtual output. For example, 'Virt Op 1' refers to the virtual output in terms of the default name-array index. The second line of the display indicates the logic state of the virtual output, as calculated by the FlexLogic equation for that output.

### 6.2.8 AUTORECLOSE

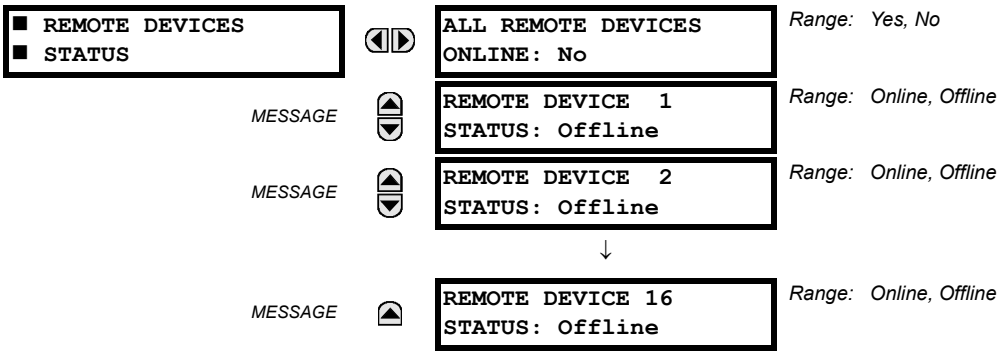
**PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ AUTORECLOSE ⇨ AUTORECLOSE 1**

The automatic reclosure shot count is shown here.

### 6.2.9 REMOTE DEVICES

#### a) STATUS

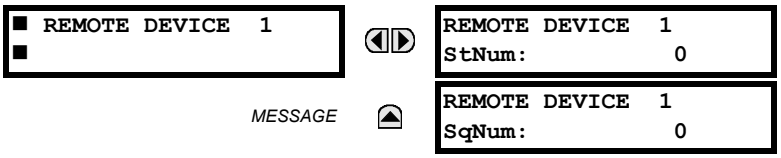
**PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ REMOTE DEVICES STATUS**




The present state of the programmed remote devices is shown here. The **ALL REMOTE DEVICES ONLINE** message indicates whether or not all programmed remote devices are online. If the corresponding state is "No", then at least one required remote device is not online.

### b) STATISTICS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ REMOTE DEVICES STATISTICS ⇨ REMOTE DEVICE 1(16)

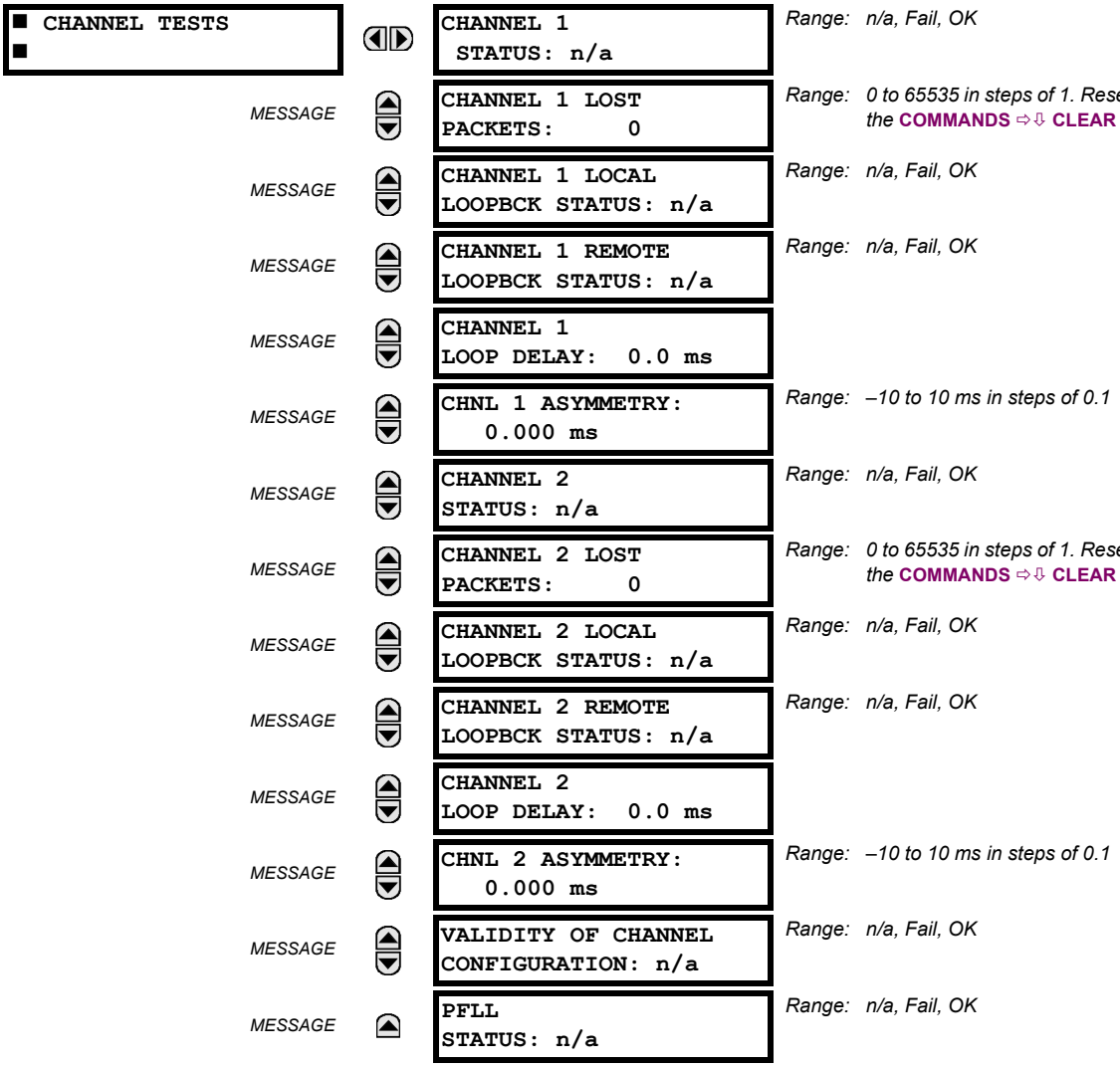



Statistical data (two types) for up to 16 programmed remote devices is shown here.

The **STNUM** number is obtained from the indicated remote device and increments whenever a change of state of at least one item occurs in the GSSE/GOOSE message. The **SQNUM** number is obtained from the indicated remote device and increments whenever a GSSE/GOOSE message, without a state change, is sent. When the GSSE/GOOSE message trasmits a state change, the **SQNUM** resets to 0. This number rolls over to zero when a count of 4,294,967,295 is incremented.

## 6.2.10 CHANNEL TESTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS




The status information for two channels is shown here. A brief description of each actual value is below:

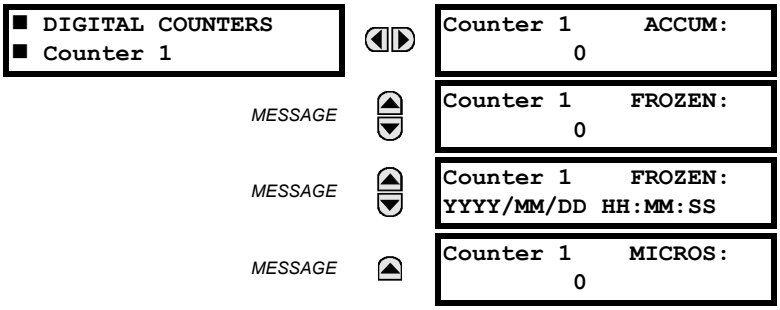
- **CHANNEL 1(2) STATUS**: This represents the receiver status of each channel. If the value is "OK", the 87L current differential element is enabled and data is being received from the remote terminal; If the value is "Fail", the 87L element is enabled and data is not being received from the remote terminal. If "n/a", the 87L element is disabled.
- **CHANNEL 1(2) LOST PACKETS**: Current, timing, and control data is transmitted to the remote terminals in data packets at a rate of two packets per cycle. The number of lost packets represents data packets lost in transmission; this count can be reset through the **COMMANDS** ⇨⇩ **CLEAR RECORDS** menu.
- **CHANNEL 1(2) LOCAL LOOPBACK STATUS:** The result of the local loopback test is displayed here.
- **CHANNEL 1(2) REMOTE LOOPBACK STATUS**: The result of the remote loopback test is displayed here.
- **CHANNEL 1(2) LOOP DELAY**: Displays the round trip channel delay (including loopback processing time of the remote relay) computed during a remote loopback test and under normal relay operation, in milliseconds (ms).
- **CHANNEL 1(2) ASYMMETRY**: The result of channel asymmetry calculations derived from GPS signal is being displayed here for both channels if **CHANNEL ASYMMETRY** is "Enabled". A positive "+" sign indicates the transit delay in the transmitting direction is less than the delay in the receiving direction; a negative "–" sign indicates the transit delay in the transmitting direction is more than the delay in the receiving direction. A displayed value of "0.0" indicates that either asymmetry is not present or can not be estimated due to failure with local/remote GPS clock source.
- **VALIDITY OF CHANNEL CONFIGURATION**: The current state of the communications channel identification check, and hence validity, is displayed here. If a remote relay ID number does not match the programmed number at the local relay, the "Fail" value is displayed. The "n/a" value appears if the local relay ID is set to a default value of "0" or if the 87L element is disabled. Refer to **SETTINGS** ⇨⇩ **SYSTEM SETUP** ⇨⇩ **L90 POWER SYSTEM** section for more information
- **PFLL STATUS**: This value represents the status of the phase and frequency locked loop (PFLL) filter which uses timing information from local and remote terminals to synchronize the clocks of all terminals. If **PFLL STATUS** is "OK", the clocks of all terminals are synchronized and 87L protection is enabled. If it is "Fail", the clocks of all terminals are not synchronized and 87L protection is disabled. If "n/a", then PFLL is disabled.

NOTE

At startup, the clocks of all terminals are not synchronized and the PFLL status displayed is "Fail". It takes up to eight seconds after startup for the value displayed to change from "Fail" to "OK".

### 6.2.11 DIGITAL COUNTERS

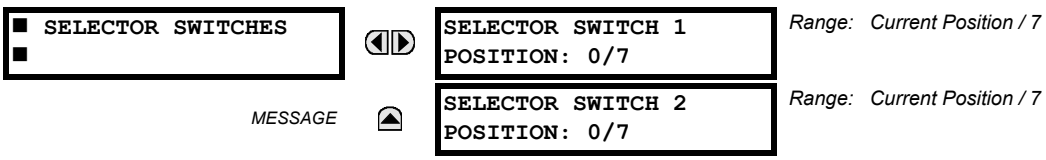
**PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ DIGITAL COUNTERS ⇨ DIGITAL COUNTERS Counter 1(8)**




The present status of the eight digital counters is shown here. The status of each counter, with the user-defined counter name, includes the accumulated and frozen counts (the count units label will also appear). Also included, is the date and time stamp for the frozen count. The **COUNTER 1 MICROS** value refers to the microsecond portion of the time stamp.

### 6.2.12 SELECTOR SWITCHES

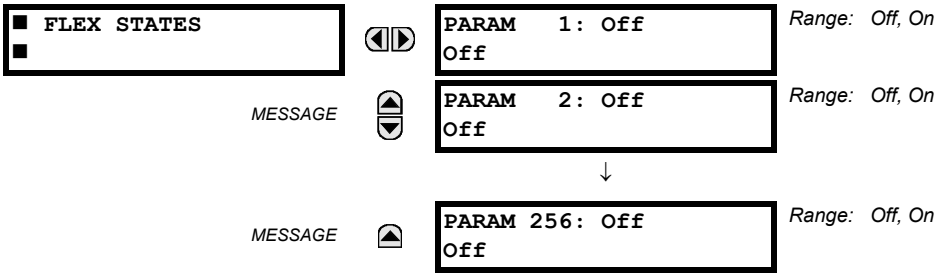
**PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ SELECTOR SWITCHES**



The display shows both the current position and the full range. The current position only (an integer from 0 through 7) is the actual value.

### 6.2.13 FLEX STATES

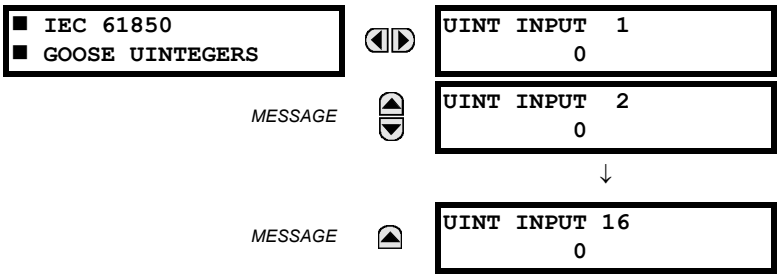
PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ FLEX STATES




There are 256 FlexState™ bits available. The second line value indicates the state of the given FlexState bit.

### 6.2.14 IEC 61850 GOOSE INTEGERS

PATH: ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ IEC 61850 GOOSE UINTEGERS

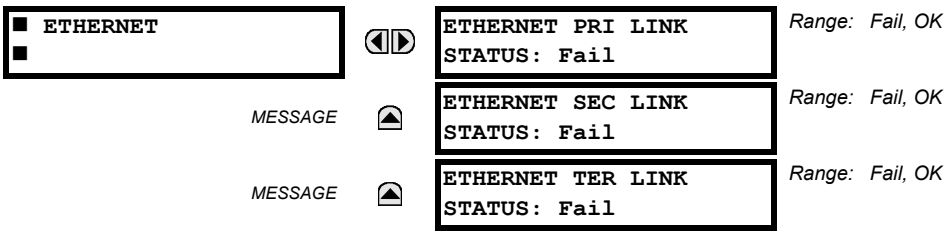


The L30 Line Current Differential System is provided with optional IEC 61850 communications capability. This feature is specified as a software option at the time of ordering. See the Order Codes section in chapter 2 for details.

The IEC 61850 GGIO5 integer input data points are displayed in this menu. The GGIO5 integer data values are received via IEC 61850 GOOSE messages sent from other devices.

### 6.2.15 ETHERNET

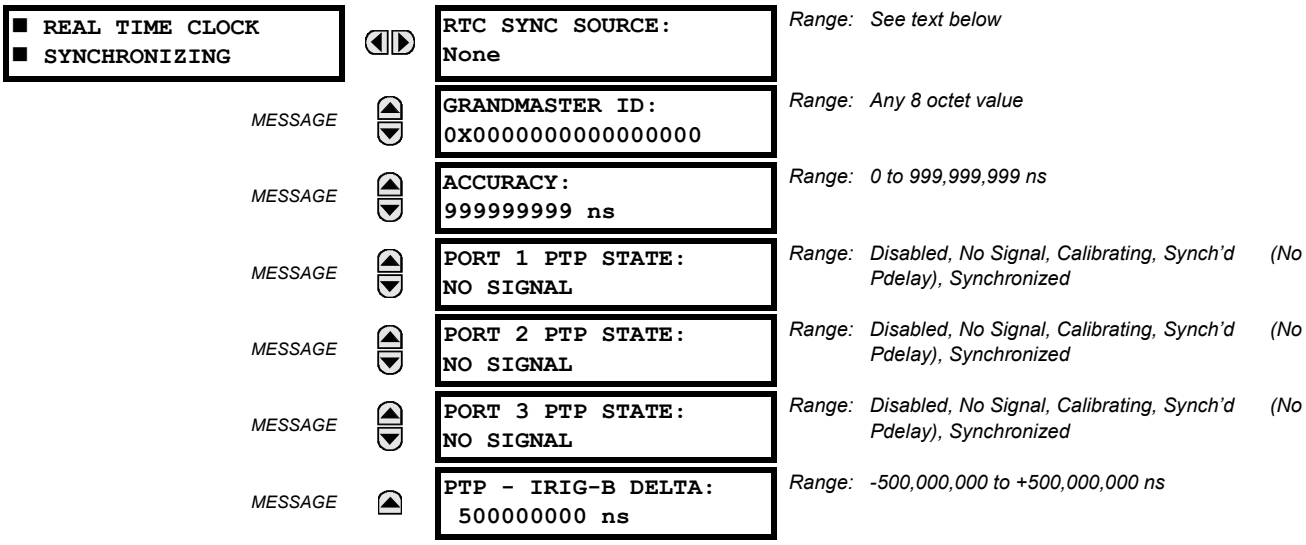
PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ ETHERNET




These values indicate the status of the first, second, and third Ethernet links.

## 6.2.16 REAL TIME CLOCK SYNCHRONIZING

PATH: ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ REAL TIME CLOCK SYNCHRONIZING




The **RTC SYNC SOURCE** actual value is the time synchronizing source the relay is using at present. Possible sources are: Port 1 PTP Clock, Port 2 PTP Clock, Port 3 PTP Clock, IRIG-B, SNTP, and None. An actual value displays when the relay includes the IEEE 1588 software option.

The **GRANDMASTER ID** is the grandmasterIdentity code being received from the present PTP grandmaster, if any. When the relay is not using any PTP grandmaster, this actual value is zero. The grandmasterIdentity code is specified by PTP to be globally unique, so one can always know which clock is grandmaster in a system with multiple grandmaster-capable clocks.

Accuracy is the estimated maximum time error at present in the RTC, considering the quality information imbedded in the received time signal. The value 999,999,999 indicates that the magnitude of the estimated error is one second or more, or that the error cannot be estimated.

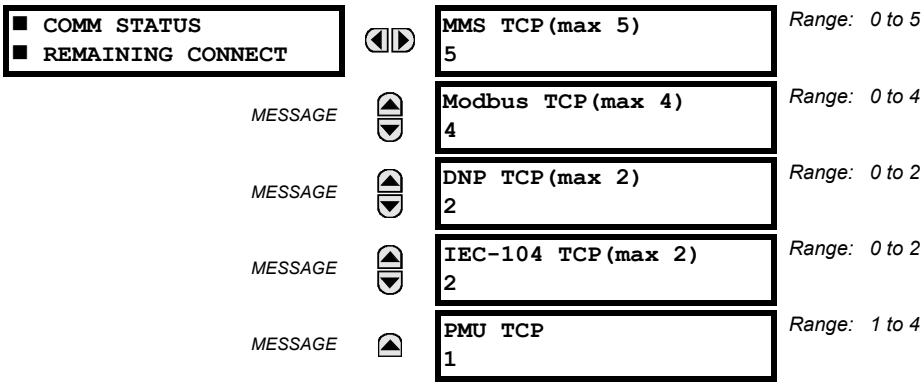
**PORT 1...3 PTP STATE** is the present state of the port's PTP clock. The PTP clock state is:

- **DISABLED** is the port's function setting is Disabled,
- **NO SIGNAL** if enabled but no signal from an active master has been found and selected,
- **CALIBRATING** if an active master has been selected but lock is not at present established,
- **SYNCH'D (NO PDELAY)** if the port is synchronized, but the peer delay mechanism is non-operational, and
- **SYNCHRONIZED** if synchronized.

**PTP - IRIG-B DELTA** is the time difference, measured in nanoseconds, between the fractional seconds portion of the time being received via PTP and that being received via IRIG-B. A positive value indicates that PTP time is fast compared to IRIG-B time.

### 6.2.17 REMAINING CONNECTION STATUS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ COMM STATUS REMAINING CONNECT




These values specify the remaining number of TCP connections still available for each protocol. The display depends on the options applicable to your device, for example the PMU entry does not display when not applicable. Each time a connection is used, the remaining number of connections decrements. When released, the remaining number of connections increments. If no connection is made over the specific protocol, the number equals the maximum number available for the specific protocol.

For example, the maximum number of Modbus TCP connections is 4. Once an EnerVista session is opened on a computer connected to the UR over Ethernet, the Modbus TCP status shows 3. If the EnerVista application is closed, the Modbus TCP status shows 4.

**MMS TCP** — The number of IEC 61850 connections remaining.

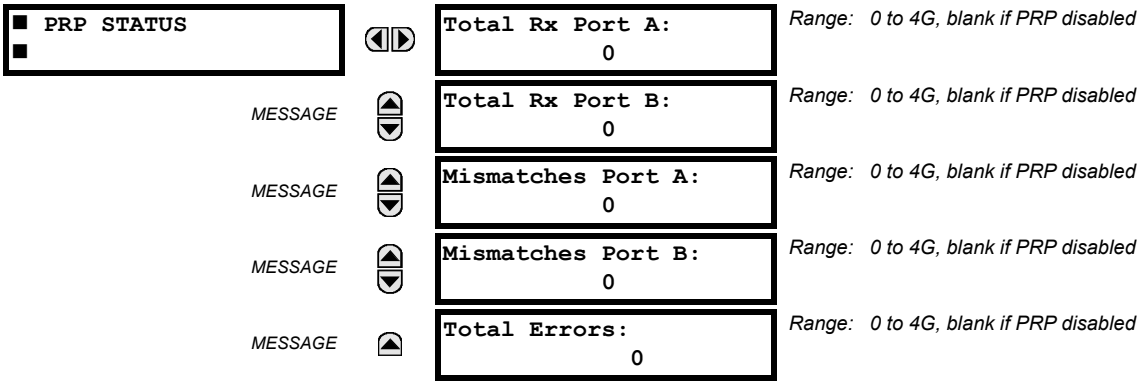
**PMU TCP** — The maximum number of PMU TCP connections matches the number of aggregators. The maximum number of aggregators for the N60 is 4. The maximum number for the C60 is 2. The maximum number is 1 for other products with a PMU. The remaining number of aggregators displays here.

6

### 6.2.18 PARALLEL REDUNDANCY PROTOCOL (PRP) STATUS

The Parallel Redundancy Protocol (PRP) defines a redundancy protocol for high availability in substation automation networks.

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ PRP STATUS



The L30 Line Current Differential System is provided with optional PRP capability. This feature is specified as a software option at the time of ordering. See the *Order Codes* section in chapter 2 for details.

**TOTAL RECEIVED PORT A** is a counter for total messages received (either from DANPs or from SANs) on Port A.

**TOTAL RECEIVED PORT B** is a counter for total messages received (either from DANPs or from SANs) on Port B.

**MISMATCHES PORT A** is a counter for total messages received with an error on Port A (PRP frame, but port received through and LAN ID in the frame do not match).

**MISMATCHES PORT B** is a counter for total messages received with an error on Port B (PRP frame, but port received through and LAN ID in the frame do not match).

**TOTAL ERRORS** is a counter for total messages received with an error (bad port code, frame length too short).

### a) UR CONVENTION FOR MEASURING POWER AND ENERGY

The following figure illustrates the conventions established for use in UR-series relays.

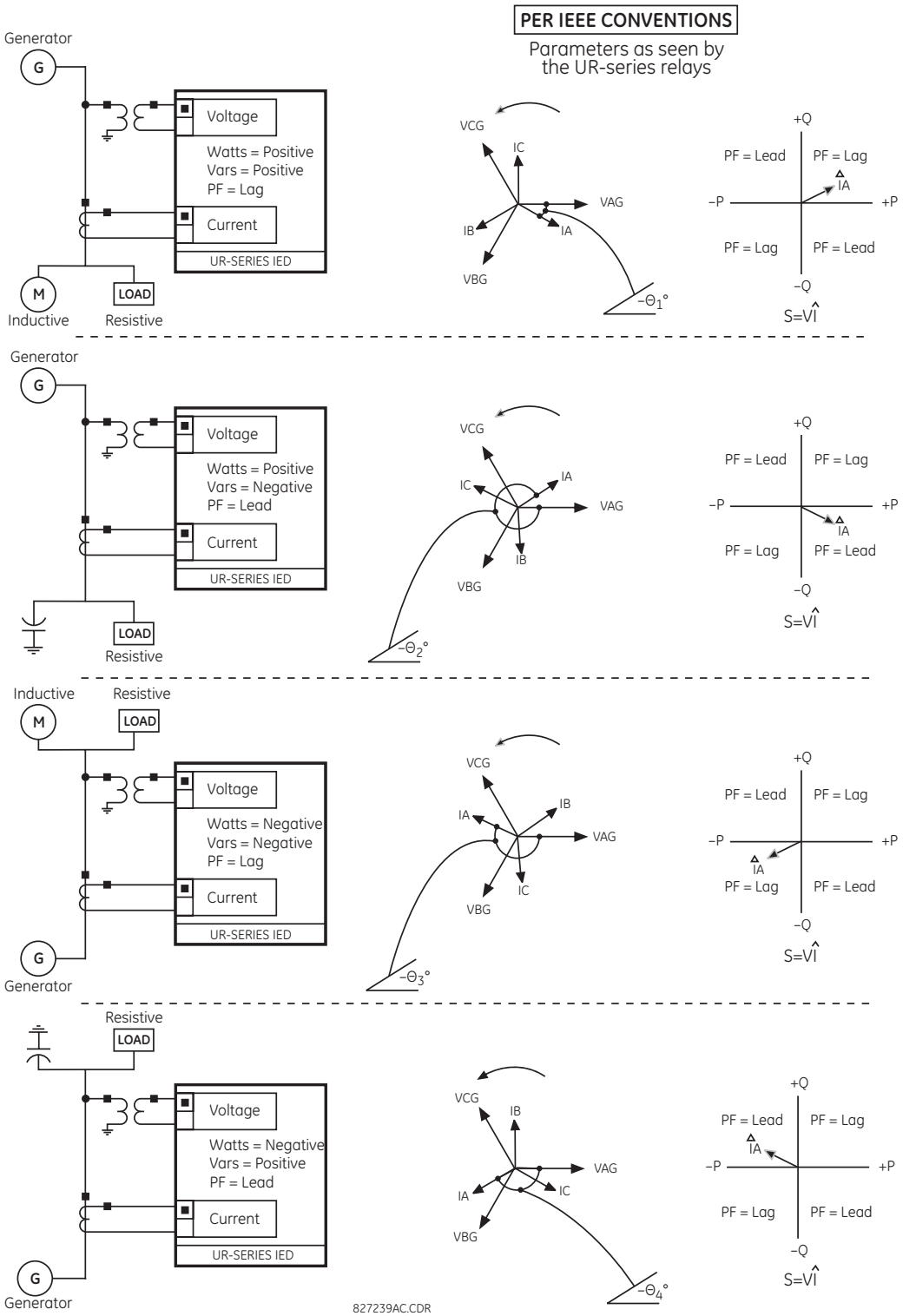



**Figure 6–1: FLOW DIRECTION OF SIGNED VALUES FOR WATTS AND VARS**

### b) UR CONVENTION FOR MEASURING PHASE ANGLES

All phasors calculated by UR-series relays and used for protection, control and metering functions are rotating phasors that maintain the correct phase angle relationships with each other at all times.

For display and oscillography purposes, all phasor angles in a given relay are referred to an AC input channel pre-selected by the **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM ⇨⇩ FREQUENCY AND PHASE REFERENCE** setting. This setting defines a particular AC signal source to be used as the reference.

The relay will first determine if any "Phase VT" bank is indicated in the source. If it is, voltage channel VA of that bank is used as the angle reference. Otherwise, the relay determines if any "Aux VT" bank is indicated; if it is, the auxiliary voltage channel of that bank is used as the angle reference. If neither of the two conditions is satisfied, then two more steps of this hierarchical procedure to determine the reference signal include "Phase CT" bank and "Ground CT" bank.

If the AC signal pre-selected by the relay upon configuration is not measurable, the phase angles are not referenced. The phase angles are assigned as positive in the leading direction, and are presented as negative in the lagging direction, to more closely align with power system metering conventions. This is illustrated below.

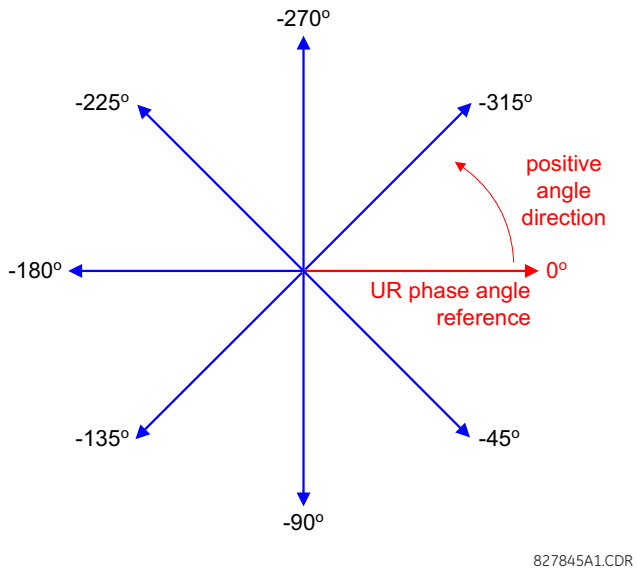



**Figure 6–2: UR PHASE ANGLE MEASUREMENT CONVENTION**

### c) UR CONVENTION FOR MEASURING SYMMETRICAL COMPONENTS

The UR-series of relays calculate voltage symmetrical components for the power system phase A line-to-neutral voltage, and symmetrical components of the currents for the power system phase A current. Owing to the above definition, phase angle relations between the symmetrical currents and voltages stay the same irrespective of the connection of instrument transformers. This is important for setting directional protection elements that use symmetrical voltages.

For display and oscillography purposes the phase angles of symmetrical components are referenced to a common reference as described in the previous sub-section.

**WYE-CONNECTED INSTRUMENT TRANSFORMERS:**

- ABC phase rotation:

$$V\_0 = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG})$$

$$V\_1 = \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG})$$

$$V\_2 = \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG})$$

- ACB phase rotation:

$$V\_0 = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG})$$

$$V\_1 = \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG})$$

$$V\_2 = \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG})$$

The above equations apply to currents as well.

**DELTA-CONNECTED INSTRUMENT TRANSFORMERS:**

- ABC phase rotation:

$$V\_0 = \text{N/A}$$
$$V\_1 = \frac{1\angle -30^\circ}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA})$$
$$V\_2 = \frac{1\angle 30^\circ}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA})$$

- ACB phase rotation:

$$V\_0 = \text{N/A}$$
$$V\_1 = \frac{1\angle 30^\circ}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA})$$
$$V\_2 = \frac{1\angle -30^\circ}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA})$$

The zero-sequence voltage is not measurable under the Delta connection of instrument transformers and is defaulted to zero. The table below shows an example of symmetrical components calculations for the ABC phase rotation.

**Table 6–1: SYMMETRICAL COMPONENTS CALCULATION EXAMPLE**

| SYSTEM VOLTAGES, SEC. V * | | | | | | VT CONN. | RELAY INPUTS, SEC. V | | | SYMM. COMP, SEC. V | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_{AG}$ | $V_{BG}$ | $V_{CG}$ | $V_{AB}$ | $V_{BC}$ | $V_{CA}$ | | F5AC | F6AC | F7AC | $V_0$ | $V_1$ | $V_2$ |
| 13.9 ∠0° | 76.2 ∠–125° | 79.7 ∠–250° | 84.9 ∠–313° | 138.3 ∠–97° | 85.4 ∠–241° | WYE | 13.9 ∠0° | 76.2 ∠–125° | 79.7 ∠–250° | 19.5 ∠–192° | 56.5 ∠–7° | 23.3 ∠–187° |
| UNKNOWN (only $V_1$ and $V_2$ can be determined) | | | 84.9 ∠0° | 138.3 ∠–144° | 85.4 ∠–288° | DELTA | 84.9 ∠0° | 138.3 ∠–144° | 85.4 ∠–288° | N/A | 56.5 ∠–54° | 23.3 ∠–234° |

* The power system voltages are phase-referenced – for simplicity – to *VAG* and *VAB*, respectively. This, however, is a relative matter. It is important to remember that the L30 displays are always referenced as specified under **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM ⇨⇩ FREQUENCY AND PHASE REFERENCE**.

The example above is illustrated in the following figure.

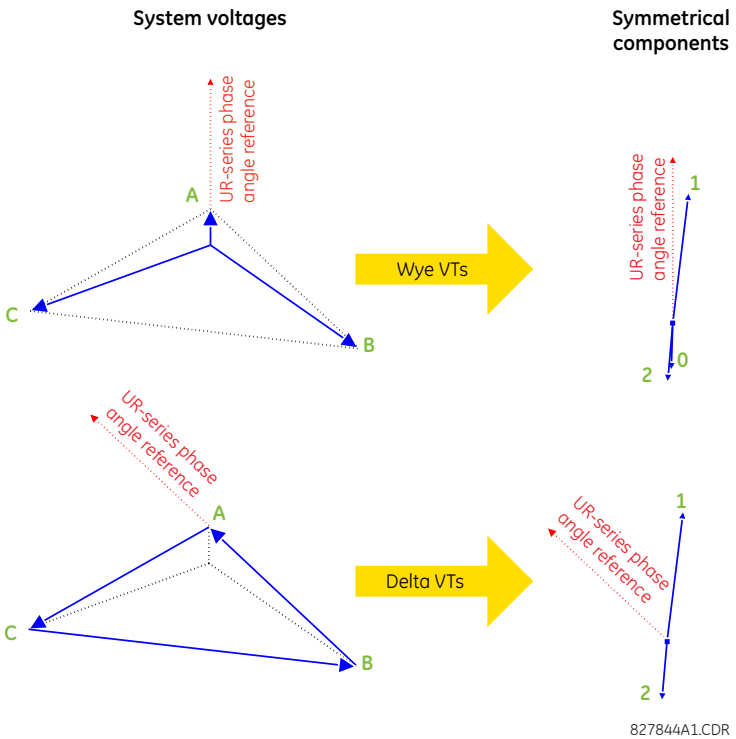
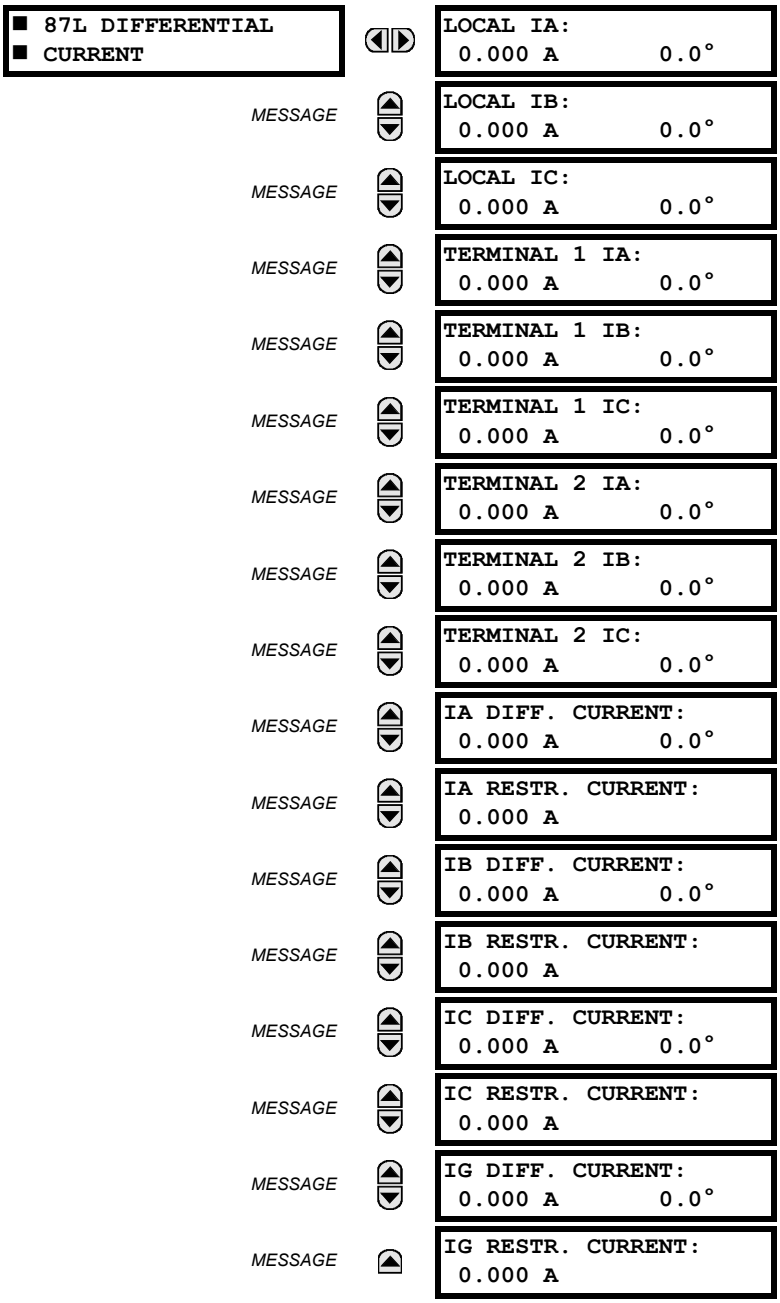



**Figure 6–3: MEASUREMENT CONVENTION FOR SYMMETRICAL COMPONENTS**

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨ 87L DIFFERENTIAL CURRENT



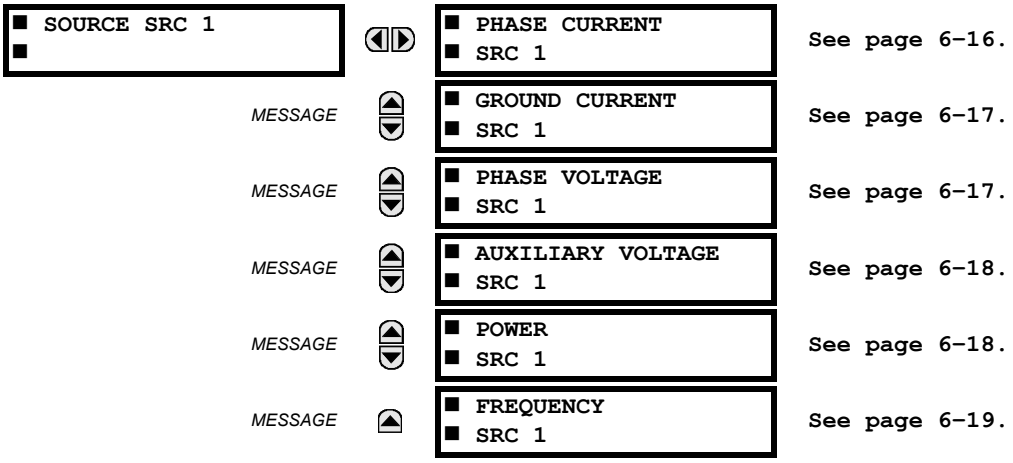

The metered current values are displayed for all line terminals in fundamental phasor form. All angles are shown with respect to the reference common for all L30 devices; that is, frequency, source currents, and voltages. The metered primary differential and restraint currents are displayed for the local relay.

NOTE

Terminal 1 refers to the communication channel 1 interface to a remote L30 at terminal 1. Terminal 2 refers to the communication channel 2 interface to a remote L30 at terminal 2.

### a) MAIN MENU

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ SOURCE SRC1

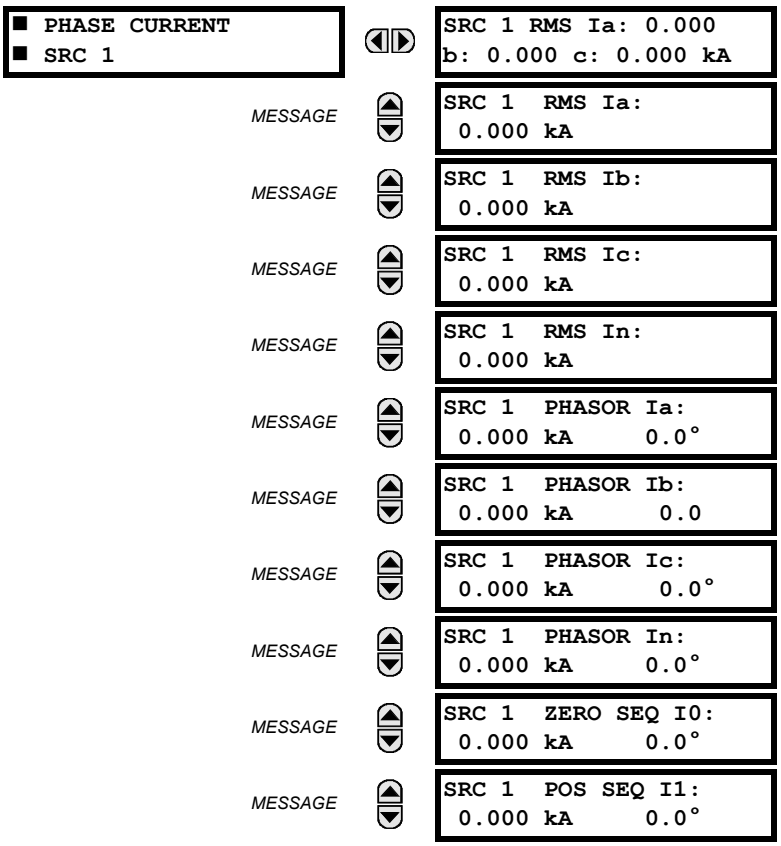



This menu displays the metered values available for each source.

Metered values presented for each source depend on the phase and auxiliary VTs and phase and ground CTs assignments for this particular source. For example, if no phase VT is assigned to this source, then any voltage, energy, and power values will be unavailable.

### b) PHASE CURRENT METERING

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨ PHASE CURRENT



MESSAGE

```
SRC 1  NEG SEQ I2:
 0.000 kA     0.0°
```

The metered phase current values are displayed in this menu. The "SRC 1" text will be replaced by whatever name was programmed by the user for the associated source (see SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES).

### c) GROUND CURRENT METERING

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨⇩ GROUND CURRENT

```
■ GROUND CURRENT
■ SRC 1
```

```
SRC 1  RMS Ig:
 0.000  A
```

MESSAGE

```
SRC 1  PHASOR Ig:
 0.000  A       0.0°
```

MESSAGE

```
SRC 1  PHASOR Igd:
 0.000  A       0.0°
```

The metered ground current values are displayed in this menu. The "SRC 1" text will be replaced by whatever name was programmed by the user for the associated source (see SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES).

### d) PHASE VOLTAGE METERING

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨ PHASE VOLTAGE

```
■ PHASE VOLTAGE
■ SRC 1
```

```
SRC 1  RMS Vag:
 0.00  V
```

MESSAGE

```
SRC 1  RMS Vbg:
 0.00  V
```

MESSAGE

```
SRC 1  RMS Vcg:
 0.00  V
```

MESSAGE

```
SRC 1  PHASOR Vag:
 0.000  V       0.0°
```

MESSAGE

```
SRC 1  PHASOR Vbg:
 0.000  V       0.0°
```

MESSAGE

```
SRC 1  PHASOR Vcg:
 0.000  V       0.0°
```

MESSAGE

```
SRC 1  RMS Vab:
 0.00  V
```

MESSAGE

```
SRC 1  RMS Vbc:
 0.00  V
```

MESSAGE

```
SRC 1  RMS Vca:
 0.00  V
```

MESSAGE

```
SRC 1  PHASOR Vab:
 0.000  V       0.0°
```

MESSAGE

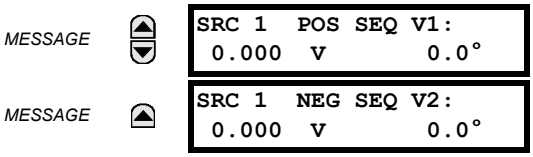
```
SRC 1  PHASOR Vbc:
 0.000  V       0.0°
```

MESSAGE

```
SRC 1  PHASOR Vca:
 0.000  V       0.0°
```

MESSAGE

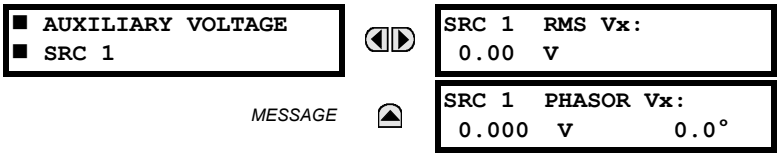
```
SRC 1  ZERO SEQ V0:
 0.000  V       0.0°
```




The metered phase voltage values are displayed in this menu. The "SRC 1" text will be replaced by whatever name was programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

### e) AUXILIARY VOLTAGE METERING

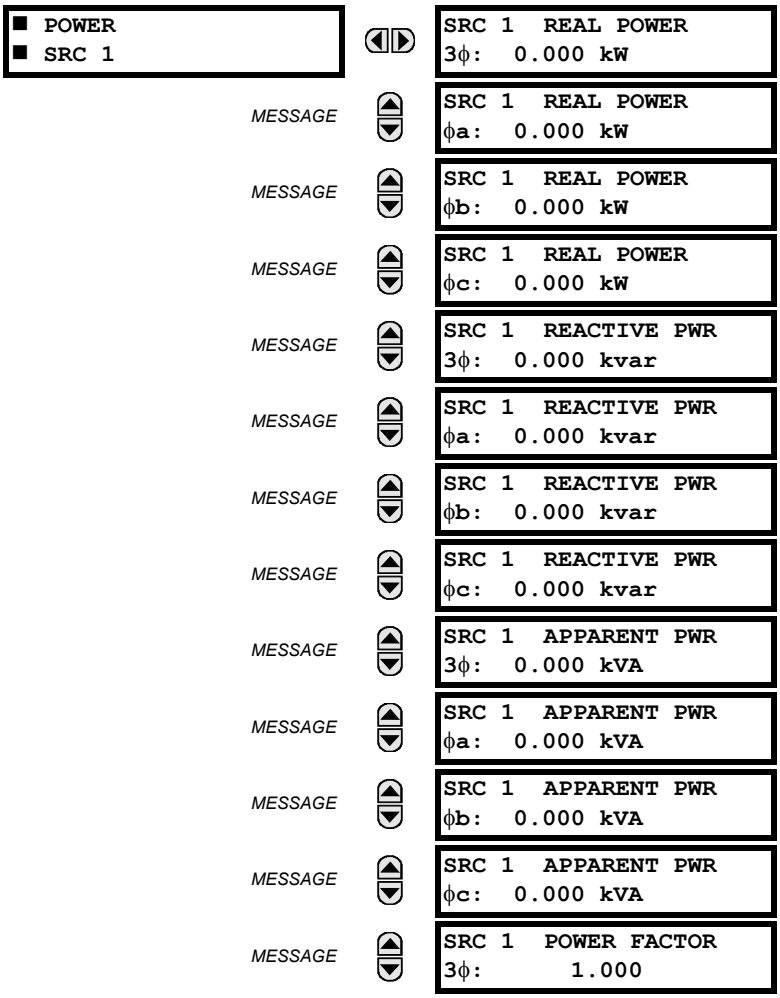
**PATH: ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨⇩ AUXILIARY VOLTAGE**

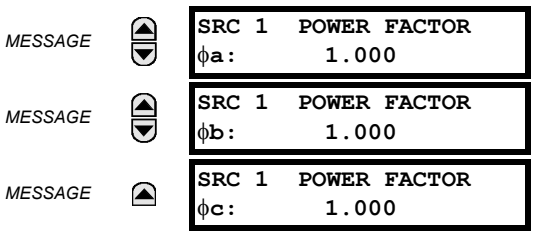



The metered auxiliary voltage values are displayed in this menu. The "SRC 1" text will be replaced by whatever name was programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

### f) POWER METERING

**PATH: ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨⇩ POWER**






The metered values for real, reactive, and apparent power, as well as power factor, are displayed in this menu. The "SRC 1" text is replaced by whatever name was programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

When VTs are configured in wye, the L30 calculates power in each phase and three-phase power is measured as

$$S = V_A \times \hat{I}_A + V_B \times \hat{I}_B + V_C \times \hat{I}_C \quad \textbf{(EQ 6.1)}$$

When VTs are configured in delta, the L30 does not calculate power in each phase and three-phase power is measured as

$$S = V_{AB} \times \hat{I}_A + V_{CB} \times \hat{I}_C \quad \textbf{(EQ 6.2)}$$

where

S is the apparent power

$V_A$, $V_B$, $V_C$, $I_A$, $I_B$, $I_C$ are phase voltage and phase current phasors

$V_{AB}$ and $V_{CB}$ are phase-to-phase voltage phasors

$\hat{I}$ is the conjugate of I

### g) FREQUENCY METERING

**PATH: ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨⇩ FREQUENCY**

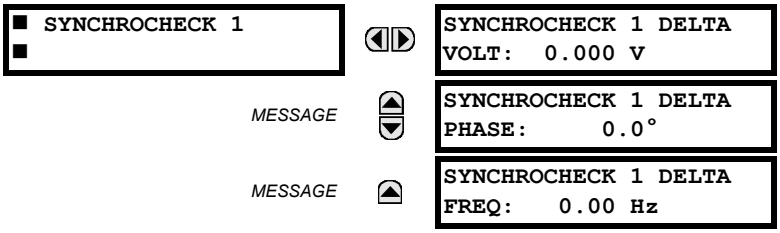
The metered frequency values are displayed in this menu. The "SRC 1" text will be replaced by whatever name was programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

**SOURCE FREQUENCY** is measured via software-implemented zero-crossing detection of an AC signal. The signal is either a Clarke transformation of three-phase voltages or currents, auxiliary voltage, or ground current as per source configuration (see the **SYSTEM SETUP ⇨⇩ POWER SYSTEM** settings). The signal used for frequency estimation is low-pass filtered. The final frequency measurement is passed through a validation filter that eliminates false readings due to signal distortions and transients.

If the 87L function is enabled, then dedicated 87L frequency tracking is engaged. In this case, the relay uses the **METERING ⇨⇩ TRACKING FREQUENCY ⇨ TRACKING FREQUENCY** value for all computations, overriding the **SOURCE FREQUENCY** value.

## 6.3.4 SYNCHROCHECK

**PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ SYNCHROCHECK ⇨ SYNCHROCHECK 1(4)**




If a synchrocheck function setting is "Disabled", the corresponding actual values menu item is not displayed.

### 6.3.5 TRACKING FREQUENCY

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRACKING FREQUENCY

The tracking frequency is displayed here. The frequency is tracked based on configuration of the reference source. The **TRACKING FREQUENCY** is based upon positive sequence current phasors from all line terminals and is synchronously adjusted at all terminals. If currents are below 0.125 pu, then the **NOMINAL FREQUENCY** is used.

### 6.3.6 FLEXELEMENTS

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ FLEXELEMENTS ⇨ FLEXELEMENT 1(8)

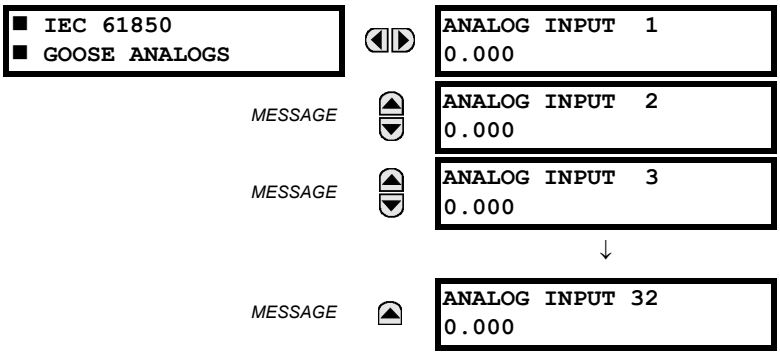
The operating signals for the FlexElements are displayed in pu values using the following definitions of the base units.

**Table 6–2: FLEXELEMENT BASE UNITS**

| | |
|---|---|
| 87L SIGNALS<br>(Local IA Mag, IB, and IC)<br>(Diff Curr IA Mag, IB, and IC)<br>(Terminal 1 IA Mag, IB, and IC)<br>(Terminal 2 IA Mag, IB and IC) | $I_{BASE}$ = maximum primary RMS value of the +IN and –IN inputs<br>(CT primary for source currents, and 87L source primary current for line differential currents) |
| 87L SIGNALS<br>(Op Square Curr IA, IB, and IC)<br>(Rest Square Curr IA, IB, and IC) | BASE = Squared CT secondary of the 87L source |
| BREAKER ACC ARCING AMPS<br>(Brk X Acc Arc Amp A, B, and C) | BASE = 2000 $kA^2 \times$ cycle |
| BREAKER ARCING AMPS<br>(Brk X Arc Amp A, B, and C) | BASE = 1 $kA^2 \times$ cycle |
| DCmA | BASE = maximum value of the **DCMA INPUT MAX** setting for the two transducers configured under the +IN and –IN inputs. |
| FAULT LOCATION | BASE = Line Length as specified in Fault Report |
| FREQUENCY | $f_{BASE}$ = 1 Hz |
| PHASE ANGLE | $\varphi_{BASE}$ = 360 degrees (see the UR angle referencing convention) |
| POWER FACTOR | $PF_{BASE}$ = 1.00 |
| RTDs | BASE = 100°C |
| SOURCE CURRENT | $I_{BASE}$ = maximum nominal primary RMS value of the +IN and –IN inputs |
| SOURCE POWER | $P_{BASE}$ = maximum value of $V_{BASE} \times I_{BASE}$ for the +IN and –IN inputs |
| SOURCE VOLTAGE | $V_{BASE}$ = maximum nominal primary RMS value of the +IN and –IN inputs |
| SYNCHROCHECK<br>(Max Delta Volts) | $V_{BASE}$ = maximum primary RMS value of all the sources related to the +IN and –IN inputs |

### 6.3.7 IEC 61580 GOOSE ANALOG VALUES

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ IEC 61850 GOOSE ANALOGS

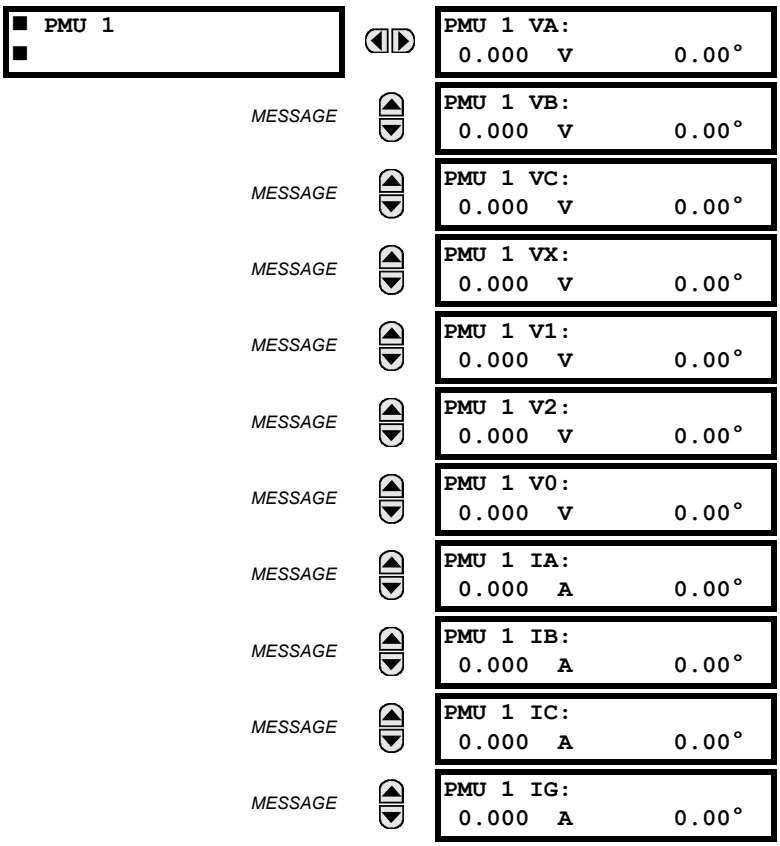


The L30 is provided with optional IEC 61850 communications capability. This feature is specified as a software option at the time of ordering. See the Order Codes section of chapter 2 for details.

The IEC 61850 GGIO3 analog input data points are displayed in this menu. The GGIO3 analog data values are received via IEC 61850 GOOSE messages sent from other devices.

### 6.3.8 PHASOR MEASUREMENT UNIT

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ PHASOR MEASUREMENT UNIT ⇨ PMU 1

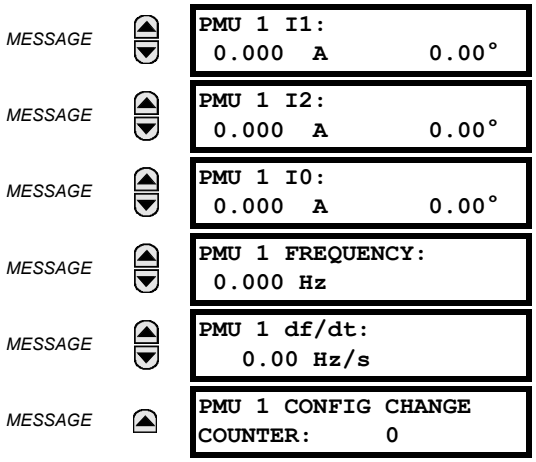



*Range: Va or Vab per VT bank connection*

*Range: Va or Vab per VT bank connection*

*Range: Va or Vab per VT bank connection*

*Range: Substituted with zero if delta-connected VTs.*




The above actual values are displayed without the corresponding time stamp as they become available per the recording rate setting. Also, the recording post-filtering setting is applied to these values.

### 6.3.9 PMU AGGREGATOR

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ PHASOR MEASUREMENT UNIT ⇨⇩ PMU AGGREGATOR 1

Actual values for the IEC 61850-90-5 PDU size are provided. These values allow you to know the approximate Ethernet frame size for the data streams from each aggregator. This can help to estimate network loading. The PDU size shown in the displays does not include the Ethernet, UDP, or IP layers. PDU sizes approaching approximately 1500 bytes result in fragmented data frames, causing increased network traffic.

### 6.3.10 TRANSDUCER INPUTS AND OUTPUTS

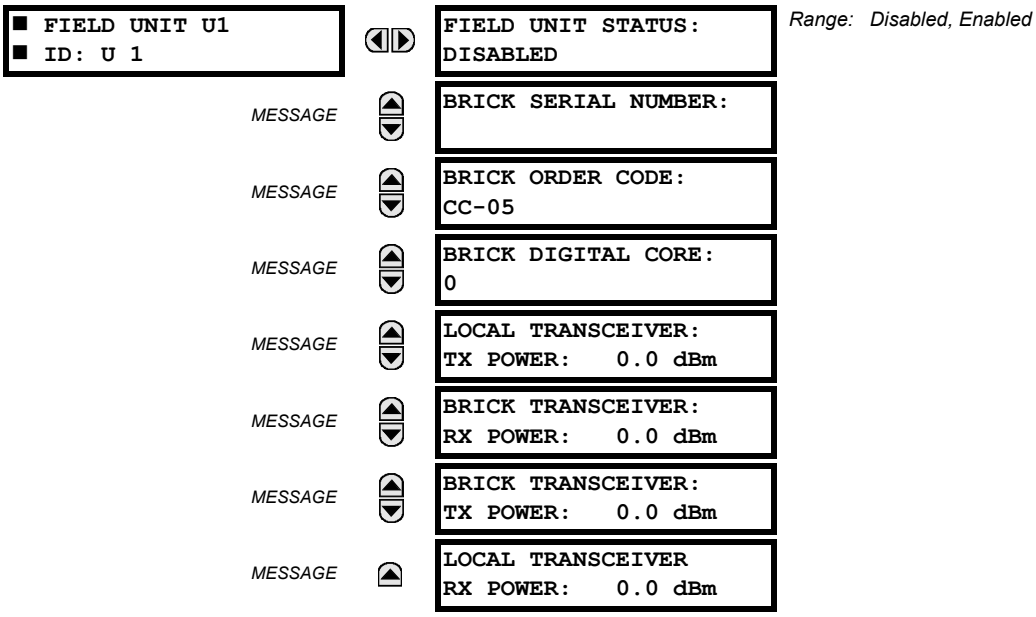
PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRANSDUCER I/O DCMA INPUTS ⇨ DCMA INPUT xx

Actual values for each DCmA input channel that is enabled are displayed with the top line as the programmed channel ID and the bottom line as the value followed by the programmed units.

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRANSDUCER I/O RTD INPUTS ⇨ RTD INPUT xx

Actual values for each RTD input channel that is enabled are displayed with the top line as the programmed channel ID and the bottom line as the value.

PATH: ACTUAL VALUES ⇨⇩ REMOTE RESOURCES ⇨⇩ FIELD UNIT U1(U8)

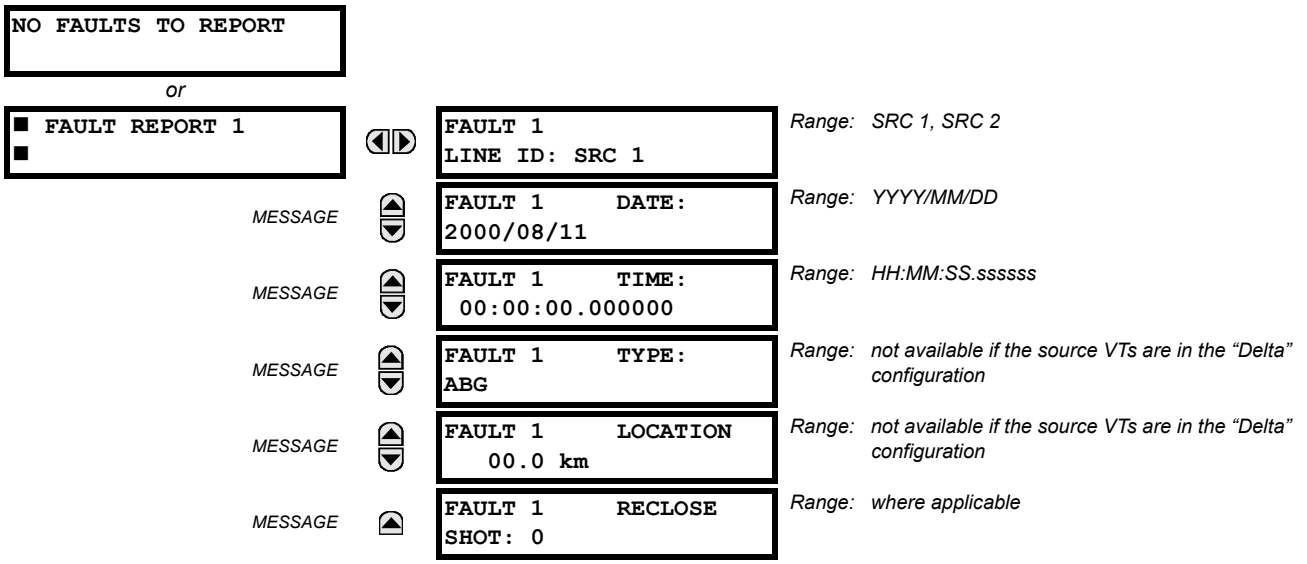



*Range: Disabled, Enabled*

This menu displays when using a Process Bus Module for a HardFiber Brick.

### 6.5.1 FAULT REPORTS

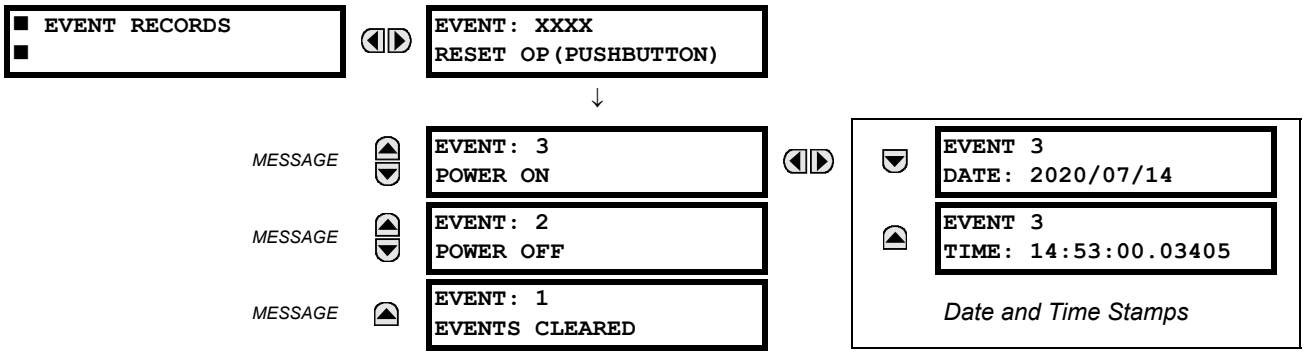
PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨ FAULT REPORTS ⇨ FAULT REPORT 1(15)




The latest 15 fault reports can be stored. The most recent fault location calculation (when applicable) is displayed in this menu, along with the date and time stamp of the event which triggered the calculation. See the SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FAULT REPORTS menu for assigning the source and trigger for fault calculations. Refer to the COMMANDS ⇨⇩ CLEAR RECORDS menu for manual clearing of the fault reports and to the SETTINGS ⇨ PRODUCT SETUP ⇨⇩ CLEAR RELAY RECORDS menu for automated clearing of the fault reports.

### 6.5.2 EVENT RECORDS

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨ EVENT RECORDS

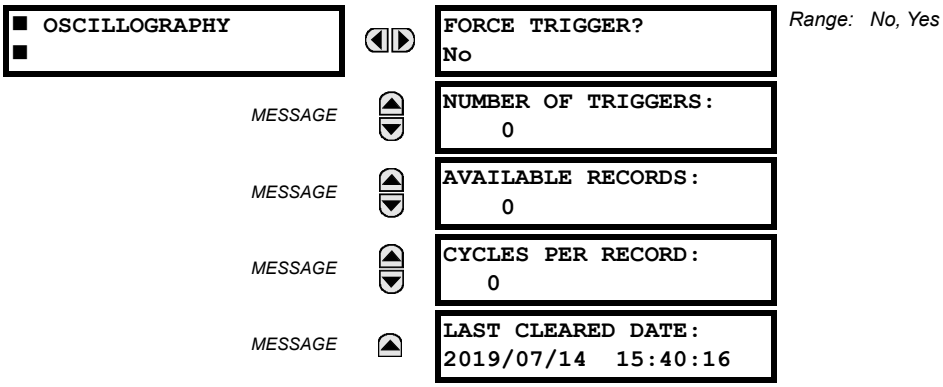



The event records menu shows the contextual data associated with up to the last 1024 events, listed in chronological order from most recent to oldest. If all 1024 event records have been filled, the oldest record will be removed as a new record is added. Each event record shows the event identifier/sequence number, cause, and date/time stamp associated with the event trigger. See the COMMANDS ⇩ CLEAR RECORDS menu for clearing event records.

Only major output operands generate events, not every operand. Elements that assert output per phase, for example, log operating phase output only without asserting the common three-phase operand event.

### 6.5.3 OSCILLOGRAPHY

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ OSCILLOGRAPHY

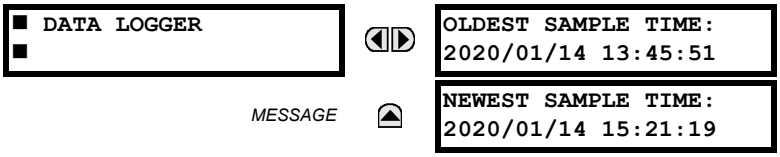



This menu allows the user to view the number of triggers involved and number of oscillography traces available. The **CYCLES PER RECORD** value is calculated to account for the fixed amount of data storage for oscillography. See the Oscillography section of chapter 5 for additional details.

A trigger can be forced here at any time by setting "Yes" to the **FORCE TRIGGER?** command. Refer to the **COMMANDS** ⇨⇩ **CLEAR RECORDS** menu for information on clearing the oscillography records.

### 6.5.4 DATA LOGGER

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ DATA LOGGER

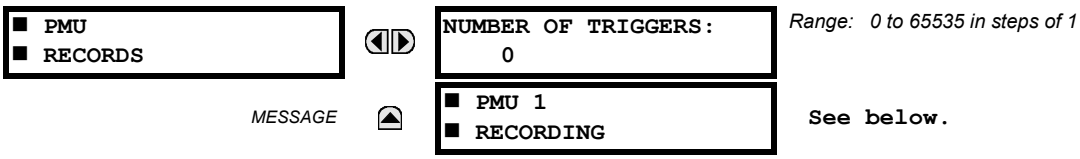



The **OLDEST SAMPLE TIME** represents the time at which the oldest available samples were taken. It is static until the log gets full, at which time it starts counting at the defined sampling rate. The **NEWEST SAMPLE TIME** represents the time the most recent samples were taken. It counts up at the defined sampling rate. If the data logger channels are defined, then both values are static.

Refer to the **COMMANDS** ⇨⇩ **CLEAR RECORDS** menu for clearing data logger records.

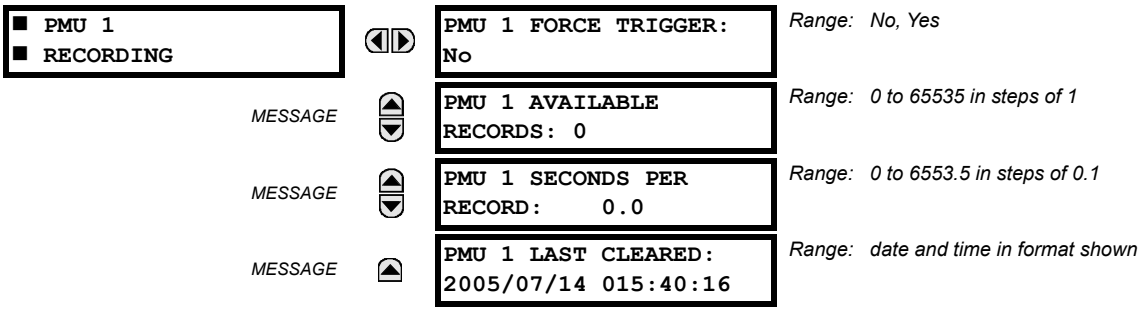
### 6.5.5 PHASOR MEASUREMENT UNIT RECORDS

PATH: ACTUAL VALUES ⇨ RECORDS ⇨⇩ PMU RECORDS



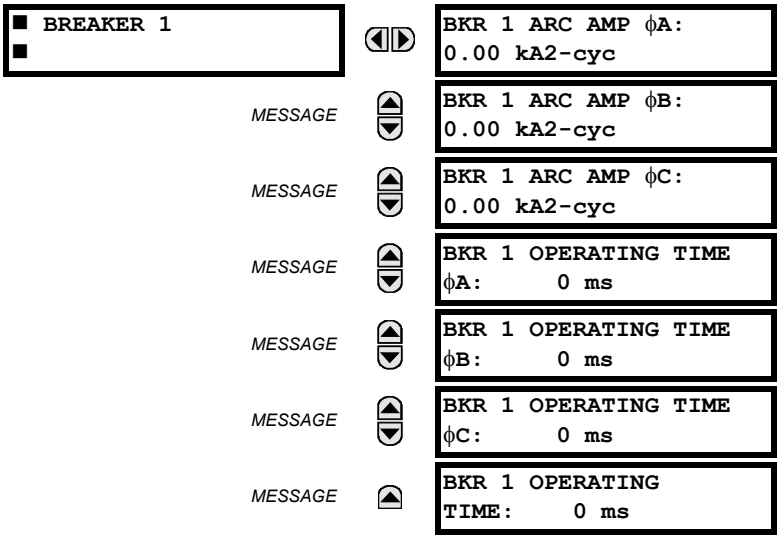

The number of triggers applicable to the phasor measurement unit recorder is indicated by the **NUMBER OF TRIGGERS** value. The status of the phasor measurement unit recorder is indicated as follows:

PATH: ACTUAL VALUES ⇨ RECORDS ⇨⇩ PMU RECORDS ⇨ PMU 1 RECORDING




## 6.5.6 BREAKER MAINTENANCE

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ MAINTENANCE ⇨ BREAKER 1(2)




There is an identical menu for each of the breakers. The **BKR 1 ARCING AMP** values are in units of $kA^2$-cycles. Refer to the **COMMANDS** ⇨⇩ **CLEAR RECORDS** menu for clearing breaker arcing current records. The **BREAKER OPERATING TIME** is defined as the slowest operating time of breaker poles that were initiated to open.

### 6.6.1 MODEL INFORMATION

PATH: ACTUAL VALUES ⇨⇩ PRODUCT INFO ⇨ MODEL INFORMATION

| | | |
|---|---|---|
| ■ MODEL INFORMATION ■ | ORDER CODE LINE 1: L30-E00-HCH-F8F-H6A | Range: standard GE order code format; example order code shown |
| MESSAGE | ORDER CODE LINE 2: | Range: standard GE order code format |
| MESSAGE | ORDER CODE LINE 3: | Range: standard GE order code format |
| MESSAGE | ORDER CODE LINE 4: | Range: standard GE order code format |
| MESSAGE | SERIAL NUMBER: | Range: standard GE serial number format |
| MESSAGE | ETHERNET MAC ADDRESS 000000000000 | Range: standard Ethernet MAC address format |
| MESSAGE | MANUFACTURING DATE: 0 | Range: YYYY/MM/DD HH:MM:SS |
| MESSAGE | OPERATING TIME: 0:00:00 | Range: operating time in HH:MM:SS |
| MESSAGE | PMU FEATURE ACTIVE: No | Range: Yes, No |
| MESSAGE | CT/ VT ADVANCED DIAG ACTIVE: No | Range: Yes, No |
| MESSAGE | LAST SETTING CHANGE: 2019/01/01 23:11:19 | Range: YYYY/MM/DD HH:MM:SS |

The order code, serial number, Ethernet MAC address, date and time of manufacture, and operating time are shown here.

**ETHERNET MAC ADDRESS** — UR devices with firmware 7.0x and above have three Ethernet ports that can be used on three networks. The MAC address displays for port 1. The MAC address for port 2 is one higher. The MAC address for port 3 is one higher than port 2. In redundant mode, the MAC addresses for ports 2 and 3 are the same as port 2.

### 6.6.2 FIRMWARE REVISIONS

PATH: ACTUAL VALUES ⇨⇩ PRODUCT INFO ⇨⇩ FIRMWARE REVISIONS

| | | |
|---|---|---|
| ■ FIRMWARE REVISIONS ■ | L30 Relay REVISION: 7.2x | Range: 0.00 to 655.35<br>Revision number of the application firmware. |
| MESSAGE | MODIFICATION FILE NUMBER: 0 | Range: 0 to 65535 (ID of the MOD FILE)<br>Value is 0 for each standard firmware release. |
| MESSAGE | BOOT PROGRAM REVISION: 7.06 | Range: 0.00 to 655.35<br>Revision number of the boot program firmware. |
| MESSAGE | FRONT PANEL PROGRAM REVISION: 2.01 | Range: 0.00 to 655.35<br>Revision number of faceplate program firmware. |
| MESSAGE | COMPILE DATE: 2021/04/09 04:55:16 | Range: Any valid date and time.<br>Date and time when product firmware was built. |
| MESSAGE | BOOT DATE: 2021/02/23 16:41:32 | Range: Any valid date and time.<br>Date and time when the boot program was built. |

MESSAGE

```
FPGA PROGRAM
REVISION  02.01
```

*Range: 0.00 to 655.35*
*Revision number for FPGA.*

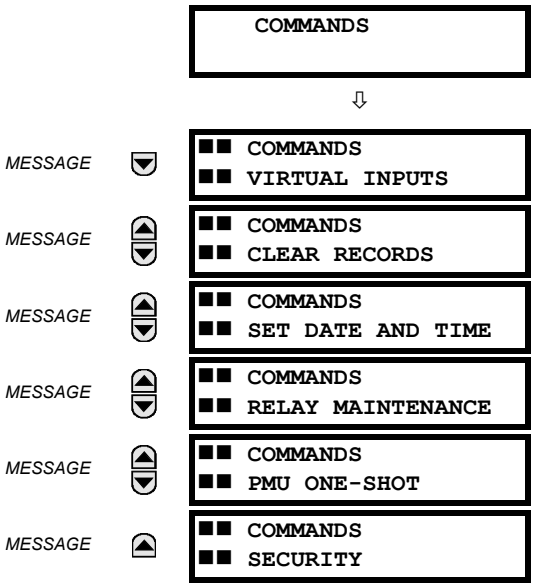
MESSAGE

```
FPGA DATE:
2013/10/09 13:13:00
```

*Range: Any valid date and time.*
*Date and time when the FPGA was built.*

The shown data is illustrative only. A modification file number of 0 indicates that, currently, no modifications have been installed.

### 7.1.1 COMMANDS MENU

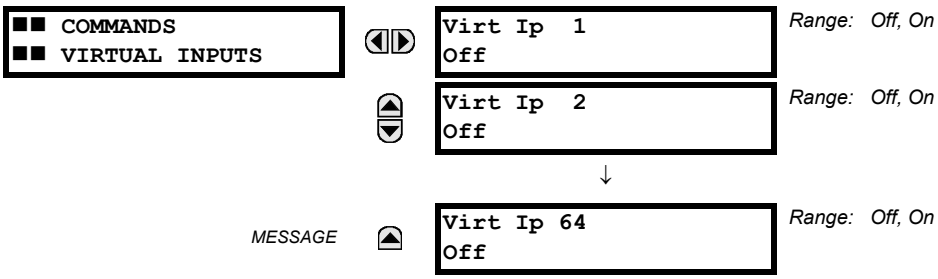



The commands menu contains relay directives intended for operations personnel. All commands can be protected from unauthorized access via the command password; see the Security section of chapter 5 for details. The following flash message appears after successfully command entry:

```
COMMAND
EXECUTED
```

### 7.1.2 VIRTUAL INPUTS

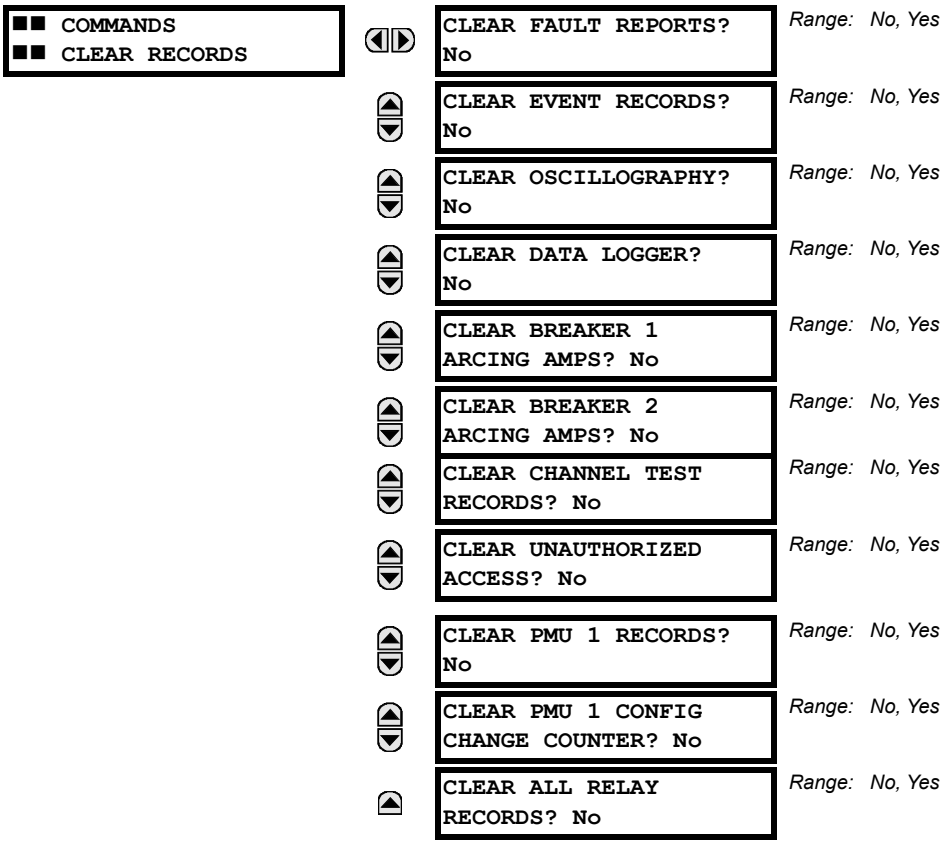
**PATH: COMMANDS ⇨ VIRTUAL INPUTS**




The states of up to 64 virtual inputs are changed here. The first line of the display indicates the ID of the virtual input. The second line indicates the current or selected status of the virtual input. This status will be a state off (logic 0) or on (logic 1).

### 7.1.3 CLEAR RECORDS

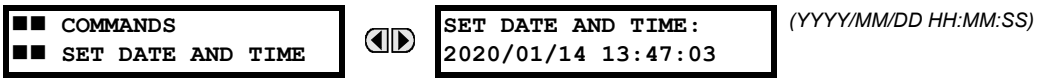
PATH: COMMANDS ⇨⇩ CLEAR RECORDS




This menu contains commands for clearing historical data such as the event records. Data is cleared by changing a command setting to "Yes" and pressing the ENTER key. After clearing data, the command setting automatically reverts to "No".

### 7.1.4 SET DATE AND TIME

PATH: COMMANDS ⇨⇩ SET DATE AND TIME

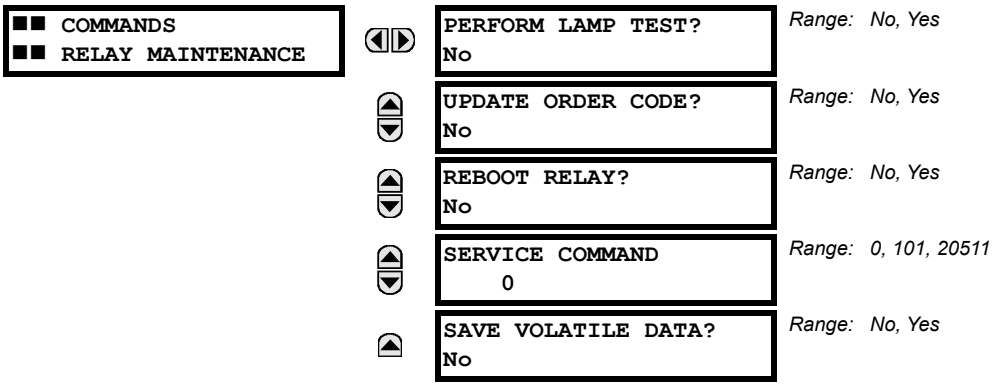



The date and time can be entered on the faceplate keypad. The time setting is based on the 24-hour clock. The complete date, as a minimum, must be entered to allow execution of this command. The new time and date take effect when the ENTER key is pressed.

When the relay is synchronizing to an external time source such as PTP, IRIG-B, or SNTP, the manually entered time is over-written.

The timescale of the entered time is **local time**, including daylight savings time where and when applicable.

PATH: COMMANDS ⇨⇩ RELAY MAINTENANCE




This menu contains commands for relay maintenance purposes. Commands for the lamp test and order code are activated by changing a command setting to "Yes" and pressing the ENTER key. The command setting will then automatically revert to "No". The service command is activated by entering a numerical code and pressing the ENTER key.

The **PERFORM LAMP TEST** command turns on all faceplate LEDs and display pixels for a short duration. The **UPDATE ORDER CODE** command causes the relay to scan the backplane for the hardware modules and update the order code to match. If an update occurs, the following message is shown.

```
UPDATING...
PLEASE WAIT
```

There is no impact if there have been no changes to the hardware modules. When an update does not occur, the **ORDER CODE NOT UPDATED** message will be shown.

The **REBOOT RELAY COMMAND** reboots the relay so that changes to configuration settings can take effect. In most cases, if changes are made to the configuration settings these changes do not take effect unless the relay is rebooted.

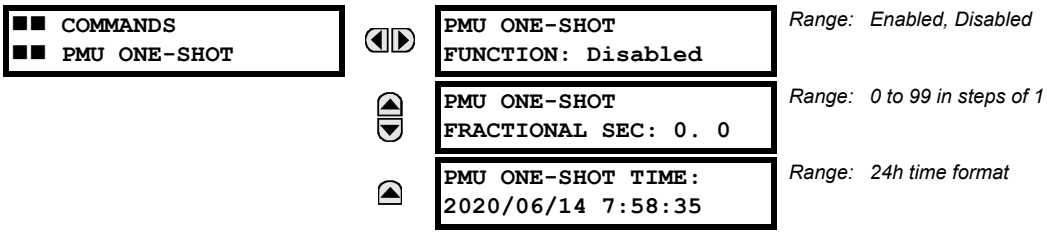
NOTE

With the CyberSentry option, the Administrator or Operator role can initiate the Reboot Relay command.

The **SERVICE COMMAND** performs specific L30 service actions. Presently, there are two service actions available. Code "20511" returns all settings to their factory default value and restarts the relay (then you re-enter IP address, restart, set unit to "Programmed"). Code "101" is used to clear factory diagnostic information stored in the non-volatile memory. If a code other than these two is entered, the command is ignored and no action is taken. Various self-checking diagnostics are performed in the background while the L30 is running, and diagnostic information is stored on the non-volatile memory from time to time based on the self-checking result. Although the diagnostic information is cleared before the L30 is shipped from the factory, the user can want to clear the diagnostic information for themselves under certain circumstances. For example, you clear diagnostic information after replacement of hardware. Once the diagnostic information is cleared, all self-checking variables are reset to their initial state and diagnostics restart from scratch.

**SAVE VOLATILE DATA** saves this data to compact flash memory prior to shutdown. This allows the saved data to be as recent as possible instead of relying on the periodic timer to save the data.

PATH: COMMANDS ⇨⇩ PMU ONE-SHOT




This feature allows pre-scheduling a PMU measurement at a specific point in time. It can be used to test for accuracy of the PMU and for manual collection of synchronized measurements through the system, as explained below.

When enabled, the function continuously compares the present time with the pre-set **PMU ONE-SHOT TIME**. When the two times match, the function compares the present sequence number of the measured synchrophasors with the pre-set **PMU ONE-SHOT FRACTIONAL SEC**. When the two numbers match, the function freezes the synchrophasor actual values and the corresponding protocol data items for 30 seconds. This allows manual read-out of the synchrophasor values for the pre-set time and pre-set sequence number (via the faceplate display, supported communication protocols such as Modbus or DNP, and the EnerVista UR Setup software).

When freezing the actual values the function also asserts a PMU ONE-SHOT OP FlexLogic operand. This operand may be configured to drive an output contact and trigger an external measuring device such as a digital scope with the intent to verify the accuracy of the PMU under test.

With reference to the figure below, the PMU one-shot function (when enabled) controls three FlexLogic operands:

- The PMU ONE-SHOT EXPIRED operand indicates that the one-shot operation has been executed, and the present time is at least 30 seconds past the scheduled one-shot time.
- The PMU ONE-SHOT PENDING operand indicates that the one-shot operation is pending; that is, the present time is before the scheduled one-shot time.
- The PMU ONE-SHOT OP operand indicates the one-shot operation and remains asserted for 30 seconds afterwards.

When the function is disabled, all three operands are de-asserted. The one-shot function applies to all logical PMUs of a given L30 relay.

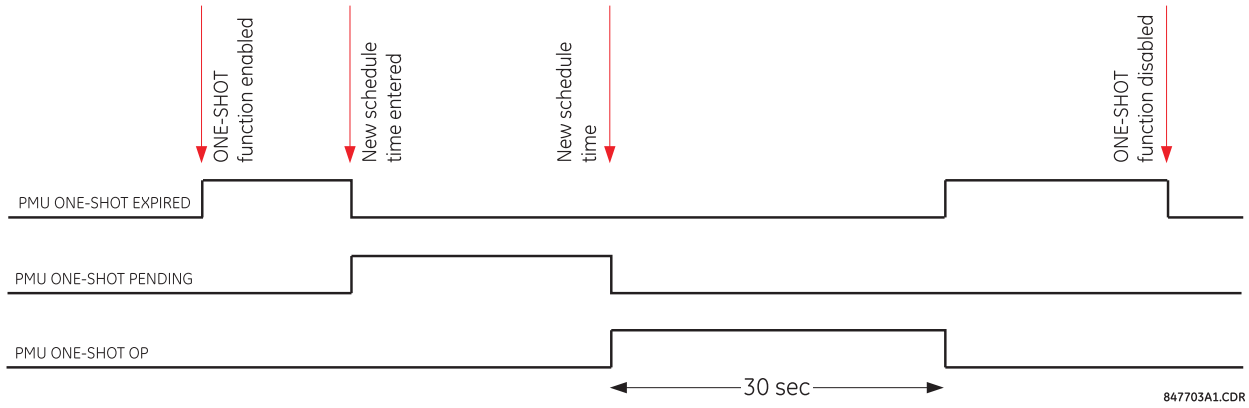



**Figure 7–1: PMU ONE-SHOT FLEXLOGIC OPERANDS**

### TESTING ACCURACY OF THE PMU

The one-shot feature can be used to test accuracy of the synchrophasor measurement. GPS-synchronized tests sets perform a similar function to PMUs: instead of measuring the phasor from physical signals with respect to the externally provided time reference, they produce the physical signals with respect to the externally provided time reference, given the desired phasor values. Therefore the GPS-synchronized test sets cannot be automatically assumed more accurate than the PMUs under test. This calls for a method to verify both the measuring device (PMU) and the source of signal (test set).

With reference to the figure below, the one-shot feature could be configured to trigger a high-accuracy scope to capture both the time reference signal (rising edge of the 1 pps signal of the IRIG-B time reference), and the measured waveform. The high-accuracy high-sampling rate record of the two signals captured by the scope can be processed using digital tools to verify the magnitude and phase angle with respect to the time reference signal. As both the time reference and the measured signals are raw inputs to the PMU under test, their independently captured record, processed using third-party software, is a good reference point for accuracy calculations. Such a record proves useful when discussing the test results, and should be retained as a part of the testing documentation.

Note that the PMU under such test does not have to be connected to a real GPS receiver as the accuracy is measured with respect to the timing reference provided to the PMU and not to the absolute UTC time. Therefore a simple IRIG-B generator could be used instead. Also, the test set does not have to support GPS synchronization. Any stable signal source can be used. If both the PMU under test and the test set use the timing reference, they should be driven from the same IRIG-B signal: either the same GPS receiver or IRIG-B generator. Otherwise, the setpoints of the test set and the PMU measurements should not be compared as they are referenced to different time scales.

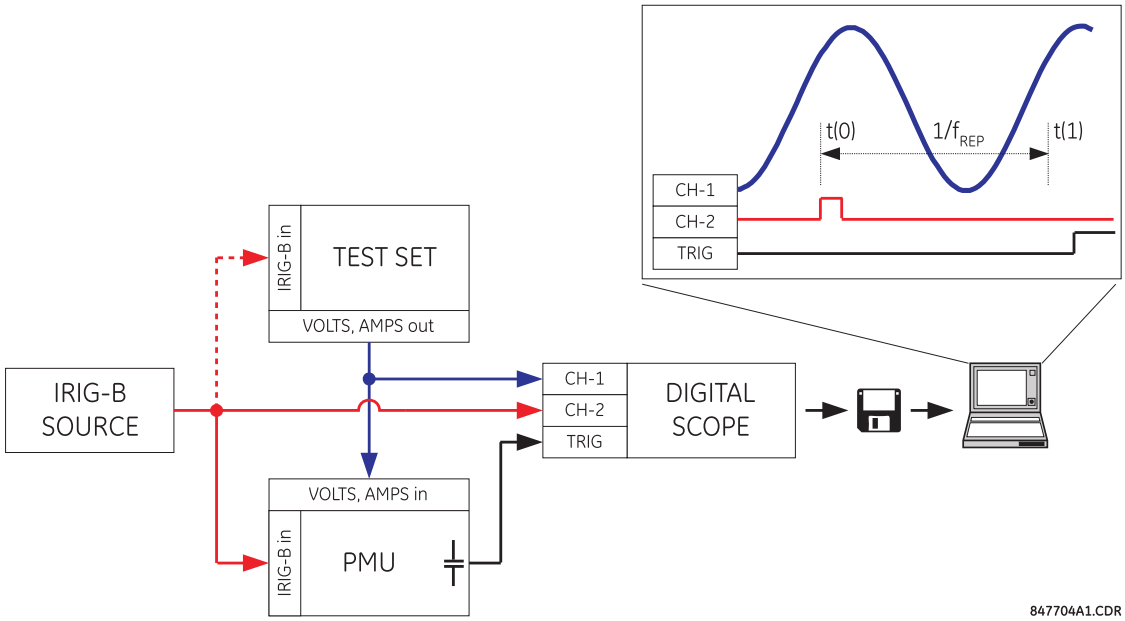



**Figure 7–2: USING THE PMU ONE-SHOT FEATURE TO TEST SYNCHROPHASOR MEASUREMENT ACCURACY**

### COLLECTING SYNCHRONIZED MEASUREMENTS *AD HOC*

The one-shot feature can be used for ad hoc collection of synchronized measurements in the network. Two or more PMU can be pre-scheduled to freeze their measurements at the same time. When frozen the measurements could be collected using EnerVista UR Setup or a protocol client.

## 7.1.7 SECURITY

**iPATH: COMMANDS ⇨⇩ SECURITY**

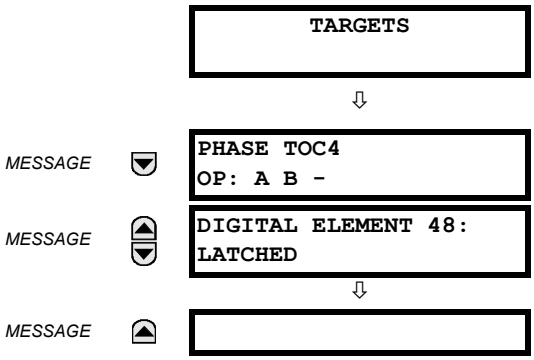
```
■■ SECURITY
■■
```

| | | |
|---|---|---|
| ⇦⇨ | ADMINISTRATOR<br>LOGOFF: No | *Range: Yes, No*<br>*Default: No* |
| ⇩ | ENGINEER<br>LOGOFF: No | *Range: Yes, No*<br>*Default: No* |
| ⇩ | OPERATOR<br>LOGOFF: No | *Range: Yes, No*<br>*Default: No* |
| ⇩ | CLEAR SECURITY DATA: | *Range: Yes, No*<br>*Default: No* |

With the CyberSentry option, this setting is available to enable or disable the following commands:

- **Administrator Logoff:** Selecting 'Yes' allows the Supervisor to forcefully logoff an administrator session.
- **Engineer Logoff:** Selecting 'Yes' allows the Supervisor to forcefully logoff an engineer session.
- **Operator Logoff:** Selecting 'Yes' allows the Supervisor to forcefully logoff an operator session.
- **Clear Security Data**: Selecting 'Yes' allows the Supervisor to forcefully clear all the security logs and clears all the operands associated with the self-tests.

### 7.2.1 TARGETS MENU




Each L30 element with a TARGET setting has a target message that when activated by its element is displayed in sequence with any other currently active target messages in the **TARGETS** menu. In the example shown, the Phase TOC4 and Digital Element 48 target settings are active and so have their targets displayed. The down arrow below the two elements indicates that there can be other active elements beyond these two.

For more information, see the description of target messages in the next section, and the Introduction to Elements section in the Settings chapter for instructions on TARGET setting.

When no targets are active, the display reads **NO TARGETS**.

### 7.2.2 TARGET MESSAGES

When there are no active targets, the first target to become active will cause the display to immediately default to that message. If there are active targets and the user is navigating through other messages, and when the default message timer times out (i.e. the keypad has not been used for a determined period of time), the display will again default back to the target message.

The range of variables for the target messages is described below. Phase information will be included if applicable. If a target message status changes, the status with the highest priority will be displayed.

**Table 7–1: TARGET MESSAGE PRIORITY STATUS**

| PRIORITY | ACTIVE STATUS | DESCRIPTION |
|---|---|---|
| 1 | OP | element operated and still picked up |
| 2 | PKP | element picked up and timed out |
| 3 | LATCHED | element had operated but has dropped out |

If a self test error is detected, a message appears indicating the cause of the error. For example **UNIT NOT PROGRAMMED** indicates that the minimal relay settings have not been programmed.

### 7.2.3 RELAY SELF-TESTS

#### a) DESCRIPTION

The relay performs a number of self-test diagnostic checks to ensure device integrity. The two types of self-tests (major and minor) are listed in the tables below. When either type of self-test error occurs, the Trouble LED Indicator will turn on and a target message displayed. All errors record an event in the event recorder. Latched errors can be cleared by pressing the RESET key, providing the condition is no longer present.

Major self-test errors also result in the following:

- The critical fail relay on the power supply module is de-energized.
- All other output relays are de-energized and are prevented from further operation.
- The faceplate In Service LED indicator is turned off.

- A RELAY OUT OF SERVICE event is recorded.

### b) MAJOR SELF-TEST ERROR MESSAGES

The major self-test errors are outlined in this section.

```
EQUIPMENT MISMATCH:
with 2nd line detail
```

- *Latched target message*: No.
- *Description of problem*: The configuration of modules does not match the order code stored in the L30. For example, "Card F8L Missing" means that hardware module 8L is missing from slot F inside the UR device.
- *How often the test is performed*: On power up. Afterwards, the backplane is checked for missing cards every five seconds.
- *What to do*: Check all modules against the order code, ensure they are inserted properly, and cycle control power. If the problem persists, contact the factory.

```
FLEXLOGIC ERROR:
with 2nd line detail
```

- *Latched target message*: No.
- *Description of problem*: A FlexLogic equation is incorrect.
- *How often the test is performed*: The test is event driven, performed whenever FlexLogic equations are modified.
- *What to do*: Finish all equation editing and use self tests to debug any errors.

```
UNIT NOT PROGRAMMED:
Check Settings
```

- *Latched target message*: No.
- *Description of problem*: The **PRODUCT SETUP** ⇨⇩ **INSTALLATION** ⇨ **RELAY SETTINGS** setting indicates the L30 is not programmed.
- *How often the test is performed*: On power up and whenever the **PRODUCT SETUP** ⇨⇩ **INSTALLATION** ⇨ **RELAY SETTINGS** setting is altered.
- *What to do*: Program all settings and then set **PRODUCT SETUP** ⇨⇩ **INSTALLATION** ⇨ **RELAY SETTINGS** to “Programmed”

```
MODULE FAILURE___:
Contact Factory (xxx)
```

- *Latched target message*: Yes.
- *Description of problem*: Module hardware failure detected. Module Failures 1 to 11 are major. The system can reboot for four of these, as follows.

  MODULE FAILURE 06 — Event message reads SYSTEM INTEGRITRY RECOVERY 06 when a reboot was required and otherwise MODULE FAILURE 06 when a failure was detected

  MODULE FAILURE 07 — Event message reads SYSTEM INTEGRITRY RECOVERY 07 when a reboot was required and otherwise MODULE FAILURE 07 when a failure was detected

  MODULE FAILURE 08 — Event message reads SYSTEM INTEGRITRY RECOVERY 08 when a reboot was required and otherwise MODULE FAILURE 08 when a failure was detected

  MODULE FAILURE 11 — Event message reads SYSTEM INTEGRITRY RECOVERY 11 when a reboot was required and otherwise MODULE FAILURE 11 when a failure was detected
- *How often the test is performed*: Module dependent.

- *What to do*: Generate the Service Report and provide it to GE customer service. The “xxx” text identifies the failed module (for example, F8L).

```
UNIT NOT CALIBRATED:
with 2nd line DSP slot
```

- *Latched target message*: Yes.
- *Description of problem*: DSP module is not calibrated or calibration data is out of range.
- *How often the test is performed*: On relay startup.
- *What to do*: The respective DSP module has to be replaced, contact factory service.

### c) MINOR SELF-TEST ERROR MESSAGES

Most of the minor self-test errors can be disabled. See the settings in the User-Programmable Self-Tests section in chapter 5.

```
MODULE FAILURE___:
Contact Factory (xxx)
```

- *Latched target message*: Yes.
- *Description of problem*: Module hardware failure detected. Module Failures 12 and 31 to 33 are minor.
- *How often the test is performed*: Module dependent.
- *What to do*: Contact the factory and supply the failure code noted in the display. The “xxx” text identifies the failed module (for example, F8L).

  For Module Failure 31, a new process card hardware is available. The process card hardware has been enhanced to support new features, such as fast distance protection, Synchrophasors Frequency, and Rate of Change of Frequency calculations to conform to C37.118 - 2005 standard. The new functionality leveraging the hardware is supported with firmware revision 7.25 and above. When using an older revision of the process card with a new firmware revision (7.25), Module Failure 31 indicates the limited functionality. If your application requires the new functionality, then new process card hardware is required and otherwise you can continue using the existing hardware. To know the revision of your hardware, contact the factory.

```
IEC 61850 DATA SET:
LLN0 GOOSE# Error
```

- *Latched target message*: No.
- *Description of problem*: A data item in a configurable GOOSE data set is not supported by the L30 order code.
- *How often the test is performed*: On power up.
- *What to do*: Verify that all the items in the GOOSE data set are supported by the L30. The EnerVista UR Setup software will list the valid items. An IEC61850 client will also show which nodes are available for the L30.

```
IEC 61850 DATA SET:
LLN0 BR# Error
```

- *Latched target message*: No.
- *Description of problem*: A data item in a configurable report data set is not supported by the L30 order code.
- *How often the test is performed*: On power up.
- *What to do*: Verify that all the items in the configurable report data set are supported by the L30. The EnerVista UR Setup software will list the valid items. An IEC 61850 client will also show which nodes are available for the L30.

```
MAINTENANCE ALERT:
Replace Battery
```

- *Latched target message*: Yes.
- *Description of problem*: The battery is not functioning.
- *How often the test is performed*: The battery is monitored every five seconds. The error message displays after 60 seconds if the problem persists.
- *What to do*: Replace the battery as outlined in the Maintenance chapter.

```
DIRECT RING BREAK:
MAINTENANCE ALERT
```

- *Latched target message*: No.
- *Description of problem*: Direct input and output settings are configured for a ring, but the connection is not in a ring.
- *How often the test is performed*: Every second.
- *What to do*: Check direct input and output configuration and wiring.

```
MAINTENANCE ALERT:
Bad IRIG-B Signal
```

- *Latched target message*: No.
- *Description of problem*: A bad IRIG-B input signal has been detected.
- *How often the test is performed*: Monitored whenever an IRIG-B signal is received.
- *What to do*: Ensure the following:
  - The IRIG-B cable is properly connected.
  - Proper cable functionality (that is, check for physical damage or perform a continuity test).
  - The IRIG-B receiver is functioning.
  - Check the input signal level (it may be less than specification).

  If none of these apply, then contact the factory.

```
MAINTENANCE ALERT:
Bad PTP Signal
```

- *Latched target message*: No.
- *Description of problem*: No PTP enabled port has good PTP signal input.
- *How often the test is performed*: Activated when no acceptable signal is being received.
- *What to do*: Ensure the following:
  - The Ethernet cable(s) are properly connected.
  - At least one PTP grandmaster-capable clock is functioning.
  - If a strict power profile (PP) is enabled, that entire network is PP compliant.
  - The network is delivering PTP messages to the relay.

```
MAINTENANCE ALERT:
SNTP Failure
```

- *Latched target message*: No.
- *Description of problem*: The SNTP server is not responding.
- *How often the test is performed*: Every 10 to 60 seconds.
- *What to do*: Check that Ethernet cable(s) are properly connected. Check that configuration for the SNTP server corresponds to the actual server settings. Check connectivity to the server (ping the server IP address).

```
MAINTENANCE ALERT:
4L Discrepancy
```

- *Latched target message*: No.
- *Description of problem*: A discrepancy has been detected between the actual and desired state of a latching contact output of an installed type “4L” module.
- *How often the test is performed*: Upon initiation of a contact output state change.
- *What to do*: Verify the state of the output contact and contact the factory if the problem persists.

```
MAINTENANCE ALERT:
Oscillatory GOOSE
```

- *Latched target message*: No.
- *Description of problem*: A data item in a configurable GOOSE data set is oscillating.
- *How often the test is performed*: Upon scanning of each configurable GOOSE data set.
- *What to do*: Evaluate all logic pertaining to this item.

```
DIRECT DEVICE OFF:
COMM Path Incomplete
```

- *Latched target message*: No.
- *Description of problem*: A direct device is configured but not connected.
- *How often the test is performed*: Every second.
- *What to do*: Check direct input and output configuration and wiring.

```
RXGOOSE OFFLINE:
COMM Path Incomplete
```

- *Latched target message*: No.
- *Description of problem*: One or more GOOSE devices are not responding.
- *How often the test is performed*: Event driven. The test is performed when a device programmed to receive GOOSE messages stops receiving. This can be from 1 to 60 seconds, depending on GOOSE packets.
- *What to do*: Check GOOSE setup.

```
AGGREGATOR ERROR:
```

- *Latched target message: No.*
- *Description of problem: The second line of this self-test error indicates the problem with the PMU Aggregator.*
- *How often the test is performed: Each time a PMU’s related settings is changed.*
- *What to do: Correct the problem indicated in the second line or contact the factory.*

```
TEMP MONITOR:
OVER TEMPERATURE
```

- *Latched target message*: Yes.
- *Description of problem*: The ambient temperature is greater than the maximum operating temperature (+80°C).
- *How often the test is performed*: Every hour.
- *What to do*: Remove the L30 from service and install in a location that meets operating temperature standards.

```
SYSTEM EXCEPTION:
Press RESET Key
```

- *Latched target message*: Yes.
- *Description of problem*: Abnormal restart from modules being removed or inserted while the L30 is powered-up, when there is an abnormal DC supply, or as a result of internal relay failure.
- *How often the test is performed*: Event driven.
- *What to do*: Contact the factory.

```
MAINTENANCE ALERT:
FIRST ETHERNET FAIL
```

```
MAINTENANCE ALERT:
SECOND ETHERNET FAIL
```

```
MAINTENANCE ALERT:
THIRD ETHERNET FAIL
```

- *Latched target message*: Yes.
- *Description of problem*: A link loss detection on an Ethernet port. The link loss is due to unplugging the cable or the switch port being down.
- *How often the test is performed*:
- *What to do*: Check the connection.

```
PROTOTYPE FIRMWARE:
Self Test Error
```

- *Description of problem*: Seen until the builds is tagged as being 'release candidate' or 'gold' builds.
- *What to do*: Update firmware to either of these builds.



```
STORAGE MEDIA ALARM:
Self Test Error
```

- *Latched target message*: No.
- *Description of problem*: The CPU module fails to read from or write to the Compact Flash (CF) card inside the module. The CF card stores certain non-volatile data, such as event records, oscillography and datalogger records, fault report values, and non-volatile actual values. Settings are not stored in CF and hence are unaffected by this self-test.
- *How often the test is performed*: On power up. Afterwards, every time the CPU accesses the CF card for reading or writing.
- *What to do*: Contact the factory.

```
RRTD COMM FAIL:
Self Test Error
```

- *Description of problem*: Communications with remote RTD unit (RRTD) or GPM-F failed for longer than 10 seconds.
- *Latched target message*: No.
- *How often the test is performed*: Runs only if "Com2 Usage" is set to RRTD or RRTD&GPM-F. Checked every five seconds.
- *What to do*: Check COM2 port settings, check RS485 cables.

```
VOLTAGE MONITOR:
with 2nd line detail
```

- *Description of problem*: The relay detected a problem with the internal voltage rails for longer than 25 seconds.
- *Latched target message*: Yes.
- *How often the test is performed*: Every five seconds.
- *What to do*: Contact GE customer service.

```
SETTINGS SAVE ERROR:
Contact Factory
```

- *Description of problem*: The relay failed to store the settings to the flash memory.
- *Latched target message*: Yes.
- *How often the test is performed*: When a setting is changed.
- *What to do*: Contact the factory.

```
LOW ON MEMORY:
with 2nd line detail
```

- *Description of problem*: The relay periodically checks the amount of free RAM memory available and the amount of free stack available for each task against pre-defined thresholds. The second line of the self-test indicates which of the tests failed. It asserts this self-test if those tests fail.
- *Latched target message*: Yes.
- *How often the test is performed*: Every five seconds.
- *What to do*: Contact the factory.

```
WRONG TRANSCEIVER:
Self Test Error
```

- *Latched target message*: Yes.
- *Description of problem*: The type of SFP does not match the CPU type.

  T-type CPU = All ports support fiber SFPs only

  U-type CPU = Maintenance port needs RJ45 SFP and the other two ports fiber SFPs

  V-type CPU = All ports support RJ45 SFPs only
- *What to do*: A web page "SFP Transceiver Information" is provided. This page displays the type of the SFP in it. This data is to be used with the CPU type to know the cause of the problem.

```
MAINTENANCE ALERT:
SFP MODULE x FAIL
```

- *Latched target message*: No.
- *Description of problem*: A faulty SFP or unplugging the SFP would generate this self test.
- *What to do*: The web page "SFP Transceiver Information" described in the previous section applies for this self test as well. The "SFP Module Fail" has higher priority and it suppresses the "Ethernet Fail" target message. The "SFP MODULE FAIL FUNCTION" setting enables/disables this self test. The target for this self test is priority-based, with the third one being the highest priority. For example, if all three SFP modules fail, then the third SFP target is activated. If the third SFP module failure resolves, then the second SFP target is activated.

### d) INSTANTANEOUS PROTECTION ELEMENTS TRIP SECURITY

Some self-tests are not fast enough to detect erroneous data and block protection elements, requiring additional measures. To secure instantaneous elements, in addition to the self-tests described, there are supervising elements that validate "fault" conditions and release IOC and differential elements operation.

These trip security elements use currents samples and phasors from the same sources as supervised protection elements to detect independently true "fault" conditions from IOC or differential. Trip security elements do not have any user settings and are enabled as soon as corresponding instantaneous elements are enabled. During laboratory testing, these elements can be disabled by activating any IED test mode via the **SETTINGS ⇨⇩ TESTING ⇨ TEST MODE FUNCTION**.

Trip security elements do not affect protection performance in any way.

**Instantaneous Overcurrent**

All enabled Phase IOC, Negative-Sequence, and Neutral IOCs in the active setting group are supervised by the trip security element. The goals of the IOC trip security are as follows:

- Detect erroneous operate current due to wiring or data acquisition problem resulting in one phase current dropping to zero, resulting in erroneous negative-sequence and neutral currents
- Justify current phasor magnitude increase with simultaneous current changes from samples

This is achieved by comparing current values of the current phasors and samples change with the values taken two cycles before. Additionally, trip security elements monitor "pre-fault" current to detect if operate condition is happening as a result of current decrease instead of increase.

The element is armed when there are no disturbances in currents for five cycles.

**Differential elements (bus, transformer, stator)**

Differential trip security runs for each differential zone. It monitors if differential current increase above the pickup setting is confirmed by the disturbance detectors for each differential zone input. When a differential zone fault occurs and at least two zone inputs carry some load, at least two disturbance detectors have to be activated. Or when there is no load at any zone inputs (zone is energized but does not carry any load), at least one disturbance detector has to be activated.

Consequently:

- If there is not any disturbance detector activation in at least one zone input — Differential trip is inhibited
- If there is just one zone input disturbance detector activation but load is present in at least two zone inputs prior to the "fault" — Differential trip is inhibited
- If there is more than one disturbance detector zone input activation — Differential trip is allowed (normal scenario)

When differential trip is inhibited by the trip security element, no setting group change is allowed.

7

## HARDFIBER SELF-TEST ERROR MESSAGES

In addition to those provided by the standard UR-series devices, the UR devices implement HardFiber self-tests. These are listed below. Any abnormal diagnostic condition indicated by the LEDs or the critical failure relay also results in a self-test message, so troubleshooting is described here. For other relays, such at the B95$^{Plus}$, see that product's instruction manual.

**Equipment Mismatch Major Self-Test**

Description: The number or type of installed hardware modules does not match the order code stored in the CPU. The standard UR-series Equipment Mismatch self-test is extended to cover the possible presence of a Process Card.

Severity: Protection is not available and all contact outputs and shared outputs are de-asserted.

If this message appears, check all modules against the order code. Ensure they are inserted properly, and cycle the control power. If a module has intentionally been added or removed use the **Update Order Code** command to notify the relay that the current module configuration is correct.

**Module Failure Major Self-Test**

Description: UR-series device module hardware failure detected.

Severity: Protection is not available and all contact outputs and shared outputs are de-asserted.

If this message appears, contact the factory and supply the failure code noted in the display. Text in the message identifies the failed module (for example, H81). If operated on a Process Card failure, the Module Fail self-test seals-in (latches) till the UR-series device is restarted.

#### Process Bus Failure Major Self-test

Description: Mission critical data is not available via the process bus. An AC quantity is considered critical if both AC bank origins and the crosschecking settings are other than none. This self-test is also initiated by an AC input discrepancy being detected. See the description of the crosschecking setting in this manual for further information. In addition, this self-test can be initiated by user logic responding to loss of critical contact input/output or other data using the **Process Bus Failure Operand** user-programmable self-test setting. This setting is located in the **Settings > Product Setup > User-Programmable Self Test** menu.

Severity: Protection is not available and all contact outputs and shared outputs are de-asserted.

If this message appears, first rectify any Process Bus Trouble and Brick Trouble self-test errors. Check the actual value of the operand referenced by the **Process Bus Failure Operand** setting, and if “On”, determine the cause and rectify.

Should the problem persist with the foregoing all clear, the cause must be an AC input discrepancy, which is typically the result of problems in the input signals to the Bricks, or faults in the Brick input conditioning hardware. If the error was annunciated the first time significant signal was encountered, suspect the former cause and check the copper connections external to the Brick. Where multiple UR-series devices have self-test errors, look for common causes.

To further isolate AC input discrepancy errors, put the relay in test-isolated mode, then one by one, temporally change an AC bank crosschecking setting to none, until the Process Bus Failure clears. Once the problem AC bank has been identified, the values from each of the two Bricks can be examined individually by temporarily mapping each to an AC bank with a single origin.

#### Process Bus Trouble Minor Self-Test

Description: Communications problems with one or more Bricks. The text of the message identifies the affected field units. This self-test is initiated by low received signal levels at either the Brick or Process Card end, and by the sustained failure to receive poll responses from the proper Brick.

Severity: This self-test error does not directly inhibit protection. However, the affected Brick inputs/outputs may not be available to the UR-series device.

If this message appears, check the field unit actual values. An indication of equipment mismatch means that messages are being received from a Brick, but there is a discrepancy between the settings and the actual Brick serial number, order code, and/or core number. Check that the correct core on the correct Brick is patched through to the correct Process Card port, and that the field unit settings are correct. An indication of communications loss means that no messages are being received. Check that the patching is correct, and that the Brick has power. If that is not the problem, use a professional optical fiber connector cleaning kit to clean both sides of all optical fiber connections from the Process Card through to the affected Brick. If the problem continues after cleaning, consult the factory.

#### Brick Trouble Minor Self-Test

Description: Brick internal self-testing has detected a trouble internal to the Brick.

Severity: This self-test error does not directly inhibit protection. However, some or all of the affected Brick inputs/outputs may not be available to the UR-series device.

If this message appears, check the Brick environment for over/under temperatures and the voltage of its power source. If the ambient temperature and supply voltage are within Brick specifications, consult the factory. Troubles resulting from a Brick output failing to respond to an output command can only be detected while the command is active, and so in this case the target is latched. A latched target can be unlatched by pressing the faceplate reset key if the command has ended, however the output may still be non-functional.

#### RTD Trouble Minor Self-Test

Description: The Brick is reporting that the sensed RTD field connection does not match that of an RTD or the reported DC input value is outside of the RTD temperature range, greater than 250°C (likely open sensor circuit fault) or less than -50°C (likely shorted sensor fault).

Latched: No.

If this message appears, check field RTD settings and connections.

### TDR Trouble Minor Self-Test

Description: The Brick is reporting that the sensed transducer field connection does not match that of a transducer, or the reported DC input value is outside of the set transducer input range, or the minimum value setting is equal to the maximum value setting.

Latched: No.

If this message appears, check field transducer settings and connections.

### 8.1.1 L30 DESIGN

All differential techniques rely on the fact that under normal conditions, the sum of the currents entering each phase of a transmission line from all connected terminals is equal to the charging current for that phase. Beyond the fundamental differential principle, the three most important technical considerations are; data consolidation, restraint characteristic, and sampling synchronization. The L30 uses new and unique concepts in these areas.

Data consolidation refers to the extraction of appropriate parameters to be transmitted from raw samples of transmission line phase currents. By employing data consolidation, a balance is achieved between transient response and bandwidth requirements. Consolidation is possible along two dimensions: time and phases. Time consolidation consists of combining a time sequence of samples to reduce the required bandwidth. Phase consolidation consists of combining information from three phases and neutral. Although phase consolidation is possible, it is generally not employed in digital schemes, because it is desired to detect which phase is faulted. The L30 relay transmits data for all three phases.

Time consolidation reduces communications bandwidth requirements. Time consolidation also improves security by eliminating the possibility of falsely interpreting a single corrupted data sample as a fault.

The L30 relay system uses a new consolidation technique called “phaselets”. Phaselets are partial sums of the terms involved in a complete phasor computation. The use of phaselets in the L30 design improves the transient response performance without increasing the bandwidth requirements.

Phaselets themselves are not the same as phasors, but they can be combined into phasors over any time window that is aligned with an integral number of phaselets (see the Phaselet Computation section in this chapter for details). The number of phaselets that must be transmitted per cycle per phase is the number of samples per cycle divided by the number of samples per phaselet. The L30 design uses 64 samples per cycle and 32 samples per phaselet, leading to a phaselet communication bandwidth requirement of 2 phaselets per cycle. Two phaselets per cycle fits comfortably within a communications bandwidth of 64 Kbaud, and can be used to detect faults within a half cycle plus channel delay.

The second major technical consideration is the restraint characteristic, which is the decision boundary between situations that are declared to be a fault and those that are not. The L30 uses an innovative adaptive decision process based on an on-line computation of the sources of measurement error. In this adaptive approach, the restraint region is an ellipse with variable major axis, minor axis, and orientation. Parameters of the ellipse vary with time to make best use of the accuracy of current measurements.

The third major element of L30 design is sampling synchronization. In order for a differential scheme to work, the data being compared must be taken at the same time. This creates a challenge when data is taken at remote locations.

The GE approach to clock synchronization relies upon distributed synchronization. Distributed synchronization is accomplished by synchronizing the clocks to each other rather than to a master clock. Clocks are phase synchronized to each other and frequency synchronized to the power system frequency. Each relay compares the phase of its clock to the phase of the other clocks and compares the frequency of its clock to the power system frequency and makes appropriate adjustments. As long as there are enough channels operating to provide protection, the clocks will be synchronized.

### 8.1.2 L30 ARCHITECTURE

The L30 system uses a peer to peer architecture in which the relays at every terminal are identical. Each relay computes differential current and clocks are synchronized to each other in a distributed fashion. The peer to peer architecture is based on two main concepts that reduce the dependence of the system on the communication channels: replication of protection and distributed synchronization.



Replication of protection means that each relay is designed to be able to provide protection for the entire system, and does so whenever it has enough information. Thus a relay provides protection whenever it is able to communicate directly with all other relays. For a multi-terminal system, the degree of replication is determined by the extent of communication interconnection. If there is a channel between every pair of relays, every relay provides protection. If channels are not provided between every pair of relays, only those relays that are connected to all other relays provide protection.

Each L30 relay measures three phase currents 64 times per cycle. Synchronization in sampling is maintained throughout the system via the distributed synchronization technique.

The next step is the removal of any decaying offset from each phase current measurement. This is done using a digital simulation of the so-called “mimic circuit” (based on the differential equation of the inductive circuit that generates the offset). Next, phaselets are computed by each L30 for each phase from the outputs of the mimic calculation, and transmitted to the

other relay terminals. Also, the sum of the squares of the raw data samples is computed for each phase, and transmitted with the phaselets.

At the receiving relay, the received phaselets are combined into phasors. Also, ground current is reconstructed from phase information. An elliptical restraint region is computed by combining sources of measurement error. In addition to the restraint region, a separate disturbance detector is used to enhance security.

The possibility of a fault is indicated by the detection of a disturbance as well as the sum of the current phasors falling outside of the elliptical restraint region. The statistical distance from the phasor to the restraint region is an indication of the severity of the fault. To provide speed of response that is commensurate with fault severity, the distance is filtered. For mild faults, filtering improves measurement precision at the expense of a slight delay, on the order of one cycle. Severe faults are detected within a single phaselet. Whenever the sum of phasors falls within the elliptical restraint region, the system assumes there is no fault, and uses whatever information is available for fine adjustment of the clocks.

### 8.1.3 REMOVAL OF DECAYING OFFSET

The inductive behavior of power system transmission lines gives rise to decaying exponential offsets during transient conditions, which could lead to errors and interfere with the determination of how well measured current fits a sinewave.

The current signals are pre-filtered using an improved digital MIMIC filter. The filter removes effectively the DC component(s) guaranteeing transient overshoot below 2% regardless of the initial magnitude and time constant of the dc component(s). The filter has significantly better filtering properties for higher frequencies as compared with a classical MIMIC filter. This was possible without introducing any significant phase delay thanks to the high sampling rate used by the relay. The output of the MIMIC calculation is the input for the phaselet computation. The MIMIC computation is applied to the data samples for each phase at each terminal. The equation shown is for one phase at one terminal.

### 8.1.4 PHASELET COMPUTATION

Phaselets are partial sums in the computation for fitting a sine function to measured samples. Each slave computes phaselets for each phase current and transmits phaselet information to the master for conversion into phasors. Phaselets enable the efficient computation of phasors over sample windows that are not restricted to an integer multiple of a half cycle at the power system frequency. Determining the fundamental power system frequency component of current data samples by minimizing the sum of the squares of the errors gives rise to the first frequency component of the Discrete Fourier Transform (DFT). In the case of a data window that is a multiple of a half cycle, the computation is simply sine and cosine weighted sums of the data samples. In the case of a window that is not a multiple of a half-cycle, there is an additional correction that results from the sine and cosine functions not being orthogonal over such a window. However, the computation can be expressed as a two by two matrix multiplication of the sine and cosine weighted sums.

Phaselets and sum of squares are computed for each phase at each terminal as follows. For the real part, we have:

$$I_{1\_Re\_A(k)} = \frac{4}{N} \sum_{p=0}^{N/2-1} i_{1\_f\_A(k-p)} \cdot \cos\left(\frac{2\pi(p+1/2)}{N}\right) \quad \textbf{(EQ 8.1)}$$

For the imaginary part, we have:

$$I_{1\_Im\_A(k)} = -\frac{4}{N} \sum_{p=0}^{N/2-1} i_{1\_f\_A(k-p)} \cdot \sin\left(\frac{2\pi(p+1/2)}{N}\right) \quad \textbf{(EQ 8.2)}$$

where: *k* is the present phaselet index,
*N* is the number of samples per cycle, and
*p* is the present sample index

The computation of phaselets and sum of squares is basically a consolidation process. The phaselet sums are converted into stationary phasors by multiplying by a precomputed matrix. Phaselets and partial sums of squares are computed and time stamped at each relay and communicated to the remote relay terminals, where they are added and the matrix multiplication is performed. Since the sampling clocks are synchronized, the time stamp is simply a sequence number.

### 8.1.5 DISTURBANCE DETECTION

A disturbance detection algorithm is used to enhance security and to improve transient response. Conditions to detect a disturbance include the magnitude of zero-sequence current, the magnitude of negative-sequence current, and changes in positive, negative, or zero-sequence current. Normally, differential protection is performed using a full-cycle Fourier transform. Continuous use of a full-cycle Fourier means that some pre-fault data is also used for computation – this may lead to a slowdown in the operation of the differential function. To improve operating time, the window is resized to the half-cycle Fourier once a disturbance is detected, thus removing pre-fault data.

### 8.1.6 FAULT DETECTION

Normally, the sum of the current phasors from all terminals is zero for each phase at every terminal. A fault is detected for a phase when the sum of the current phasors from each terminal for that phase falls outside of a dynamic elliptical restraint boundary for that phase. The severity of the fault is computed as follows for each phase.

The differential current is calculated as a sum of local and remote currents. The real part is expressed as:

$$I_{DIFF\_RE\_A} = I_{LOC\_PHASOR\_RE\_A} + I_{REM1\_PHASOR\_RE\_A} + I_{REM2\_PHASOR\_RE\_A} \quad \textbf{(EQ 8.3)}$$

The imaginary part is expressed as:

$$I_{DIFF\_IM\_A} = I_{LOC\_PHASOR\_IM\_A} + I_{REM1\_PHASOR\_IM\_A} + I_{REM2\_PHASOR\_IM\_A} \quad \textbf{(EQ 8.4)}$$

The differential current is squared for the severity equation:

$$(I_{DIFF\_A})^2 = (I_{DIFF\_RE\_A})^2 + (I_{DIFF\_IM\_A})^2 \quad \textbf{(EQ 8.5)}$$

The restraint current is composed from two distinctive terms: traditional and adaptive. Each relay calculates local portion of the traditional and restraint current to be used locally and sent to remote peers for use with differential calculations. If more than one CT are connected to the relay (breaker-and-the half applications), then a maximum of all (up to 4) currents is chosen to be processed for traditional restraint:

The current chosen is expressed as:

$$(I_{LOC\_TRAD\_A})^2 = \max((I_{1\_MAG\_A})^2, (I_{2\_MAG\_A})^2, (I_{3\_MAG\_A})^2, (I_{4\_MAG\_A})^2, (I_{q\_MAG\_A})^2) \quad \textbf{(EQ 8.6)}$$

This current is then processed with the slope ($S_1$ and $S_2$) and breakpoint (BP) settings to form a traditional part of the restraint term for the local current as follows. For two-terminal systems, we have:

$$\begin{aligned} &\text{If } (I_{LOC\_TRAD\_A})^2 < \mathrm{BP}^2 \\ &\text{then } (I_{LOC\_REST\_TRAD\_A})^2 = 2(S_1 \cdot I_{LOC\_TRAD\_A})^2 \\ &\text{else } (I_{LOC\_REST\_TRAD\_A})^2 = 2((S_2 \cdot I_{LOC\_TRAD\_A})^2 - (S_2 \cdot \mathrm{BP})^2) + 2(S_1 \cdot \mathrm{BP})^2 \end{aligned} \quad \textbf{(EQ 8.7)}$$

For three-terminal systems we have

$$\begin{aligned} &\text{If } (I_{LOC\_TRAD\_A})^2 < \mathrm{BP}^2 \\ &\text{then } (I_{LOC\_REST\_TRAD\_A})^2 = \frac{4}{3}(S_1 \cdot I_{LOC\_TRAD\_A})^2 \\ &\text{else } (I_{LOC\_REST\_TRAD\_A})^2 = \frac{4}{3}((S_2 \cdot I_{LOC\_TRAD\_A})^2 - (S_2 \cdot \mathrm{BP})^2) + \frac{4}{3}(S_1 \cdot \mathrm{BP})^2 \end{aligned} \quad \textbf{(EQ 8.8)}$$

The final restraint current sent to peers and used locally in differential calculations is as follows:

$$I_{LOC\_RESTRAINT\_A} = \sqrt{(I_{LOC\_REST\_TRAD\_A})^2 + \mathrm{MULT}_A \cdot (I_{LOC\_ADA\_A})^2} \quad \textbf{(EQ 8.9)}$$

where: $\mathrm{MULT}_A$ is a multiplier that increases restraint if CT saturation is detected (see *CT Saturation Detection* for details);
$I_{LOC\_ADA\_A}$ is an adaptive restraint term (see *Online Estimate Of Measurement Error* for details)

The squared restraining current is calculated as a sum of squared local and all remote restraints:

$$(I_{REST\_A})^2 = (I_{LOC\_PHASOR\_RESTRAINT\_A})^2 + (I_{REM1\_PHASOR\_RESTRAINT\_A})^2 + (I_{REM2\_PHASOR\_RESTRAINT\_A})^2 \quad \text{(EQ 8.10)}$$

The fault severity for each phase is determined by following equation:

$$S_A = (I_{DIFF\_A})^2 - (2P^2 + (I_{REST\_A})^2) \quad \text{(EQ 8.11)}$$

where $P$ is the pickup setting.

This equation is based on the adaptive strategy and yields an elliptical restraint characteristic. The elliptical area is the restraint region. When the adaptive portion of the restraint current is small, the restraint region shrinks. When the adaptive portion of the restraint current increases, the restraint region grows to reflect the uncertainty of the measurement. The computed severity increases with the probability that the sum of the measured currents indicates a fault. With the exception of "Restraint", all quantities are defined in previous sections. "Adaptive Restraint" is a restraint multiplier, analogous to the slope setting of traditional differential approaches, for adjusting the sensitivity of the relay.

Raising the restraint multiplier corresponds to demanding a greater confidence interval, and has the effect of decreasing sensitivity while lowering it is equivalent to relaxing the confidence interval and increases sensitivity. Thus, the restraint multiplier is an application adjustment that is used to achieve the desired balance between sensitivity and security. The computed severity is zero when the operate phasor is on the elliptical boundary, is negative inside the boundary, and positive outside the boundary. Outside of the restraint boundary, the computed severity grows as the square of the fault current. The restraint area grows as the square of the error in the measurements.

### 8.1.7 GROUND DIFFERENTIAL ELEMENT

The line ground differential function allows sensitive ground protection for single-line to-ground faults, allowing the phase differential element to be set higher (above load) to provide protection for multi-phase faults. The L30 ground differential function calculates ground differential current from all terminal phase currents. The maximum phase current is used for the restraint. The L30 is applied in dual-breaker applications to cope with significant through current at remote terminals that may cause CT errors or saturation.

The line ground differential function uses the same CT matched and time-aligned phasors as the phase-segregated current differential function. The operate signal is calculated for both real and imaginary parts as follows:

$$I_{OP\_87G\_RE} = I_{LOC\_PHASOR\_RE\_A} + I_{LOC\_PHASOR\_RE\_B} + I_{LOC\_PHASOR\_RE\_C} + I_{REM1\_PHASOR\_RE\_A} + I_{REM1\_PHASOR\_RE\_B} + I_{REM1\_PHASOR\_RE\_C} + I_{REM2\_PHASOR\_RE\_A} + I_{REM2\_PHASOR\_RE\_B} + I_{REM2\_PHASOR\_RE\_C} \quad \text{(EQ 8.12)}$$

$$I_{OP\_87G\_IM} = I_{LOC\_PHASOR\_IM\_A} + I_{LOC\_PHASOR\_IM\_B} + I_{LOC\_PHASOR\_IM\_C} + I_{REM1\_PHASOR\_IM\_A} + I_{REM1\_PHASOR\_IM\_B} + I_{REM1\_PHASOR\_IM\_C} + I_{REM2\_PHASOR\_IM\_A} + I_{REM2\_PHASOR\_IM\_B} + I_{REM2\_PHASOR\_IM\_C} \quad \text{(EQ 8.13)}$$

The terms for the second remote terminal are omitted in two-terminal applications.

The maximum through current is available locally and re-constructed from the received remote restraint based on the maximum remote restraint current shown in the previous section and as indicated below.

For two-terminal applications:

$$\text{If } (I_{REM\_REST\_A})^2 < BP^2, \text{ then } (I_{REM\_REST\_A})^2 = \frac{(I_{REM\_RESTRAINT\_A})^2}{2S_1^2}$$
$$\text{else } (I_{REM\_REST\_A})^2 = \frac{(I_{REM\_RESTRAINT\_A})^2 - 2(S_1 \times BP)^2}{2S_2^2} + BP^2 \quad \text{(EQ 8.14)}$$

For three-terminal applications:

$$\text{If } (I_{\text{REM\_REST\_A}})^2 < \text{BP}^2, \text{ then } (I_{\text{REM\_REST\_A}})^2 = \frac{(I_{\text{REM\_RESTRAINT\_A}})^2}{\frac{4}{3} \times S_1^2}$$

$$\text{else } (I_{\text{REM\_REST\_A}})^2 = \frac{(I_{\text{REM\_RESTRAINT\_A}})^2 - \frac{4}{3}(S_1 \times \text{BP})^2}{\frac{4}{3} \times S_2^2} + \text{BP}^2 \quad \textbf{(EQ 8.15)}$$

The 87G restraining signal is calculated as follows:

$$(I_{\text{RES\_87G}})^2 = \max((I_{\text{LOC\_REST\_A}})^2, (I_{\text{LOC\_REST\_B}})^2, (I_{\text{LOC\_REST\_C}})^2, (I_{\text{REM1\_REST\_A}})^2, (I_{\text{REM1\_REST\_B}})^2, (I_{\text{REM1\_REST\_C}})^2, (I_{\text{REM2\_REST\_A}})^2, (I_{\text{REM2\_REST\_B}})^2, (I_{\text{REM2\_REST\_C}})^2) \quad \textbf{(EQ 8.16)}$$

The terms for the second remote terminal are omitted in two-terminal applications.

The operate signal for the ground differential function, $(I_{\text{OP\_87G}})^2$, is then calculated as:

$$(I_{\text{OP\_87G}})^2 = (I_{\text{OP\_87G\_RE}})^2 + (I_{\text{OP\_87G\_IM}})^2 \quad \textbf{(EQ 8.17)}$$

The restraint signal, $(I_{87\text{G}})^2$, is calculated as follows for two-terminal applications:

$$(I_{87\text{G}})^2 = 2S_{87\text{G}}{}^2 \times (I_{\text{RES\_87G}})^2 \quad \textbf{(EQ 8.18)}$$

The restraint signal, $(I_{87\text{G}})^2$, is calculated as follows for three-terminal applications:

$$(I_{87\text{G}})^2 = \frac{4}{3} \times S_{87\text{G}}{}^2 \times (I_{\text{RES\_87G}})^2 \quad \textbf{(EQ 8.19)}$$

where $S_{87\text{G}}$ is the slope setting for the ground differential function.

The ground differential element picks up if the following condition holds.

$$((I_{\text{OP\_87G}})^2 - (2P_{87\text{G}}{}^2 + (I_{87\text{G}})^2) > 0) \text{ and } ((I_{\text{RES\_87G}})^2 < (3 \text{ pu})^2) \quad \textbf{(EQ 8.20)}$$

where $P_{87\text{G}}$ is the pickup setting for the ground differential function.

In other words, when the squared magnitude of the operating signal is greater than the total restraining squared signal, the element operates. For additional security, the function is blocked if the restraining signal is high, indicating the 87LG function is not required to clear high-current faults, allowing for more sensitive settings to be used for the 87LG function.

### 8.1.8 CLOCK SYNCHRONIZATION

Synchronization of data sampling clocks is needed in a digital differential protection scheme, because measurements must be made at the same time. Synchronization errors show up as phase angle and transient errors in phasor measurements at the terminals. By phase angle errors, we mean that identical currents produce phasors with different phase angles. By transient errors, we mean that when currents change at the same time, the effect is seen at different times at different measurement points. For best results, samples should be taken simultaneously at all terminals.

In the case of peer to peer architecture, synchronization is accomplished by synchronizing the clocks to each other rather than to a master clock. Each relay compares the phase of its clock to the phase of the other clocks and compares the frequency of its clock to the power system frequency and makes appropriate adjustments. The frequency and phase tracking algorithm keeps the measurements at all relays within a plus or minus 25 microsecond error during normal conditions for a 2 or 3 terminal system. For 4 or more terminals the error may be somewhat higher, depending on the quality of the communications channels. The algorithm is unconditionally stable. In the case of 2 and 3 terminal systems, asymmetric communications channel delay is automatically compensated for. In all cases, an estimate of phase error is computed and used to automatically adapt the restraint region to compensate. Frequency tracking is provided that will accommodate any frequency shift normally encountered in power systems.

### 8.1.9 FREQUENCY TRACKING AND PHASE LOCKING

Each relay has a digital clock that determines when to take data samples and which is phase synchronized to all other clocks in the system and frequency synchronized to the power system frequency. Phase synchronization drives the relative timing error between clocks to zero, and is needed to control the uncertainty in the phase angle of phasor measurements, which will be held to under 26 microseconds (0.6 degrees). Frequency synchronization to the power system eliminates a source of error in phasor measurements that arises when data samples do not exactly span one cycle.

The block diagram for clock control for a two terminal system is shown in the following figure. Each relay makes a local estimate of the difference between the power system frequency and the clock frequency based on the rotation of phasors. Each relay also makes a local estimate of the time difference between its clock and the other clocks either by exchanging timing information over communications channels or from information that is in the current phasors, depending on whichever one is more accurate at any given time. A loop filter then uses the frequency and phase angle deviation information to make fine adjustments to the clock frequency. Frequency tracking starts if the current at one or more terminals is above 0.125 pu of nominal; otherwise, the nominal frequency is used.

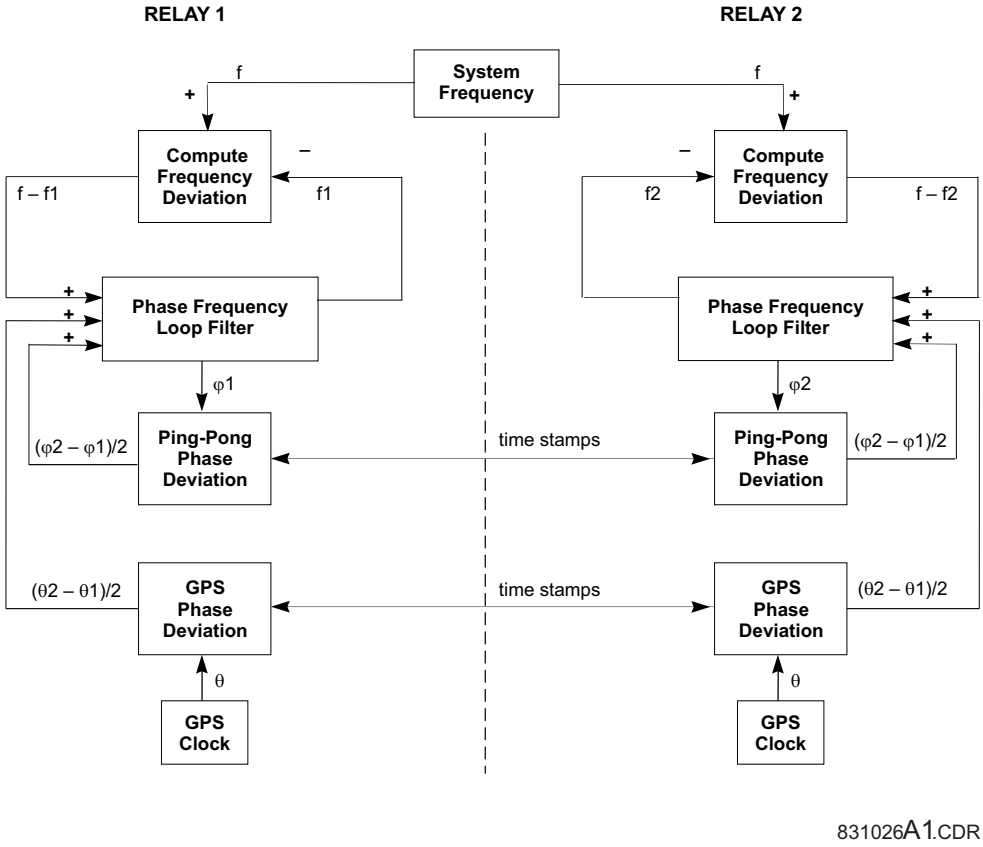



**Figure 8–1: BLOCK DIAGRAM FOR CLOCK SYNCHRONIZATION IN A TWO-TERMINAL SYSTEM**

The L30 provides sensitive digital current differential protection by computing differential current from current phasors. To improve sensitivity, the clocks are controlling current sampling are closely synchronized via the ping-pong algorithm. However, this algorithm assumes the communication channel delay is identical in each direction. If the delays are not the same, the error between current phasors is equal to half of the transmit-receive time difference. If the error is high enough, the relay perceives the “apparent” differential current and misoperates.

For applications where the communication channel is not symmetric (for example, SONET ring), the L30 allows the use of GPS (Global Positioning System) to compensate for the channel delay asymmetry. This feature requires a GPS receiver to provide a GPS clock signal to the L30. With this option there are two clocks as each terminal: a local sampling clock and a local GPS clock. The sampling clock controls data sampling while the GPS clock provides an accurate, absolute time refer-

ence used to measure channel asymmetry. The local sampling clocks are synchronized to each other in phase and to the power system in frequency. The local GPS clocks are synchronized to GPS time using the externally provided GPS time signal.

GPS time stamp is included in the transmitted packet along with the sampling clock time stamp. Both sampling clock deviation and channel asymmetry are computed from the four time-stamps. One half of the channel asymmetry is then subtracted from the computed sampling clock deviation. The compensated deviation drives the phase and frequency lock loop (PFLL) as shown on the diagram above. If GPS time reference is lost, the channel asymmetry compensation is not enabled, and the relay clock may start to drift and accumulate differential error. In this case, the 87L function has to be blocked. See the Application of Settings chapter for samples of how to program the relay.

### 8.1.10 FREQUENCY DETECTION

Estimation of frequency deviation is done locally at each relay based on rotation of positive sequence current, or on rotation of positive sequence voltage, if it is available. The counter clockwise rotation rate is proportional to the difference between the desired clock frequency and the actual clock frequency. With the peer to peer architecture, there is redundant frequency tracking, so it is not necessary that all terminals perform frequency detection.

Normally each relay will detect frequency deviation, but if there is no current flowing nor voltage measurement available at a particular relay, it will not be able to detect frequency deviation. In that case, the frequency deviation input to the loop filter is set to zero and frequency tracking is still achieved because of phase locking to the other clocks. If frequency detection is lost at all terminals because there is no current flowing then the clocks continue to operate at the frequency present at the time of the loss of frequency detection. Tracking will resume as soon as there is current.

The rotational rate of phasors is equal to the difference between the power system frequency and the ratio of the sampling frequency divided by the number of samples per cycle. The correction is computed once per power system cycle at each relay. For conciseness, we use a phasor notation:

$$\begin{aligned}
&\overline{I(n)} = \mathrm{Re}(\mathrm{Phasor}_n) + j \cdot \mathrm{Im}(\mathrm{Phasor}_n) \\
&\overline{I_{a,k}(n)} = \overline{I(n)} \quad \text{for phase } a \text{ from the } k\text{th terminal at time step } n \\
&\overline{I_{b,k}(n)} = \overline{I(n)} \quad \text{for phase } b \text{ from the } k\text{th terminal at time step } n \\
&\overline{I_{c,k}(n)} = \overline{I(n)} \quad \text{for phase } c \text{ from the } k\text{th terminal at time step } n
\end{aligned} \qquad \textbf{(EQ 8.21)}$$

Each terminal computes positive sequence current:

$$\overline{I_{pos,k}(n)} = \frac{1}{3}\left(\overline{I_{a,k}(n)} + \overline{I_{b,k}(n)} \cdot e^{j2\pi/3} + \overline{I_{c,k}(n)} \cdot e^{j2\pi/3}\right) \qquad \textbf{(EQ 8.22)}$$

Each relay computes a quantity derived from the positive sequence current that is indicative of the amount of rotation from one cycle to the next, by computing the product of the positive sequence current times the complex conjugate of the positive sequence current from the previous cycle:

$$\overline{\mathrm{Deviation}_k(n)} = \overline{I_{pos,k}(n)} \times \overline{I_{pos,k}(n-N)}^* \qquad \textbf{(EQ 8.23)}$$

The angle of the deviation phasor for each relay is proportional to the frequency deviation at that terminal. Since the clock synchronization method maintains frequency synchronism, the frequency deviation is approximately the same for each relay. The clock deviation frequency is computed from the deviation phasor:

$$\mathrm{FrequencyDeviation} = \frac{\Delta f}{f} = \frac{\tan^{-1}\left(\mathrm{Im}(\overline{\mathrm{Deviation}}) / \mathrm{Re}(\overline{\mathrm{Deviation}})\right)}{2\pi} \qquad \textbf{(EQ 8.24)}$$

Note that a four quadrant arctangent can be computed by taking the imaginary and the real part of the deviation separately for the two arguments of the four quadrant arctangent. Also note that the input to the loop filter is in radian frequency which is two pi times the frequency in cycles per second; that is, $\Delta\omega = 2\pi \cdot \Delta f$.

So the radian frequency deviation can be calculated simply as:

$$\Delta\omega = \Delta f \cdot \tan^{-1}\left(\mathrm{Im}(\overline{\mathrm{Deviation}}) / \mathrm{Re}(\overline{\mathrm{Deviation}})\right) \qquad \textbf{(EQ 8.25)}$$

### 8.1.11 PHASE DETECTION

There are two separate sources of clock phase information; exchange of time stamps over the communications channels and the current measurements themselves (although voltage measurements can be used to provide frequency information, they cannot be used for phase detection). Current measurements can generally provide the most accurate information, but are not always available and may contain large errors during faults or switching transients. Time stamped messages are the most reliable source of phase information but suffer from a phase offset due to a difference in the channel delays in each direction between a pair of relays. In some cases, one or both directions may be switched to a different physical path, leading to gross phase error.

The primary source of phase information are CPU time-tagged messages. If GPS compensation is enabled, GPS time stamps are used to compensate for asymmetry. In all cases, frequency deviation information is also used when available. The phase difference between a pair of clocks is computed by an exchange of time stamps. Each relay exchanges time stamps with all other relays that can be reached.

It is not necessary to exchange stamps with every relay, and the method works even with some of the channels failed. For each relay that a given relay can exchange time stamps with, the clock deviation is computed each time a complete set of time stamps arrives. The net deviation is the total deviation divided by the total number of relays involved in the exchange.

For example, in the case of two terminals, each relay computes a single time deviation from time stamps, and divides the result by two. In the case of three terminals, each relay computes two time deviations and divides the result by three. If a channel is lost, the single deviation that remains is divided by two.

Four time stamps are needed to compute round trip delay time and phase deviation. Three stamps are included in the message in each direction. The fourth time stamp is the time when the message is received. Each time a message is received the oldest two stamps of the four time stamps are saved to become the first two time stamps of the next outgoing message. The third time stamp of an outgoing message is the time when the message is transmitted. A fixed time shift is allowed between the stamp values and the actual events, provided the shift for outgoing message time stamps is the same for all relays, and the shift incoming message time stamps is also identical.

To reduce bandwidth requirements, time stamps are spread over 3 messages. In the case of systems with 4 messages per cycle, time stamps are sent out on three of the four messages, so a complete set is sent once per cycle. In the case of systems with 1 message per cycle, three time stamps are sent out each cycle in a single message. The transmit and receive time stamps are based on the first message in the sequence.

One of the strengths of this approach is that it is not necessary to explicitly identify or match time stamp messages. Usually, two of the time stamps in an outgoing message are simply taken from the last incoming message. The third time stamp is the transmittal time. However, there are two circumstances when these time stamps are not available. One situation is when the first message is transmitted by a given relay. The second is when the exchange is broken long enough to invalidate the last received set of time stamps (if the exchange is broken for longer than 66 ms, the time stamps from a given clock could roll over twice, invalidating time difference computations). In either of these situations, the next outgoing set of time stamps is a special start-up set containing transmittal time only. When such a message is received, nothing is computed from it, except the message time stamp and the received time stamp are saved for the next outgoing message (it is neither necessary nor desirable to “reset” the local clock when such a message is received).

Error analysis shows that time stamp requirements are not very stringent because of the smoothing behavior of the phase locked loop. The time stamp can be basically a sample count with enough bits to cover the worst round trip, including channel delay and processing delay. An 8 bit time stamp with 1 bit corresponding to 1/64 of a cycle will accommodate a round trip delay of up to 4 cycles, which should be more than adequate.

The computation of round trip delay and phase offset from four time stamps is as follows:

$$a = T_{i-2} - T_{i-3}$$
$$b = T_i - T_{i-1}$$
$$\delta_i = a + b \qquad \text{(EQ 8.26)}$$
$$\theta_i = \frac{a - b}{2}$$

The *T*s are the time stamps, with $T_i$ the newest. Delta is the round trip delay. Theta is the clock offset, and is the correct sign for the feedback loop. Note that the time stamps are unsigned numbers that wrap around, while *a* and *b* can be positive or negative; $\delta_i$ must be positive and $\theta_i$ can be positive or negative. Some care must be taken in the arithmetic to take into account possible roll over of any of the time stamps. If $T_{i-2}$ is greater than $T_{i-1}$, there was a roll over in the clock responsible for those two time stamps.

To correct for the roll over, subtract 256 from the round trip and subtract 128 from the phase angle. If $T_{i-3}$ is greater than $T_i$, add 256 to the round trip and add 128 to the phase angle. Also, if the above equations are computed using integer values of time stamps, a conversion to phase angle in radians is required by multiplying by $\pi$ / 32.

Time stamp values are snapshots of the local 256 bit sample counter taken at the time of the transmission or receipt of the first message in a time stamp sequence. This could be done either in software or hardware, provided the jitter is limited to less than plus or minus 130 $\mu$s. A fixed bias in the time stamp is acceptable, provided it is the same for all terminals.

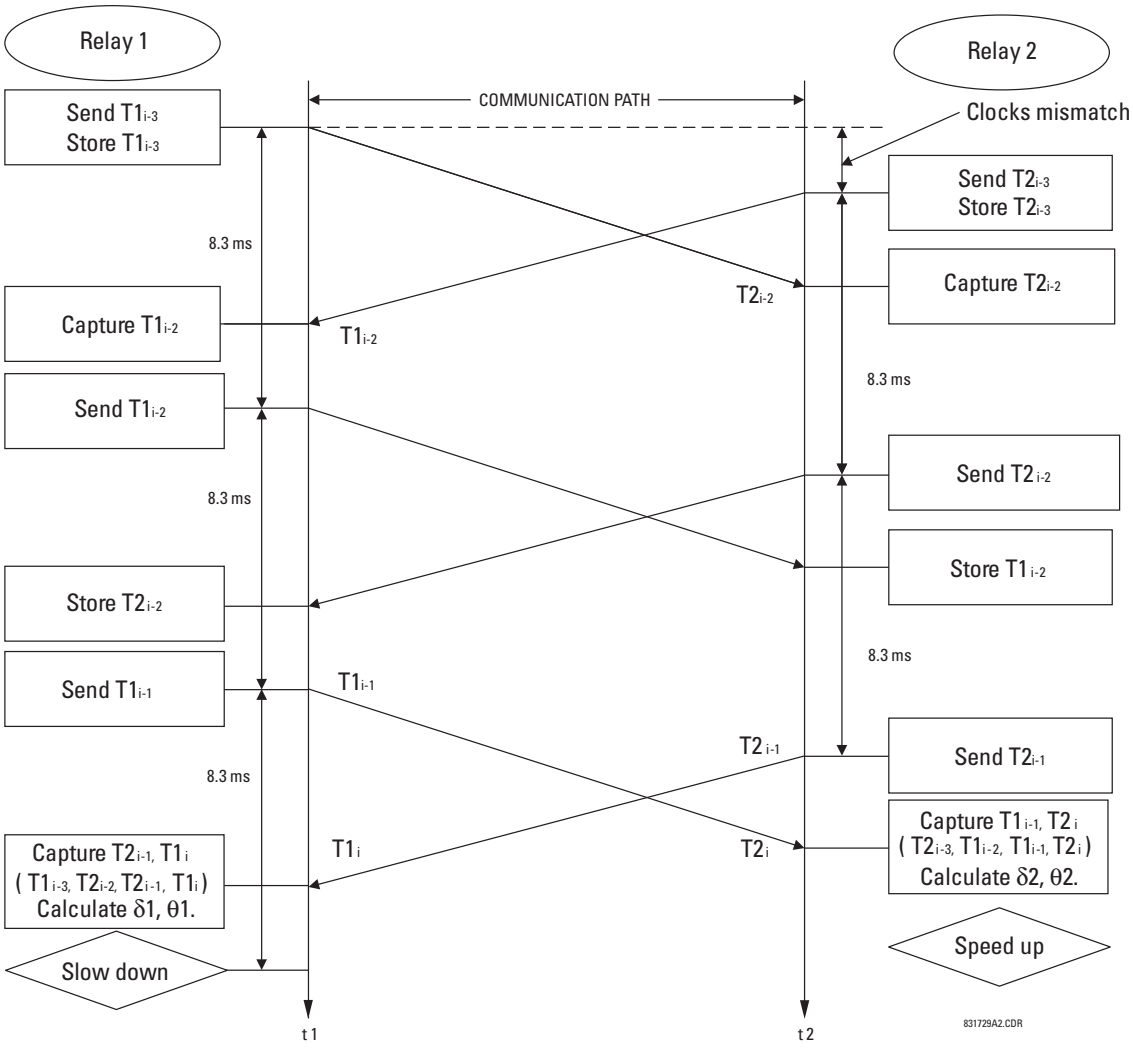



**Figure 8–2: ROUND TRIP DELAY AND CLOCK OFFSET COMPUTATION FROM TIME STAMPS**

### 8.1.12 PHASE LOCKING FILTER

Filters are used in the phase locked loop to assure stability, to reduce phase and frequency noise. This is well known technology. The primary feedback mechanism shown in the Loop Block Diagram is phase angle information through the well known proportional plus integral (PI) filter (the *Z* in the diagram refers to a unit delay, and 1 / (*Z* – 1) represents a simple digital first order integrator). This loop is used to provide stability and zero steady state error.

A PI filter has two time parameters that determine dynamic behavior: the gain for the proportional term and the gain for the integral. Depending on the gains, the transient behavior of the loop can be underdamped, critically damped, or over damped. For this application, critically damped is a good choice.

This sets a constraint relating the two parameters. A second constraint is derived from the desired time constants of the loop. By considering the effects of both phase and frequency noise in this application it can be shown that optimum behavior results with a certain proportion between phase and frequency constraints.

A secondary input is formed through the frequency deviation input of the filter. Whenever frequency deviation information is available, it is used for this input; otherwise, the input is zero. Because frequency is the derivative of phase information, the appropriate filter for frequency deviation is an integrator, which is combined with the integrator of the PI filter for the phase. It is very important to combine these two integrators into a single function because it can be shown if two separate integrators are used, they can drift in opposite directions into saturation, because the loop would only drive their sum to zero.

In normal operation, frequency tracking at each terminal matches the tracking at all other terminals, because all terminals will measure approximately the same frequency deviation. However, if there is not enough current at a terminal to compute frequency deviation, frequency tracking at that terminal is accomplished indirectly via phase locking to other terminals. A small phase deviation must be present for the tracking to occur.

Also shown in the loop is the clock itself, because it behaves like an integrator. The clock is implemented in hardware and software with a crystal oscillator and a counter.

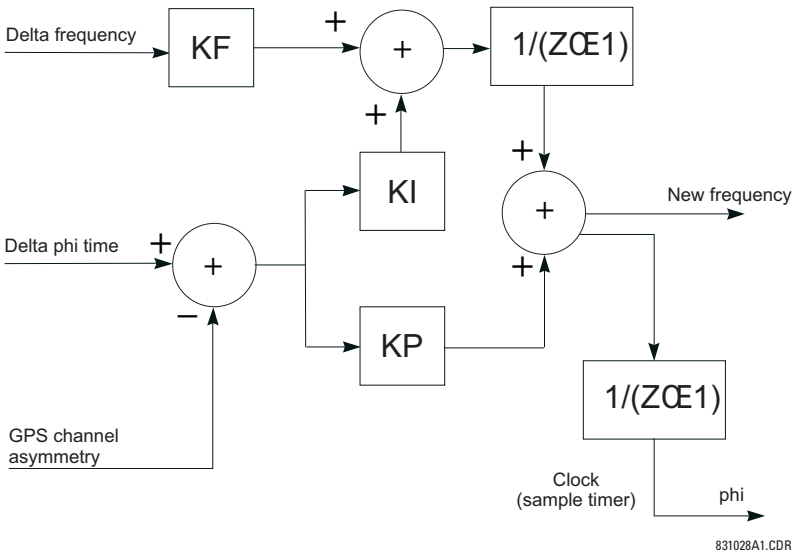



**Figure 8–3: BLOCK DIAGRAM OF LOOP FILTER**

There are 4 gains in the filter that must be selected once and for all as part of the design of the system. The gains are determined by the time step of the integrators, and the desired time constants of the system as follows:

$$KI = \frac{T_{repeat}}{T_{phase}^2}, \quad KP = \frac{2}{T_{phase}}, \quad KF = \frac{T_{repeat}}{T_{frequency}} \qquad \textbf{(EQ 8.27)}$$

where: $T_{repeat}$ = the time between execution of the filter algorithm
$T_{phase}$ = time constant for the primary phase locked loop
$T_{frequency}$ = time constant for the frequency locked loop

### 8.1.13 MATCHING PHASELETS

An algorithm is needed to match phaselets, detect lost messages, and detect communications channel failure. Channel failure is defined by a sequence of lost messages, where the length of the sequence is a design parameter. In any case, the sequence should be no longer than the maximum sequence number (4 cycles) in order to be able to match up messages when the channel is assumed to be operating normally.

A channel failure can be detected by a watchdog software timer that times the interval between consecutive incoming messages. If the interval exceeds a maximum limit, channel failure is declared and the channel recovery process is initiated.

While the channel is assumed to be operating normally, it is still possible for an occasional message to be lost, in which case fault protection is suspended for the time period that depends on that message, and is resumed on the next occasional message. A lost message is detected simply by looking at the sequence numbers of incoming messages. A lost message will show up as a gap in the sequence.

Sequence numbers are also used to match messages for the protection computation. Whenever a complete set of current measurements from all terminals with matching sequence numbers are available, the differential protection function is computed using that set of measurements.

### 8.1.14 START-UP

Initialization in our peer-to-peer architecture is done independently at each terminal. Relays can be turned on in any order with the power system either energized or de-energized. Synchronization and protection functions are accomplished automatically whenever enough information is available.

After a relay completes other initialization tasks such as resetting of buffer pointers and determining relay settings, initial values are computed for any state variables in the loop filters or the protection functions. The relay starts its clock at the nominal power system frequency. Phaselet information is computed and transmitted.

- Outgoing messages over a given channel are treated in the same way as during the channel recovery process. The special start-up message is sent each time containing only a single time step value.
- When incoming messages begin arriving over a channel, that channel is placed in service and the loop filters are started up for that channel.
- Whenever the total clock uncertainty is less than a fixed threshold, the phase locking filter is declared locked and differential protection is enabled.

### 8.1.15 HARDWARE AND COMMUNICATION REQUIREMENTS

The average total channel delay in each direction is not critical, provided the total round trip delay is less than 4 power system cycles. The jitter is important, and should be less than ±130 μs in each direction. The effect of a difference in the average delay between one direction and the other depends on the number of terminals. In the case of a 2 or 3 terminal system, the difference is not critical, and can even vary with time. In the case of a 4 or more terminal system, variation in the difference limits the sensitivity of the system.

- The allowable margin of 130 μs jitter includes jitter in servicing the interrupt generated by an incoming message. For both incoming and outgoing messages, the important parameter is the jitter between when the time stamp is read and when the message begins to go out or to come in.
- The quality of the crystal driving the clock and software sampling is not critical, because of the compensation provided by the phase and frequency tracking algorithm, unless it is desired to perform under or over frequency protection. From the point of view of current differential protection only, the important parameter is the rate of drift of crystal frequency, which should be less than 100 parts per million per minute.
- A 6 Mhz clock with a 16-bit hardware counter is adequate, provided the method is used for achieving the 32-bit resolution that is described in this document.
- An 8-bit time stamp is adequate provided time stamp messages are exchanged once per cycle.
- A 4-bit message sequence number is adequate.

Depending on the 87L settings, channel asymmetry (the difference in the transmitting and receiving paths channel delay) cannot be higher than 1 to 1.5 ms if channel asymmetry compensation is not used. However, if the relay detects asymmetry higher than 1.5 ms, the 87L DIFF CH ASYM DET FlexLogic™ operand is set high and the event and target are raised (if they are enabled in the **CURRENT DIFFERENTIAL** menu) to provide an indication about potential danger.

### 8.1.16 ONLINE ESTIMATE OF MEASUREMENT ERRORS

GE's adaptive elliptical restraint characteristic is a good approximation to the cumulative effects of various sources of error in determining phasors. Sources of error include power system noise, transients, inaccuracy in line charging current computation, current sensor gain, phase and saturation error, clock error, and asynchronous sampling. Errors that can be controlled are driven to zero by the system. For errors that cannot be controlled, all relays compute and sum the error for each source of error for each phase. The relay computes the error caused by power system noise, CT saturation, harmonics, and transients. These errors arise because power system currents are not always exactly sinusoidal. The intensity of these errors varies with time; for example, growing during fault conditions, switching operations, or load variations. The system treats these errors as a Gaussian distribution in the real and in the imaginary part of each phasor, with a standard deviation that is estimated from the sum of the squares of the differences between the data samples and the sine function that is used to fit them. This error has a spectrum of frequencies. Current transformer saturation is included with noise and transient error. The error for noise, harmonics, transients, and current transformer saturation is computed as follows. First, the sum of the squares of the errors in the data samples is computed from the sum of squares information for the present phaselet:

$$\text{SumSquares}_{1\_A(k)} = \frac{4}{N}\sum_{p=0}^{N/2-1}\left(i_{1\_f\_A(k-p)}\right)^2 \quad \textbf{(EQ 8.28)}$$

Then fundamental magnitude is computed as follows for the same phaselet:

$$I_{1\_MAG\_A} = \sqrt{\left(I_{1\_RE\_A}\right)^2 + \left(I_{1\_IM\_A}\right)^2} \quad \textbf{(EQ 8.29)}$$

Finally, the local adaptive restraint term is computed as follows, for each local current:

$$\left(I_{1\_ADA\_A}\right)^2 = \frac{4}{N}\left(\text{SumSquares}_{1\_A(k)} - \left(I_{1\_MAG\_A}\right)^2\right) \quad \textbf{(EQ 8.30)}$$

Another source of the measurement errors is clock synchronization error, resulting in a clock uncertainty term. The L30 algorithm accounts for two terms of synchronization error corresponding to:

- *Raw clock deviation computed from time stamps*. There are several effects that cause it to not track exactly. First, the ping-pong algorithm inherently produces slightly different estimates of clock deviation at each terminal. Second, because the transmission of time stamps is spread out over several packets, the clock deviation estimate is not up to date with other information it is combined with. Channel asymmetry also contributes to this term. The clock deviation computation is indicated in equation 8.15 as $\theta_i$. If 2 channels are used, clock deviation is computed for both channels and then average of absolute values is computed. If GPS compensation is used, then GPS clock compensation is subtracted from the clock deviation.
- *Startup error*. This term is used to estimate the initial startup transient of PFLLs. During startup conditions, a decaying exponential is computed to simulate envelope of the error during startup

The clock uncertainty is expressed as:

$$\text{clock\_unc} = \text{clock\_dev} + \text{start\_up\_error} \quad \textbf{(EQ 8.31)}$$

Eventually, the local clock error is computed as:

$$\text{CLOCK}_A = \frac{(\text{clock\_unc})^2}{9} \cdot \left(\left(I_{LOC\_RE\_A}\right)^2 + \left(I_{LOC\_IM\_A}\right)^2\right) \quad \textbf{(EQ 8.32)}$$

The local squared adaptive restraint is computed from all local current sources (1 to 4) and is obtained as follows:

$$\left(I_{LOC\_ADA\_A}\right)^2 = 18 \cdot \left(\left(I_{1\_ADA\_A}\right)^2 + \left(I_{2\_ADA\_A}\right)^2 + \left(I_{3\_ADA\_A}\right)^2 + \left(I_{4\_ADA\_A}\right)^2 + \left(I_{q\_ADA\_A}\right)^2 + \text{CLOCK}_A\right) \quad \textbf{(EQ 8.33)}$$

### 8.1.17 CT SATURATION DETECTION

Current differential protection is inherently dependent on adequate CT performance at all terminals of the protected line, especially during external faults. CT saturation, particularly when it happens at only one terminal of the line, introduces a spurious differential current that may cause the differential protection to misoperate.

The L30 applies a dedicated mechanism to cope with CT saturation and ensure security of protection for external faults. The relay dynamically increases the weight of the square of errors (the so-called 'sigma') portion in the total restraint quantity, but for external faults only. The following logic is applied:

- First, the terminal currents are compared against a threshold of 3 pu to detect overcurrent conditions that may be caused by a fault and may lead to CT saturation.
- For all the terminal currents that are above the 3 pu level, the relative angle difference is calculated. If all three terminals see significant current, then all three pairs (1, 2), (2, 3), and (1, 3) are considered and the maximum angle difference is used in further calculations.
- Depending on the angle difference between the terminal currents, the value of sigma used for the adaptive restraint current is increased by the multiple factor of 1, 5, or 2.5 to 5 as shown below. As seen from the figure, a factor of 1 is used for internal faults, and a factor of 2.5 to 5 is used for external faults. This allows the relay to be simultaneously sensitive for internal faults and robust for external faults with a possible CT saturation.

If more than one CT is connected to the relay (breaker-and-the half applications), the CT saturation mechanism is executed between the maximum local current against the sum of all others, then between the maximum local and remote currents to select the secure multiplier MULT. A Maximum of two (local and remote) is selected and then applied to adaptive restraint.

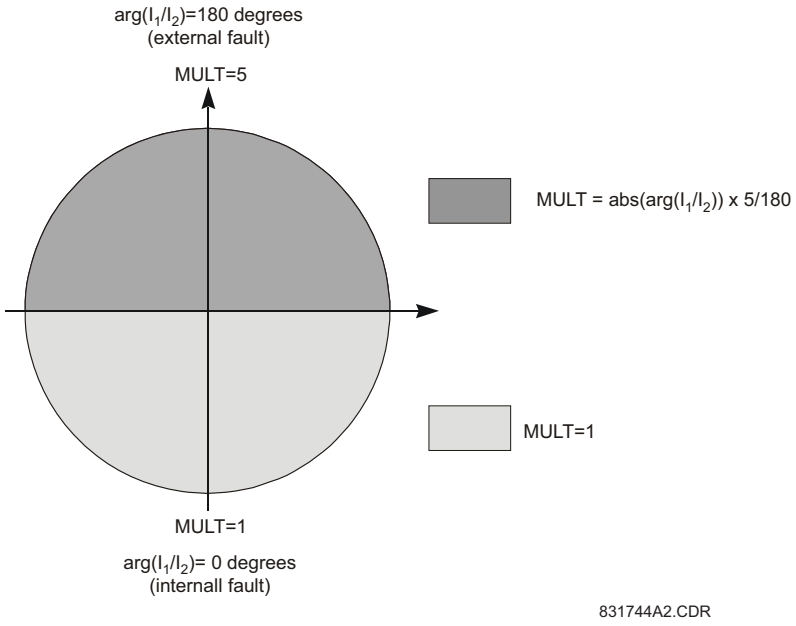



**Figure 8–4: CT SATURATION ADAPTIVE RESTRAINT MULTIPLIER**

### 8.1.18 CHARGING CURRENT COMPENSATION

The basic premise for the operation of differential protection schemes in general, and of the L30 line differential element in particular, is that the sum of the currents entering the protected zone is zero. In the case of a power system transmission line, this is not entirely true because of the capacitive charging current of the line. For short transmission lines the charging current is a small factor and can therefore be treated as an unknown error. In this application the L30 can be deployed without voltage sensors and the line charging current is included as a constant term in the total variance, increasing the differential restraint current. For long transmission lines the charging current is a significant factor, and should be computed to provide increased sensitivity to fault current.

Compensation for charging current requires the voltage at the terminals be supplied to the relays. The algorithm calculates $I_q = C \times (dV)/dt$ for each phase, which is then subtracted from the measured currents at both ends of the line. This is a simple approach that provides adequate compensation of the capacitive current at the fundamental power system frequency. Traveling waves on the transmission line are not compensated, and contribute to restraint by increasing the measurement of errors in the data set.

The underlying single-phase model for compensation for a two- and three-terminal system are shown below.

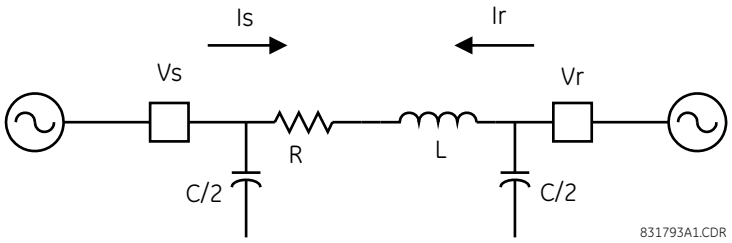



**Figure 8–5: 2-TERMINAL TRANSMISSION LINE SINGLE-PHASE MODEL FOR COMPENSATION**

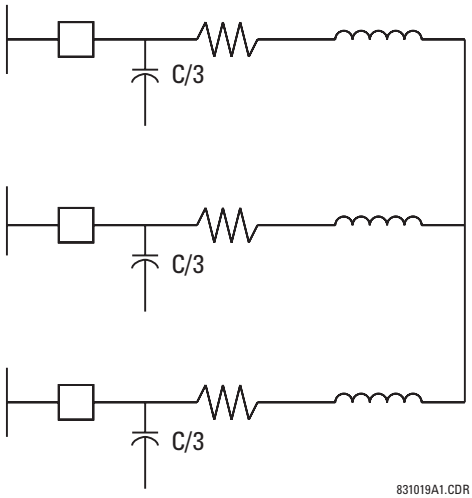



**Figure 8–6: 3-TERMINAL TRANSMISSION LINE SINGLE-PHASE MODEL FOR COMPENSATION**

Apportioning the total capacitance among the terminals is not critical for compensating the fundamental power system frequency charging current as long as the total capacitance is correct. Compensation at other frequencies will be approximate.

If the VTs are connected in wye, the compensation is accurate for both balanced conditions (i.e. all positive, negative and zero sequence components of the charging current are compensated). If the VTs are connected in delta, the compensation is accurate for positive and negative sequence components of the charging current. Since the zero sequence voltage is not available, the L30 cannot compensate for the zero sequence current.

The compensation scheme continues to work with the breakers open, provided the voltages are measured on the line side of the breakers.

For very long lines, the distributed nature of the line leads to the classical transmission line equations which can be solved for voltage and current profiles along the line. What is needed for the compensation model is the effective positive and zero sequence capacitance seen at the line terminals.

Finally, in some applications the effect of shunt reactors needs to be taken into account. With very long lines shunt reactors may be installed to provide some of the charging current required by the line. This reduces the amount of charging current flowing into the line. In this application, the setting for the line capacitance should be the residual capacitance remaining after subtracting the shunt inductive reactance from the total capacitive reactance at the power system frequency.

### 8.1.19 DIFFERENTIAL ELEMENT CHARACTERISTICS

The differential element is completely dependent on receiving data from the relay at the remote end of the line, therefore, upon startup, the differential element is disabled until the time synchronization system has aligned both relays to a common time base. After synchronization is achieved, the differential is enabled. Should the communications channel delay time increase, such as caused by path switching in a SONET system or failure of the communications power supply, the relay will act as outlined in the next section.

The L30 incorporates an adaptive differential algorithm based on the traditional percent differential principle. In the traditional percent differential scheme, the operating parameter is based on the phasor sum of currents in the zone and the restraint parameter is based on the scalar (or average scalar) sum of the currents in the protected zone - when the operating parameter divided by the restraint parameter is above the slope setting, the relay will operate. During an external fault, the operating parameter is relatively small compared to the restraint parameter, whereas for an internal fault, the operating parameter is relatively large compared to the restraint parameter. Because the traditional scheme is not adaptive, the element settings must allow for the maximum amount of error anticipated during an out-of-zone fault, when CT errors may be high and/or CT saturation may be experienced.

The major difference between the L30 differential scheme and a percent differential scheme is the use of an estimate of errors in the input currents to increase the restraint parameter during faults, permitting the use of more sensitive settings than those used in the traditional scheme. The inclusion of the adaptive feature in the scheme produces element characteristic equations that appear to be different from the traditional scheme, but the differences are minimal during system steady-state conditions. The element equations are shown in the Operating Condition Calculations section.

### 8.1.20 RELAY SYNCHRONIZATION

On startup of the relays, the channel status is checked first. If channel status is OK, all relays send a special "startup" message and the synchronization process is initiated. It takes about five to seven seconds to declare phase and frequency lock loop (PFLL) status as OK and to start performing current differential calculations. If one of the relays is powered off during the operation, the synchronization process restarts from the beginning. Relays tolerate channel delay (resulting sometimes in a step change in communication paths) or interruptions up to four power cycles round trip time (about 66 ms at 60 Hz) without any deterioration in performance. If communications are interrupted for more than four cycles, the following applies:

**In two-terminal mode**:

With a second, redundant channel, relays do not lose functionality at all if the second channel is live. The relay uses a true data redundancy concept where data is sent continuously and simultaneously over both channels. As such there is no channel switching going on. Even if data is lost/corrupted or a channel failed completely, the relay picks the data from the healthy channel immediately and continues providing protection.

With one channel only, relays have a five-second time window. If the channel is restored within this time, it takes about two to three power cycles of valid PFLL calculations (and if estimated error is still within margin) to declare that PFLL is OK. If the channel is restored later than five seconds, PFLL at both relays is declared as failed and the re-synchronization process is initiated (about five to seven seconds) after channel status becomes OK.

**In three-terminal mode**:

If one of the channels fails, the configuration reverts from master-master to master-slave where the master relay has both channels live. The master relay PFLL keeps the two slave relays in synchronization, and therefore there is no time limit for functionality. The PFLL of the slave relays is suspended (that is, the 87L function is not performed at these relays but they can still trip via DTT from the master relay) until the channel is restored. If the estimated error is within margin upon channel restoration and after two to three power cycles of valid PFLL calculations, the PFLL is declared as OK and the configuration reverts back to master-master.

If two channels fail, PFLL at all relays is declared as failed, and when the channels are back in service the resynchronization process is initiated (about five to seven seconds) after channel status becomes OK.

Depending on the system configuration (number of terminals and channels), the 87L function operation depends on the status of channel(s), status of synchronization, and status of channel(s), and channel(s)ID validation. All these states are available as FlexLogic operands, for viewing in actual values, logged in the event recorder (if events are enabled in 87L menu), and also trigger targets (if targets are enabled in the 87L function). These FlexLogic operands can to be used to trigger alarms, illuminate LEDs, and be captured in oscillography.

However, the 87L BLOCKED FlexLogic operand reflects whether the local current differential function is blocked due to communications. The state of this operand is based on the combination of conditions previously outlined. As such, it is recommended that it be used to enable backup protection if 87L is not available.

The 87L DIFF BLOCKED operand is set based on the conditions shown in the figure.

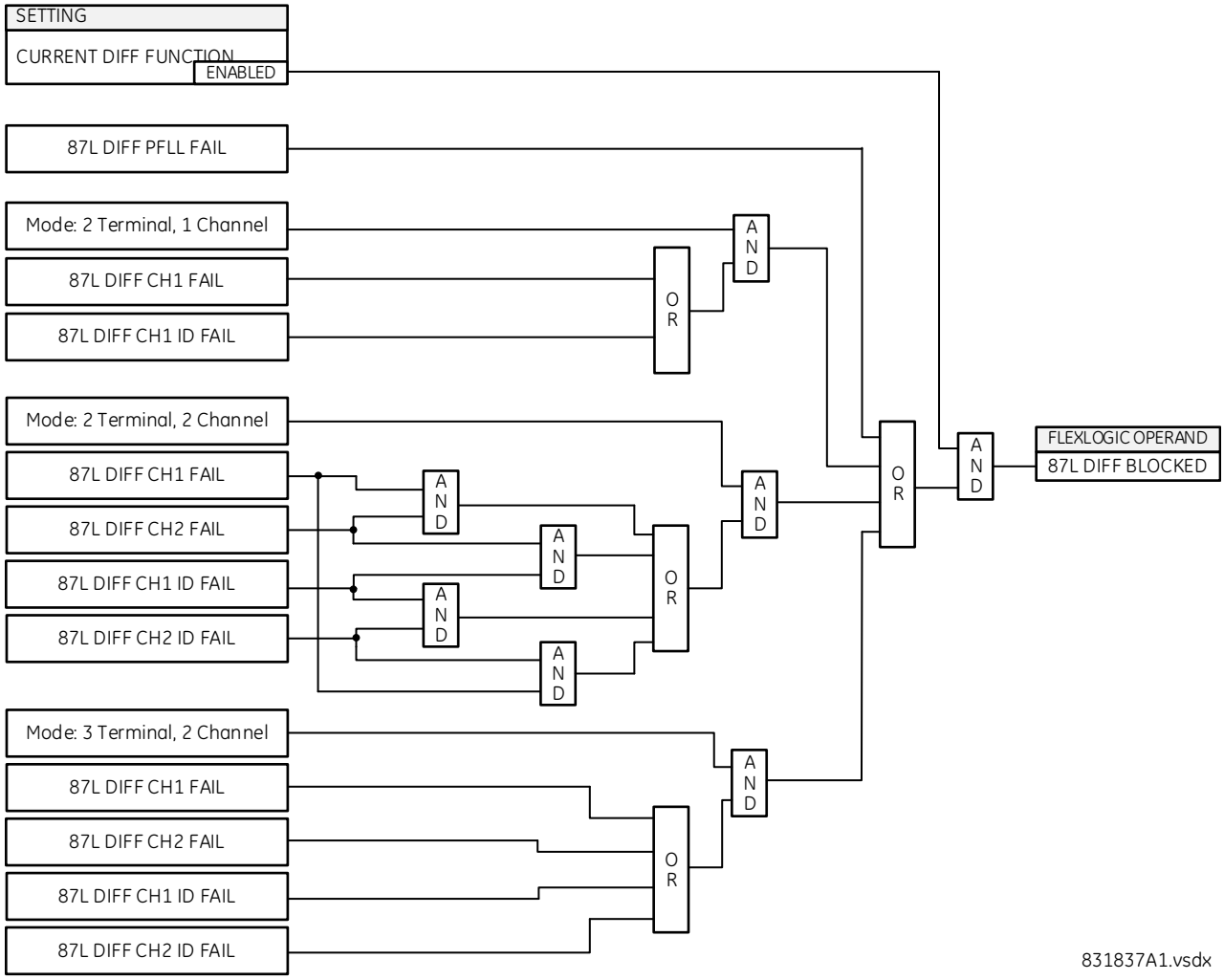



**Figure 8–7: BLOCKING LOGIC**

Communications alarms are categorized as major or minor.

The major alarms are CHANNEL FAIL, PFLL FAIL, and CHANNEL ID FAIL. The relay is blocked automatically if any of these conditions occur. Therefore, there is no need to assign these operands to a current differential block setting.

The minor alarms are CRC FAIL and LOST PACKET, which are indicators of a poor or noisy communications channel. If the relay recognizes that a packet is lost or corrupted, the 87L feature is not processed at that protection pass. Instead, it waits for the next valid packet.

The following conditions apply for alarm declaration.

**CHANNEL FAIL** — Channel is declared failed (assertion of 87L DIFF CHn FAIL) based on the conditions shown in the next figure.

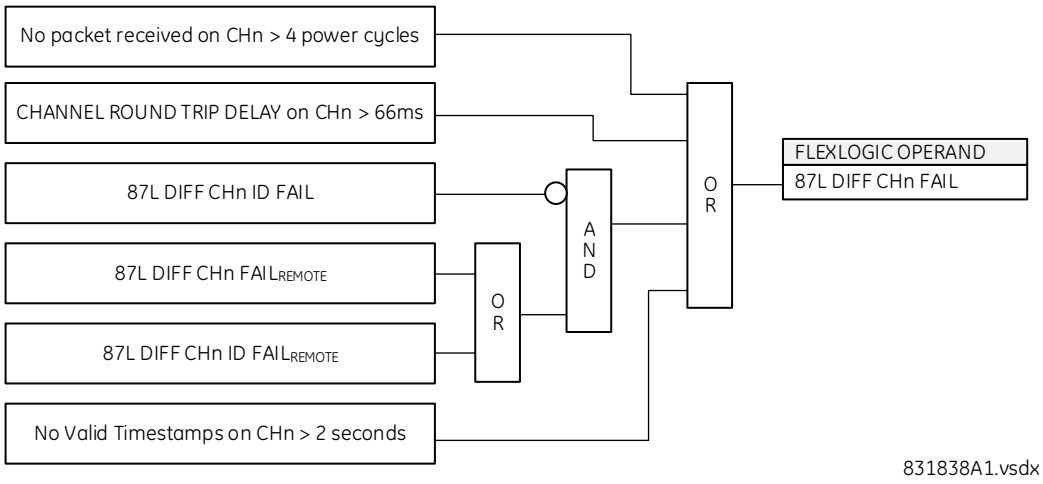



**Figure 8–8: CHANNEL FAIL LOGIC**

**PFFL FAIL** — In addition to the conditions explained earlier in the two-terminal and three-terminal mode operation of the relay, the PFLL failure also is declared (operand 87L DIFF PFLL FAIL gets asserted) if clock offset exceeds 1/8th of a power cycle.

**CHANNEL ID FAIL** — Channel ID failure is declared (operand 87L DIFF CH1 ID FAIL gets asserted) when the relay ID number contained in the packet received from the remote end does not match the programmed ID number at the local relay. This ensures that the data used by the relay is coming from the correct relay.

**CRC FAIL** — CRC failure for a channel is declared (operand 87L DIFF CH1 CRCFAIL gets asserted) when two or more out of the last eight consecutive packets fail the CRC check. CRC Fail logic is evaluated only after the arrival of eight new packets.

**LOST PACKET** — Operand 87L DIFF CH1 LOSTPKT gets asserted when two or more of the last eight consecutive packets are lost. Lost Packet logic is evaluated only after the arrival of eight new packets. The accumulated number of lost packets over a channel are available at **ACTUAL VALUES** ⇨ **STATUS** ⇨⇩ **CHANNEL TESTS** ⇨⇩ **CHANNEL 1 LOST PACKETS**.

8

### 8.2.1 DESCRIPTION

Characteristics of differential elements can be shown in the complex plane. The operating characteristics of the L30 are fundamentally dependent on the relative ratios of the local and remote current phasor magnitudes and the angles of $I_{loc}$ / $I_{rem}$ as shown in the next figure.

The main factors affecting the trip-restraint decisions are:

1. Difference in angles (+ real represents pure internal fault when currents are essentially in phase, – real represents external fault when currents are 180° apart).
2. The magnitude of remote current.
3. The magnitude of the local current.
4. Dynamically estimated errors in calculations.
5. Settings.

The following figure also shows the relay's capability to handle week-infeed conditions by increasing the restraint ellipse when the remote current is relatively small (1.5 pu). Therefore, uncertainty is greater when compared with higher remote currents (3 pu). The characteristic shown is also dependent on settings. The second graph shows how the relay's trip-restraint calculation is made with respect to the variation in angle difference between local and remote currents. The characteristic for 3 terminal mode is similar where both remote currents are combined together.

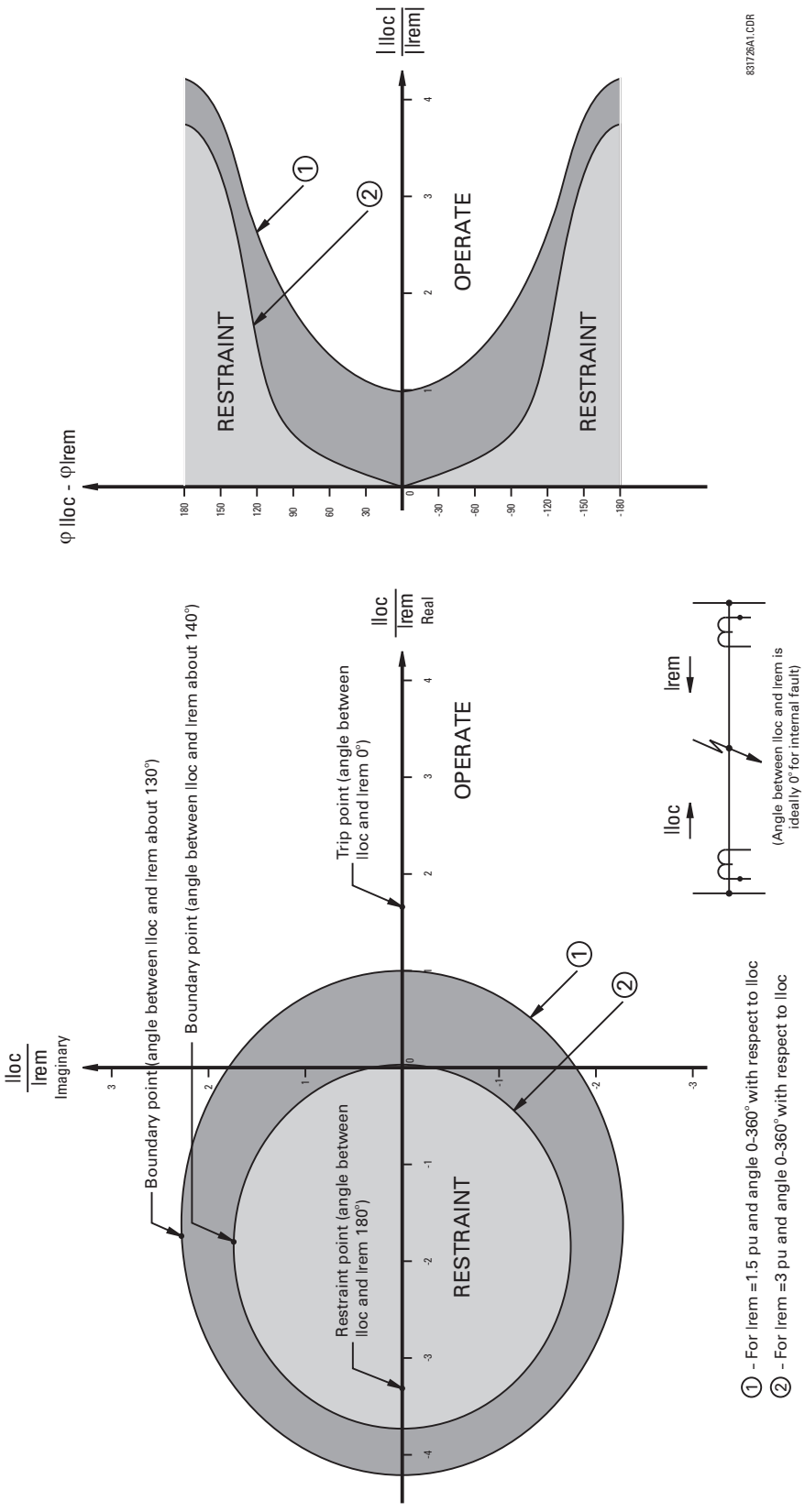



**Figure 8–9: RESTRAINT CHARACTERISTICS**

### 8.2.2 TRIP DECISION EXAMPLE

Assume the following settings:

- Slope 1: $S_1$ = 10%
- Slope 2: $S_2$ = 10%
- Breakpoint: BP = 5 pu secondary
- Pickup: $P$ = 0.5 pu

Assume the following local and remote currents:

- Local current: $I_{local}$ = 4.0 pu ∠0°
- Remote current: $I_{remote}$= 0.8 pu ∠180°

The assumed condition is a radial line with a high resistance fault, with the source at the local end only, and through a resistive load current. The operating current is:

$$I_{op}^2 = |I\_L + I\_R|^2 = |4.0\angle 0° + 0.8\angle 180°|^2 = 10.24 \quad \textbf{(EQ 8.34)}$$

Since the current at both ends is less than the breakpoint value of 5.0, the equation for two-terminal mode is used to calculate restraint as follows.

$$\begin{aligned} I_{Rest}^2 &= (2 \cdot S_1^2 \cdot |I\_L|^2) + (2 \cdot S_1^2 \cdot |I\_R|^2) + 2P^2 + \sigma \\ &= (2 \cdot (0.1)^2 \cdot |4|^2) + (2 \cdot (0.1)^2 \cdot |0.8|^2) + 2 \cdot (0.5)^2 + 0 \\ &= 0.8328 \end{aligned} \quad \textbf{(EQ 8.35)}$$

where $\sigma$ = 0, assuming a pure sine wave.

### 8.2.3 TRIP DECISION TEST

The trip condition is shown below.

$$\frac{I_{Op}^2}{I_{Rest}^2} > 1 \Rightarrow \frac{10.24}{0.8328} = 12.3 > 1 \Rightarrow \text{Trip} \quad \textbf{(EQ 8.36)}$$

The use of the **CURRENT DIFF PICKUP**, **CURRENT DIFF RESTRAINT 1**, **CURRENT DIFF RESTRAINT 2**, and **CURRENT DIFF BREAK PT** settings are discussed in the Current Differential section of chapter 5.

The following figure shows how the L30 settings affect the restraint characteristics. The local and remote currents are 180° apart, which represents an external fault. The breakpoint between the two slopes indicates the point where the restraint area is becoming wider to override uncertainties from CT saturation, fault noise, harmonics, etc. Increasing the slope percentage increases the width of the restraint area.

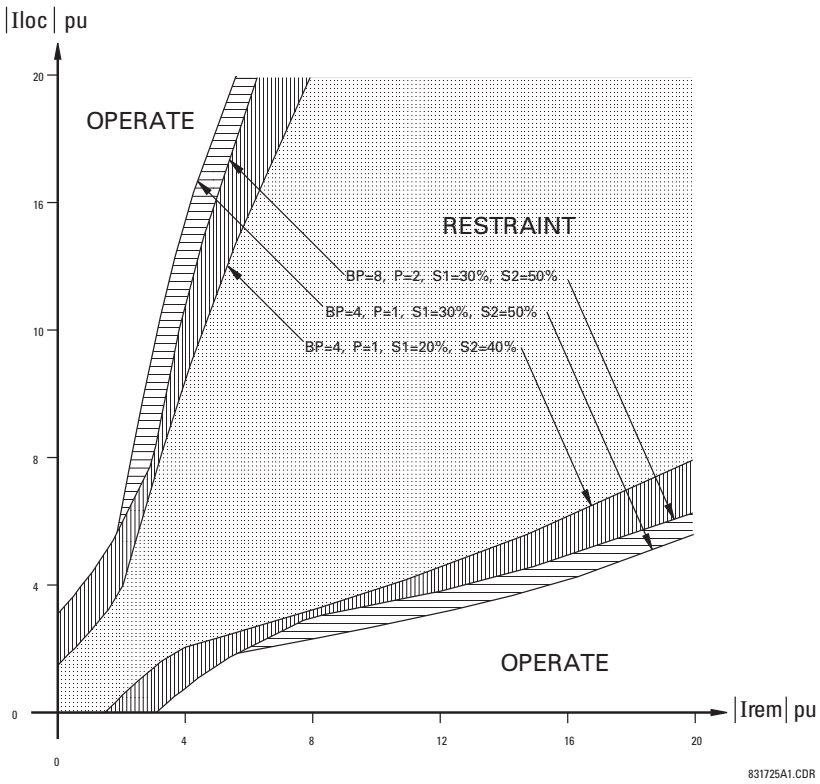



**Figure 8–10: SETTINGS IMPACT ON RESTRAINT CHARACTERISTIC**

### 8.3.1 DESCRIPTION

Fault type determination is required for calculation of fault location – the algorithm uses the angle between the negative and positive sequence components of the relay currents. To improve accuracy and speed of operation, the fault components of the currents are used; that is, the pre-fault phasors are subtracted from the measured current phasors. In addition to the angle relationships, certain extra checks are performed on magnitudes of the negative and zero-sequence currents.

The single-ended fault location method assumes that the fault components of the currents supplied from the local (A) and remote (B) systems are in phase. The figure below shows an equivalent system for fault location.

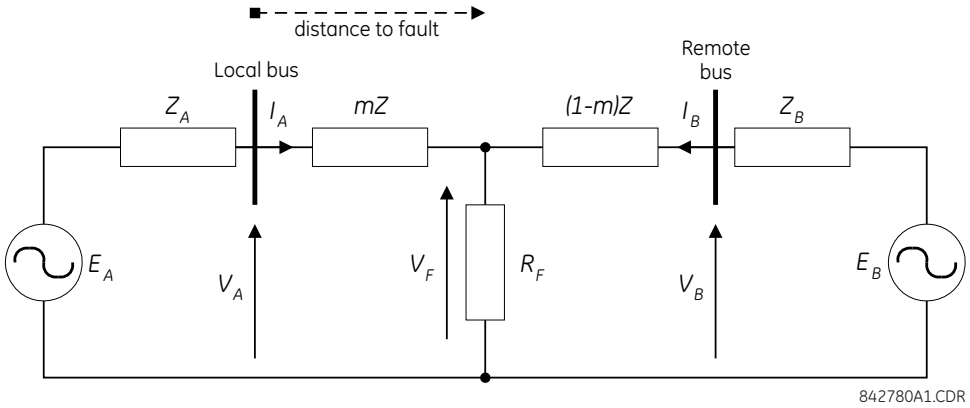



**Figure 8–11: EQUIVALENT SYSTEM FOR FAULT LOCATION**

The following equations hold true for this equivalent system.

$$V_A = m \cdot Z \cdot I_A + R_F \cdot (I_A + I_B) \quad \textbf{(EQ 8.37)}$$

where: $m$ = sought pu distance to fault, $Z$ = positive sequence impedance of the line.

The currents from the local and remote systems can be parted between their fault (F) and pre-fault load (pre) components:

$$I_A = I_{AF} + I_{Apre} \quad \textbf{(EQ 8.38)}$$

and neglecting shunt parameters of the line:

$$I_B = I_{BF} - I_{Apre} \quad \textbf{(EQ 8.39)}$$

Inserting the $I_A$ and $I_B$ equations into the $V_A$ equation and solving for the fault resistance yields:

$$R_F = \frac{V_A - m \cdot Z \cdot I_A}{I_{AF} \cdot \left(1 + \frac{I_{BF}}{I_{AF}}\right)} \quad \textbf{(EQ 8.40)}$$

Assuming the fault components of the currents, $I_{AF}$ and $I_{BF}$ are in phase, and observing that the fault resistance, as impedance, does not have any imaginary part gives:

$$\mathrm{Im}\left(\frac{V_A - m \cdot Z \cdot I_A}{I_{AF}}\right) = 0 \quad \textbf{(EQ 8.41)}$$

where: Im() represents the imaginary part of a complex number. Solving the above equation for the unknown $m$ creates the following fault location algorithm:

$$m = \frac{\mathrm{Im}(V_A \cdot I_{AF}^*)}{\mathrm{Im}(Z \cdot I_A \cdot I_{AF}^*)} \quad \textbf{(EQ 8.42)}$$

where * denotes the complex conjugate and $I_{AF} = I_A - I_{Apre}$.

Depending on the fault type, appropriate voltage and current signals are selected from the phase quantities before applying the two equations above (the superscripts denote phases, the subscripts denote stations).

For AG faults:

$$V_A = V_A^A, \quad I_A = I_A^A + K_0 \cdot I_{0A}, \quad I_{AF} = I_A^A - I_{Apre}^A \tag{EQ 8.43}$$

For BG faults:

$$V_A = V_A^B, \quad I_A = I_A^B + K_0 \cdot I_{0A}, \quad I_{AF} = I_A^B - I_{Apre}^B \tag{EQ 8.44}$$

For CG faults:

$$V_A = V_A^C, \quad I_A = I_A^C + K_0 \cdot I_{0A}, \quad I_{AF} = I_A^C - I_{Apre}^C \tag{EQ 8.45}$$

For AB and ABG faults:

$$V_A = V_A^A - V_A^B, \quad I_A = I_A^A - I_A^B \tag{EQ 8.46}$$

For BC and BCG faults:

$$V_A = V_A^B - V_A^C, \quad I_A = I_A^B - I_A^C \tag{EQ 8.47}$$

For CA and CAG faults:

$$V_A = V_A^C - V_A^A, \quad I_A = I_A^C - I_A^A \tag{EQ 8.48}$$

where $K_0$ is the zero sequence compensation factor (for the first six equations above)

For ABC faults, all three AB, BC, and CA loops are analyzed and the final result is selected based upon consistency of the results

The element calculates the distance to the fault (with *m* in miles or kilometers) and the phases involved in the fault.

The relay allows locating faults from delta-connected VTs. If the **FAULT REPORT 1 VT SUBSTITUTION** setting is set to “None”, and the VTs are connected in wye, the fault location is performed based on the actual phase to ground voltages. If the VTs are connected in delta, fault location is suspended.

If the **FAULT REPORT 1 VT SUBSTITUTION** setting value is “V0” and the VTs are connected in a wye configuration, the fault location is performed based on the actual phase to ground voltages. If the VTs are connected in a delta configuration, fault location is performed based on the delta voltages and externally supplied neutral voltage:

$$\begin{aligned} V_A &= \frac{1}{3}(V_N + V_{AB} - V_{CA}) \\ V_B &= \frac{1}{3}(V_N + V_{BC} - V_{AB}) \\ V_B &= \frac{1}{3}(V_N + V_{CA} - V_{BC}) \end{aligned} \tag{EQ 8.49}$$

If the **FAULT REPORT 1 VT SUBSTITUTION** setting value is “I0” and the VTs are connected in a wye configuration, the fault location is performed based on the actual phase to ground voltages. If the VTs are connected in a delta configuration, fault location is performed based on the delta voltages and zero-sequence voltage approximated based on the zero-sequence current:

$$\begin{aligned} V_A &= \frac{1}{3}(V_{AB} - V_{CA}) - Z_{SYS0} I_0 \\ V_B &= \frac{1}{3}(V_{BC} - V_{AB}) - Z_{SYS0} I_0 \\ V_B &= \frac{1}{3}(V_{CA} - V_{BC}) - Z_{SYS0} I_0 \end{aligned} \tag{EQ 8.50}$$

where $Z_{SYS0}$ is the equivalent zero-sequence impedance behind the relay as entered under the fault report setting menu.

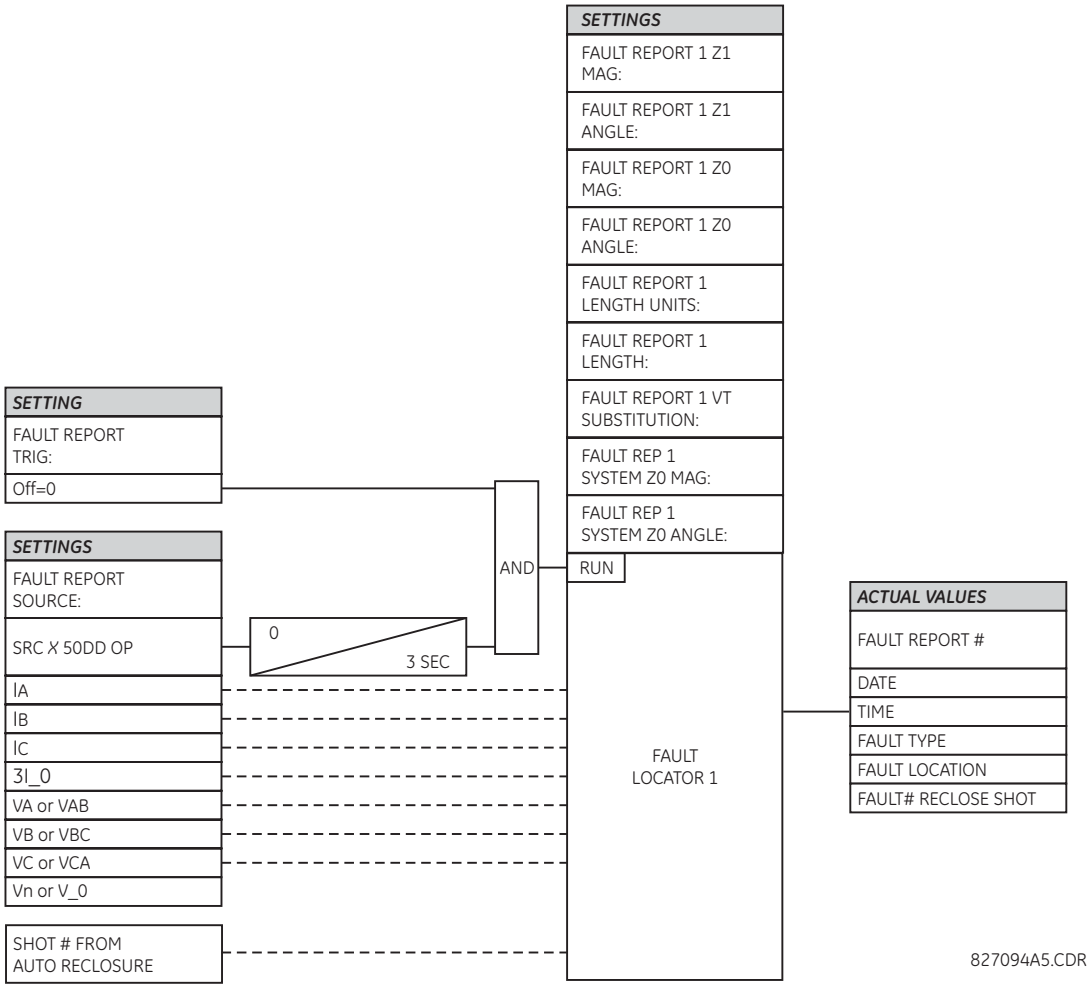



**Figure 8–12: FAULT LOCATOR SCHEME**

### 9.1.1 INTRODUCTION

In general, proper CT selection is required to provide both adequate fault sensitivity and prevention of operation on high-current external faults that can result from CT saturation. The use of high-quality CTs (such as class X) improves relay stability during transients and CT saturation and can increase relay sensitivity. A current differential scheme is highly dependent on adequate signals from the source CTs. Ideally, CTs selected for line current differential protection are based on the criteria described as follows, which presents the high-level CT requirements to avoid saturation and to provide undistorted CT secondary current.

Check the capability of the CTs, and the connected burden, as follows:

1. The CTs should be class TPX or TPY, or IEC class 5P20 or better. Use class TPZ only after discussion with both the manufacturer of the CT and GE Multilin.
2. The CT primary current rating should be somewhat higher than the maximum continuous load current, but not too high relative to the minimum fault current because the differential element minimum pickup setting is 0.2 x CT rating for the phase differential and 0.1 x CT rating for ground differential. Too high CT primary current rating limits sensitivity of the differential element for high-resistive faults.
3. As per the IEEE C37.110-2007 "Guide for the Application of Current Transformers Used for Protective Relaying Purposes," the CT must be capable of a secondary saturation voltage $V_K$ to avoid AC saturation:

$$V_K > I_S \times Z_S \quad \textbf{(EQ 9.1)}$$

   where

   $I_S$ is maximum CT secondary fault current

   $Z_S$ is total secondary burden $Z_S = R_{CT} + 2 \times R_L + R_R$

4. As per the IEEE C37.110-2007 "Guide for the Application of Current Transformers Used for Protective Relaying Purposes," the CT must be capable of a secondary saturation voltage $V_K$ to avoid DC saturation:

$$V_K > I_S \times \left(\frac{X}{R} + 1\right) \times Z_S \quad \textbf{(EQ 9.2)}$$

   where

   X/R is primary system reactance / resistance ratio

   $R_{CT}$ is CT secondary winding resistance

   $R_L$ is AC secondary wiring resistance (one-way)

   $R_R$ is relay burden at rated secondary current

5. Practically, it is difficult to meet this criteria and avoid saturation completely. The L30 provides several means to ensure security during an external fault, including dual-slope restraint characteristics, adaptive restraint, and CT saturation mechanism, allowing the relay to be secure during severe external faults, while maintaining excellent performance for internal faults. Therefore, knee point voltage requirements with a default 87L settings can be approximately estimated by the following equation:

$$V_K > K_{tf} \times I_S \times Z_S \quad \textbf{(EQ 9.3)}$$

   where

   $K_{tf}$ is 2 for system X/R > 20 and $K_{tf}$ is 1.5 for system X/R ≤ 20

This is however applicable, where CT ratios are the same, CT burdens at both sides of the line are very close, and when just one CT at each side is used. When CTs are different at both sides (different CT characteristics, CT ratio and burden) or when more than one CT at each side is used, these equation may not provide correct estimation of the required knee point voltage.

For this situation GE provides a CT saturation analysis tool, described in the following section.

### 9.1.2 CT SATURATION ANALYSIS TOOL

The CT saturation analysis tool is an Excel spreadsheet provided for users to analyze the L30 reliability during CT saturation caused by an external fault, to investigate the effect of adjusting 87L settings, and to examine the possibility of reducing the CT requirement.

The tool utilizes the CT model and CT saturation calculation algorithm proposed by the IEEE Power System Relaying Committee (PSRC), and it simulates the analog/digital signal processing and data calculations in the L30. The figure shows the interface.

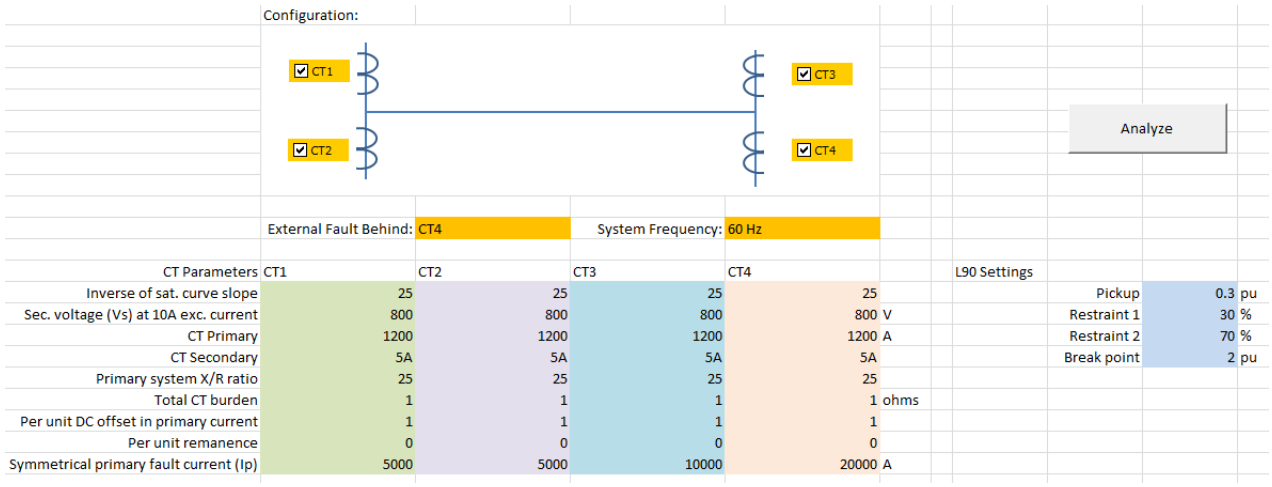



**Figure 9–1: CT SATURATION ANALYSIS TOOL MAIN PAGE**

For a system where the CTs are already installed, the CT and system parameters are known. Use the procedure described in the tool to analyze the L30 security during CT saturation and investigate the effect of adjusting 87L settings.

The CT saturation analysis tool allows you to check the application, knowing CT parameters, fault current levels, and distribution through all breakers from short circuit studies, and to analyze L30 performance, having an ability to adjust settings as needed. The tool has all instructions to perform analysis.

Once all data is entered, by clicking the **Analyze** button, you can observe differential and restraint currents through the simulated fault in the **Results** tab, shown as follows. The application is considered secure when the worst through the plot Irestr/Idiff > 1.25 with selected settings and all fault scenarios considered.

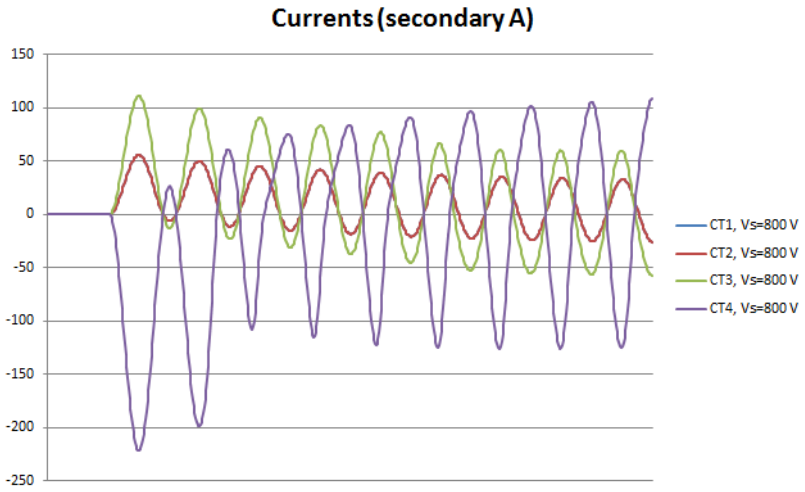



**Figure 9–2: TOOL RESULTS FOR CURRENTS**

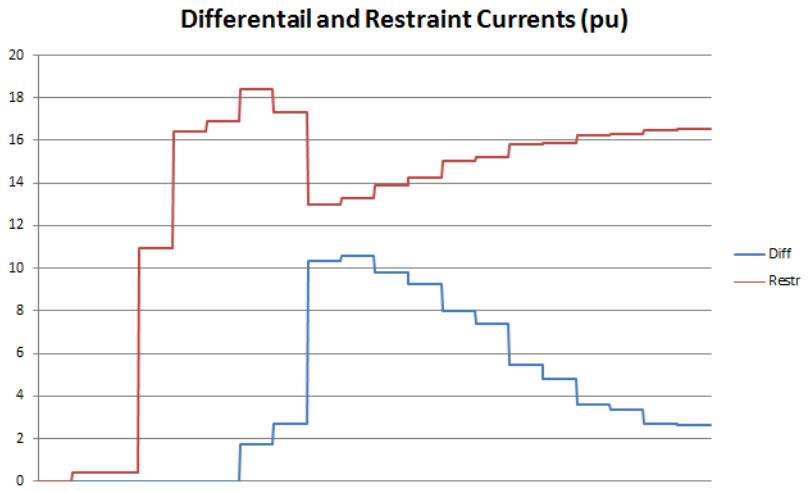



**Figure 9–3: TOOL RESULTS FOR DIFFERENTIAL AND RESTRAINT CURRENTS**

You are encouraged to test different fault locations and different fault levels and distributions per short circuit studies. Alternatively, the tool can help to estimate required CT parameters (ratio and knee point voltage), based on some pre-determined criteria.

### 9.2.1 INTRODUCTION

NOTE

Software is available from the GE Grid Solutions website that is helpful in selecting settings for the specific application. Checking the performance of selected element settings with respect to known power system fault parameters makes it relatively simple to choose the optimum settings for the application.

This software program is also useful for establishing test parameters. It is strongly recommended this program be downloaded.

The differential characteristic is defined by four settings: **CURRENT DIFF PICKUP**, **CURRENT DIFF RESTRAINT 1**, **CURRENT DIFF RESTRAINT 2**, and **CURRENT DIFF BREAK PT** (breakpoint). As is typical for current-based differential elements, the settings are a trade-off between operation on internal faults against restraint during external faults.

### 9.2.2 CURRENT DIFFERENTIAL PICKUP

This setting established the sensitivity of the element to high impedance faults, and it is therefore desirable to choose a low level, but this can cause a maloperation for an external fault causing CT saturation. The selection of this setting is influenced by the decision to use charging current compensation. If charging current compensation is Enabled, pickup should be set to a minimum of 150% of the steady-state line charging current, to a lower limit of 10% of CT rating. If charging current compensation is Disabled, pickup should be set to a minimum of 250% of the steady-state line charging current to a lower limit of 10% of CT rating.

If the CT at one terminal can saturate while the CTs at other terminals do not, this setting should be increased by approximately 20 to 50% (depending on how heavily saturated the one CT is while the other CTs are not saturated) of CT rating to prevent operation on a close-in external fault.

### 9.2.3 CURRENT DIFF RESTRAINT 1

This setting controls the element characteristic when current is below the breakpoint, where CT errors and saturation effects are not expected to be significant. The setting is used to provide sensitivity to high impedance internal faults, or when system configuration limits the fault current to low values. A setting of 10 to 20% is appropriate in most cases, but this should be raised to 30% if the CTs can perform quite differently during faults.

### 9.2.4 CURRENT DIFF RESTRAINT 2

This setting controls the element characteristic when current is above the breakpoint, where CT errors and saturation effects are expected to be significant. The setting is used to provide security against high current external faults. A setting of 30 to 40% is appropriate in most cases, but this should be raised to 70% if the CTs can perform quite differently during faults.

NOTE

Assigning the **CURRENT DIFF RESTRAINT 1(2)** settings to the same value reverts dual slope bias characteristics into single slope bias characteristics.

### 9.2.5 CURRENT DIFF BREAK POINT

This setting controls the threshold where the relay changes from using the restraint 1 to the restraint 2 characteristics. Two approaches can be considered.

1. Program the setting to 150 to 200% of the maximum emergency load current on the line, on the assumption that a maintained current above this level is a fault.
2. Program the setting below the current level where CT saturation and spurious transient differential currents can be expected.

The first approach gives comparatively more security and less sensitivity; the second approach provides less security for more sensitivity.

### 9.2.6 CT TAP

If the CT ratios at the line terminals are different, the **CURRENT DIFF CT TAP 1(2)** setting must be used to correct the ratios to a common base. In this case, a user should modify the **CURRENT DIFF BREAK PT** and **CURRENT DIFF PICKUP** settings because the local current phasor is used as a reference to determine which differential equation is used, based on the value of local and remote currents. If the setting is not modified, the responses of individual relays, especially during an external fault, can be asymmetrical, as one relay can be below the breakpoint and the other above the breakpoint. There are two methods to overcome this potential problem:

1. Set **CURRENT DIFF RESTRAINT 1** and **CURRENT DIFF RESTRAINT 2** to the same value (e.g. 40% or 50%). This converts the relay characteristics from dual slope into single slope and the breakpoint becomes immaterial. Next, adjust differential pickup at all terminals according to CT ratios, referencing the desired pickup to the line primary current (see below).
2. Set the breakpoints in each relay individually in accordance with the local CT ratio and the **CT TAP** setting. Next, adjust the differential pickup setting according to the terminal CT ratios. The slope value must be identical at all terminals.

Consider a two-terminal configuration with the following CT ratios for relays 1 and 2.

$$\begin{aligned} CT_{ratio}(\text{relay 1}) &= 1000/5 \\ CT_{ratio}(\text{relay 2}) &= 2000/5 \end{aligned} \quad \textbf{(EQ 9.4)}$$

Consequently, we have the following CT tap value for relays 1 and 2.

$$\begin{aligned} CT_{tap}(\text{relay 1}) &= 2.0 \\ CT_{tap}(\text{relay 2}) &= 0.5 \end{aligned} \quad \textbf{(EQ 9.5)}$$

To achieve maximum differential sensitivity, the minimum pickup is set as 0.2 pu at the terminal with the higher CT primary current; in this case 2000:5 for relay 2. The other terminal pickup is adjusted accordingly. The pickup values are set as follows:

$$\begin{aligned} \text{Pickup}(\text{relay 1}) &= 0.4 \\ \text{Pickup}(\text{relay 2}) &= 0.2 \end{aligned} \quad \textbf{(EQ 9.6)}$$

Choosing relay 1 as a reference with a breakpoint of 5.0, the break point at relay 2 is chosen as follows:

$$\begin{aligned} \text{Breakpoint}(\text{relay 2}) &= \text{Breakpoint}(\text{relay 1}) \times \frac{CT_{ratio}(\text{relay 1})}{CT_{ratio}(\text{relay 2})} \\ &= 5.0 \times \frac{1000/5}{2000/5} = 2.5 \end{aligned} \quad \textbf{(EQ 9.7)}$$

Use the following equality the verify the calculated breakpoint:

$$\text{Breakpoint}(\text{relay 1}) \times CT_{ratio}(\text{relay 1}) = \text{Breakpoint}(\text{relay 2}) \times CT_{ratio}(\text{relay 2}) \quad \textbf{(EQ 9.8)}$$

Therefore, we have a breakpoint of 5.0 for relay 1 and 2.5 for relay 2.

Now, consider a three-terminal configuration with the following CT ratios for relays 1, 2, and 3.

$$\begin{aligned} CT_{ratio}(\text{relay 1}) &= 1000/5 \\ CT_{ratio}(\text{relay 2}) &= 2000/5 \\ CT_{ratio}(\text{relay 3}) &= 500/5 \end{aligned} \quad \textbf{(EQ 9.9)}$$

Consequently, we have the following CT tap value for relays 1, 2, and 3.

$$\begin{aligned} CT_{tap1}(\text{relay 1}) &= 2.00 \quad CT_{tap2}(\text{relay 1}) = 0.50 \\ CT_{tap1}(\text{relay 2}) &= 0.50 \quad CT_{tap2}(\text{relay 2}) = 0.25 \\ CT_{tap1}(\text{relay 3}) &= 2.00 \quad CT_{tap2}(\text{relay 3}) = 4.00 \end{aligned} \quad \textbf{(EQ 9.10)}$$

In this case, the relay channels communicate as follows:

- For relay 1, channel 1 communicates to relay 2 and channel 2 communicates to relay 3
- For relay 2, channel 1 communicates to relay 1 and channel 2 communicates to relay 3

- For relay 3, channel 1 communicates to relay 1 and channel 2 communicates to relay 2

Consequently, to achieve the maximum sensitivity of 0.2 pu at the terminal with a CT ratio of 2000/5 (400 amps line primary differential current), the following pickup values are chosen:

$$\begin{aligned} \text{Pickup}(\text{relay 1}) &= 0.4 \\ \text{Pickup}(\text{relay 2}) &= 0.2 \\ \text{Pickup}(\text{relay 3}) &= 0.8 \end{aligned} \quad \textbf{(EQ 9.11)}$$

Choosing relay as a reference with a breakpoint value of 5.0 pu, breakpoints for relays 2 and 3 are calculated as follows:

$$\begin{aligned} \text{Breakpoint}(\text{relay 2}) &= \text{Breakpoint}(\text{relay 1}) \times \frac{\text{CT}_{\text{ratio}}(\text{relay 1})}{\text{CT}_{\text{ratio}}(\text{relay 2})} \\ &= 5.0 \times \frac{1000/5}{2000/5} = 2.5 \end{aligned} \quad \textbf{(EQ 9.12)}$$

$$\begin{aligned} \text{Breakpoint}(\text{relay 3}) &= \text{Breakpoint}(\text{relay 1}) \times \frac{\text{CT}_{\text{ratio}}(\text{relay 1})}{\text{CT}_{\text{ratio}}(\text{relay 3})} \\ &= 5.0 \times \frac{1000/5}{500/5} = 10.0 \end{aligned} \quad \textbf{(EQ 9.13)}$$

To verify the calculated values, we have:

$$\begin{aligned} \text{Breakpoint}(\text{relay 1}) \times \text{CT}_{\text{ratio}}(\text{relay 1}) &= 5.0 \times 1000/5 = 1000 \\ \text{Breakpoint}(\text{relay 2}) \times \text{CT}_{\text{ratio}}(\text{relay 2}) &= 2.5 \times 2000/5 = 1000 \\ \text{Breakpoint}(\text{relay 3}) \times \text{CT}_{\text{ratio}}(\text{relay 3}) &= 10.0 \times 5000/5 = 1000 \end{aligned} \quad \textbf{(EQ 9.14)}$$

This satisfies the equality condition indicated earlier.

During on-load tests, the differential current at all terminals should be the same and generally equal to the charging current if the tap and CT ratio settings are chosen correctly.

### 9.3.1 DESCRIPTION

As indicated in the Settings chapter, the L30 provides three basic methods of applying channel asymmetry compensation using GPS. Channel asymmetry can also be monitored with actual values and an indication signalled (FlexLogic operands 87L DIFF 1(2) MAX ASYM asserted) if channel asymmetry exceeds preset values. Depending on the implemented relaying philosophy, the relay can be programmed to perform the following on the loss of the GPS signal:

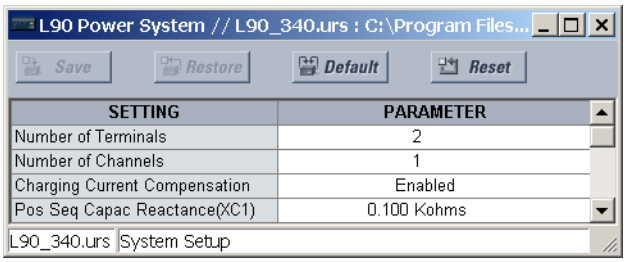
1. Enable GPS compensation on the loss of the GPS signal at any terminal and continue to operate the 87L element (using the memorized value of the last asymmetry) until a change in the channel round-trip delay is detected.
2. Enable GPS compensation on the loss of the GPS signal at any terminal and block the 87L element after a specified time.
3. Continuously operate the 87L element but only enable GPS compensation when *valid* GPS signals are available. This provides less sensitive protection on the loss of the GPS signal at any terminal and runs with higher pickup and restraint settings.

### 9.3.2 COMPENSATION METHOD 1

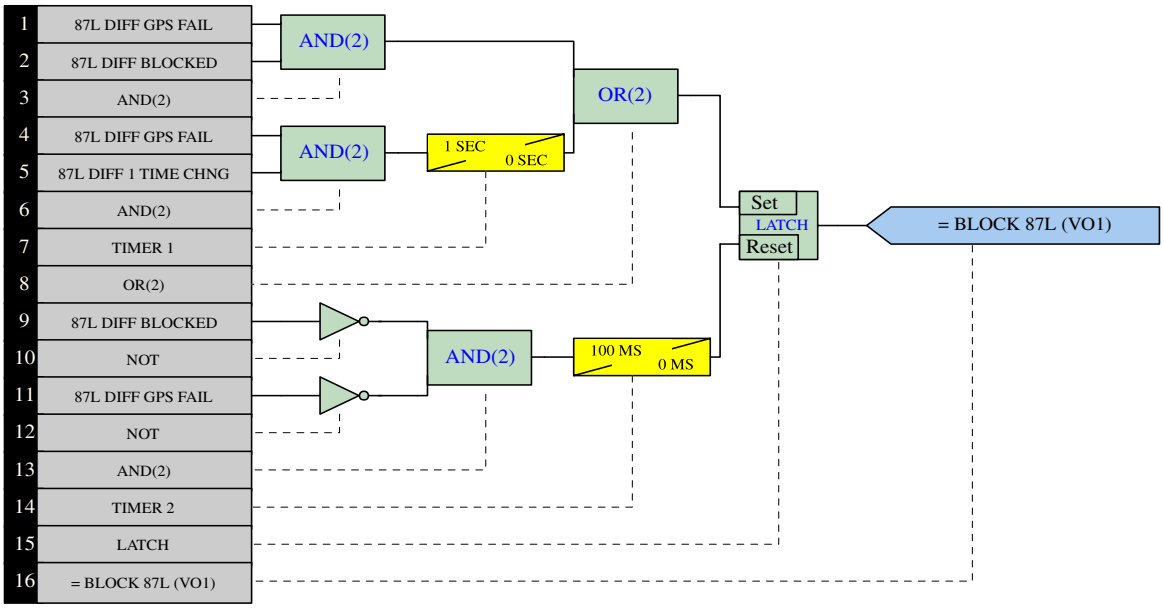
*Enable GPS compensation on the loss of the GPS signal at any terminal and continue to operate the 87L element until a change in the channel round-trip delay is detected.*

If GPS is enabled at all terminals and the GPS signal is present, the L30 compensates for the channel asymmetry. On the loss of the GPS signal, the L30 stores the last measured value of the channel asymmetry per channel and compensates for the asymmetry until the GPS clock is available. However, if the channel was switched to another physical path during GPS loss conditions, the 87L element must be blocked, since the channel asymmetry cannot be measured and system is no longer accurately synchronized. The value of the step change in the channel is preset in **L30 POWER SYSTEM** settings menu and signaled by the 87L DIFF 1(2) TIME CHNG FlexLogic™ operand. To implement this method, follow the steps below:

1. Enable Channel Asymmetry compensation by setting it to ON. Assign the GPS receiver failsafe alarm contact with the setting Block GPS Time Ref.




2. Create FlexLogic™ similar to that shown below to block the 87L element on GPS loss if step change in the channel delay occurs during GPS loss conditions or on a startup before the GPS signal is valid. For three-terminal systems, the 87L DIFF 1 TIME CHNG operand must be ORed with the 87L DIFF 2 TIME CHNG FlexLogic™ operand. The Block 87L (VO1) output is reset if the GPS signal is restored and the 87L element is ready to operate.




3. Assign virtual output BLOCK 87L (VO1) to the 87L Current Differential Block setting. It can be used to enable backup protection, raise an alarm, and perform other functions as per the given protection philosophy.

### 9.3.3 COMPENSATION METHOD 2

*Enable GPS compensation on the loss of the GPS signal at any terminal and block the 87L element after a specified time.*

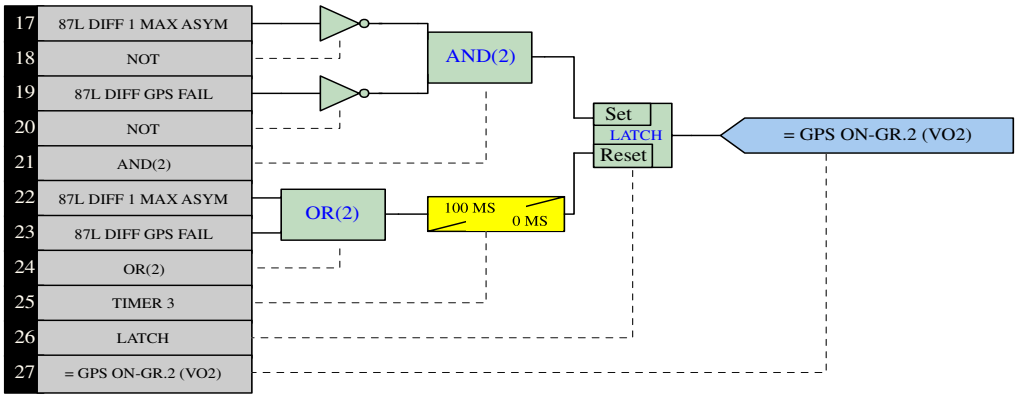
This is a simple and conservative way of using the GPS feature. Follow steps 1 and 3 in compensation method 1. The FlexLogic™ is simple: 87L DIFF GPS FAIL-Timer-Virtual Output Block 87L (VO1). It is recommended that the timer be set no higher than 10 seconds.

### 9.3.4 COMPENSATION METHOD 3

*Continuously operate the 87L element but enable GPS compensation only when valid GPS signals are available. This provides less sensitive protection on GPS signal loss at any terminal and runs with higher pickup and restraint settings.*

This approach can be used carefully if maximum channel asymmetry is known and doesn't exceed certain values (2.0 to 2.5 ms). The 87L DIFF MAX ASYM operand can be used to monitor and signal maximum channel asymmetry. Essentially, the L30 switches to another setting group with higher pickup and restraint settings, sacrificing sensitivity to keep the 87L function operational.

1. Create FlexLogic similar to that shown below to switch the 87L element to Settings Group 2 (with most sensitive settings) if the L30 has a valid GPS time reference. If a GPS or 87L communications failure occurs, the L30 will switch back to Settings Group 1 with less sensitive settings.




2. Set the 87L element with different differential settings for Settings Groups 1 and 2 as shown below

Current Differential // L90_340.urs : C:\Program...

Save | Restore | Default | Reset

| SETTING | PARAMETER |
|---|---|
| Function | Enabled |
| Signal Source | SRC 1 (SRC 1) |
| Block | OFF |
| Pickup | 0.50 pu |
| CT Tap 1 | 1.00 |
| Restraint 1 | 40 % |
| Restraint 2 | 70 % |
| Breakpoint | 1.0 pu |
| DTT | Enabled |
| Key DTT | OFF |
| Target | Latched |
| Events | Disabled |

L90_340.urs | Grouped Elements: Group 1: Line Differential Elements

Current Differential // L90_340.urs : C:\Program...

Save | Restore | Default | Reset

| SETTING | PARAMETER |
|---|---|
| Function | Enabled |
| Signal Source | SRC 1 (SRC 1) |
| Block | OFF |
| Pickup | 0.20 pu |
| CT Tap 1 | 1.00 |
| Restraint 1 | 20 % |
| Restraint 2 | 40 % |
| Breakpoint | 1.0 pu |
| DTT | Enabled |
| Key DTT | OFF |
| Target | Latched |
| Events | Disabled |

L90_340.urs | Grouped Elements: Group 2: Line Differential Elements

3. Enable GPS compensation when the GPS signal is valid and switch to Settings Group 2 (with more sensitive settings) as shown below.

Setting Groups // L90_340.urs : C:\Program File...

Save | Restore | Default | Reset

| SETTING | PARAMETER |
|---|---|
| Function | Enabled |
| Block | OFF |
| Group 2 Activate On | GPS ON-Gr.2 On (VO2) |
| Group 3 Activate On | OFF |
| Group 4 Activate On | OFF |
| Group 5 Activate On | OFF |
| Group 6 Activate On | OFF |
| Events | Disabled |

L90_340.urs | Control Elements

L90 Power System // L90_340.urs : C:\Program Files...

Save | Restore | Default | Reset

| SETTING | PARAMETER |
|---|---|
| Chan Asymmetry Comp | GPS ON-Gr.2 On (VO2) |
| Block GPS Time Ref | GPS failsafe On(H5a) |
| Max Chan Asymmetry | 1.5 ms |
| Round Trip Time Change | 1.5 ms |

L90_340.urs | System Setup

### 9.4.1 INSTANTANEOUS ELEMENT ERROR DURING L30 SYNCHRONIZATION

Two or three L30 relays are synchronized to each other and to system frequency to provide line current differential protection and accurate measurements for other protection and control elements. When an L30 system starts up, the relays adjust their tracking frequency aggressively to bring all relays into synchronization within the system quickly. The tracking frequency can differ from the nominal (or system frequency) by a few hertz, especially during the first second of synchronization, with one relay having tracking frequency above system frequency and another below system frequency. The same re-synchronization process happens if a channel fails for a long time, leading to phase and frequency lock loop (PFLL) failure and then the channel is restored and relays are re-synchronized to each other again.

The 87L element is blocked during synchronization; therefore, the difference between system frequency and relay sampling frequency does not affect 87L element itself. However, instantaneous protection elements can experience additional error caused by the difference between signal frequency and tracking frequency.

The following curves demonstrate the maximum error with tracking frequency both above and below system frequency. At time t=0 s, the channel is restored and in approximately 100 ms required to check channel reliability and to receive valid timestamps, while the re-synchronization process starts. As can be observed, instantaneous current, voltage, and impedance elements experience accuracy error, especially during first 100 to 330 ms during the re-synchronization process after either system start up or recovering from the communications failure. Because relay tracking frequency can be above or below system frequency randomly, consider the worst error depending on the element type. For example, for overvoltage or overcurrent, the worst case happens when error causes the measured quantity to appear above system value (positive error), which occurs when relay tracking frequency is below system frequency. For undervoltage or impedance, the worst case happens when error causes the measured quantity to appear below system value (negative error), which occurs when relay tracking frequency is above system frequency.

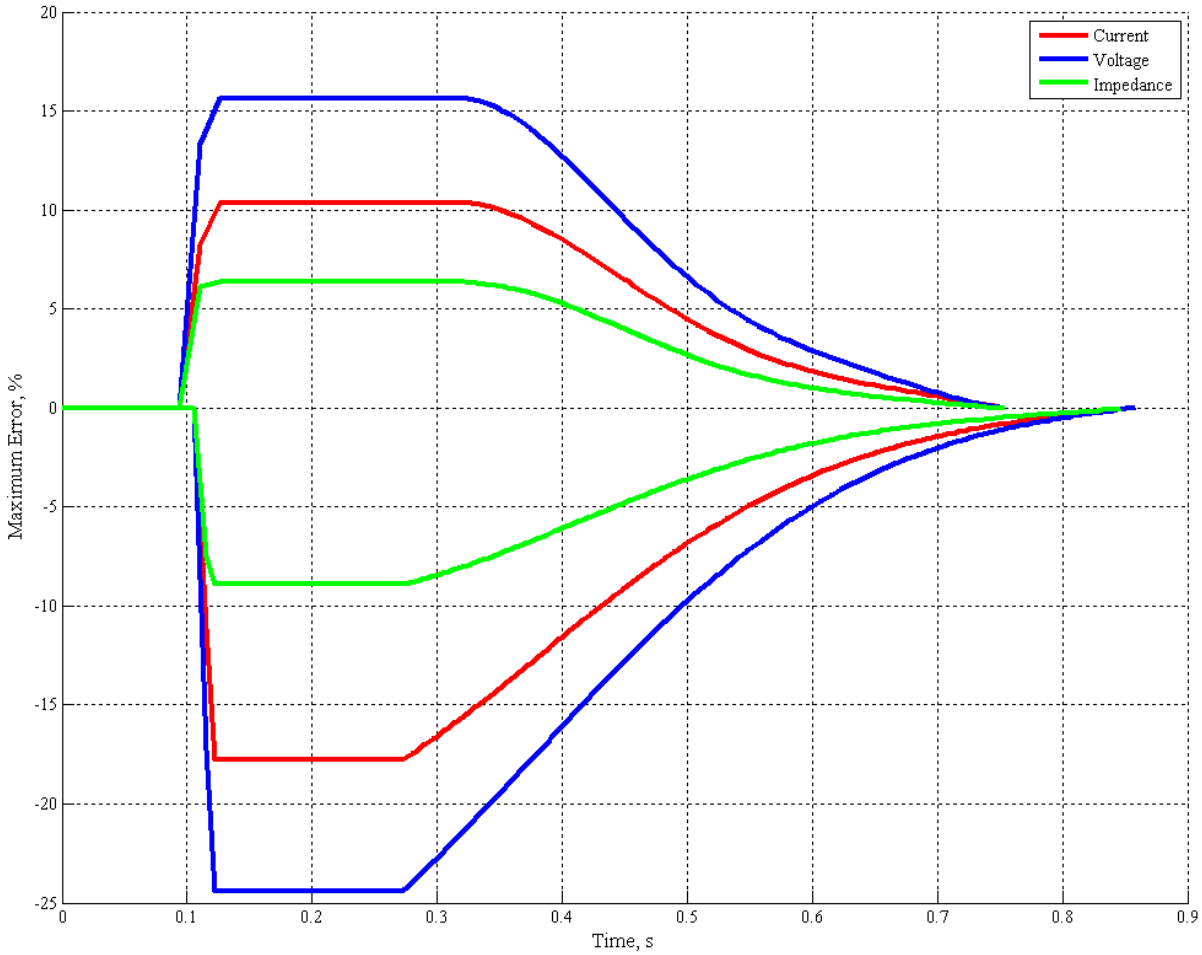



**Figure 9–4: MAXIMUM ERROR FOR 60 HZ SYSTEM**

Not all instantaneous elements have to be blocked during the re-synchronization process. For example, the impedance element maximum error is 8.86% at 60 Hz. With a typical margin of 15 percent, this is still well below impedance reach point. Another example is Phase IOC; typically, these elements have very sufficient margin for the overload conditions and are set high enough above these conditions. But voltage-based elements can be set quite close to the system nominal voltage or operating voltage and can require attention.

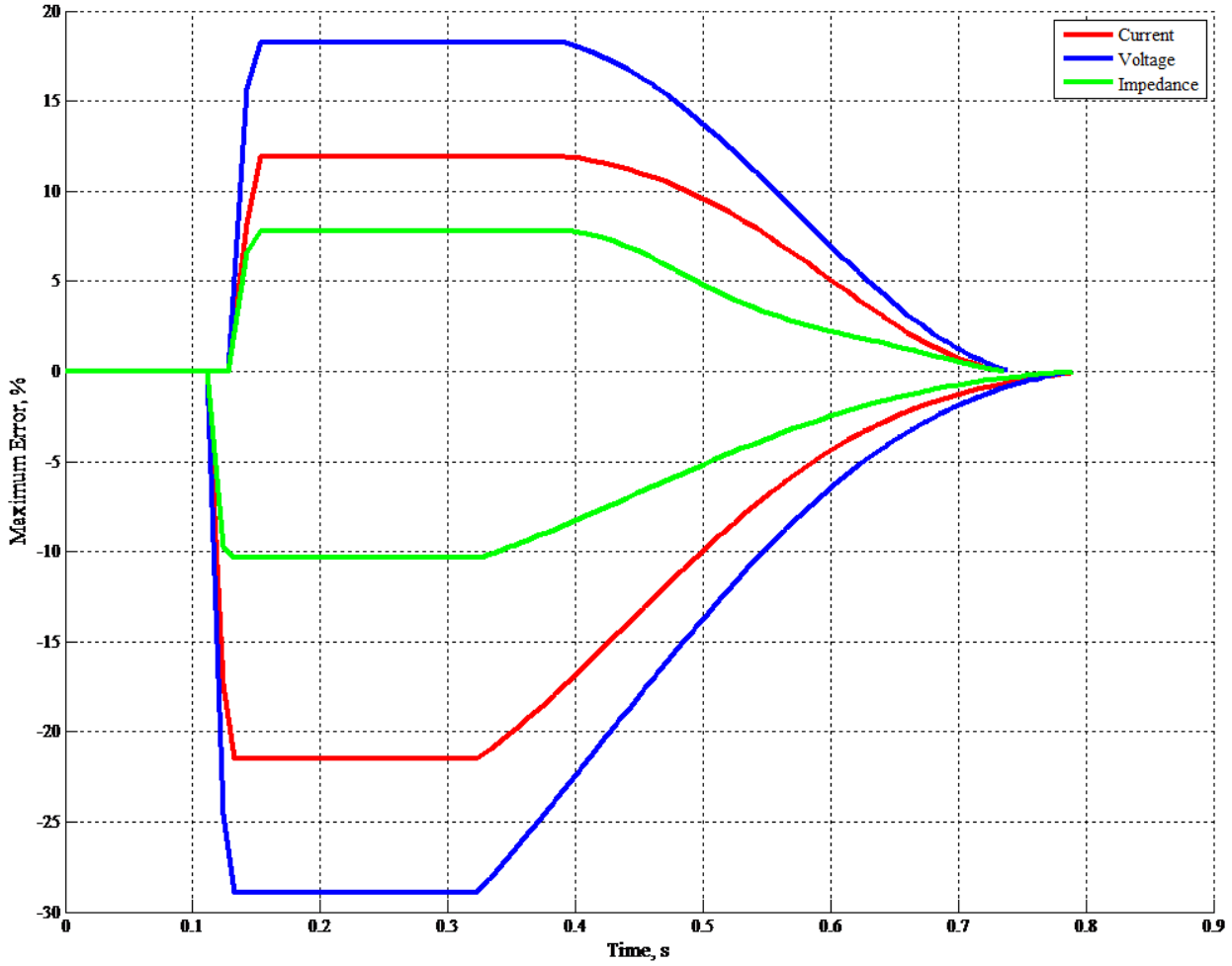



Figure 9–5: MAXIMUM ERROR FOR 50 HZ SYSTEM

To secure instantaneous element operation, it is recommended to use either FlexLogic as shown next to block the instantaneous elements during synchronization, or to use a different setting group with more conservative pickup for this brief interval. A 700 ms drop-off timer in the logic is shown as an example to guarantee error below 3 percent, but delay can be realistically even shorter, if the setting security margin allows this.

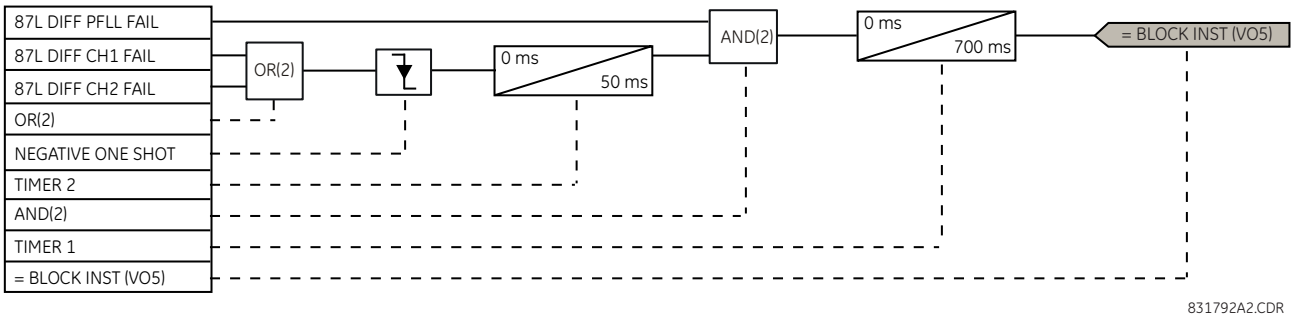



Figure 9–6: FLEXLOGIC TO BLOCK INSTANTANEOUS ELEMENT DURING 87L STARTUP

The elements must be treated selectively. If, for example, the phase over or under voltage setting includes margin or time delay sufficient to accommodate the maximum additional error on re-synchronization, blocking or delay are not needed for these elements. Similarly, if the phase instantaneous overcurrent setting has sufficient margin, blocking is not needed. Note that significant zero-sequence and negative-sequence current or voltage error do not appear during L30 startup, therefore all sequence-based elements using these quantities are safe.

For the three-terminal line, the synchronization process is longer and block times need to be three times longer than two-terminal line block times.

### 10.1.1 CHANNEL TESTING

The communications system transmits and receives data between two or three terminals for the 87L function. The system is designed to work with multiple channel options including direct and multiplexed optical fiber, G.703, and RS422. The speed is 64 Kbaud in a transparent synchronous mode with automatic synchronous character detection and CRC insertion.

The Local Loopback Channel Test verifies the L30 communication modules are working properly. The Remote Loopback Channel Test verifies the communication link between the relays meets requirements (BER less than $10^{-4}$). All tests are verified by using the internal channel monitoring and the monitoring in the Channel Tests. All of the tests presented in this section must be either OK or PASSED.

1. Verify that a type “W” module is placed in slot ‘W’ in both relays (e.g. W7J).
2. Interconnect the two relays using the proper media (e.g. single mode fiber cable) observing correct connection of receiving (Rx) and transmitting (Tx) communications paths and turn power on to both relays.
3. Verify that the Order Code in both relays is correct.
4. Cycle power off/on in both relays.
5. Verify and record that both relays indicate In Service on the front display.
6. Make the following setting change in both relays: **GROUPED ELEMENTS ⇨⇩ GROUP 1 ⇨⇩ CURRENT DIFFERENTIAL ELEMENTS ⇨ CURRENT DIFFERENTIAL ⇨ CURRENT DIFF FUNCTION:** “Enabled”.
7. Verify and record that both relays have established communications with the following status checks:

   **ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1 STATUS**: “OK”
   **ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 2 STATUS**: “OK” (If used)
8. Make the following setting change in both relays: **TESTING ⇨ TEST MODE**: “Enabled”.
9. Make the following setting change in both relays:

   **TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ LOCAL LOOPBACK TEST ⇨⇩ LOCAL LOOPBACK CHANNEL NUMBER:** "1"
10. Initiate the Local Loopback Channel Tests by making the following setting change:

    **TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ LOCAL LOOPBACK TEST ⇨⇩ LOCAL LOOPBACK FUNCTION:** "Yes"

    *Expected result*: In a few seconds “Yes” should change to “Local Loopback Test PASSED” and then to “No”, signifying the test was successfully completed and the communication modules operated properly.
11. If Channel 2 is used, make the following setting change and repeat Step 10 for Channel 2 as performed for channel 1:

    **TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ LOCAL LOOPBACK TEST ⇨⇩ LOCAL LOOPBACK CHANNEL NUMBER:** "2"
12. Verify and record that the Local Loopback Test was performed properly with the following status check:

    **ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1(2) LOCAL LOOPBACK STATUS**: "OK"
13. Make the following setting change in one of the relays:

    **TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK TEST ⇨⇩ REMOTE LOOPBACK CHANNEL NUMBER:** "1"
14. Initiate the Remote Loopback Channel Tests by making the following setting change:

    **TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK ⇨ REMOTE LOOPBACK FUNCTION:** "Yes"

    *Expected result*: The “Running Remote Loopback Test” message appears; within 60 to 100 sec. the “Remote Loopback Test PASSED” message appears for a few seconds and then changes to “No”, signifying the test successfully completed and communications with the relay were successfully established. The “Remote Loopback Test FAILED” message indicates that either the communication link quality does not meet requirements (BER less than $10^{-4}$) or the channel is not established – check the communications link connections.
15. If Channel 2 is used, make the following setting change and repeat Step 14 for Channel 2 as performed for Channel 1:

    **TESTING ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK TEST ⇨⇩ REMOTE LOOPBACK CHANNEL NUMBER:** "2"
16. Verify and record the Remote Loopback Test was performed properly with the following status check:

    **ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1(2) REMOTE LOOPBACK STATUS:** "OK"

17. Verify and record that Remote Loopback Test fails during communications failures as follows: start test as per Steps 13 to 14 and in 2 to 5 seconds disconnect the fiber Rx cable on the corresponding channel.

    *Expected result*: The "Running Remote Loopback Test" message appears. When the channel is momentarily cut off, the "Remote Loopback Test FAILED" message is displayed. The status check should read as follows: **ACTUAL VALUES ⇩ STATUS ⇩ CHANNEL TESTS ⇨ CHANNEL 1(2) LOCAL LOOPBACK STATUS:** "Fail"

18. Re-connect the fiber Rx cable. Repeat Steps 13 to 14 and verify that Remote Loopback Test performs properly again.

19. Verify and record that Remote Loopback Test fails if communications are not connected properly by disconnecting the fiber Rx cable and repeating Steps 13 to 14.

    *Expected result*: The **ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1(2) REMOTE LOOPBACK TEST:** "Fail" message should be constantly on the display.

20. Repeat Steps 13 to 14 and verify that Remote Loopback Test is correct.

21. Make the following setting change in both relays: **TESTING ⇨ TEST MODE**: "Disabled"

NOTE

During channel tests, verify in the **ACTUAL VALUES ⇨⇩ STATUS ⇨⇩ CHANNEL TESTS ⇨ CHANNEL 1(2) LOST PACKETS** display that the values are very low – even 0. If values are comparatively high, settings of communications equipment (if applicable) should be checked.

### 10.1.2 CLOCK SYNCHRONIZATION TESTS

The 87L clock synchronization is based upon a peer-to-peer architecture in which all relays are Masters. The relays are synchronized in a distributed fashion. The clocks are phase synchronized to each other and frequency synchronized to the power system frequency. The performance requirement for the clock synchronization is a maximum error of ±130 μs.

All tests are verified by using PFLL status displays. All PFLL status displays must be either OK or Fail.

1. Ensure that Steps 1 through 7 inclusive of the previous section are completed.

2. Verify and record that both relays have established communications with the following checks after 60 to 120 seconds:

   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1(2) STATUS:** "OK"
   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK STATUS:** "n/a"
   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ PFLL STATUS:** "OK"

3. Disconnect the fiber Channel 1(2) Tx cable for less than 66 ms (not possible with direct fiber module).

   *Expected result:* **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1(2) STATUS:** "OK"
   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK STATUS:** "n/a"
   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ PFLL STATUS:** "OK"

   If fault conditions are applied to the relay during these tests, it trips with a specified 87L operation time.

4. Disconnect the fiber Channel 1(2) Tx cable for more than 66 ms but less than 5 seconds.

   Expected result: **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1(2) STATUS:** "OK"
   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK STATUS:** "n/a"
   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ PFLL STATUS:** "OK"

   If fault conditions are applied to the relay (after the channel is brought back) during these tests, it trips with a specified 87L operation time plus 50 to 80 ms required for establishing PFLL after such interruption.

5. Disconnect the fiber Channel 1(2) Tx cable for more than 5 seconds.

   *Expected result*: **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ CHANNEL 1(2) STATUS:** "OK"
   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK STATUS:** "n/a"
   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ PFLL STATUS:** "Fail"

6. Reconnect the fiber Channel 1(2) Tx cable and in 6 to 8 seconds confirm that the relays have re-established communications again with the following status checks:

   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨ CHANNEL 1(2) STATUS:** "OK"
   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ REMOTE LOOPBACK STATUS:** "n/a"
   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨⇩ PFLL STATUS:** "OK"

7. Apply a current of 0.5 pu at a frequency 1 to 3% higher or lower than nominal only to local relay phase A to verify that frequency tracking will not affect PFLL when only one relay has a current input and both relays track frequency. Wait 200 seconds and verify the following:

   **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS ⇨ PFLL STATUS:** "OK"
   **ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRACKING FREQUENCY ⇨ TRACKING FREQUENCY:** actual frequency at both relays

NOTE For 3-terminal configuration, the above-indicated tests should be carried out accordingly.

### 10.1.3 CURRENT DIFFERENTIAL

The 87L element has adaptive restraint and dual slope characteristics. The pickup slope settings and the breakpoint settings determine the element characteristics. The relay displays both local and remote current magnitudes and angles and the differential current which helps with start-up activities. When a differential condition is detected, the output operands from the element will be asserted along with energization of faceplate event indicators.

1. Ensure that relay will not issue any undesired signals to other equipment.
2. Ensure that relays are connected to the proper communication media, communications tests have been performed and the CHANNEL and PFLL STATUS displays indicate OK.
3. Minimum pickup test with local current only:
   - Ensure that all 87L setting are properly entered into the relay and connect a test set to the relay to inject current into Phase A.
   - Slowly increase the current until the relay operates and note the pickup value. The theoretical value of operating current below the breakpoint is given by the following formula, where $P$ is the pickup setting and $S_1$ is the Slope 1 setting (in decimal format):

$$I_{op} = \sqrt{2 \times \frac{P^2}{1 - 2S_1^2}} \quad \text{(EQ 10.1)}$$

   - Repeat the above test for different slope and pickup settings, if desired.
   - Repeat the above tests for Phases B and C.
4. Minimum pickup test with local current and simulated remote current (pure internal fault simulation):
   - Disconnect the local relay from the communications channel.
   - Loop back the transmit signal to the receive input on the back of the relay.
   - Wait until the CHANNEL and PFLL status displays indicate OK.
   - Slowly increase the current until the relay operates and note the pickup value. The theoretical value of operating current below breakpoint is given by the following formula:

$$I_{op} = \sqrt{\frac{2P^2}{(1 + \text{TAP})^2 - 2S_1^2(1 + \text{TAP}^2)}} \quad \text{(EQ 10.2)}$$

     where TAP represents the CT Tap setting for the corresponding channel.
   - Repeat the above test for different slope and pickup settings, if desired.
   - During the tests, observe the current phasor at **ACTUAL VALUES ⇨⇩ METERING ⇨ 87L DIFF CURRENT ⇨ LOCAL IA**. This phasor should also be seen at **ACTUAL VALUES ⇨⇩ METERING ⇨ 87L DIFF CURRENT ⇨⇩ TERMINAL 1(2) IA** along with a phasor of twice the magnitude at **ACTUAL VALUES ⇨⇩ METERING ⇨ 87L DIFF CURRENT ⇨⇩ IA DIFF**.
   - Repeat the above tests for Phases B and C.
   - Restore the communication circuits to normal.

NOTE Download the UR Test software from (http://www.gegridsolutions.com/products/support/ur/l90test.zip) or contact GE Grid Solutions for information about the UR current differential test program which allows the user to simulate different operating conditions for verifying correct responses of the relays during commissioning activities.

## 10.1.4 LOCAL-REMOTE RELAY TESTS

### a) DIRECT TRANSFER TRIP (DTT) TESTS

The direct transfer trip is a function by which one relay sends a signal to a remote relay to cause a trip of remote equipment. The local relay trip outputs will close upon receiving a direct transfer trip from the remote relay. The test procedure is as follows:

1. Ensure that relay will not issue any undesired signals to other equipment and all previous tests have been completed successfully.
2. Cycle power off/on in both relays.
3. Verify and record that both relays indicate In Service on the faceplate display.
4. Make the following setting change in the **SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨⇩ LINE DIFFERENTIAL ELEMENT ⇨ CURRENT DIFFERENTIAL** menu of both relays:

   **CURRENT DIFF FUNCTION**: "Enabled"
5. Verify and record that both relays have established communications by performing the following status check thorough the **ACTUAL VALUES ⇨ STATUS ⇨⇩ CHANNEL TESTS** menu:

   **CHANNEL 1(2) STATUS:** "OK"
6. At the remote relay, make the following changes in the **SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨⇩ LINE DIFFERENTIAL ELEMENT ⇨⇩ CURRENT DIFFERENTIAL** menu:

   **CURRENT DIFF DTT:** "Enabled"
7. At the Local relay, make the following changes in the **SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUT N1** menu:

   **CONTACT OUTPUT N1 OPERATE:** "87L DIFF RECVD DTT"
8. At the Local relay, verify that **ACTUAL VALUES ⇨ STATUS ⇨⇩ CONTACT OUTPUTS ⇨⇩ Cont Op N1** is in the "Off" state.
9. Apply current to phase A of the remote relay and increase until 87L operates.
10. At the Local relay, observe **ACTUAL VALUES ⇨ STATUS ⇨⇩ CONTACT OUTPUTS ⇨⇩ Cont Op N1** is now in the "On" state.
11. Repeat steps 8 through 10 for phases A and B and observe Contact Outputs N2 and N3, respectively.
12. Repeat steps 8 through 11 with the Remote and Local relays inter-changed.
13. Make the following setting change in the **SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨⇩ LINE DIFFERENTIAL ELEMENT ⇨ CURRENT DIFFERENTIAL** menu of both relays:

   **CURRENT DIFF FUNCTION**: "Disabled"
14. At the Remote relay, set **SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUT N1 ⇨⇩ CONTACT OUTPUT N1 OPERATE** to the CURRENT DIFF KEY DTT operand.
15. At the Local relay, observe under the **ACTUAL VALUES ⇨ STATUS ⇨⇩ CONTACT OUTPUTS** menu that **CONTACT OUTPUT N1**, **N2** and **N3** are "Off".
16. At the Remote relay, set **SETTINGS ⇨⇩ TESTING ⇨⇩ FORCE CONTACT INPUTS ⇨ FORCE Cont Ip N1** to "Closed".
17. At the Local relay, observe under **ACTUAL VALUES ⇨ STATUS ⇨⇩ CONTACT OUTPUTS** that **CONTACT OUTPUT N1**, **N2** and **N3** are now "On".
18. At both the Local and Remote relays, return all settings to normal.

### b) FINAL TESTS

As proper operation of the relay is fundamentally dependent on the correct installation and wiring of the CTs, it must be confirmed that correct data is brought into the relays by an on-load test in which simultaneous measurements of current and voltage phasors are made at all line terminals. These phasors and differential currents can be monitored at the **ACTUAL VALUES ⇨⇩ METERING ⇨ 87L DIFFERENTIAL CURRENT** menu where all current magnitudes and angles can be observed and conclusions of proper relay interconnections can be made.

**WARNING** **Withdraw or insert a module only when control power has been removed from the unit, and be sure to insert only the correct module type into a slot, else personal injury, damage to the unit or connected equipment, or undesired operation can result.**

**NOTICE** To avoid damage to the equipment, use proper electrostatic discharge protection (for example, a static strap) when coming in contact with modules while the relay is energized.

The relay, being modular in design, allows for the withdrawal and insertion of modules. Modules must only be replaced with like modules in their original factory configured slots.

The enhanced faceplate can be opened to the left, once the thumb screw has been removed, as shown below. This allows for easy accessibility of the modules for withdrawal. The new wide-angle hinge assembly in the enhanced front panel opens completely and allows easy access to all modules in the L30.

842812A1.CDR

**Figure 11–1: UR MODULE WITHDRAWAL AND INSERTION (ENHANCED FACEPLATE)**

The basic faceplate can be opened to the left, once the sliding latch on the right side has been pushed up, as shown below. This allows for easy accessibility of the modules for withdrawal.

842760A1.CDR

**Figure 11–2: UR MODULE WITHDRAWAL AND INSERTION (BASIC FACEPLATE)**

To properly remove a module, the ejector/inserter clips, located at the top and bottom of each module, must be pulled simultaneously. Before performing this action, **control power must be removed from the relay**. Record the original location of the module to ensure that the same or replacement module is inserted into the correct slot. While modules with current input provide automatic shorting of external CT circuits, for CT/VT modules it is recommended to short/isolate external circuits accordingly for maximum safety.

To properly insert a module, ensure that the **correct** module type is inserted into the **correct** slot position. The ejector/inserter clips located at the top and at the bottom of each module must be in the disengaged position as the module is smoothly inserted into the slot. Once the clips have cleared the raised edge of the chassis, engage the clips simultaneously. When the clips have locked into position, the module will be fully inserted.

NOTE

CPU connections must be individually disconnected from the module before the module can be removed from the chassis.

A battery powers the real time clock on startup of the device.

When required, the battery can be replaced. The power supply modules were upgraded in 2014 to SH/SL from RH/RL, but the order code when purchasing a UR with redundant power supply remained as RH/RL so that customers can continue to use the same order codes. The order code can read RH or RL, while the module inside the unit reads SH or SL. The order code for replacement redundant power supply modules was changed to SH/SL. To determine which procedure to use, see the power supply module or use the photographs here.

### a) REPLACE BATTERY FOR RH/RL POWER SUPPLY

The power supply module contains the battery.

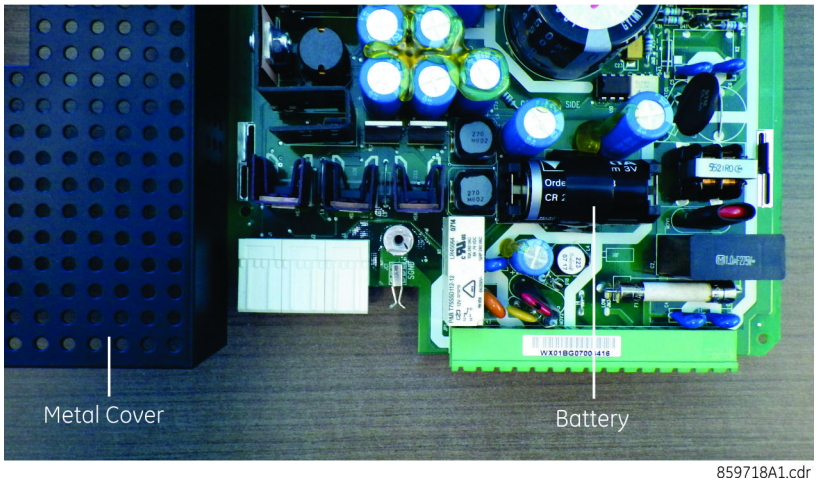
**⚠CAUTION** **To avoid injury, ensure that the unit has been powered off for a minimum of three minutes before replacing the battery.**

**Risk of fire if battery is replaced with incorrect type or polarity.**

To replace the battery:

1. Turn off the power to the unit.
2. Wait a minimum of three minutes to ensure that there is no power to the battery.
3. As outlined in the previous section, open the unit by sliding up the plastic latch on the right side of the front panel (basic front panel) or unscrewing the panel (enhanced front panel).
4. For the basic front panel, it needs to be removed in order to access the power supply module, which is typically in the first slot on the left side and blocked by the hinge of the front panel. To remove the front panel, unscrew the bracket on the front left side of the unit.
5. Simultaneously pull the ejector clips at the top and bottom of the power supply module and remove the module.
6. Unscrew the screw that attaches the metal cover to the module.
7. Slide the metal cover away from the clips about 1 cm (1/4 inch) and remove the cover.
8. Unclip the black plastic holder that keeps the battery in place. The plastic clips into the socket at the bottom on both sides. Use a flat-head screwdriver if you cannot unclip the plastic with your fingers.
9. Observe the + and - polarity of the battery and replace it with the same polarity as marked on the battery holder. Replace the battery with the identical make and model. For example, do not use a rechargeable battery.

**Figure 11–3: BATTERY LOCATION ON RH/RL POWER SUPPLY MODULE**




859718A1.cdr

10. Reinstall the battery clip and the metal cover, and reinsert the power supply module into the unit.
11. Power on the unit.
12. Dispose of the old battery as outlined in the next section.

### b) REPLACE BATTERY FOR SH/SL POWER SUPPLY

The power supply module contains the battery.

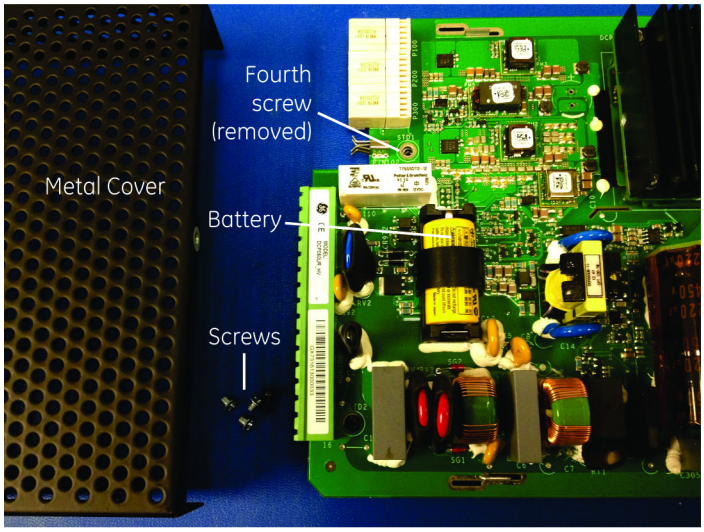
**⚠CAUTION** **To avoid injury, ensure that the unit has been powered off for a minimum of three minutes before replacing the battery.**

**Risk of fire if battery is replaced with incorrect type or polarity.**

To replace the battery:

13. Turn off the power to the unit.
14. Wait a minimum of three minutes to ensure that there is no power to the battery.
15. As outlined in the previous section, open the unit by sliding up the plastic latch on the right side of the front panel (basic front panel) or unscrewing the panel (enhanced front panel).
16. For the basic front panel, it needs to be removed in order to access the power supply module, which is typically in the first slot on the left side and blocked by the hinge of the front panel. To remove the front panel, unscrew the bracket on the left side of the unit.
17. Remove the power supply module by simultaneously pulling the ejector clips at the top and bottom of the module and sliding it out.
18. Unscrew all four screws (not three) that attach the metal cover to the module. The fourth screw is at the back end of the module, on the opposite side from the clips, beside the white electronics part (see figure).
19. Slide the metal cover away from the clips about 0.5 cm (1/8 inch) and remove the cover.
20. Unclip the black plastic holder that keeps the battery in place. The plastic clips into the socket at the bottom on both sides—pull the plastic away from the battery. Use a flat-head screwdriver if you cannot unclip the plastic with your fingers.
21. Replace the battery with the identical make and model. For example, do not use a rechargeable battery. Observe the + and - polarity of the battery and replace it with the same polarity as marked on the battery holder.

**Figure 11–4: BATTERY LOCATION ON SH/SL POWER SUPPLY MODULE**




859717A1.cdr

22. Reinstall the battery holder and the metal cover, and reinsert the power supply module into the unit.
23. Power on the unit.
24. Dispose of the old battery as outlined in the next section.

**EN Battery Disposal**
This product contains a battery that cannot be disposed of as unsorted municipal waste in the European Union. See the product documentation for specific battery information. The battery is marked with this symbol, which may include lettering to indicate cadmium (Cd), lead (Pb), or mercury (Hg). For proper recycling return the battery to your supplier or to a designated collection point. For more information see: www.recyclethis.info.

**CS Nakládání s bateriemi**
Tento produkt obsahuje baterie, které nemohou být zneškodněny v Evropské unii jako netříděný komunální odpadu. Viz dokumentace k produktu pro informace pro konkrétní baterie. Baterie je označena tímto symbolem, který může zahrnovat i uvedena písmena, kadmium (Cd), olovo (Pb), nebo rtuť (Hg). Pro správnou recyklaci baterií vraťte svémudodavateli nebo na určeném sběrném místě. Pro více informací viz: www.recyclethis.info.

**DA Batteri affald**
Dette produkt indeholder et batteri som ikke kan bortskaffes sammen med almindeligt husholdningsaffald i Europa. Se produktinformation for specifikke informationer om batteriet. Batteriet er forsynet med indgraveret symboler for hvad batteriet indeholder: kadmium (Cd), bly (Pb) og kviksølv (Hg). Europæiske brugere af elektrisk udstyr skal aflevere kasserede produkter til genbrug eller til leverandøren. Yderligere oplysninger findes på webstedet www.recyclethis.info.

**DE Entsorgung von Batterien**
Dieses Produkt beinhaltet eine Batterie, die nicht als unsortierter städtischer Abfall in der europäischen Union entsorgt werden darf. Beachten Sie die spezifischen Batterie-informationen in der Produktdokumentation. Die Batterie ist mit diesem Symbol gekennzeichnet, welches auch Hinweise auf möglicherweise enthaltene Stoffe wie Kadmium (Cd), Blei (Pb) oder Quecksilber (Hektogramm) darstellt. Für die korrekte Wiederverwertung bringen Sie diese Batterie zu Ihrem lokalen Lieferanten zurück oder entsorgen Sie das Produkt an den gekennzeichneten Sammelstellen. Weitere Informationen hierzu finden Sie auf der folgenden Website: www.recyclethis.info.

**EL Απόρριψη μπαταριών**
Αυτό το προϊόν περιέχει μια μπαταρία που δεν πρέπει να απορρίπτεται σε δημόσια συστήματα απόρριψης στην Ευρωπαϊκή Κοινότητα. Δείτε την τεκμηρίωση του προϊόντος για συγκεκριμένες πληροφορίες που αφορούν τη μπαταρία. Η μπαταρία είναι φέρει σήμανση με αυτό το σύμβολο, το οποίο μπορεί να περιλαμβάνει γράμματα για να δηλώσουν το κάδμιο (Cd), τον μόλυβδο (Pb), ή τον υδράργυρο (Hg). Για την κατάλληλη ανακύκλωση επιστρέψτε την μπαταρία στον προμηθευτή σας ή σε καθορισμένο σημείο συλλογής. Για περισσότερες πληροφορίες δείτε: www.recyclethis.info.

**ES Eliminacion de baterias**
Este producto contiene una batería que no se pueda eliminar como basura normal sin clasificar en la Unión Europea. Examine la documentación del producto para la información específica de la batería. La batería se marca con este símbolo, que puede incluir siglas para indicar el cadmio (Cd), el plomo (Pb), o el mercurio (Hg ). Para el reciclaje apropiado, devuelva este producto a su distribuidor ó deshágase de él en los puntos de reciclaje designados. Para mas información : wwwrecyclethis.info.

**ET Patareide kõrvaldamine**
Käesolev toode sisaldab patareisid, mida Euroopa Liidus ei tohi kõrvaldada sorteerimata olmejäätmetena. Andmeid patareide kohta vaadake toote dokumentatsioonist. Patareid on märgistatud käesoleva sümboliga, millel võib olla kaadmiumi (Cd), pliid (Pb) või elavhõbedat (Hg) tähistavad tähed. Nõuetekohaseks ringlusse võtmiseks tagastage patarei tarnijale või kindlaksmääratud vastuvõtupunkti. Lisainformatsiooni saab Internetist aadressil: www.recyclethis.info.

**FI Paristoje ja akkujen hävittäminen**
Tuote sisältää pariston, jota ei saa hävittää Euroopan Unionin alueella talousjätteen mukana. Tarkista tuoteselosteesta tuotteen tiedot. Paristo on merkitty tällä symbolilla ja saattaa sisältää cadmiumia (Cd), lyijyä (Pb) tai elohopeaa (Hg). Oikean kierrätystavan varmistamiseksi palauta tuote paikalliselle jälleenmyyjälle tai palauta se paristojen keräyspisteeseen. Lisätietoja sivuilla www.recyclethis.info.

**FR Élimination des piles**
Ce produit contient une batterie qui ne peuvent être éliminés comme déchets municipaux non triés dans l'Union européenne. Voir la documentation du produit au niveau des renseignements sur la pile. La batterie est marqué de ce symbole, qui comprennent les indications cadmium (Cd), plomb (Pb), ou mercure (Hg). Pour le recyclage, retourner la batterie à votre fournisseur ou à un point de collecte. Pour plus d'informations, voir: www.recyclethis.info.

**HU Akkumulátor hulladék kezelése**
Ezen termék akkumulátort tartalmaz, amely az Európai Unión belül csak a kijelölt módon és helyen dobható ki. A terméken illetve a mellékelt ismertetőn olvasható a kadmium (Cd), ólom (Pb) vagy higany (Hg) tartalomra utaló betűjelzés. A hulladék akkumulátor leadható a termék forgalmazójánál új akkumulátor vásárlásakor, vagy a kijelölt elektronikai hulladékudvarokban. További információ a www.recyclethis.info oldalon.

**IT Smaltimento batterie**
Questo prodotto contiene una batteria che non può essere smaltita nei comuni contenitori per lo smaltimento rifiuti, nell' Unione Europea. Controllate la documentazione del prodotto per le informazioni specifiche sulla batteria. La batteria è contrassegnata con questo simbolo e può includere alcuni caratteri ad indicare la presenza di cadmio (Cd), piombo (Pb) oppure mercurio (Hg). Per il corretto smaltimento, potete restituirli al vostro fornitore locale, oppure rivolgervi e consegnarli presso i centri di raccolta preposti. Per maggiori informazioni vedere: ww.recyclethis.info.

**LT Baterijų šalinimas**
Šios įrangos sudėtyje yra baterijų, kurias draudžiama šalinti Europos Sąjungos viešose nerūšiuotų atliekų šalinimo sistemose. Informaciją apie baterijas galite rasti įrangos techninėje dokumentacijoje. Baterijos žymimos šiuo simboliu, papildomai gali būti nurodoma kad baterijų sudėtyje yra kadmio (Cd), švino (Pb) ar gyvsidabrio (Hg). Eksploatavimui nebetinkamas baterijas pristatykite į tam skirtas surinkimo vietas arba grąžinkite jas tiesioginiam tiekėjui, kad jos būtų tinkamai utilizuotos. Daugiau informacijos rasite šioje interneto svetainėje: www.recyclethis.info.

**LV Bateriju likvidēšana**
Šis produkts satur bateriju vai akumulatoru, kuru nedrīkst izmest Eiropas Savienībā esošajās sadzīves atkritumu sistēmās. Sk. produkta dokumentācijā, kur ir norādīta konkrēta informācija par bateriju vai akumulatoru. Baterijas vai akumulatora marķējumā ir šis simbols, kas var ietvert burtus, kuri norāda kadmiju (Cd), svinu (Pb) vai dzīvsudrabu (Hg). Pēc ekspluatācijas laika beigām baterijas vai akumulatori jānodod piegādātājam vai specializētā bateriju savākšanas vietā. Sīkāku informāciju var iegūt vietnē: www.recyclethis.info.

**NL Verwijderen van baterijen**
Dit product bevat een batterij welke niet kan verwijdert worden via de gemeentelijke huisvuilscheiding in de Europese Gemeenschap. Gelieve de product documentatie te controleren voor specifieke batterij informatie. De batterijen met deze label kunnen volgende indictaies bevatten cadium (Cd), lood (Pb) of kwik (Hg). Voor correcte vorm van kringloop, geef je de producten terug aan jou locale leverancier of geef het af aan een gespecialiseerde verzamelpunt. Meer informatie vindt u op de volgende website: www.recyclethis.info.

**NO Retur av batteri**
Dette produkt inneholder et batteri som ikke kan kastes med usortert kommunalt søppel i den Europeiske Unionen. Se produktdokumentasjonen for spesifikk batteriinformasjon. Batteriet er merket med dette symbolet som kan inkludere symboler for å indikere at kadmium (Cd), bly (Pb), eller kvikksølv (Hg) forekommer. Returner batteriet til leverandøren din eller til et dedikert oppsamlingspunkt for korrekt gjenvinning. For mer informasjon se: www.recyclethis.info.

**PL Pozbywanie się zużytych baterii**
Ten produkt zawiera baterie, które w Unii Europejskiej mogą być usuwane tylko jako posegregowane odpady komunalne. Dokładne informacje dotyczące użytych baterii znajdują się w dokumentacji produktu. Baterie oznaczone tym symbolem mogą zawierać dodatkowe oznaczenia literowe wskazujące na zawartość kadmu (Cd), ołowiu (Pb) lub rtęci (Hg). Dla zapewnienia właściwej utylizacji, należy zwrócić baterie do dostawcy albo do wyznaczonego punktu zbiórki. Więcej informacji można znaleźć na stronie internetowej www.recyclethis.info.

**PT Eliminação de Baterias**
Este produto contêm uma bateria que não pode ser considerado lixo municipal na União Europeia. Consulte a documentação do produto para obter informação específica da bateria. A bateria é identificada por meio de este símbolo, que pode incluir a rotulação para indicar o cádmio (Cd), chumbo (Pb), ou o mercúrio (hg). Para uma reciclagem apropriada envie a bateria para o seu fornecedor ou para um ponto de recolha designado. Para mais informação veja: www.recyclethis.info.

**RU Утилизация батарей**
Согласно европейской директиве об отходах электрического и электронного оборудования, продукты, содержащие батареи, нельзя утилизировать как обычные отходы на территории ЕС. Более подробную информацию вы найдете в документации к продукту. На этом символе могут присутствовать буквы, которые означают, что батарея собержит кадмий (Cd), свинец (Pb) или ртуть (Hg). Для надлежащей утилизации по окончании срока эксплуатации пользователь должен возвратить батареи локальному поставщику или сдать в специальный пункт приема. Подробности можно найти на веб-сайте: www.recyclethis.info.

**SK Zaobchádzanie s batériami**
Tento produkt obsahuje batériu, s ktorou sa v Európskej únii nesmie nakladať ako s netriedeným komunálnym odpadom. Dokumentácia k produktu obsahuje špecifické informácie o batérii. Batéria je označená týmto symbolom, ktorý môže obsahovať písmená na označenie kadmia (Cd), olova (Pb), alebo ortuti (Hg). Na správnu recykláciu vráťte batériu vášmu lokálnemu dodávateľovi alebo na určené zberné miesto. Pre viac informácii pozrite: www.recyclethis.info.

**SL Odlaganje baterij**
Ta izdelek vsebuje baterijo, ki je v Evropski uniji ni dovoljeno odstranjevati kot nesortiran komunalni odpadek. Za posebne informacije o bateriji glejte dokumentacijo izdelka. Baterija je označena s tem simbolom, ki lahko vključuje napise, ki označujejo kadmij (Cd), svinec (Pb) ali živo srebro (Hg). Za ustrezno recikliranje baterijo vrnite dobavitelju ali jo odstranite na določenem zbirališču. Za več informacij obiščite spletno stran: www.recyclethis.info.

**SV Kassering av batteri**

Denna produkt innehåller ett batteri som inte får kastas i allmänna sophanteringssytem inom den europeiska unionen. Se produktdokumentationen för specifik batteriinformation. Batteriet är märkt med denna symbol, vilket kan innebära att det innehåller kadmium (Cd), bly (Pb) eller kvicksilver (Hg). För korrekt återvinning skall batteriet returneras till leverantören eller till en därför avsedd deponering. För mer information, se: www.recyclethis.info.

**TR Pil Geri Dönüşümü**

Bu ürün Avrupa Birliği genel atık sistemlerine atılmaması gereken pil içermektedir. Daha detaylı pil bilgisi için ürünün kataloğunu inceleyiniz. Bu sembolle işaretlenmiş piller Kadmiyum(Cd), Kurşun(Pb) ya da Civa(Hg) içerebilir. Doğru geri dönüşüm için ürünü yerel tedarikçinize geri veriniz ya da özel işaretlenmiş toplama noktlarına atınız. Daha fazla bilgi için: www.recyclethis.info.

**Global Contacts**

| | |
|---|---|
| North America | 905-294-6222 |
| Latin America | +55 11 3614 1700 |
| Europe, Middle East, Africa | +(34) 94 485 88 00 |
| Asia | +86-21-2401-3208 |
| India | +91 80 41314617 |

From GE Part Number 1604-0021-A1, GE Publication Number GEK-113574

### 11.3.1 UNINSTALL AND CLEAR FILES AND DATA

The unit can be decommissioned by turning off power to the unit and disconnecting the wires to it.

To clear files and settings in the UR:

1. On the UR front panel, navigate to **COMMANDS** ⇨⇩ **RELAY MAINTENANCE** ⇨⇩ **SERVICE COMMAND**, enter the value 20511, and press the **ENTER** key. The relay restarts and clears the UR.
2. Clear the flash memory using the **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **CLEAR RELAY RECORDS** command.

To clear files and settings on the computer:

1. Uninstall the EnerVista UR Setup software.
2. Find and delete the following UR files:
   - .URS, .CID, and .ICD settings
   - .EVT event records
   - .CFG and .DAT COMTRADE

### 11.4.1 REPAIRS

The battery and modules inside the case can be replaced without return of the device to the factory. The firmware and software can be upgraded without return of the device to the factory.

Fuses in the power supply module are not field-replaceable.

For issues not solved by troubleshooting, the process to return the device to the factory for repair is as follows:

- Contact a GE Grid Solutions Technical Support Center. Contact information is found in the first chapter.
- Obtain a Return Materials Authorization (RMA) number from the Technical Support Center.
- Verify that the RMA and Commercial Invoice received have the correct information.
- Tightly pack the unit in a box with bubble wrap, foam material, or styrofoam inserts or packaging peanuts to cushion the item(s). You may also use double boxing whereby you place the box in a larger box that contains at least 5 cm of cushioning material.
- Ship the unit by courier or freight forwarder, along with the Commercial Invoice and RMA, to the factory.

  GE GRID SOLUTIONS
  650 MARKLAND STREET
  MARKHAM, ONTARIO
  CANADA L6C 0M1

  ATTN: SERVICE DEPT.

  RMA# : _____

  Customers are responsible for shipping costs to the factory, regardless of whether the unit is under warranty.
- Fax a copy of the shipping information to the GE Grid Solutions service department in Canada at +1 905 927 5098.

Use the detailed return procedure outlined at

https://www.gegridsolutions.com/multilin/support/ret_proc.htm

The current warranty and return information are outlined at

https://www.gegridsolutions.com/multilin/warranty.htm

### 11.5.1 STORAGE

Store the unit indoors in a cool, dry place. If possible, store in the original packaging. Follow the storage temperature range outlined in the Specifications.

**NOTICE** To avoid deterioration of electrolytic capacitors, power up units that are stored in a de-energized state once per year, for one hour continuously.

### 11.6.1 DISPOSAL

Other than the battery, there are no special requirements for disposal of the unit at the end its service life. For customers located in the European Union, dispose of the battery as outlined earlier. To prevent non-intended use of the unit, remove the modules as outlined earlier, dismantle the unit, and recycle the metal when possible. See the UR Family Recycling and Disposal Instructions (GET-20096).

A FlexAnalog parameter is an analog parameter.

FlexAnalog items are also viewable in a web browser. Enter the IP address of the UR, access the **Device Information Menu** option, then the **FlexAnalog Parameter Listing** option. Entries displayed online depend on order code.

**Table A–1: FLEXANALOG DATA ITEMS (Sheet 1 of 9)**

| DECIMAL ADDRESS | FLEXANALOG NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 5688 | Channel 1 Asymmetry | ms | Channel 1 asymmetry |
| 5690 | Channel 2 Asymmetry | ms | Channel 2 asymmetry |
| 5824 | Field RTD 1 Value | --- | Field RTD 1 value |
| 5825 | Field RTD 2 Value | --- | Field RTD 2 value |
| 5826 | Field RTD 3 Value | --- | Field RTD 3 value |
| 5827 | Field RTD 4 Value | --- | Field RTD 4 value |
| 5828 | Field RTD 5 Value | --- | Field RTD 5 value |
| 5829 | Field RTD 6 Value | --- | Field RTD 6 value |
| 5830 | Field RTD 7 Value | --- | Field RTD 7 value |
| 5831 | Field RTD 8 Value | --- | Field RTD 8 value |
| 5832 | Field TDR 1 Value | --- | Field TDR 1 value |
| 5834 | Field TDR 2 Value | --- | Field TDR 2 value |
| 5836 | Field TDR 3 Value | --- | Field TDR 3 value |
| 5838 | Field TDR 4 Value | --- | Field TDR 4 value |
| 5840 | Field TDR 5 Value | --- | Field TDR 5 value |
| 5842 | Field TDR 6 Value | --- | Field TDR 6 value |
| 5844 | Field TDR 7 Value | --- | Field TDR 7 value |
| 5846 | Field TDR 8 Value | --- | Field TDR 8 value |
| 6144 | SRC 1 Ia RMS | Amps | Source 1 phase A current RMS |
| 6146 | SRC 1 Ib RMS | Amps | Source 1 phase B current RMS |
| 6148 | SRC 1 Ic RMS | Amps | Source 1 phase C current RMS |
| 6150 | SRC 1 In RMS | Amps | Source 1 neutral current RMS |
| 6152 | SRC 1 Ia Mag | Amps | Source 1 phase A current magnitude |
| 6154 | SRC 1 Ia Angle | Degrees | Source 1 phase A current angle |
| 6155 | SRC 1 Ib Mag | Amps | Source 1 phase B current magnitude |
| 6157 | SRC 1 Ib Angle | Degrees | Source 1 phase B current angle |
| 6158 | SRC 1 Ic Mag | Amps | Source 1 phase C current magnitude |
| 6160 | SRC 1 Ic Angle | Degrees | Source 1 phase C current angle |
| 6161 | SRC 1 In Mag | Amps | Source 1 neutral current magnitude |
| 6163 | SRC 1 In Angle | Degrees | Source 1 neutral current angle |
| 6164 | SRC 1 Ig RMS | Amps | Source 1 ground current RMS |
| 6166 | SRC 1 Ig Mag | Amps | Source 1 ground current magnitude |
| 6168 | SRC 1 Ig Angle | Degrees | Source 1 ground current angle |
| 6169 | SRC 1 I_0 Mag | Amps | Source 1 zero-sequence current magnitude |
| 6171 | SRC 1 I_0 Angle | Degrees | Source 1 zero-sequence current angle |
| 6172 | SRC 1 I_1 Mag | Amps | Source 1 positive-sequence current magnitude |
| 6174 | SRC 1 I_1 Angle | Degrees | Source 1 positive-sequence current angle |
| 6175 | SRC 1 I_2 Mag | Amps | Source 1 negative-sequence current magnitude |
| 6177 | SRC 1 I_2 Angle | Degrees | Source 1 negative-sequence current angle |
| 6178 | SRC 1 Igd Mag | Amps | Source 1 differential ground current magnitude |

**Table A–1: FLEXANALOG DATA ITEMS (Sheet 2 of 9)**

| DECIMAL ADDRESS | FLEXANALOG NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 6180 | SRC 1 Igd Angle | Degrees | Source 1 differential ground current angle |
| 6208 | SRC 2 Ia RMS | Amps | Source 2 phase A current RMS |
| 6210 | SRC 2 Ib RMS | Amps | Source 2 phase B current RMS |
| 6212 | SRC 2 Ic RMS | Amps | Source 2 phase C current RMS |
| 6214 | SRC 2 In RMS | Amps | Source 2 neutral current RMS |
| 6216 | SRC 2 Ia Mag | Amps | Source 2 phase A current magnitude |
| 6218 | SRC 2 Ia Angle | Degrees | Source 2 phase A current angle |
| 6219 | SRC 2 Ib Mag | Amps | Source 2 phase B current magnitude |
| 6221 | SRC 2 Ib Angle | Degrees | Source 2 phase B current angle |
| 6222 | SRC 2 Ic Mag | Amps | Source 2 phase C current magnitude |
| 6224 | SRC 2 Ic Angle | Degrees | Source 2 phase C current angle |
| 6225 | SRC 2 In Mag | Amps | Source 2 neutral current magnitude |
| 6227 | SRC 2 In Angle | Degrees | Source 2 neutral current angle |
| 6228 | SRC 2 Ig RMS | Amps | Source 2 ground current RMS |
| 6230 | SRC 2 Ig Mag | Amps | Source 2 ground current magnitude |
| 6232 | SRC 2 Ig Angle | Degrees | Source 2 ground current angle |
| 6233 | SRC 2 I_0 Mag | Amps | Source 2 zero-sequence current magnitude |
| 6235 | SRC 2 I_0 Angle | Degrees | Source 2 zero-sequence current angle |
| 6236 | SRC 2 I_1 Mag | Amps | Source 2 positive-sequence current magnitude |
| 6238 | SRC 2 I_1 Angle | Degrees | Source 2 positive-sequence current angle |
| 6239 | SRC 2 I_2 Mag | Amps | Source 2 negative-sequence current magnitude |
| 6241 | SRC 2 I_2 Angle | Degrees | Source 2 negative-sequence current angle |
| 6242 | SRC 2 Igd Mag | Amps | Source 2 differential ground current magnitude |
| 6244 | SRC 2 Igd Angle | Degrees | Source 2 differential ground current angle |
| 6656 | SRC 1 Vag RMS | Volts | Source 1 phase AG voltage RMS |
| 6658 | SRC 1 Vbg RMS | Volts | Source 1 phase BG voltage RMS |
| 6660 | SRC 1 Vcg RMS | Volts | Source 1 phase CG voltage RMS |
| 6662 | SRC 1 Vag Mag | Volts | Source 1 phase AG voltage magnitude |
| 6664 | SRC 1 Vag Angle | Degrees | Source 1 phase AG voltage angle |
| 6665 | SRC 1 Vbg Mag | Volts | Source 1 phase BG voltage magnitude |
| 6667 | SRC 1 Vbg Angle | Degrees | Source 1 phase BG voltage angle |
| 6668 | SRC 1 Vcg Mag | Volts | Source 1 phase CG voltage magnitude |
| 6670 | SRC 1 Vcg Angle | Degrees | Source 1 phase CG voltage angle |
| 6671 | SRC 1 Vab RMS | Volts | Source 1 phase AB voltage RMS |
| 6673 | SRC 1 Vbc RMS | Volts | Source 1 phase BC voltage RMS |
| 6675 | SRC 1 Vca RMS | Volts | Source 1 phase CA voltage RMS |
| 6677 | SRC 1 Vab Mag | Volts | Source 1 phase AB voltage magnitude |
| 6679 | SRC 1 Vab Angle | Degrees | Source 1 phase AB voltage angle |
| 6680 | SRC 1 Vbc Mag | Volts | Source 1 phase BC voltage magnitude |
| 6682 | SRC 1 Vbc Angle | Degrees | Source 1 phase BC voltage angle |
| 6683 | SRC 1 Vca Mag | Volts | Source 1 phase CA voltage magnitude |
| 6685 | SRC 1 Vca Angle | Degrees | Source 1 phase CA voltage angle |
| 6686 | SRC 1 Vx RMS | Volts | Source 1 auxiliary voltage RMS |
| 6688 | SRC 1 Vx Mag | Volts | Source 1 auxiliary voltage magnitude |
| 6690 | SRC 1 Vx Angle | Degrees | Source 1 auxiliary voltage angle |
| 6691 | SRC 1 V_0 Mag | Volts | Source 1 zero-sequence voltage magnitude |
| 6693 | SRC 1 V_0 Angle | Degrees | Source 1 zero-sequence voltage angle |

**Table A–1: FLEXANALOG DATA ITEMS (Sheet 3 of 9)**

| DECIMAL ADDRESS | FLEXANALOG NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 6694 | SRC 1 V_1 Mag | Volts | Source 1 positive-sequence voltage magnitude |
| 6696 | SRC 1 V_1 Angle | Degrees | Source 1 positive-sequence voltage angle |
| 6697 | SRC 1 V_2 Mag | Volts | Source 1 negative-sequence voltage magnitude |
| 6699 | SRC 1 V_2 Angle | Degrees | Source 1 negative-sequence voltage angle |
| 6720 | SRC 2 Vag RMS | Volts | Source 2 phase AG voltage RMS |
| 6722 | SRC 2 Vbg RMS | Volts | Source 2 phase BG voltage RMS |
| 6724 | SRC 2 Vcg RMS | Volts | Source 2 phase CG voltage RMS |
| 6726 | SRC 2 Vag Mag | Volts | Source 2 phase AG voltage magnitude |
| 6728 | SRC 2 Vag Angle | Degrees | Source 2 phase AG voltage angle |
| 6729 | SRC 2 Vbg Mag | Volts | Source 2 phase BG voltage magnitude |
| 6731 | SRC 2 Vbg Angle | Degrees | Source 2 phase BG voltage angle |
| 6732 | SRC 2 Vcg Mag | Volts | Source 2 phase CG voltage magnitude |
| 6734 | SRC 2 Vcg Angle | Degrees | Source 2 phase CG voltage angle |
| 6735 | SRC 2 Vab RMS | Volts | Source 2 phase AB voltage RMS |
| 6737 | SRC 2 Vbc RMS | Volts | Source 2 phase BC voltage RMS |
| 6739 | SRC 2 Vca RMS | Volts | Source 2 phase CA voltage RMS |
| 6741 | SRC 2 Vab Mag | Volts | Source 2 phase AB voltage magnitude |
| 6743 | SRC 2 Vab Angle | Degrees | Source 2 phase AB voltage angle |
| 6744 | SRC 2 Vbc Mag | Volts | Source 2 phase BC voltage magnitude |
| 6746 | SRC 2 Vbc Angle | Degrees | Source 2 phase BC voltage angle |
| 6747 | SRC 2 Vca Mag | Volts | Source 2 phase CA voltage magnitude |
| 6749 | SRC 2 Vca Angle | Degrees | Source 2 phase CA voltage angle |
| 6750 | SRC 2 Vx RMS | Volts | Source 2 auxiliary voltage RMS |
| 6752 | SRC 2 Vx Mag | Volts | Source 2 auxiliary voltage magnitude |
| 6754 | SRC 2 Vx Angle | Degrees | Source 2 auxiliary voltage angle |
| 6755 | SRC 2 V_0 Mag | Volts | Source 2 zero-sequence voltage magnitude |
| 6757 | SRC 2 V_0 Angle | Degrees | Source 2 zero-sequence voltage angle |
| 6758 | SRC 2 V_1 Mag | Volts | Source 2 positive-sequence voltage magnitude |
| 6760 | SRC 2 V_1 Angle | Degrees | Source 2 positive-sequence voltage angle |
| 6761 | SRC 2 V_2 Mag | Volts | Source 2 negative-sequence voltage magnitude |
| 6763 | SRC 2 V_2 Angle | Degrees | Source 2 negative-sequence voltage angle |
| 7168 | SRC 1 P | Watts | Source 1 three-phase real power |
| 7170 | SRC 1 Pa | Watts | Source 1 phase A real power |
| 7172 | SRC 1 Pb | Watts | Source 1 phase B real power |
| 7174 | SRC 1 Pc | Watts | Source 1 phase C real power |
| 7176 | SRC 1 Q | Vars | Source 1 three-phase reactive power |
| 7178 | SRC 1 Qa | Vars | Source 1 phase A reactive power |
| 7180 | SRC 1 Qb | Vars | Source 1 phase B reactive power |
| 7182 | SRC 1 Qc | Vars | Source 1 phase C reactive power |
| 7184 | SRC 1 S | VA | Source 1 three-phase apparent power |
| 7186 | SRC 1 Sa | VA | Source 1 phase A apparent power |
| 7188 | SRC 1 Sb | VA | Source 1 phase B apparent power |
| 7190 | SRC 1 Sc | VA | Source 1 phase C apparent power |
| 7192 | SRC 1 PF | --- | Source 1 three-phase power factor |
| 7193 | SRC 1 Phase A PF | --- | Source 1 phase A power factor |
| 7194 | SRC 1 Phase B PF | --- | Source 1 phase B power factor |
| 7195 | SRC 1 Phase C PF | --- | Source 1 phase C power factor |

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**Table A–1: FLEXANALOG DATA ITEMS (Sheet 4 of 9)**

| DECIMAL ADDRESS | FLEXANALOG NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 7200 | SRC 2 P | Watts | Source 2 three-phase real power |
| 7202 | SRC 2 Pa | Watts | Source 2 phase A real power |
| 7204 | SRC 2 Pb | Watts | Source 2 phase B real power |
| 7206 | SRC 2 Pc | Watts | Source 2 phase C real power |
| 7208 | SRC 2 Q | Vars | Source 2 three-phase reactive power |
| 7210 | SRC 2 Qa | Vars | Source 2 phase A reactive power |
| 7212 | SRC 2 Qb | Vars | Source 2 phase B reactive power |
| 7214 | SRC 2 Qc | Vars | Source 2 phase C reactive power |
| 7216 | SRC 2 S | VA | Source 2 three-phase apparent power |
| 7218 | SRC 2 Sa | VA | Source 2 phase A apparent power |
| 7220 | SRC 2 Sb | VA | Source 2 phase B apparent power |
| 7222 | SRC 2 Sc | VA | Source 2 phase C apparent power |
| 7224 | SRC 2 PF | --- | Source 2 three-phase power factor |
| 7225 | SRC 2 Phase A PF | --- | Source 2 phase A power factor |
| 7226 | SRC 2 Phase B PF | --- | Source 2 phase B power factor |
| 7227 | SRC 2 Phase C PF | --- | Source 2 phase C power factor |
| 7552 | SRC 1 Frequency | Hz | Source 1 frequency |
| 7554 | SRC 2 Frequency | Hz | Source 2 frequency |
| 8672 | Brk 1 Arc Amp A | $kA^2$-cyc | Breaker 1 arcing amp phase A |
| 8674 | Brk 1 Arc Amp B | $kA^2$-cyc | Breaker 1 arcing amp phase B |
| 8676 | Brk 1 Arc Amp C | $kA^2$-cyc | Breaker 1 arcing amp phase C |
| 8678 | Brk 1 Op Time A | ms | Breaker 1 operating time phase A |
| 8679 | Brk 1 Op Time B | ms | Breaker 1 operating time phase B |
| 8680 | Brk 1 Op Time C | ms | Breaker 1 operating time phase C |
| 8681 | Brk 1 Op Time | ms | Breaker 1 operating time |
| 8682 | Brk 2 Arc Amp A | $kA^2$-cyc | Breaker 2 arcing amp phase A |
| 8684 | Brk 2 Arc Amp B | $kA^2$-cyc | Breaker 2 arcing amp phase B |
| 8686 | Brk 2 Arc Amp C | $kA^2$-cyc | Breaker 2 arcing amp phase C |
| 8688 | Brk 2 Op Time A | ms | Breaker 2 operating time phase A |
| 8689 | Brk 2 Op Time B | ms | Breaker 2 operating time phase B |
| 8690 | Brk 2 Op Time C | ms | Breaker 2 operating time phase C |
| 8691 | Brk 2 Op Time | ms | Breaker 2 operating time |
| 9024 | Prefault Ia Mag [1] | Amps | Fault 1 pre-fault phase A current magnitude |
| 9026 | Prefault Ia Ang [1] | Degrees | Fault 1 pre-fault phase A current angle |
| 9027 | Prefault Ib Mag [1] | Amps | Fault 1 pre-fault phase B current magnitude |
| 9029 | Prefault Ib Ang [1] | Degrees | Fault 1 pre-fault phase B current angle |
| 9030 | Prefault Ic Mag [1] | Amps | Fault 1 pre-fault phase C current magnitude |
| 9032 | Prefault Ic Ang [1] | Degrees | Fault 1 pre-fault phase C current angle |
| 9033 | Prefault Va Mag [1] | Volts | Fault 1 pre-fault phase A voltage magnitude |
| 9035 | Prefault Va Ang [1] | Degrees | Fault 1 pre-fault phase A voltage angle |
| 9036 | Prefault Vb Mag [1] | Volts | Fault 1 pre-fault phase B voltage magnitude |
| 9038 | Prefault Vb Ang [1] | Degrees | Fault 1 pre-fault phase B voltage angle |
| 9039 | Prefault Vc Mag [1] | Volts | Fault 1 pre-fault phase C voltage magnitude |
| 9041 | Prefault Vc Ang [1] | Degrees | Fault 1 pre-fault phase C voltage angle |
| 9042 | Fault Ia Mag [1] | Amps | Fault 1 phase A current magnitude |
| 9044 | Fault Ia Ang [1] | Degrees | Fault 1 phase A current angle |

**Table A–1: FLEXANALOG DATA ITEMS (Sheet 5 of 9)**

| DECIMAL ADDRESS | FLEXANALOG NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 9045 | Fault Ib Mag [1] | Amps | Fault 1 phase B current magnitude |
| 9047 | Fault Ib Ang [1] | Degrees | Fault 1 phase B current angle |
| 9048 | Fault Ic Mag [1] | Amps | Fault 1 phase C current magnitude |
| 9050 | Fault Ic Ang [1] | Degrees | Fault 1 phase C current angle |
| 9051 | Fault Va Mag [1] | Volts | Fault 1 phase A voltage magnitude |
| 9053 | Fault Va Ang [1] | Degrees | Fault 1 phase A voltage angle |
| 9054 | Fault Vb Mag [1] | Volts | Fault 1 phase B voltage magnitude |
| 9056 | Fault Vb Ang [1] | Degrees | Fault 1 phase B voltage angle |
| 9057 | Fault Vc Mag [1] | Volts | Fault 1 phase C voltage magnitude |
| 9059 | Fault Vc Ang [1] | Degrees | Fault 1 phase C voltage angle |
| 9060 | Fault Type [1] | --- | Fault 1 type |
| 9061 | Fault Location [1] | --- | Fault 1 location |
| 9216 | Synchchk 1 Delta V | Volts | Synchrocheck 1 delta voltage |
| 9218 | Synchchk 1 Delta F | Hz | Synchrocheck 1 delta frequency |
| 9219 | Synchchk 1 Delta Phs | Degrees | Synchrocheck 1 delta phase |
| 9220 | Synchchk 2 Delta V | Volts | Synchrocheck 2 delta voltage |
| 9222 | Synchchk 2 Delta F | Hz | Synchrocheck 2 delta frequency |
| 9223 | Synchchk 2 Delta Phs | Degrees | Synchrocheck 2 delta phase |
| 9224 | Synchchk 3 Delta V | Volts | Synchrocheck 3 delta voltage |
| 9226 | Synchchk 3 Delta F | Hz | Synchrocheck 3 delta frequency |
| 9227 | Synchchk 3 Delta Phs | Degrees | Synchrocheck 3 delta phase |
| 9228 | Synchchk 4 Delta V | Volts | Synchrocheck 4 delta voltage |
| 9230 | Synchchk 4 Delta F | Hz | Synchrocheck 4 delta frequency |
| 9231 | Synchchk 4 Delta Phs | Degrees | Synchrocheck 4 delta phase |
| 9344 | Local IA Mag | Amps | Local terminal phase A current magnitude |
| 9346 | Local IB Mag | Amps | Local terminal phase B current magnitude |
| 9348 | Local IC Mag | Amps | Local terminal phase C current magnitude |
| 9350 | Terminal 1 IA Mag | Amps | Remote terminal 1 phase A current magnitude |
| 9352 | Terminal 1 IB Mag | Amps | Remote terminal 1 phase B current magnitude |
| 9354 | Terminal 1 IC Mag | Amps | Remote terminal 1 phase C current magnitude |
| 9356 | Terminal 2 IA Mag | Amps | Remote terminal 2 phase A current magnitude |
| 9358 | Terminal 2 IB Mag | Amps | Remote terminal 2 phase B current magnitude |
| 9360 | Terminal 2 IC Mag | Amps | Remote terminal 2 phase C current magnitude |
| 9362 | Diff Curr IA Mag | Amps | Differential current phase A magnitude |
| 9364 | Diff Curr IB Mag | Amps | Differential current phase B magnitude |
| 9366 | Diff Curr IC Mag | Amps | Differential current phase C magnitude |
| 9368 | Local IA Angle | Degrees | Local terminal current phase A angle |
| 9369 | Local IB Angle | Degrees | Local terminal current phase B angle |
| 9370 | Local IC Angle | Degrees | Local terminal current phase C angle |
| 9371 | Terminal 1 IA Angle | Degrees | Remote terminal 1 current phase A angle |
| 9372 | Terminal 1 IB Angle | Degrees | Remote terminal 1 current phase B angle |
| 9373 | Terminal 1 IC Angle | Degrees | Remote terminal 1 current phase C angle |
| 9374 | Terminal 2 IA Angle | Degrees | Remote terminal 2 current phase A angle |
| 9375 | Terminal 2 IB Angle | Degrees | Remote terminal 2 current phase B angle |
| 9376 | Terminal 2 IC Angle | Degrees | Remote terminal 2 current phase C angle |
| 9377 | Diff Curr IA Angle | Degrees | Differential current phase A angle |
| 9378 | Diff Curr IB Angle | Degrees | Differential current phase B angle |

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**Table A–1: FLEXANALOG DATA ITEMS (Sheet 6 of 9)**

| DECIMAL ADDRESS | FLEXANALOG NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 9379 | Diff Curr IC Angle | Degrees | Differential current phase C angle |
| 9380 | Op Square Curr IA | Amps | Phase A operating square current |
| 9382 | Op Square Curr IB | Amps | Phase B operating square current |
| 9384 | Op Square Curr IC | Amps | Phase C operating square current |
| 9386 | Rest Square Curr IA | Amps | Phase A restraint square current |
| 9388 | Rest Square Curr IB | Amps | Phase B restraint square current |
| 9390 | Rest Square Curr IC | Amps | Phase C restraint square current |
| 9392 | Rest Curr IA | Amps | Restraint current IA |
| 9394 | Rest Curr IB | Amps | Restraint current IB |
| 9396 | Rest Curr IC | Amps | Restraint current IC |
| 9398 | Diff Curr IG Mag | Amps | Differential current IG Magnitude |
| 9400 | Diff Curr IG Angle | Degrees | Differential current IG Angle |
| 9401 | Rest Curr IG | Amps | Restraint current IG |
| 9403 | Local IG Mag | Amps | Local IG magnitude |
| 9405 | Local IG Angle | Degrees | Local IG angle |
| 9406 | Terminal 1 IG Mag | Amps | Remote 1 IG magnitude |
| 9408 | Terminal 1 IG Angle | Degrees | Remote 1 IG angle |
| 9409 | Terminal 2 IG Mag | Amps | Remote 2 IG magnitude |
| 9411 | Terminal 2 IG Angle | Amps | Remote 2 IG angle |
| 9421 | 87L Harm2 Iad Mag | Amps | Current differential second harmonic Iad magnitude |
| 9423 | 87L Harm2 Ibd Mag | Amps | Current differential second harmonic Ibd magnitude |
| 9425 | 87L Harm2 Icd Mag | Amps | Current differential second harmonic Icd magnitude |
| 9581 | PMU 1 Va Mag | Volts | Phasor measurement unit 1 phase A voltage magnitude |
| 9583 | PMU 1 Va Angle | Degrees | Phasor measurement unit 1 phase A voltage angle |
| 9584 | PMU 1 Vb Mag | Volts | Phasor measurement unit 1 phase B voltage magnitude |
| 9586 | PMU 1 Vb Angle | Degrees | Phasor measurement unit 1 phase B voltage angle |
| 9587 | PMU 1 Vc Mag | Volts | Phasor measurement unit 1 phase C voltage magnitude |
| 9589 | PMU 1 Vc Angle | Degrees | Phasor measurement unit 1 phase C voltage angle |
| 9590 | PMU 1 Vx Mag | Volts | Phasor measurement unit 1 auxiliary voltage magnitude |
| 9592 | PMU 1 Vx Angle | Degrees | Phasor measurement unit 1 auxiliary voltage angle |
| 9593 | PMU 1 V1 Mag | Volts | Phasor measurement unit 1 positive-sequence voltage magnitude |
| 9595 | PMU 1 V1 Angle | Degrees | Phasor measurement unit 1 positive-sequence voltage angle |
| 9596 | PMU 1 V2 Mag | Volts | Phasor measurement unit 1 negative-sequence voltage magnitude |
| 9598 | PMU 1 V2 Angle | Degrees | Phasor measurement unit 1 negative-sequence voltage angle |
| 9599 | PMU 1 V0 Mag | Volts | Phasor measurement unit 1 zero-sequence voltage magnitude |
| 9601 | PMU 1 V0 Angle | Degrees | Phasor measurement unit 1 zero-sequence voltage angle |
| 9602 | PMU 1 Ia Mag | Amps | Phasor measurement unit 1 phase A current magnitude |
| 9604 | PMU 1 Ia Angle | Degrees | Phasor measurement unit 1 phase A current angle |
| 9605 | PMU 1 Ib Mag | Amps | Phasor measurement unit 1 phase B current magnitude |
| 9607 | PMU 1 Ib Angle | Degrees | Phasor measurement unit 1 phase B current angle |
| 9608 | PMU 1 Ic Mag | Amps | Phasor measurement unit 1 phase C current magnitude |
| 9610 | PMU 1 Ic Angle | Degrees | Phasor measurement unit 1 phase C current angle |
| 9611 | PMU 1 Ig Mag | Amps | Phasor measurement unit 1 ground current magnitude |
| 9613 | PMU 1 Ig Angle | Degrees | Phasor measurement unit 1 ground current angle |
| 9614 | PMU 1 I1 Mag | Amps | Phasor measurement unit 1 positive-sequence current magnitude |
| 9616 | PMU 1 I1 Angle | Degrees | Phasor measurement unit 1 positive-sequence current angle |
| 9617 | PMU 1 I2 Mag | Amps | Phasor measurement unit 1 negative-sequence current magnitude |

**Table A–1: FLEXANALOG DATA ITEMS (Sheet 7 of 9)**

| DECIMAL ADDRESS | FLEXANALOG NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 9619 | PMU 1 I2 Angle | Degrees | Phasor measurement unit 1 negative-sequence current angle |
| 9620 | PMU 1 I0 Mag | Amps | Phasor measurement unit 1 zero-sequence current magnitude |
| 9622 | PMU 1 I0 Angle | Degrees | Phasor measurement unit 1 zero-sequence current angle |
| 9623 | PMU 1 Freq | Hz | Phasor measurement unit 1 frequency |
| 9625 | PMU 1 df dt | Hz/s | Phasor measurement unit 1 rate of change of frequency |
| 9626 | PMU 1 Conf Ch | --- | Phasor measurement unit 1 configuration change counter |
| 12306 | Oscill Num Triggers | --- | Oscillography number of triggers |
| 13504 | DCmA Ip 1 | mA | DCmA input 1 actual value |
| 13506 | DCmA Ip 2 | mA | DCmA input 2 actual value |
| 13508 | DCmA Ip 3 | mA | DCmA input 3 actual value |
| 13510 | DCmA Ip 4 | mA | DCmA input 4 actual value |
| 13512 | DCmA Ip 5 | mA | DCmA input 5 actual value |
| 13514 | DCmA Ip 6 | mA | DCmA input 6 actual value |
| 13516 | DCmA Ip 7 | mA | DCmA input 7 actual value |
| 13518 | DCmA Ip 8 | mA | DCmA input 8 actual value |
| 13520 | DCmA Ip 9 | mA | DCmA input 9 actual value |
| 13522 | DCmA Ip 10 | mA | DCmA input 10 actual value |
| 13524 | DCmA Ip 11 | mA | DCmA input 11 actual value |
| 13526 | DCmA Ip 12 | mA | DCmA input 12 actual value |
| 13528 | DCmA Ip 13 | mA | DCmA input 13 actual value |
| 13530 | DCmA Ip 14 | mA | DCmA input 14 actual value |
| 13532 | DCmA Ip 15 | mA | DCmA input 15 actual value |
| 13534 | DCmA Ip 16 | mA | DCmA input 16 actual value |
| 13536 | DCmA Ip 17 | mA | DCmA input 17 actual value |
| 13538 | DCmA Ip 18 | mA | DCmA input 18 actual value |
| 13540 | DCmA Ip 19 | mA | DCmA input 19 actual value |
| 13542 | DCmA Ip 20 | mA | DCmA input 20 actual value |
| 13544 | DCmA Ip 21 | mA | DCmA input 21 actual value |
| 13546 | DCmA Ip 22 | mA | DCmA input 22 actual value |
| 13548 | DCmA Ip 23 | mA | DCmA input 23 actual value |
| 13550 | DCmA Ip 24 | mA | DCmA input 24 actual value |
| 13552 | RTD Ip 1 | --- | RTD input 1 actual value |
| 13553 | RTD Ip 2 | --- | RTD input 2 actual value |
| 13554 | RTD Ip 3 | --- | RTD input 3 actual value |
| 13555 | RTD Ip 4 | --- | RTD input 4 actual value |
| 13556 | RTD Ip 5 | --- | RTD input 5 actual value |
| 13557 | RTD Ip 6 | --- | RTD input 6 actual value |
| 13558 | RTD Ip 7 | --- | RTD input 7 actual value |
| 13559 | RTD Ip 8 | --- | RTD input 8 actual value |
| 13560 | RTD Ip 9 | --- | RTD input 9 actual value |
| 13561 | RTD Ip 10 | --- | RTD input 10 actual value |
| 13562 | RTD Ip 11 | --- | RTD input 11 actual value |
| 13563 | RTD Ip 12 | --- | RTD input 12 actual value |
| 13564 | RTD Ip 13 | --- | RTD input 13 actual value |
| 13565 | RTD Ip 14 | --- | RTD input 14 actual value |
| 13566 | RTD Ip 15 | --- | RTD input 15 actual value |
| 13567 | RTD Ip 16 | --- | RTD input 16 actual value |

**Table A–1: FLEXANALOG DATA ITEMS (Sheet 8 of 9)**

| DECIMAL ADDRESS | FLEXANALOG NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 13568 | RTD Ip 17 | --- | RTD input 17 actual value |
| 13569 | RTD Ip 18 | --- | RTD input 18 actual value |
| 13570 | RTD Ip 19 | --- | RTD input 19 actual value |
| 13571 | RTD Ip 20 | --- | RTD input 20 actual value |
| 13572 | RTD Ip 21 | --- | RTD input 21 actual value |
| 13573 | RTD Ip 22 | --- | RTD input 22 actual value |
| 13574 | RTD Ip 23 | --- | RTD input 23 actual value |
| 13575 | RTD Ip 24 | --- | RTD input 24 actual value |
| 13576 | RTD Ip 25 | --- | RTD input 25 actual value |
| 13577 | RTD Ip 26 | --- | RTD input 26 actual value |
| 13578 | RTD Ip 27 | --- | RTD input 27 actual value |
| 13579 | RTD Ip 28 | --- | RTD input 28 actual value |
| 13580 | RTD Ip 29 | --- | RTD input 29 actual value |
| 13581 | RTD Ip 30 | --- | RTD input 30 actual value |
| 13582 | RTD Ip 31 | --- | RTD input 31 actual value |
| 13583 | RTD Ip 32 | --- | RTD input 32 actual value |
| 13584 | RTD Ip 33 | --- | RTD input 33 actual value |
| 13585 | RTD Ip 34 | --- | RTD input 34 actual value |
| 13586 | RTD Ip 35 | --- | RTD input 35 actual value |
| 13587 | RTD Ip 36 | --- | RTD input 36 actual value |
| 13588 | RTD Ip 37 | --- | RTD input 37 actual value |
| 13589 | RTD Ip 38 | --- | RTD input 38 actual value |
| 13590 | RTD Ip 39 | --- | RTD input 39 actual value |
| 13591 | RTD Ip 40 | --- | RTD input 40 actual value |
| 13592 | RTD Ip 41 | --- | RTD input 41 actual value |
| 13593 | RTD Ip 42 | --- | RTD input 42 actual value |
| 13594 | RTD Ip 43 | --- | RTD input 43 actual value |
| 13595 | RTD Ip 44 | --- | RTD input 44 actual value |
| 13596 | RTD Ip 45 | --- | RTD input 45 actual value |
| 13597 | RTD Ip 46 | --- | RTD input 46 actual value |
| 13598 | RTD Ip 47 | --- | RTD input 47 actual value |
| 13599 | RTD Ip 48 | --- | RTD input 48 actual value |
| 13600 | Ohm Inputs 1 Value | Ohms | Ohm inputs 1 value |
| 13601 | Ohm Inputs 2 Value | Ohms | Ohm inputs 2 value |
| 14189 | PTP–IRIG-B Delta | ns | PTP time minus IRIG-B time |
| 24432 | Communications Group | --- | Groups communications group |
| 24447 | Active Setting Group | --- | Current setting group |
| 32768 | Tracking Frequency | Hz | Tracking frequency |
| 39168 | FlexElement 1 Value | --- | FlexElement 1 actual value |
| 39170 | FlexElement 2 Value | --- | FlexElement 2 actual value |
| 39172 | FlexElement 3 Value | --- | FlexElement 3 actual value |
| 39174 | FlexElement 4 Value | --- | FlexElement 4 actual value |
| 39176 | FlexElement 5 Value | --- | FlexElement 5 actual value |
| 39178 | FlexElement 6 Value | --- | FlexElement 6 actual value |
| 39180 | FlexElement 7 Value | --- | FlexElement 7 actual value |
| 39182 | FlexElement 8 Value | --- | FlexElement 8 actual value |
| 41132 | V0 3rd Harmonic 1 | Volts | VTFF 1 V0 3rd Harmonic |

**Table A–1: FLEXANALOG DATA ITEMS (Sheet 9 of 9)**

| DECIMAL ADDRESS | FLEXANALOG NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 41134 | V0 3rd Harmonic 2 | Volts | VTFF 2 V0 3rd Harmonic |
| 45584 | GOOSE Analog In 1 | --- | IEC 61850 GOOSE analog input 1 |
| 45586 | GOOSE Analog In 2 | --- | IEC 61850 GOOSE analog input 2 |
| 45588 | GOOSE Analog In 3 | --- | IEC 61850 GOOSE analog input 3 |
| 45590 | GOOSE Analog In 4 | --- | IEC 61850 GOOSE analog input 4 |
| 45592 | GOOSE Analog In 5 | --- | IEC 61850 GOOSE analog input 5 |
| 45594 | GOOSE Analog In 6 | --- | IEC 61850 GOOSE analog input 6 |
| 45596 | GOOSE Analog In 7 | --- | IEC 61850 GOOSE analog input 7 |
| 45598 | GOOSE Analog In 8 | --- | IEC 61850 GOOSE analog input 8 |
| 45600 | GOOSE Analog In 9 | --- | IEC 61850 GOOSE analog input 9 |
| 45602 | GOOSE Analog In 10 | --- | IEC 61850 GOOSE analog input 10 |
| 45604 | GOOSE Analog In 11 | --- | IEC 61850 GOOSE analog input 11 |
| 45606 | GOOSE Analog In 12 | --- | IEC 61850 GOOSE analog input 12 |
| 45608 | GOOSE Analog In 13 | --- | IEC 61850 GOOSE analog input 13 |
| 45610 | GOOSE Analog In 14 | --- | IEC 61850 GOOSE analog input 14 |
| 45612 | GOOSE Analog In 15 | --- | IEC 61850 GOOSE analog input 15 |
| 45614 | GOOSE Analog In 16 | --- | IEC 61850 GOOSE analog input 16 |
| 45616 | GOOSE Analog In 17 | --- | IEC 61850 GOOSE analog input 17 |
| 45618 | GOOSE Analog In 18 | --- | IEC 61850 GOOSE analog input 18 |
| 45620 | GOOSE Analog In 19 | --- | IEC 61850 GOOSE analog input 19 |
| 45622 | GOOSE Analog In 20 | --- | IEC 61850 GOOSE analog input 20 |
| 45624 | GOOSE Analog In 21 | --- | IEC 61850 GOOSE analog input 21 |
| 45626 | GOOSE Analog In 22 | --- | IEC 61850 GOOSE analog input 22 |
| 45628 | GOOSE Analog In 23 | --- | IEC 61850 GOOSE analog input 23 |
| 45630 | GOOSE Analog In 24 | --- | IEC 61850 GOOSE analog input 24 |
| 45632 | GOOSE Analog In 25 | --- | IEC 61850 GOOSE analog input 25 |
| 45634 | GOOSE Analog In 26 | --- | IEC 61850 GOOSE analog input 26 |
| 45636 | GOOSE Analog In 27 | --- | IEC 61850 GOOSE analog input 27 |
| 45638 | GOOSE Analog In 28 | --- | IEC 61850 GOOSE analog input 28 |
| 45640 | GOOSE Analog In 29 | --- | IEC 61850 GOOSE analog input 29 |
| 45642 | GOOSE Analog In 30 | --- | IEC 61850 GOOSE analog input 30 |
| 45644 | GOOSE Analog In 31 | --- | IEC 61850 GOOSE analog input 31 |
| 45646 | GOOSE Analog In 32 | --- | IEC 61850 GOOSE analog input 32 |
| 61439 | PMU Num Triggers | --- | Phasor measurement unit recording number of triggers |

## A.1.2 FLEXINTEGER ITEMS

FlexInteger items are also viewable in a web browser. In the browser, enter the IP address of the UR, access the **Device Information Menu** option, then the **FlexInteger Parameter Listing** option.

**Table A–2: FLEXINTEGER DATA ITEMS**

| ADDRESS | FLEXINTEGER NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 9881 | PMU 1 SOC | seconds | PMU 1 SOC timestamps |
| 9883 | PMU 1 FRACSEC | seconds | PMU 1 FRACSEC timestamps |
| 9885 | PMU 1 STAT | --- | PMU 1 STAT flags |
| 9968 | GOOSE UInt Input 1 | --- | IEC61850 GOOSE UInteger input 1 |
| 9970 | GOOSE UInt Input 2 | --- | IEC61850 GOOSE UInteger input 2 |
| 9972 | GOOSE UInt Input 3 | --- | IEC61850 GOOSE UInteger input 3 |

**Table A–2: FLEXINTEGER DATA ITEMS**

| ADDRESS | FLEXINTEGER NAME | UNITS | DESCRIPTION |
|---|---|---|---|
| 9974 | GOOSE UInt Input 4 | --- | IEC61850 GOOSE UInteger input 4 |
| 9976 | GOOSE UInt Input 5 | --- | IEC61850 GOOSE UInteger input 5 |
| 9978 | GOOSE UInt Input 6 | --- | IEC61850 GOOSE UInteger input 6 |
| 9980 | GOOSE UInt Input 7 | --- | IEC61850 GOOSE UInteger input 7 |
| 9982 | GOOSE UInt Input 8 | --- | IEC61850 GOOSE UInteger input 8 |
| 9984 | GOOSE UInt Input 9 | --- | IEC61850 GOOSE UInteger input 9 |
| 9986 | GOOSE UInt Input 10 | --- | IEC61850 GOOSE UInteger input 10 |
| 9988 | GOOSE UInt Input 11 | --- | IEC61850 GOOSE UInteger input 11 |
| 9990 | GOOSE UInt Input 12 | --- | IEC61850 GOOSE UInteger input 12 |
| 9992 | GOOSE UInt Input 13 | --- | IEC61850 GOOSE UInteger input 13 |
| 9994 | GOOSE UInt Input 14 | --- | IEC61850 GOOSE UInteger input 14 |
| 9996 | GOOSE UInt Input 15 | --- | IEC61850 GOOSE UInteger input 15 |
| 9998 | GOOSE UInt Input 16 | --- | IEC61850 GOOSE UInteger input 16 |

### B.1.1 INTRODUCTION

The UR series supports several communications protocols to allow connection to equipment such as personal computers, remote terminal units (RTUs), supervisory control and data acquisition (SCADA) masters, and programmable logic controllers. The Modicon Modbus protocol is the most basic protocol supported by the UR. Modbus RTU is available via the RS232 and RS485 serial links, and Modbus TCP/IP is available over Ethernet. The following description is intended primarily for users who want to develop their own master communication drivers. Note that:

- The UR always acts as a slave device, meaning that it never initiates communications. It listens and responds to requests issued by a master computer.
- A subset of Modbus RTU and Modbus TCP/IP protocol format is supported that allows extensive monitoring, programming, and control functions using read and write register commands.



### B.1.2 PHYSICAL LAYER

Each data byte is transmitted in an asynchronous format consisting of 1 start bit, 8 data bits, 1 stop bit, and possibly 1 parity bit. This produces a 10 or 11 bit data frame. This can be important for transmission through modems at high bit rates (11 bit data frames are not supported by many modems at baud rates greater than 300).

The faceplate RS232 port is intended for local use and is fixed at 19200 bit/s baud and even parity. The rear terminal RS485 port can be set for baud rates of 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, or 115200 bps, and even, odd, and no parity options are available. See the Communications section of chapter 5 for details.

The Modbus TCP/IP protocol is available on each of the rear Ethernet ports. These ports are 100Base-FX.

### B.1.3 DATA LINK LAYER

Modbus RTU communications takes place in packets that are groups of asynchronously framed byte data. The master transmits a packet to the slave and the slave responds with a packet. The following information describes the general format for both transmit and receive packets. For details on packet formatting, see subsequent sections describing each function code.

**Table B–1: MODBUS RTU PACKET FORMAT**

| DESCRIPTION | SIZE |
|---|---|
| SLAVE ADDRESS | 1 byte |
| FUNCTION CODE | 1 byte |
| DATA | N bytes |
| CRC | 2 bytes |
| DEAD TIME | 3.5 bytes transmission time |

- **SLAVE ADDRESS:** This is the address of the slave device that is intended to receive the packet sent by the master and to perform the desired action. Each slave device on a communications bus must have a unique address to prevent bus contention. All of the relay's ports have the same address which is programmable from 1 to 254; see chapter 5 for details. Only the addressed slave will respond to a packet that starts with its address. Note that the faceplate port is an exception to this rule; it will act on a message containing any slave address.

  A master transmit packet with slave address 0 indicates a broadcast command. All slaves on the communication link take action based on the packet, but none respond to the master.
- **FUNCTION CODE:** This is one of the supported functions codes of the unit which tells the slave what action to perform. See the Supported Function Codes section for details. An exception response from the slave is indicated by setting the high order bit of the function code in the response packet. See the Exception Responses section for details.
- **DATA:** This will be a variable number of bytes depending on the function code. This may include actual values, settings, or addresses sent by the master to the slave or by the slave to the master.
- **CRC:** This is a two byte error checking code. The RTU version of Modbus includes a 16-bit cyclic redundancy check (CRC-16) with every packet which is an industry standard method used for error detection. If a Modbus slave device receives a packet in which an error is indicated by the CRC, the slave device does not act upon or respond to the

packet thus preventing any erroneous operations. See the CRC-16 Algorithm section for details on calculating the CRC.

- **DEAD TIME:** A packet is terminated when no data is received for a period of 3.5 byte transmission times (about 15 ms at 2400 bps, 2 ms at 19200 bps, and 300 µs at 115200 bps). Consequently, the transmitting device must not allow gaps between bytes longer than this interval. Once the dead time has expired without a new byte transmission, all slaves start listening for a new packet from the master except for the addressed slave.



Modbus-TCP/IP communications takes place in application data units (ADUs), which are wrapped in the TCP/IP/Ethernet protocols. Ethernet provides Layer 2 addressing and CRC-32 error checking. IP provides Layer 3 addressing. TCP provides communication establishment and ending and manages data flow. The Parallel Redundancy Protocol (PRP) can also be used to provide seamless data flow in case of a single failure in the network, by using a combination of LAN duplication and frame duplication. See chapter 5 in the instruction manual for information on setting up TCP for Modbus (in the Modbus section), IP and PRP (Network section).

The ADU is described as follows.

**Table B–2: MODBUS TCP/IP FORMAT**

| DESCRIPTION | | SIZE |
|---|---|---|
| MBAP header | Transaction identifier | 2 bytes |
| | Protocol identifier | 2 bytes |
| | Length | 2 bytes |
| | Unit identifier | 1 byte |
| FUNCTION CODE | | 1 byte |
| DATA | | N bytes |

**MBAP header**: This Modbus Application Protocol header contains the following fields:

- Transaction Identifier: Used for transaction pairing. The Modbus server copies in the response the transaction identifier of the request.
- Protocol Identifier: Used for intra-system multiplexing. The Modbus protocol is identified by the value 0.
- Length: The length field is a byte count of the following fields, including the Unit Identifier and data fields.
  - Unit Identifier: For the purposes of the UR, this field is equivalent to the Modbus RTU SLAVE ADDRESS field. The client must use the same value here as programmed in the UR setting **MODBUS SLAVE ADDRESS**.

**FUNCTION CODE**: This is the same as the Modbus RTU function code field described above.

**DATA**: This is the same as the Modbus RTU data field described above.

### B.1.4 MODBUS RTU CRC-16 ALGORITHM

The Modbus TPC/IP CRC-32 algorithm is universally executed in hardware, so there is no need to describe it here.

The Modbus RTU CRC-16 algorithm essentially treats the entire data stream (data bits only; start, stop and parity ignored) as one continuous binary number. This number is first shifted left 16 bits and then divided by a characteristic polynomial (1100000000000101b). The 16-bit remainder of the division is appended to the end of the packet, MSByte first. The resulting packet including CRC, when divided by the same polynomial at the receiver will give a zero remainder if no transmission errors have occurred. This algorithm requires the characteristic polynomial to be reverse bit ordered. The most significant bit of the characteristic polynomial is dropped, since it does not affect the value of the remainder.

A C programming language implementation of the CRC algorithm will be provided upon request.

### Table B–3: MODBUS RTU CRC-16 ALGORITHM

| | | |
|---|---|---|
| **SYMBOLS:** | --> | data transfer |
| | A | 16 bit working register |
| | Alow | low order byte of A |
| | Ahigh | high order byte of A |
| | CRC | 16 bit CRC-16 result |
| | i,j | loop counters |
| | (+) | logical EXCLUSIVE-OR operator |
| | N | total number of data bytes |
| | Di | i-th data byte (i = 0 to N-1) |
| | G | 16 bit characteristic polynomial = 1010000000000001 (binary) with MSbit dropped and bit order reversed |
| | shr (x) | right shift operator (th LSbit of x is shifted into a carry flag, a '0' is shifted into the MSbit of x, all other bits are shifted right one location) |

| | | | |
|---|---|---|---|
| **ALGORITHM:** | 1. | FFFF (hex) --> A | |
| | 2. | 0 --> i | |
| | 3. | 0 --> j | |
| | 4. | Di (+) Alow --> Alow | |
| | 5. | j + 1 --> j | |
| | 6. | shr (A) | |
| | 7. | Is there a carry? | No: go to 8; Yes: G (+) A --> A and continue. |
| | 8. | Is j = 8? | No: go to 5; Yes: continue |
| | 9. | i + 1 --> i | |
| | 10. | Is i = N? | No: go to 3; Yes: continue |
| | 11. | A --> CRC | |

### B.2.1 SUPPORTED FUNCTION CODES

Modbus officially defines function codes from 1 to 127 though only a small subset is generally needed. The relay supports some of these functions, as summarized in the following table. Subsequent sections describe each function code in detail.

| FUNCTION CODE | | MODBUS DEFINITION | GE MULTILIN DEFINITION |
|---|---|---|---|
| HEX | DEC | | |
| 03 | 3 | Read holding registers | Read actual values or settings |
| 04 | 4 | Read holding registers | Read actual values or settings |
| 05 | 5 | Force single coil | Execute operation |
| 06 | 6 | Preset single register | Store single setting |
| 10 | 16 | Preset multiple registers | Store multiple settings |

### B.2.2 READ ACTUAL VALUES OR SETTINGS (FUNCTION CODE 03/04H)

This function code allows the master to read one or more consecutive data registers (actual values or settings) from a relay. The maximum number of registers that can be read in a single packet is 125. See the Modbus Memory Map table for exact details on the data registers.

Since some PLC implementations of Modbus only support one of function codes 03h and 04h. The UR interpretation allows either function code to be used for reading one or more consecutive data registers. The data starting address will determine the type of data being read. Function codes 03h and 04h are therefore identical.

The following table shows the format of the master and slave packets in Modbus RTU. Modbus TCP/IP ADUs have a MBAP instead of slave address, and CRC is in another stack layer. The example shows a master device requesting three register values starting at address 4050h from slave device 11h (17 decimal); the slave device responds with the values 40, 300, and 0 from registers 4050h, 4051h, and 4052h, respectively.

**Table B–4: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE**

| MASTER TRANSMISSION | |
|---|---|
| PACKET FORMAT | EXAMPLE (HEX) |
| SLAVE ADDRESS | 11 |
| FUNCTION CODE | 04 |
| DATA STARTING ADDRESS - high | 40 |
| DATA STARTING ADDRESS - low | 50 |
| NUMBER OF REGISTERS - high | 00 |
| NUMBER OF REGISTERS - low | 03 |
| CRC - low | A7 |
| CRC - high | 4A |

| SLAVE RESPONSE | |
|---|---|
| PACKET FORMAT | EXAMPLE (HEX) |
| SLAVE ADDRESS | 11 |
| FUNCTION CODE | 04 |
| BYTE COUNT | 06 |
| DATA #1 - high | 00 |
| DATA #1 - low | 28 |
| DATA #2 - high | 01 |
| DATA #2 - low | 2C |
| DATA #3 - high | 00 |
| DATA #3 - low | 00 |
| CRC - low | 0D |
| CRC - high | 60 |

### B.2.3 EXECUTE OPERATION (FUNCTION CODE 05H)

This function code allows the master to perform various operations in the relay. Available operations are shown in the Summary of Operation Codes table below.

The following table shows the format of the master and slave packets in Modbus RTU. Modbus TCP/IP ADUs have a MBAP instead of slave address, and CRC is in another stack layer. The example shows a master device requesting the slave device 11h (17 decimal) to perform a reset. The high and low code value bytes always have the values "FF" and "00" respectively and are a remnant of the original Modbus definition of this function code.



**Table B–5: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE**

| MASTER TRANSMISSION | |
|---|---|
| **PACKET FORMAT** | **EXAMPLE (HEX)** |
| SLAVE ADDRESS | 11 |
| FUNCTION CODE | 05 |
| OPERATION CODE - high | 00 |
| OPERATION CODE - low | 01 |
| CODE VALUE - high | FF |
| CODE VALUE - low | 00 |
| CRC - low | DF |
| CRC - high | 6A |

| SLAVE RESPONSE | |
|---|---|
| **PACKET FORMAT** | **EXAMPLE (HEX)** |
| SLAVE ADDRESS | 11 |
| FUNCTION CODE | 05 |
| OPERATION CODE - high | 00 |
| OPERATION CODE - low | 01 |
| CODE VALUE - high | FF |
| CODE VALUE - low | 00 |
| CRC - low | DF |
| CRC - high | 6A |

**Table B–6: SUMMARY OF OPERATION CODES FOR FUNCTION 05H**

| OPERATION CODE (HEX) | DEFINITION | DESCRIPTION |
|---|---|---|
| 0000 | NO OPERATION | Does not do anything. |
| 0001 | RESET | Performs the same function as the faceplate RESET key. |
| 0005 | CLEAR EVENT RECORDS | Performs the same function as the faceplate **CLEAR EVENT RECORDS** menu command. |
| 0006 | CLEAR OSCILLOGRAPHY | Clears all oscillography records. |
| 1000 to 103F | VIRTUAL IN 1 to 64 ON/OFF | Sets the states of Virtual Inputs 1 to 64 either "ON" or "OFF". |

### B.2.4 STORE SINGLE SETTING (FUNCTION CODE 06H)

This function code allows the master to modify the contents of a single setting register in an relay. Setting registers are always 16 bit (two byte) values transmitted high order byte first. The following table shows the format of the master and slave packets in Modbus RTU. Modbus TCP/IP ADUs have a MBAP instead of slave address, and CRC is in another stack layer. The example shows a master device storing the value 200 at memory map address 4051h to slave device 11h (17 dec).

**Table B–7: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE**

| MASTER TRANSMISSION | |
|---|---|
| **PACKET FORMAT** | **EXAMPLE (HEX)** |
| SLAVE ADDRESS | 11 |
| FUNCTION CODE | 06 |
| DATA STARTING ADDRESS - high | 40 |
| DATA STARTING ADDRESS - low | 51 |
| DATA - high | 00 |
| DATA - low | C8 |
| CRC - low | CE |
| CRC - high | DD |

| SLAVE RESPONSE | |
|---|---|
| **PACKET FORMAT** | **EXAMPLE (HEX)** |
| SLAVE ADDRESS | 11 |
| FUNCTION CODE | 06 |
| DATA STARTING ADDRESS - high | 40 |
| DATA STARTING ADDRESS - low | 51 |
| DATA - high | 00 |
| DATA - low | C8 |
| CRC - low | CE |
| CRC - high | DD |

### B.2.5 STORE MULTIPLE SETTINGS (FUNCTION CODE 10H)

This function code allows the master to modify the contents of a one or more consecutive setting registers in a relay. Setting registers are 16-bit (two byte) values transmitted high order byte first. The maximum number of setting registers that can be stored in a single packet is 123. The following table shows the format of the master and slave packets in Modbus RTU. Modbus TCP/IP ADUs have a MBAP instead of slave address, and CRC is in another stack layer. The example shows a master device storing the value 200 at memory map address 4051h, and the value 1 at memory map address 4052h to slave device 11h (17 decimal).



**Table B–8: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE**

| MASTER TRANSMISSION | |
|---|---|
| **PACKET FORMAT** | **EXAMPLE (HEX)** |
| SLAVE ADDRESS | 11 |
| FUNCTION CODE | 10 |
| DATA STARTING ADDRESS - hi | 40 |
| DATA STARTING ADDRESS - lo | 51 |
| NUMBER OF SETTINGS - hi | 00 |
| NUMBER OF SETTINGS - lo | 02 |
| BYTE COUNT | 04 |
| DATA #1 - high order byte | 00 |
| DATA #1 - low order byte | C8 |
| DATA #2 - high order byte | 00 |
| DATA #2 - low order byte | 01 |
| CRC - low order byte | 12 |
| CRC - high order byte | 62 |

| SLAVE RESPONSE | |
|---|---|
| **PACKET FORMAT** | **EXAMPLE (HEX)** |
| SLAVE ADDRESS | 11 |
| FUNCTION CODE | 10 |
| DATA STARTING ADDRESS - hi | 40 |
| DATA STARTING ADDRESS - lo | 51 |
| NUMBER OF SETTINGS - hi | 00 |
| NUMBER OF SETTINGS - lo | 02 |
| CRC - lo | 07 |
| CRC - hi | 64 |

### B.2.6 EXCEPTION RESPONSES

Programming or operation errors usually happen because of illegal data in a packet. These errors result in an exception response from the slave. The slave detecting one of these errors sends a response packet to the master with the high order bit of the function code set to 1.

The following table shows the format of the master and slave packets in Modbus RTU. Modbus TCP/IP ADUs have a MBAP instead of slave address, and CRC is in another stack layer. The example shows a master device sending the unsupported function code 39h to slave device 11h.

**Table B–9: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE**

| MASTER TRANSMISSION | |
|---|---|
| **PACKET FORMAT** | **EXAMPLE (HEX)** |
| SLAVE ADDRESS | 11 |
| FUNCTION CODE | 39 |
| CRC - low order byte | CD |
| CRC - high order byte | F2 |

| SLAVE RESPONSE | |
|---|---|
| **PACKET FORMAT** | **EXAMPLE (HEX)** |
| SLAVE ADDRESS | 11 |
| FUNCTION CODE | B9 |
| ERROR CODE | 01 |
| CRC - low order byte | 93 |
| CRC - high order byte | 95 |

#### a) DESCRIPTION

The UR relay has a generic file transfer facility, meaning that you use the same method to obtain all of the different types of files from the unit. The Modbus registers that implement file transfer are found in the "Modbus File Transfer (Read/Write)" and "Modbus File Transfer (Read Only)" modules, starting at address 3100h in the Modbus Memory Map. To read a file from the UR relay, use the following steps:

1. Write the filename to the "Name of file to read" register using a write multiple registers command. If the name is shorter than 80 characters, you may write only enough registers to include all the text of the filename. Filenames are not case sensitive.
2. Repeatedly read all the registers in "Modbus File Transfer (Read Only)" using a read multiple registers command. It is not necessary to read the entire data block, since the UR relay will remember which was the last register you read. The "position" register is initially zero and thereafter indicates how many bytes (2 times the number of registers) you have read so far. The "size of..." register indicates the number of bytes of data remaining to read, to a maximum of 244.
3. Keep reading until the "size of..." register is smaller than the number of bytes you are transferring. This condition indicates end of file. Discard any bytes you have read beyond the indicated block size.
4. If you need to re-try a block, read only the "size of.." and "block of data", without reading the position. The file pointer is only incremented when you read the position register, so the same data block will be returned as was read in the previous operation. On the next read, check to see if the position is where you expect it to be, and discard the previous block if it is not (this condition would indicate that the UR relay did not process your original read request).

The UR relay retains connection-specific file transfer information, so files may be read simultaneously on multiple Modbus connections.

#### b) OTHER PROTOCOLS

All the files available via Modbus may also be retrieved using the standard file transfer mechanisms in other protocols (for example, TFTP or MMS).

#### c) COMTRADE, OSCILLOGRAPHY, AND DATA LOGGER FILES

Oscillography and data logger files are formatted using the COMTRADE file format per IEEE C37.111-1999 Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems. The files can be obtained in either text or binary COMTRADE format.

#### d) READING OSCILLOGRAPHY FILES

Familiarity with the oscillography feature is required to understand the following description. See the *Oscillography* section in chapter 5 for details.

The "Oscillography Number of Triggers" register increments by one every time a new oscillography file is triggered (captured) and cleared to zero when oscillography data is cleared. When a new trigger occurs, the associated oscillography file is assigned a file identifier number equal to the incremented value of this register; the newest file number is equal to the "Oscillography Number of Triggers" register. This register can be used to determine if any new data has been captured by periodically reading it to see if the value has changed; if the number has increased then new data is available.

The "Oscillography Number of Records" register specifies the maximum number of files (and the number of cycles of data per file) that can be stored in memory of the relay. The "Oscillography Available Records" register specifies the actual number of files that are stored and still available to be read out of the relay.

Writing “Yes” (that is, the value 1) to the "Oscillography Clear Data" register clears oscillography data files, clears both the "Oscillography Number of Triggers" and "Oscillography Available Records" registers to zero, and sets the "Oscillography Last Cleared Date" to the present date and time.

To read binary COMTRADE oscillography files, read the following filenames:

`OSCnnnn.CFG` and `OSCnnn.DAT`

#### e) READING DATA LOGGER FILES

Familiarity with the data logger feature is required to understand this description. Refer to the Data Logger section of Chapter 5 for details. To read the entire data logger in binary COMTRADE format, read the following files.

datalog.cfg and datalog.dat

To read the entire data logger in ASCII COMTRADE format, read the following files.

dataloga.cfg and dataloga.dat

To limit the range of records to be returned in the COMTRADE files, append the following to the filename before writing it:

- To read from a specific time to the end of the log: <space> startTime
- To read a specific range of records: <space> startTime <space> endTime
- Replace <startTime> and <endTime> with the number of seconds since Jan. 1 1970 as numeric text

### f) READING EVENT RECORDER FILES

To read the entire event recorder contents in ASCII format (the only available format), use the following filename:

EVT.TXT

To read from a specific record to the end of the log, use the following filename:

EVTnnn.TXT (replace nnn with the desired starting record number)

To read from a specific record to another specific record, use the following filename:

EVT.TXT xxxxx yyyyy (replace xxxxx with the starting record number and yyyyy with the ending record number)

### g) READING FAULT REPORT FILES

Fault report data has been available via the L30 file retrieval mechanism since UR firmware version 2.00. The file name is **faultReport#####.htm**. The ##### refers to the fault report record number. The fault report number is a counter that indicates how many fault reports have ever occurred. The counter rolls over at a value of 65535. Only the last ten fault reports are available for retrieval; a request for a non-existent fault report file will yield a null file. The current value fault report counter is available in “Number of Fault Reports” Modbus register at location 0x3020.

For example, if 14 fault reports have occurred then the files faultReport5.htm, faultReport6.htm, up to faultReport14.htm are available to be read. The expected use of this feature has an external master periodically polling the “Number of Fault Reports' register. If the value changes, then the master reads all the new files.

The contents of the file is in standard HTML notation and can be viewed via any commercial browser.

### B.4.1 MODBUS MEMORY MAP

The table provides the Modbus memory map. The addresses in the table are expressed in hexadecimal. The particular registers actually present depend on the UR product and on the order codes software and module options.

The map is also viewable in a web browser. In the browser, enter the IP address of the UR and click the option.

In the table, "Grouped Setting" refers to content in the **Settings > Grouped Elements > Group** menus.

The data format tables that follow the memory map provide more information for some entries.



**Table B–10: MODBUS MEMORY MAP (Sheet 1 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| **Product Information (Read Only)** | | | | | | |
| 0000 | UR Product Type | 0 to 65535 | --- | 1 | F001 | 0 |
| 0002 | Product Version | 0 to 655.35 | --- | 0.01 | F001 | 1 |
| 0003 | Boot Configuration Register | 0 to 65535 | --- | 1 | F001 | 0 |
| **Product Information (Read Only -- Written by Factory)** | | | | | | |
| 0010 | Serial Number | --- | --- | --- | F203 | “0” |
| 0020 | Manufacturing Date | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 0022 | Modification Number | 0 to 65535 | --- | 1 | F001 | 0 |
| 0040 | Order Code | --- | --- | --- | F204 | “Order Code x” |
| 0090 | Ethernet MAC Address | --- | --- | --- | F072 | 0 |
| 0093 | Reserved (13 items) | --- | --- | --- | F001 | 0 |
| 00A0 | CPU Module Serial Number | --- | --- | --- | F203 | (none) |
| 00B0 | CPU Supplier Serial Number | --- | --- | --- | F203 | (none) |
| 00C0 | Ethernet Sub Module Serial Number (8 items) | --- | --- | --- | F203 | (none) |
| **Product Information (Read Only -- Written by Factory)** | | | | | | |
| 0110 | FPGA Version | --- | --- | --- | F206 | (none) |
| 0113 | FPGA Date | 0 to 4294967295 | -- | 1 | F050 | 0 |
| **Product Information (Read/Write)** | | | | | | |
| 0120 | Undefined | 0 to 1 | --- | 1 | F102 | 0 |
| **Self Test Targets (Read Only)** | | | | | | |
| 0200 | Self Test States (4 items) | 0 to 4294967295 | 0 | 1 | F143 | 0 |
| **Front Panel (Read Only)** | | | | | | |
| 0208 | LED Column *n* State, *n* = 1 to 10 (10 items) | 0 to 65535 | --- | 1 | F501 | 0 |
| 0220 | Display Message | --- | --- | --- | F204 | (none) |
| 0248 | Last Key Pressed | 0 to 47 | --- | 1 | F530 | 0 (None) |
| **Keypress Emulation (Read/Write)** | | | | | | |
| 0280 | Simulated keypress -- write zero before each keystroke | 0 to 46 | --- | 1 | F190 | 0 (No key -- use between real keys) |
| **Virtual Input Commands (Read/Write Command) (64 modules)** | | | | | | |
| 0400 | Virtual Input 1 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0401 | Virtual Input 2 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0402 | Virtual Input 3 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0403 | Virtual Input 4 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0404 | Virtual Input 5 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0405 | Virtual Input 6 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0406 | Virtual Input 7 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0407 | Virtual Input 8 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0408 | Virtual Input 9 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0409 | Virtual Input 10 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 040A | Virtual Input 11 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 040B | Virtual Input 12 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 040C | Virtual Input 13 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 040D | Virtual Input 14 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 040E | Virtual Input 15 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |

**Table B–10: MODBUS MEMORY MAP (Sheet 2 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 040F | Virtual Input 16 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0410 | Virtual Input 17 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0411 | Virtual Input 18 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0412 | Virtual Input 19 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0413 | Virtual Input 20 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0414 | Virtual Input 21 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0415 | Virtual Input 22 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0416 | Virtual Input 23 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0417 | Virtual Input 24 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0418 | Virtual Input 25 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0419 | Virtual Input 26 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 041A | Virtual Input 27 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 041B | Virtual Input 28 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 041C | Virtual Input 29 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 041D | Virtual Input 30 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 041E | Virtual Input 31 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 041F | Virtual Input 32 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0420 | Virtual Input 33 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0421 | Virtual Input 34 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0422 | Virtual Input 35 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0423 | Virtual Input 36 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0424 | Virtual Input 37 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0425 | Virtual Input 38 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0426 | Virtual Input 39 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0427 | Virtual Input 40 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0428 | Virtual Input 41 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0429 | Virtual Input 42 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 042A | Virtual Input 43 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 042B | Virtual Input 44 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 042C | Virtual Input 45 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 042D | Virtual Input 46 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 042E | Virtual Input 47 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 042F | Virtual Input 48 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0430 | Virtual Input 49 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0431 | Virtual Input 50 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0432 | Virtual Input 51 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0433 | Virtual Input 52 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0434 | Virtual Input 53 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0435 | Virtual Input 54 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0436 | Virtual Input 55 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0437 | Virtual Input 56 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0438 | Virtual Input 57 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 0439 | Virtual Input 58 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 043A | Virtual Input 59 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 043B | Virtual Input 60 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 043C | Virtual Input 61 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 043D | Virtual Input 62 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 043E | Virtual Input 63 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 043F | Virtual Input 64 State | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| **IEC103 Protocol Settings (Read/Write Setting)** | | | | | | |
| 0582 | IEC103 Common ASDU Address | 0 to 254 | --- | 1 | F001 | 0 |
| 0583 | IEC103 Sync Timeout | 1 to 1440 | min | 1 | F001 | 1 |
| **IEC 103 Binary Inputs (Read/Write Setting) (96 modules)** | | | | | | |
| 0584 | IEC103 Binary Input 1 FUN | 0 to 255 | --- | 1 | F001 | 0 |

**Table B–10: MODBUS MEMORY MAP (Sheet 3 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 0585 | IEC103 Binary Input 1 INF | 0 to 255 | --- | 1 | F001 | 0 |
| 0586 | IEC103 Binary Input 1 Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 0588 | ...Repeated for Binary Input 2 | | | | | |
| 058C | ...Repeated for Binary Input 3 | | | | | |
| 0590 | ...Repeated for Binary Input 4 | | | | | |
| 0594 | ...Repeated for Binary Input 5 | | | | | |
| 0598 | ...Repeated for Binary Input 6 | | | | | |
| 059C | ...Repeated for Binary Input 7 | | | | | |
| 05A0 | ...Repeated for Binary Input 8 | | | | | |
| 05A4 | ...Repeated for Binary Input 9 | | | | | |
| 05A8 | ...Repeated for Binary Input 10 | | | | | |
| 05AC | ...Repeated for Binary Input 11 | | | | | |
| 05B0 | ...Repeated for Binary Input 12 | | | | | |
| 05B4 | ...Repeated for Binary Input 13 | | | | | |
| 05B8 | ...Repeated for Binary Input 14 | | | | | |
| 05BC | ...Repeated for Binary Input 15 | | | | | |
| 05C0 | ...Repeated for Binary Input 16 | | | | | |
| 05C4 | ...Repeated for Binary Input 17 | | | | | |
| 05C8 | ...Repeated for Binary Input 18 | | | | | |
| 05CC | ...Repeated for Binary Input 19 | | | | | |
| 05D0 | ...Repeated for Binary Input 20 | | | | | |
| 05D4 | ...Repeated for Binary Input 21 | | | | | |
| 05D8 | ...Repeated for Binary Input 22 | | | | | |
| 05DC | ...Repeated for Binary Input 23 | | | | | |
| 05E0 | ...Repeated for Binary Input 24 | | | | | |
| 05E4 | ...Repeated for Binary Input 25 | | | | | |
| 05E8 | ...Repeated for Binary Input 26 | | | | | |
| 05EC | ...Repeated for Binary Input 27 | | | | | |
| 05F0 | ...Repeated for Binary Input 28 | | | | | |
| 05F4 | ...Repeated for Binary Input 29 | | | | | |
| 05F8 | ...Repeated for Binary Input 30 | | | | | |
| 05FC | ...Repeated for Binary Input 31 | | | | | |
| 0600 | ...Repeated for Binary Input 32 | | | | | |
| 0604 | ...Repeated for Binary Input 33 | | | | | |
| 0608 | ...Repeated for Binary Input 34 | | | | | |
| 060C | ...Repeated for Binary Input 35 | | | | | |
| 0610 | ...Repeated for Binary Input 36 | | | | | |
| 0614 | ...Repeated for Binary Input 37 | | | | | |
| 0618 | ...Repeated for Binary Input 38 | | | | | |
| 061C | ...Repeated for Binary Input 39 | | | | | |
| 0620 | ...Repeated for Binary Input 40 | | | | | |
| 0624 | ...Repeated for Binary Input 41 | | | | | |
| 0628 | ...Repeated for Binary Input 42 | | | | | |
| 062C | ...Repeated for Binary Input 43 | | | | | |
| 0630 | ...Repeated for Binary Input 44 | | | | | |
| 0634 | ...Repeated for Binary Input 45 | | | | | |
| 0638 | ...Repeated for Binary Input 46 | | | | | |
| 063C | ...Repeated for Binary Input 47 | | | | | |
| 0640 | ...Repeated for Binary Input 48 | | | | | |
| 0644 | ...Repeated for Binary Input 49 | | | | | |
| 0648 | ...Repeated for Binary Input 50 | | | | | |
| 064C | ...Repeated for Binary Input 51 | | | | | |
| 0650 | ...Repeated for Binary Input 52 | | | | | |
| 0654 | ...Repeated for Binary Input 53 | | | | | |

**Table B–10: MODBUS MEMORY MAP (Sheet 4 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 0658 | ...Repeated for Binary Input 54 | | | | | |
| 065C | ...Repeated for Binary Input 55 | | | | | |
| 0660 | ...Repeated for Binary Input 56 | | | | | |
| 0664 | ...Repeated for Binary Input 57 | | | | | |
| 0668 | ...Repeated for Binary Input 58 | | | | | |
| 066C | ...Repeated for Binary Input 59 | | | | | |
| 0670 | ...Repeated for Binary Input 60 | | | | | |
| 0674 | ...Repeated for Binary Input 61 | | | | | |
| 0678 | ...Repeated for Binary Input 62 | | | | | |
| 067C | ...Repeated for Binary Input 63 | | | | | |
| 0680 | ...Repeated for Binary Input 64 | | | | | |
| 0684 | ...Repeated for Binary Input 65 | | | | | |
| 0688 | ...Repeated for Binary Input 66 | | | | | |
| 068C | ...Repeated for Binary Input 67 | | | | | |
| 0690 | ...Repeated for Binary Input 68 | | | | | |
| 0694 | ...Repeated for Binary Input 69 | | | | | |
| 0698 | ...Repeated for Binary Input 70 | | | | | |
| 069C | ...Repeated for Binary Input 71 | | | | | |
| 06A0 | ...Repeated for Binary Input 72 | | | | | |
| 06A4 | ...Repeated for Binary Input 73 | | | | | |
| 06A8 | ...Repeated for Binary Input 74 | | | | | |
| 06AC | ...Repeated for Binary Input 75 | | | | | |
| 06B0 | ...Repeated for Binary Input 76 | | | | | |
| 06B4 | ...Repeated for Binary Input 77 | | | | | |
| 06B8 | ...Repeated for Binary Input 78 | | | | | |
| 06BC | ...Repeated for Binary Input 79 | | | | | |
| 06C0 | ...Repeated for Binary Input 80 | | | | | |
| 06C4 | ...Repeated for Binary Input 81 | | | | | |
| 06C8 | ...Repeated for Binary Input 82 | | | | | |
| 06CC | ...Repeated for Binary Input 83 | | | | | |
| 06D0 | ...Repeated for Binary Input 84 | | | | | |
| 06D4 | ...Repeated for Binary Input 85 | | | | | |
| 06D8 | ...Repeated for Binary Input 86 | | | | | |
| 06DC | ...Repeated for Binary Input 87 | | | | | |
| 06E0 | ...Repeated for Binary Input 88 | | | | | |
| 06E4 | ...Repeated for Binary Input 89 | | | | | |
| 06E8 | ...Repeated for Binary Input 90 | | | | | |
| 06EC | ...Repeated for Binary Input 91 | | | | | |
| 06F0 | ...Repeated for Binary Input 92 | | | | | |
| 06F4 | ...Repeated for Binary Input 93 | | | | | |
| 06F8 | ...Repeated for Binary Input 94 | | | | | |
| 06FC | ...Repeated for Binary Input 95 | | | | | |
| 0700 | ...Repeated for Binary Input 96 | | | | | |
| **IEC 103 ASDU Settings (Read/Write Setting) (4 modules)** | | | | | | |
| 0704 | IEC103 ASDU1 TYP | 0 to 1 | --- | 1 | F630 | 1(9) |
| 0705 | IEC103 ASDU 1 FUN | 0 to 255 | --- | 1 | F001 | 0 |
| 0706 | IEC103 ASDU 1 INF | 0 to 255 | --- | 1 | F001 | 0 |
| 0707 | IEC103 ASDU 1 Scan Timeout | 0 to 1000 | --- | 1 | F001 | 0 |
| 0708 | IEC103 ASDU 1 Analog Param 1 | 0 to 65535 | --- | 1 | F600 | 0 |
| 0709 | IEC103 ASDU 1 Analog Factor 1 | 0 to 65.535 | --- | 0.001 | F001 | 1000 |
| 070A | IEC103 ASDU 1 Analog Offset 1 | -32768 to 32767 | --- | 1 | F002 | 0 |
| 070B | IEC103 ASDU 1 Analog Param 2 | 0 to 65535 | --- | 1 | F600 | 0 |
| 070C | IEC103 ASDU 1 Analog Factor 2 | 0 to 65.535 | --- | 0.001 | F001 | 1000 |
| 070D | IEC103 ASDU 1 Analog Offset 2 | -32768 to 32767 | --- | 1 | F002 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 5 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 070E | IEC103 ASDU 1 Analog Param 3 | 0 to 65535 | --- | 1 | F600 | 0 |
| 070F | IEC103 ASDU 1 Analog Factor 3 | 0 to 65.535 | --- | 0.001 | F001 | 1000 |
| 0710 | IEC103 ASDU 1 Analog Offset 3 | -32768 to 32767 | --- | 1 | F002 | 0 |
| 0711 | IEC103 ASDU 1 Analog Param 4 | 0 to 65535 | --- | 1 | F600 | 0 |
| 0712 | IEC103 ASDU 1 Analog Factor 4 | 0 to 65.535 | --- | 0.001 | F001 | 1000 |
| 0713 | IEC103 ASDU 1 Analog Offset 4 | -32768 to 32767 | --- | 1 | F002 | 0 |
| 0714 | IEC103 ASDU 1 Analog Param 5 | 0 to 65535 | --- | 1 | F600 | 0 |
| 0715 | IEC103 ASDU 1 Analog Factor 5 | 0 to 65.535 | --- | 0.001 | F001 | 1000 |
| 0716 | IEC103 ASDU 1 Analog Offset 5 | -32768 to 32767 | --- | 1 | F002 | 0 |
| 0717 | IEC103 ASDU 1 Analog Param 6 | 0 to 65535 | --- | 1 | F600 | 0 |
| 0718 | IEC103 ASDU 1 Analog Factor 6 | 0 to 65.535 | --- | 0.001 | F001 | 1000 |
| 0719 | IEC103 ASDU 1 Analog Offset 6 | -32768 to 32767 | --- | 1 | F002 | 0 |
| 071A | IEC103 ASDU 1 Analog Param 7 | 0 to 65535 | --- | 1 | F600 | 0 |
| 071B | IEC103 ASDU 1 Analog Factor 7 | 0 to 65.535 | --- | 0.001 | F001 | 1000 |
| 071C | IEC103 ASDU 1 Analog Offset 7 | -32768 to 32767 | --- | 1 | F002 | 0 |
| 071D | IEC103 ASDU 1 Analog Param 8 | 0 to 65535 | --- | 1 | F600 | 0 |
| 071E | IEC103 ASDU 1 Analog Factor 8 | 0 to 65.535 | --- | 0.001 | F001 | 1000 |
| 071F | IEC103 ASDU 1 Analog Offset 8 | -32768 to 32767 | --- | 1 | F002 | 0 |
| 0720 | IEC103 ASDU 1 Analog Param 9 | 0 to 65535 | --- | 1 | F600 | 0 |
| 0721 | IEC103 ASDU 1 Analog Factor 9 | 0 to 65.535 | --- | 0.001 | F001 | 1000 |
| 0722 | IEC103 ASDU 1 Analog Offset 9 | -32768 to 32767 | --- | 1 | F002 | 0 |
| 0723 | ...Repeated for IEC103 ASDU 2 | | | | | |
| 0742 | ...Repeated for IEC103 ASDU 3 | | | | | |
| 0761 | ...Repeated for IEC103 ASDU 4 | | | | | |
| **IEC 103 Commands (Read/Write Setting) (32 modules)** | | | | | | |
| 0780 | IEC103 Command 1 FUN | 0 to 255 | --- | 1 | F001 | 0 |
| 0781 | IEC103 Command 1 INF | 0 to 255 | --- | 1 | F001 | 0 |
| 0782 | IEC103 Command 1 Param ON | 0 to 64 | --- | 1 | F631 | 0 (OFF) |
| 0783 | IEC103 Command 1 Param OFF | 0 to 64 | --- | 1 | F631 | 0 (OFF) |
| 0784 | ...Repeated for IEC103 Command 2 | | | | | |
| 0788 | ...Repeated for IEC103 Command 3 | | | | | |
| 078C | ...Repeated for IEC103 Command 4 | | | | | |
| 0790 | ...Repeated for IEC103 Command 5 | | | | | |
| 0794 | ...Repeated for IEC103 Command 6 | | | | | |
| 0798 | ...Repeated for IEC103 Command 7 | | | | | |
| 079C | ...Repeated for IEC103 Command 8 | | | | | |
| 07A0 | ...Repeated for IEC103 Command 9 | | | | | |
| 07A4 | ...Repeated for IEC103 Command 10 | | | | | |
| 07A8 | ...Repeated for IEC103 Command 11 | | | | | |
| 07AC | ...Repeated for IEC103 Command 12 | | | | | |
| 07B0 | ...Repeated for IEC103 Command 13 | | | | | |
| 07B4 | ...Repeated for IEC103 Command 14 | | | | | |
| 07B8 | ...Repeated for IEC103 Command 15 | | | | | |
| 07BC | ...Repeated for IEC103 Command 16 | | | | | |
| 07C0 | ...Repeated for IEC103 Command 17 | | | | | |
| 07C4 | ...Repeated for IEC103 Command 18 | | | | | |
| 07C8 | ...Repeated for IEC103 Command 19 | | | | | |
| 07CC | ...Repeated for IEC103 Command 20 | | | | | |
| 07D0 | ...Repeated for IEC103 Command 21 | | | | | |
| 07D4 | ...Repeated for IEC103 Command 22 | | | | | |
| 07D8 | ...Repeated for IEC103 Command 23 | | | | | |
| 07DC | ...Repeated for IEC103 Command 24 | | | | | |
| 07E0 | ...Repeated for IEC103 Command 25 | | | | | |
| 07E4 | ...Repeated for IEC103 Command 26 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 6 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 07E8 | ...Repeated for IEC103 Command 27 | | | | | |
| 07EC | ...Repeated for IEC103 Command 28 | | | | | |
| 07F0 | ...Repeated for IEC103 Command 29 | | | | | |
| 07F4 | ...Repeated for IEC103 Command 30 | | | | | |
| 07F8 | ...Repeated for IEC103 Command 31 | | | | | |
| 07FC | ...Repeated for IEC103 Command 32 | | | | | |
| **Digital Counter States Actual Values (Read Only Non-Volatile) (8 modules)** | | | | | | |
| 0800 | Digital Counter 1 Value | -2147483647 to 2147483647 | --- | 1 | F004 | 0 |
| 0802 | Digital Counter 1 Frozen | -2147483647 to 2147483647 | --- | 1 | F004 | 0 |
| 0804 | Digital Counter 1 Frozen Time Stamp | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 0806 | Digital Counter 1 Frozen Time Stamp µs (microsecond part of time stamp) | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 0808 | ...Repeated for Digital Counter 2 | | | | | |
| 0810 | ...Repeated for Digital Counter 3 | | | | | |
| 0818 | ...Repeated for Digital Counter 4 | | | | | |
| 0820 | ...Repeated for Digital Counter 5 | | | | | |
| 0828 | ...Repeated for Digital Counter 6 | | | | | |
| 0830 | ...Repeated for Digital Counter 7 | | | | | |
| 0838 | ...Repeated for Digital Counter 8 | | | | | |
| **FlexStates (Read Only)** | | | | | | |
| 0900 | FlexState Bits (16 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| **Element States (Read Only)** | | | | | | |
| 1000 | Element Operate States (64 items) | 0 to 65535 | --- | 1 | F502 | 0 |
| **User Displays Actuals (Read Only)** | | | | | | |
| 1080 | Formatted user-definable displays (16 items) | --- | --- | --- | F200 | (none) |
| **Modbus User Map Actuals (Read Only)** | | | | | | |
| 1200 | User Map Values (256 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| **Element Targets (Read Only)** | | | | | | |
| 14E0 | Target Sequence | 0 to 65535 | --- | 1 | F001 | 0 |
| 14E1 | Number of Targets | 0 to 65535 | --- | 1 | F001 | 0 |
| **Element Targets (Read/Write)** | | | | | | |
| 14E2 | Target to Read | 0 to 65535 | --- | 1 | F001 | 0 |
| **Element Targets (Read Only)** | | | | | | |
| 14E3 | Target Message | --- | --- | --- | F200 | "." |
| **Contact Input/Output States (Read Only)** | | | | | | |
| 1500 | Contact Input States (6 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 1508 | Virtual Input States (8 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 1510 | Contact Output States (4 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 1518 | Contact Output Current States (4 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 1520 | Contact Output Voltage States (4 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 1528 | Virtual Output States (6 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 1530 | Contact Output Detectors (4 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| **Remote Input/Output States (Read Only)** | | | | | | |
| 1540 | Remote Device States (2 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 1542 | Remote Input States (4 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 1550 | Remote Devices Online | 0 to 1 | --- | 1 | F126 | 0 (No) |
| 1551 | Remote Double-Point Status Input 1 State | 0 to 3 | --- | 1 | F605 | 3 (Bad) |
| 1552 | Remote Double-Point Status Input 2 State | 0 to 3 | --- | 1 | F605 | 3 (Bad) |
| 1553 | Remote Double-Point Status Input 3 State | 0 to 3 | --- | 1 | F605 | 3 (Bad) |
| 1554 | Remote Double-Point Status Input 4 State | 0 to 3 | --- | 1 | F605 | 3 (Bad) |
| 1555 | Remote Double-Point Status Input 5 State | 0 to 3 | --- | 1 | F605 | 3 (Bad) |
| **Direct Input/Output States (Read Only)** | | | | | | |
| 15A0 | Direct Input 1-1 State (8 items) | 0 to 1 | --- | 1 | F108 | 0 (Off) |

### Table B–10: MODBUS MEMORY MAP (Sheet 7 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 15A8 | Direct Input 1-2 State (8 items) | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 15B0 | Direct Input 1 State | 0 to 65535 | --- | 1 | F500 | 0 |
| 15B1 | Direct Input 2 State | 0 to 65535 | --- | 1 | F500 | 0 |
| **Field Unit Input/Output States (Read Only)** | | | | | | |
| 15E0 | Field Unit Contact Input States (3 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 15E3 | Field Unit Contact Input Output Operand States (8 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 15EB | Field Contact Output Physical States (8 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 15F3 | Field Contact Output Current States (8 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 15FB | Field Contact Output Physical States (8 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 1603 | Field Shared Input States | 0 to 65535 | --- | 1 | F500 | 0 |
| 1604 | Field Shared Input Channel States | 0 to 65535 | --- | 1 | F500 | 0 |
| 1605 | Field Shared Input Test States | 0 to 65535 | --- | 1 | F500 | 0 |
| 1606 | Field Shared Output Operand States | 0 to 65535 | --- | 1 | F500 | 0 |
| 1607 | Field Latching Output Open Operand States | 0 to 65535 | --- | 1 | F500 | 0 |
| 1608 | Field Latching Output Close Operand States | 0 to 65535 | --- | 1 | F500 | 0 |
| 1609 | Field Latching Output Open Driver States | 0 to 65535 | --- | 1 | F500 | 0 |
| 160A | Field Latching Output Close Driver States | 0 to 65535 | --- | 1 | F500 | 0 |
| 160B | Field Latching Output Physical States | 0 to 65535 | --- | 1 | F500 | 0 |
| 160C | Field Unit Online/Offline States | 0 to 65535 | --- | 1 | F500 | 0 |
| 160D | Field RTD Input Trouble States | 0 to 65535 | --- | 1 | F500 | 0 |
| 160E | Field Transducer Input Trouble States | 0 to 65535 | --- | 1 | F500 | 0 |
| **Ethernet Fibre Channel Status (Read Only)** | | | | | | |
| 1610 | Ethernet Primary Fibre Channel Status | 0 to 2 | --- | 1 | F134 | 0 (Fail) |
| 1611 | Ethernet Secondary Fibre Channel Status | 0 to 2 | --- | 1 | F134 | 0 (Fail) |
| 1612 | Ethernet Tertiary Fibre Channel Status | 0 to 2 | --- | 1 | F134 | 0 (Fail) |
| **Data Logger Actual Values (Read Only)** | | | | | | |
| 1618 | Data Logger Channel Count | 0 to 16 | channel | 1 | F001 | 0 |
| 1619 | Time of Oldest Available Samples | 0 to 4294967295 | seconds | 1 | F050 | 0 |
| 161B | Time of Newest Available Samples | 0 to 4294967295 | seconds | 1 | F050 | 0 |
| 161D | Data Logger Duration | 0 to 999.9 | days | 0.1 | F001 | 0 |
| **87L Channel Status Actual Values (Read Only)** | | | | | | |
| 1638 | Channel 1 Asymmetry | -65.535 to 65.535 | ms | 0.001 | F004 | 0 |
| 163A | Channel 2 Asymmetry | -99.999 to 99.999 | ms | 0.001 | F004 | 0 |
| **Field Unit RTD Actuals (Read Only) (8 modules)** | | | | | | |
| 16C0 | Field RTD 1 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 16C1 | ...Repeated for Field RTD 2 | | | | | |
| 16C2 | ...Repeated for Field RTD 3 | | | | | |
| 16C3 | ...Repeated for Field RTD 4 | | | | | |
| 16C4 | ...Repeated for Field RTD 5 | | | | | |
| 16C5 | ...Repeated for Field RTD 6 | | | | | |
| 16C6 | ...Repeated for Field RTD 7 | | | | | |
| 16C7 | ...Repeated for Field RTD 8 | | | | | |
| **Field Unit Transducer Actuals (Read Only) (8 modules)** | | | | | | |
| 16C8 | Field Transducer 1 Value | -32.768 to 32.767 | --- | 0.001 | F004 | 0 |
| 16CA | ...Repeated for Field Transducer 2 | | | | | |
| 16CC | ...Repeated for Field Transducer 3 | | | | | |
| 16CE | ...Repeated for Field Transducer 4 | | | | | |
| 16D0 | ...Repeated for Field Transducer 5 | | | | | |
| 16D2 | ...Repeated for Field Transducer 6 | | | | | |
| 16D4 | ...Repeated for Field Transducer 7 | | | | | |
| 16D6 | ...Repeated for Field Transducer 8 | | | | | |
| **Source Current (Read Only) (2 modules)** | | | | | | |
| 1800 | Source 1 Phase A Current RMS | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 1802 | Source 1 Phase B Current RMS | 0 to 999999.999 | A | 0.001 | F060 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 8 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 1804 | Source 1 Phase C Current RMS | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 1806 | Source 1 Neutral Current RMS | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 1808 | Source 1 Phase A Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 180A | Source 1 Phase A Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 180B | Source 1 Phase B Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 180D | Source 1 Phase B Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 180E | Source 1 Phase C Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 1810 | Source 1 Phase C Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1811 | Source 1 Neutral Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 1813 | Source 1 Neutral Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1814 | Source 1 Ground Current RMS | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 1816 | Source 1 Ground Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 1818 | Source 1 Ground Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1819 | Source 1 Zero Sequence Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 181B | Source 1 Zero Sequence Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 181C | Source 1 Positive Sequence Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 181E | Source 1 Positive Sequence Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 181F | Source 1 Negative Sequence Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 1821 | Source 1 Negative Sequence Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1822 | Source 1 Differential Ground Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 1824 | Source 1 Differential Ground Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1825 | Reserved (27 items) | --- | --- | --- | F001 | 0 |
| 1840 | ...Repeated for Source 2 | | | | | |
| **Source Voltage (Read Only) (2 modules)** | | | | | | |
| 1A00 | Source 1 Phase AG Voltage RMS | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A02 | Source 1 Phase BG Voltage RMS | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A04 | Source 1 Phase CG Voltage RMS | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A06 | Source 1 Phase AG Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A08 | Source 1 Phase AG Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1A09 | Source 1 Phase BG Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A0B | Source 1 Phase BG Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1A0C | Source 1 Phase CG Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A0E | Source 1 Phase CG Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1A0F | Source 1 Phase AB or AC Voltage RMS | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A11 | Source 1 Phase BC or BA Voltage RMS | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A13 | Source 1 Phase CA or CB Voltage RMS | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A15 | Source 1 Phase AB or AC Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A17 | Source 1 Phase AB or AC Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1A18 | Source 1 Phase BC or BA Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A1A | Source 1 Phase BC or BA Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1A1B | Source 1 Phase CA or CB Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A1D | Source 1 Phase CA or CB Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1A1E | Source 1 Auxiliary Voltage RMS | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A20 | Source 1 Auxiliary Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A22 | Source 1 Auxiliary Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1A23 | Source 1 Zero Sequence Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A25 | Source 1 Zero Sequence Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1A26 | Source 1 Positive Sequence Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A28 | Source 1 Positive Sequence Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1A29 | Source 1 Negative Sequence Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 1A2B | Source 1 Negative Sequence Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 1A2C | Reserved (20 items) | --- | --- | --- | F001 | 0 |
| 1A40 | ...Repeated for Source 2 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 9 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| **Source Power (Read Only) (2 modules)** | | | | | | |
| 1C00 | Source 1 Three Phase Real Power | -1000000000000 to 1000000000000 | W | 0.001 | F060 | 0 |
| 1C02 | Source 1 Phase A Real Power | -1000000000000 to 1000000000000 | W | 0.001 | F060 | 0 |
| 1C04 | Source 1 Phase B Real Power | -1000000000000 to 1000000000000 | W | 0.001 | F060 | 0 |
| 1C06 | Source 1 Phase C Real Power | -1000000000000 to 1000000000000 | W | 0.001 | F060 | 0 |
| 1C08 | Source 1 Three Phase Reactive Power | -1000000000000 to 1000000000000 | var | 0.001 | F060 | 0 |
| 1C0A | Source 1 Phase A Reactive Power | -1000000000000 to 1000000000000 | var | 0.001 | F060 | 0 |
| 1C0C | Source 1 Phase B Reactive Power | -1000000000000 to 1000000000000 | var | 0.001 | F060 | 0 |
| 1C0E | Source 1 Phase C Reactive Power | -1000000000000 to 1000000000000 | var | 0.001 | F060 | 0 |
| 1C10 | Source 1 Three Phase Apparent Power | -1000000000000 to 1000000000000 | VA | 0.001 | F060 | 0 |
| 1C12 | Source 1 Phase A Apparent Power | -1000000000000 to 1000000000000 | VA | 0.001 | F060 | 0 |
| 1C14 | Source 1 Phase B Apparent Power | -1000000000000 to 1000000000000 | VA | 0.001 | F060 | 0 |
| 1C16 | Source 1 Phase C Apparent Power | -1000000000000 to 1000000000000 | VA | 0.001 | F060 | 0 |
| 1C18 | Source 1 Three Phase Power Factor | -0.999 to 1 | --- | 0.001 | F013 | 0 |
| 1C19 | Source 1 Phase A Power Factor | -0.999 to 1 | --- | 0.001 | F013 | 0 |
| 1C1A | Source 1 Phase B Power Factor | -0.999 to 1 | --- | 0.001 | F013 | 0 |
| 1C1B | Source 1 Phase C Power Factor | -0.999 to 1 | --- | 0.001 | F013 | 0 |
| 1C1C | Reserved (4 items) | --- | --- | --- | F001 | 0 |
| 1C20 | ...Repeated for Source 2 | | | | | |
| **Source Frequency (Read Only) (2 modules)** | | | | | | |
| 1D80 | Frequency for Source 1 | 2 to 90 | Hz | 0.001 | F003 | 0 |
| 1D82 | Frequency for Source 2 | 2 to 90 | Hz | 0.001 | F003 | 0 |
| **Breaker Arcing Current Actual Values (Read Only Non-Volatile) (2 modules)** | | | | | | |
| 21E0 | Breaker 1 Arcing Current Phase A | 0 to 99999999 | $kA^2$-cyc | 1 | F060 | 0 |
| 21E2 | Breaker 1 Arcing Current Phase B | 0 to 99999999 | $kA^2$-cyc | 1 | F060 | 0 |
| **Breaker Arcing Current Actual Values (Read Only Non-Volatile) (2 modules)** | | | | | | |
| 21E4 | Breaker 1 Arcing Current Phase C | 0 to 99999999 | $kA^2$-cyc | 1 | F060 | 0 |
| **Breaker Arcing Current Actual Values (Read Only Non-Volatile) (2 modules)** | | | | | | |
| 21E6 | Breaker 1 Operating Time Phase A | 0 to 65535 | ms | 1 | F001 | 0 |
| 21E7 | Breaker 1 Operating Time Phase B | 0 to 65535 | ms | 1 | F001 | 0 |
| **Breaker Arcing Current Actual Values (Read Only Non-Volatile) (2 modules)** | | | | | | |
| 21E8 | Breaker 1 Operating Time Phase C | 0 to 65535 | ms | 1 | F001 | 0 |
| 21E9 | Breaker 1 Operating Time | 0 to 65535 | ms | 1 | F001 | 0 |
| 21EA | ...Repeated for module number 2 | | | | | |
| **Breaker Arcing Current Actual Values (Read Only Non-Volatile) (2 modules)** | | | | | | |
| 21EE | ...Repeated for module number 2 | | | | | |
| **Breaker Arcing Current Actual Values (Read Only Non-Volatile) (2 modules)** | | | | | | |
| 21F1 | ...Repeated for module number 2 | | | | | |
| **Breaker Arcing Current Commands (Read/Write Command) (2 modules)** | | | | | | |
| 2224 | Breaker 1 Arcing Current Clear Command | 0 to 1 | --- | 1 | F126 | 0 (No) |
| 2225 | Breaker 2 Arcing Current Clear Command | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **Passwords Unauthorized Access (Read/Write Command)** | | | | | | |
| 2230 | Reset Unauthorized Access | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **Fault Location (Read Only) (5 modules)** | | | | | | |
| 2340 | Fault 1 Prefault Phase A Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2342 | Fault 1 Prefault Phase A Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 10 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 2343 | Fault 1 Prefault Phase B Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2345 | Fault 1 Prefault Phase B Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 2346 | Fault 1 Prefault Phase C Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2348 | Fault 1 Prefault Phase C Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 2349 | Fault 1 Prefault Phase A Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 234B | Fault 1 Prefault Phase A Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 234C | Fault 1 Prefault Phase B Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 234E | Fault 1 Prefault Phase B Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 234F | Fault 1 Prefault Phase C Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 2351 | Fault 1 Prefault Phase C Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 2352 | Fault 1 Phase A Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2354 | Fault 1 Phase A Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 2355 | Fault 1 Phase B Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2357 | Fault 1 Phase B Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 2358 | Fault 1 Phase C Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 235A | Fault 1 Phase C Current Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 235B | Fault 1 Phase A Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 235D | Fault 1 Phase A Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 235E | Fault 1 Phase B Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 2360 | Fault 1 Phase B Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 2361 | Fault 1 Phase C Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 2363 | Fault 1 Phase C Voltage Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 2364 | Fault 1 Type | 0 to 11 | --- | 1 | F148 | 0 (NA) |
| 2365 | Fault 1 Location based on Line length units (km or miles) | -3276.7 to 3276.7 | --- | 0.1 | F002 | 0 |
| 2366 | ...Repeated for Fault 2 | | | | | |
| 238C | ...Repeated for Fault 3 | | | | | |
| 23B2 | ...Repeated for Fault 4 | | | | | |
| 23D8 | ...Repeated for Fault 5 | | | | | |
| **Synchrocheck Actual Values (Read Only) (4 modules)** | | | | | | |
| 2400 | Synchrocheck 1 Delta Voltage | -1000000000000 to 1000000000000 | V | 1 | F060 | 0 |
| 2402 | Synchrocheck 1 Delta Frequency | 0 to 655.35 | Hz | 0.01 | F001 | 0 |
| 2403 | Synchrocheck 1 Delta Phase | 0 to 180 (not 0 to 359.9) | degrees | 0.1 | F001 | 0 |
| 2404 | ...Repeated for Synchrocheck 2 | | | | | |
| 2408 | ...Repeated for Synchrocheck 3 | | | | | |
| 240C | ...Repeated for Synchrocheck 4 | | | | | |
| **Autoreclose Status (Read Only) (2 modules)** | | | | | | |
| 2410 | Autoreclose 1 Count | 0 to 65535 | --- | 1 | F001 | 0 |
| 2411 | Autoreclose 2 Count | 0 to 65535 | --- | 1 | F001 | 0 |
| **Field Unit Raw Data Settings (Read/Write Setting)** | | | | | | |
| 2460 | Field Raw Data Port | 0 to 7 | --- | 1 | F244 | 6 (H1a) |
| 2461 | Field Raw Data Freeze | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **87L Current Differential Actual Values (Read Only)** | | | | | | |
| 2480 | Local IA Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2482 | Local IB Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2484 | Local IC Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2486 | Terminal 1 IA Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2488 | Terminal 1 IB Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 248A | Terminal 1 IC Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 248C | Terminal 2 IA Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 248E | Terminal 2 IB Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2490 | Terminal 2 IC Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2492 | Differential Current IA Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2494 | Differential Current IB Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 11 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 2496 | Differential Current IC Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2498 | Local IA Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 2499 | Local IB Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 249A | Local IC Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 249B | Terminal 1 IA Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 249C | Terminal 1 IB Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 249D | Terminal 1 IC Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 249E | Terminal 2 IA Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 249F | Terminal 2 IB Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 24A0 | Terminal 2 IC Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 24A1 | Differential Current IA Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 24A2 | Differential Current IB Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 24A3 | Differential Current IC Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 24A4 | Op Square Current IA | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24A6 | Op Square Current IB | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24A8 | Op Square Current IC | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24AA | Restraint Square Current IA | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24AC | Restraint Square Current IB | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24AE | Restraint Square Current IC | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24B0 | Restraint Current IA | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24B2 | Restraint Current IB | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24B4 | Restraint Current IC | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24B6 | Differential Current IG Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24B8 | Differential Current IG Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 24B9 | Restraint Current IG | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24BB | Local IG Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24BD | Local IG Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 24BE | Terminal 1 IG Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24C0 | Terminal 1 IG Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| 24C1 | Terminal 2 IG Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24C3 | Terminal 2 IG Angle | -359.9 to 0 | degrees | 0.1 | F002 | 0 |
| **87L Second Harmonics Differential Current (Read Only)** | | | | | | |
| 24CD | Line Current Differential (87L) Second Harmonic Iad Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24CF | Line Current Differential (87L) Second Harmonic Ibd magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 24D1 | Line Current Differential (87L) Second Harmonic Icd Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| **Remote Double-Point Status Inputs (Read/Write Setting Registers) (5 modules)** | | | | | | |
| 2540 | Remote Double-point Status Input 1 Device | 1 to 32 | --- | 1 | F001 | 1 |
| 2541 | Remote Double-point Status Input 1 Item | 0 to 64 | --- | 1 | F606 | 0 (None) |
| 2542 | Remote Double-point Status Input 1 Name | 1 to 64 | --- | 1 | F205 | "RemDPS Ip 1" |
| 2548 | Remote Double-point Status Input 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 2549 | ... Repeated for Remote Double-point Status Input 2 | | | | | |
| 2552 | ... Repeated for Remote Double-point Status Input 3 | | | | | |
| 255B | ... Repeated for Remote Double-point Status Input 4 | | | | | |
| 2564 | ... Repeated for Remote Double-point Status Input 5 | | | | | |
| **Phasor Measurement Unit Actual Values (Read Only)** | | | | | | |
| 256D | PMU 1 Phase A Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 256F | PMU Unit 1 Phase A Voltage Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 2570 | PMU 1 Phase B Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 2572 | PMU 1 Phase B Voltage Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 2573 | PMU 1 Phase C Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 2575 | PMU 1 Phase C Voltage Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 2576 | PMU 1 Auxiliary Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 12 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 2578 | PMU 1 Auxiliary Voltage Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 2579 | PMU 1 Positive Sequence Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 257B | PMU 1 Positive Sequence Voltage Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 257C | PMU 1 Negative Sequence Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 257E | PMU 1 Negative Sequence Voltage Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 257F | PMU 1 Zero Sequence Voltage Magnitude | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| 2581 | PMU 1 Zero Sequence Voltage Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 2582 | PMU 1 Phase A Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2584 | PMU 1 Phase A Current Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 2585 | PMU 1 Phase B Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2587 | PMU 1 Phase B Current Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 2588 | PMU 1 Phase C Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 258A | PMU 1 Phase C Current Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 258B | PMU 1 Ground Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 258D | PMU 1 Ground Current Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 258E | PMU 1 Positive Sequence Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2590 | PMU 1 Positive Sequence Current Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 2591 | PMU 1 Negative Sequence Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2593 | PMU 1 Negative Sequence Current Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 2594 | PMU 1 Zero Sequence Current Magnitude | 0 to 999999.999 | A | 0.001 | F060 | 0 |
| 2596 | PMU 1 Zero Sequence Current Angle | -180 to 180 | ° | 0.01 | F002 | 0 |
| 2597 | PMU 1 Frequency | 2 to 90 | Hz | 0.001 | F003 | 0 |
| 2599 | PMU 1 df/dt | -327.67 to 327.67 | Hz/s | 0.01 | F002 | 0 |
| 259A | PMU 1 Configuration Change Counter | 0 to 65535 | --- | 1 | F001 | 0 |
| 259B | Reserved (4 items) | 0 to 1 | --- | 1 | F001 | 0 |
| **Phasor Measurement Unit Integer (Read Only)** | | | | | | |
| 2699 | PMU 1 SOC Timestamp | 0 to 4294967295 | seconds | 1 | F003 | 0 |
| 269B | PMU 1 FRAMESEC Timestamp | 0 to 4294967295 | seconds | 1 | F003 | 0 |
| 269D | PMU 1 STAT Flags | 0 to 4294967295 | --- | 1 | F003 | 0 |
| **Phasor Measurement Unit Aggregator Actual Values (Read Only)** | | | | | | |
| 26BD | PMU 1 Aggregator PDU Size | --- | --- | --- | F001 | 0 |
| **IEC 61850 GGIO5 Configuration (Read/Write Setting Registers) (16 modules)** | | | | | | |
| 26D0 | IEC 61850 GGIO5 uinteger Input 1 Operand | --- | --- | --- | F612 | 0 |
| 26D1 | IEC 61850 GGIO5 uinteger Input 2 Operand | --- | --- | --- | F612 | 0 |
| 26D2 | IEC 61850 GGIO5 uinteger Input 3 Operand | --- | --- | --- | F612 | 0 |
| 26D3 | IEC 61850 GGIO5 uinteger Input 4 Operand | --- | --- | --- | F612 | 0 |
| 26D4 | IEC 61850 GGIO5 uinteger Input 5 Operand | --- | --- | --- | F612 | 0 |
| 26D5 | IEC 61850 GGIO5 uinteger Input 6 Operand | --- | --- | --- | F612 | 0 |
| 26D6 | IEC 61850 GGIO5 uinteger Input 7 Operand | --- | --- | --- | F612 | 0 |
| 26D7 | IEC 61850 GGIO5 uinteger Input 8 Operand | --- | --- | --- | F612 | 0 |
| 26D8 | IEC 61850 GGIO5 uinteger Input 9 Operand | --- | --- | --- | F612 | 0 |
| 26D9 | IEC 61850 GGIO5 uinteger Input 10 Operand | --- | --- | --- | F612 | 0 |
| 26DA | IEC 61850 GGIO5 uinteger Input 11 Operand | --- | --- | --- | F612 | 0 |
| 26DB | IEC 61850 GGIO5 uinteger Input 12 Operand | --- | --- | --- | F612 | 0 |
| 26DC | IEC 61850 GGIO5 uinteger Input 13 Operand | --- | --- | --- | F612 | 0 |
| 26DD | IEC 61850 GGIO5 uinteger Input 14 Operand | --- | --- | --- | F612 | 0 |
| 26DE | IEC 61850 GGIO5 uinteger Input 15 Operand | --- | --- | --- | F612 | 0 |
| 26DF | IEC 61850 GGIO5 uinteger Input 16 Operand | --- | --- | --- | F612 | 0 |
| **IEC 61850 Received Integers (Read Only Actual Values) (16 modules)** | | | | | | |
| 26F0 | IEC 61850 Received uinteger 1 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 26F2 | IEC 61850 Received uinteger 2 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 26F4 | IEC 61850 Received uinteger 3 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 26F6 | IEC 61850 Received uinteger 4 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 26F8 | IEC 61850 Received uinteger 5 | 0 to 4294967295 | --- | 1 | F003 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 13 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 26FA | IEC 61850 Received uinteger 6 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 26FC | IEC 61850 Received uinteger 7 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 26FE | IEC 61850 Received uinteger 8 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 2700 | IEC 61850 Received uinteger 9 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 2702 | IEC 61850 Received uinteger 10 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 2704 | IEC 61850 Received uinteger 11 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 2706 | IEC 61850 Received uinteger 12 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 2708 | IEC 61850 Received uinteger 13 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 270A | IEC 61850 Received uinteger 14 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 270C | IEC 61850 Received uinteger 15 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 270E | IEC 61850 Received uinteger 16 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| **Expanded FlexStates (Read Only)** | | | | | | |
| 2B00 | FlexStates, one per register (256 items) | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| **Expanded Contact Input/Output States (Read Only)** | | | | | | |
| 2D00 | Contact Input States, one per register (96 items) | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 2D80 | Contact Output States, one per register (64 items) | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 2E00 | Virtual Output States, one per register (96 items) | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| **Expanded Remote Input/Output Status (Read Only)** | | | | | | |
| 2F00 | Remote Device States, one per register (32 items) | 0 to 1 | --- | 1 | F155 | 0 (Offline) |
| 2F80 | Remote Input States, one per register (64 items) | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| **Oscillography Values (Read Only)** | | | | | | |
| 3000 | Oscillography Number of Triggers | 0 to 65535 | --- | 1 | F001 | 0 |
| 3001 | Oscillography Available Records | 0 to 65535 | --- | 1 | F001 | 0 |
| 3002 | Oscillography Last Cleared Date | 0 to 400000000 | --- | 1 | F050 | 0 |
| 3004 | Oscillography Number Of Cycles Per Record | 0 to 65535 | --- | 1 | F001 | 0 |
| **Oscillography Commands (Read/Write Command)** | | | | | | |
| 3005 | Oscillography Force Trigger | 0 to 1 | --- | 1 | F126 | 0 (No) |
| 3011 | Oscillography Clear Data | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **Oscillography Analog Values (Read Only)** | | | | | | |
| 3012 | Oscillography Number of Triggers | 0 to 32767 | --- | 1 | F001 | 0 |
| **Fault Report Indexing (Read Only Non-Volatile)** | | | | | | |
| 3020 | Number of Fault Reports | 0 to 65535 | --- | 1 | F001 | 0 |
| **Fault Report Actual Values (Read Only Non-Volatile) (15 modules)** | | | | | | |
| 3030 | Fault Report 1 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 3032 | Fault Report 2 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 3034 | Fault Report 3 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 3036 | Fault Report 4 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 3038 | Fault Report 5 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 303A | Fault Report 6 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 303C | Fault Report 7 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 303E | Fault Report 8 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 3040 | Fault Report 9 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 3042 | Fault Report 10 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 3044 | Fault Report 11 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 3046 | Fault Report 12 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 3048 | Fault Report 13 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 304A | Fault Report 14 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| 304C | Fault Report 15 Time | 0 to 4294967295 | --- | 1 | F050 | 0 |
| **Modbus File Transfer (Read/Write)** | | | | | | |
| 3100 | Name of file to read | --- | --- | --- | F204 | (none) |
| **Modbus File Transfer Values (Read Only)** | | | | | | |
| 3200 | Character position of current block within file | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 3202 | Size of currently-available data block | 0 to 65535 | --- | 1 | F001 | 0 |
| 3203 | Block of data from requested file (122 items) | 0 to 65535 | --- | 1 | F001 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 14 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| **Security (Read/Write Setting)** | | | | | | |
| 3280 | Administrator Alphanumeric Password Setting | --- | --- | --- | F202 | (none) |
| **Security (Read Only)** | | | | | | |
| 328A | Administrator Alphanumeric Password Status | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Security (Read/Write)** | | | | | | |
| 328B | Administrator Alphanumeric Password Entry | --- | --- | --- | F202 | (none) |
| **Security (Read/Write Setting)** | | | | | | |
| 3295 | Supervisor Alphanumeric Password Setting | --- | --- | --- | F202 | (none) |
| **Security (Read Only)** | | | | | | |
| 329F | Supervisor Alphanumeric Password Status | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Security (Read/Write)** | | | | | | |
| 32A0 | Supervisor Alphanumeric Password Entry | --- | --- | --- | F202 | (none) |
| **Security (Read/Write Setting)** | | | | | | |
| 32AA | Engineer Alphanumeric Password Setting | --- | --- | --- | F202 | (none) |
| **Security (Read Only)** | | | | | | |
| 32B4 | Engineer Alphanumeric Password Status | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Security (Read/Write)** | | | | | | |
| 32B5 | Engineer Alphanumeric Password Entry | --- | --- | --- | F202 | (none) |
| **Security (Read/Write Setting)** | | | | | | |
| 32BF | Operator Alphanumeric Password Setting | --- | --- | --- | F202 | (none) |
| **Security (Read Only)** | | | | | | |
| 32C9 | Operator Alphanumeric Password Status | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Security (Read/Write)** | | | | | | |
| 32CA | Operator Alphanumeric Password Entry | --- | --- | --- | F202 | (none) |
| **Security (Read/Write Setting)** | | | | | | |
| 32D4 | Observer Alphanumeric Password Setting | --- | --- | --- | F202 | (none) |
| **Security (Read Only)** | | | | | | |
| 32DE | Observer Alphanumeric Password Status | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Security (Read/Write)** | | | | | | |
| 32DF | Observer Alphanumeric Password Entry | --- | --- | 1 | F202 | (none) |
| **Security (Read Only)** | | | | | | |
| 32E9 | Reserved for password settings of future roles (63 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| 3328 | Security Status Indicator | 0 to 65535 | --- | 1 | F618 | 0 |
| **Security (Read/Write Setting)** | | | | | | |
| 3329 | Session Lockout | 0 to 99 | --- | 1 | F001 | 3 |
| 332A | Session Lockout Period | 0 to 9999 | min | 1 | F001 | 3 |
| 332B | Load Factory Defaults | 0 to 1 | --- | 1 | F126 | 0 (No) |
| 332C | Syslog Server IP Address | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 332E | Syslog Server Port Number | 1 to 65535 | --- | 1 | F001 | 514 |
| **Security Supervisory (Read/Write Setting)** | | | | | | |
| 3331 | Device Authentication Enable | 0 to 1 | --- | 1 | F126 | 1 (Yes) |
| 3332 | Supervisor Role Enable | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 3333 | Lock Relay | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 3334 | Factory Service Mode Enable | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 3335 | Failed Authentication Alarm Enable | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 3336 | Firmware Lock Alarm | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 3337 | Settings Lock Alarm | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 3338 | Bypass Access | 0 to 3 | --- | 1 | F628 | 0 (Disabled) |
| 333A | Serial Inactivity Timeout | 1 to 9999 | --- | 1 | F001 | 1 |
| **Security Command (Read/Write Command)** | | | | | | |
| 3350 | Operator Logoff | 0 to 1 | --- | 1 | F126 | 0 (No) |
| 3351 | Engineer Logoff | 0 to 1 | --- | 1 | F126 | 0 (No) |
| 3352 | Administrator Logoff | 0 to 1 | --- | 1 | F126 | 0 (No) |
| 3353 | Clear Security Data | 0 to 1 | --- | 1 | F126 | 0 (No) |

### Table B–10: MODBUS MEMORY MAP (Sheet 15 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| **Security Reserved Modbus Registers (Read/Write)** | | | | | | |
| 3360 | Address 0x3360 reserved for serial login (20 items) | 0 to 9999 | --- | 1 | F001 | 3 |
| 3374 | Address 0x3374 reserved for serial logout | 0 to 9999 | --- | 1 | F001 | 3 |
| **Security Reserved Modbus Registers (Read Only)** | | | | | | |
| 3375 | Address 0x3374 reserved for serial logout | 0 to 5 | --- | 1 | F617 | 3 (Engineer) |
| **Event Recorder Actual Values (Read Only)** | | | | | | |
| 3400 | Events Since Last Clear | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 3402 | Number of Available Events | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 3404 | Event Recorder Last Cleared Date | 0 to 4294967295 | --- | 1 | F050 | 0 |
| **Event Recorder Commands (Read/Write Command)** | | | | | | |
| 3406 | Event Recorder Clear Command | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **DCmA Input Values (Read Only) (24 modules)** | | | | | | |
| 34C0 | DCmA Inputs 1 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34C2 | DCmA Inputs 2 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34C4 | DCmA Inputs 3 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34C6 | DCmA Inputs 4 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34C8 | DCmA Inputs 5 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34CA | DCmA Inputs 6 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34CC | DCmA Inputs 7 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34CE | DCmA Inputs 8 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34D0 | DCmA Inputs 9 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34D2 | DCmA Inputs 10 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34D4 | DCmA Inputs 11 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34D6 | DCmA Inputs 12 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34D8 | DCmA Inputs 13 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34DA | DCmA Inputs 14 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34DC | DCmA Inputs 15 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34DE | DCmA Inputs 16 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34E0 | DCmA Inputs 17 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34E2 | DCmA Inputs 18 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34E4 | DCmA Inputs 19 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34E6 | DCmA Inputs 20 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34E8 | DCmA Inputs 21 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34EA | DCmA Inputs 22 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34EC | DCmA Inputs 23 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 34EE | DCmA Inputs 24 Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| **RTD Input Values (Read Only) (48 modules)** | | | | | | |
| 34F0 | RTD Input 1 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34F1 | RTD Input 2 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34F2 | RTD Input 3 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34F3 | RTD Input 4 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34F4 | RTD Input 5 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34F5 | RTD Input 6 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34F6 | RTD Input 7 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34F7 | RTD Input 8 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34F8 | RTD Input 9 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34F9 | RTD Input 10 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34FA | RTD Input 11 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34FB | RTD Input 12 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34FC | RTD Input 13 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34FD | RTD Input 14 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34FE | RTD Input 15 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 34FF | RTD Input 16 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3500 | RTD Input 17 Value | -32768 to 32767 | °C | 1 | F002 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 16 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 3501 | RTD Input 18 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3502 | RTD Input 19 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3503 | RTD Input 20 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3504 | RTD Input 21 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3505 | RTD Input 22 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3506 | RTD Input 23 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3507 | RTD Input 24 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3508 | RTD Input 25 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3509 | RTD Input 26 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 350A | RTD Input 27 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 350B | RTD Input 28 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 350C | RTD Input 29 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 350D | RTD Input 30 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 350E | RTD Input 31 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 350F | RTD Input 32 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3510 | RTD Input 33 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3511 | RTD Input 34 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3512 | RTD Input 35 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3513 | RTD Input 36 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3514 | RTD Input 37 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3515 | RTD Input 38 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3516 | RTD Input 39 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3517 | RTD Input 40 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3518 | RTD Input 41 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 3519 | RTD Input 42 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 351A | RTD Input 43 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 351B | RTD Input 44 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 351C | RTD Input 45 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 351D | RTD Input 46 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 351E | RTD Input 47 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| 351F | RTD Input 48 Value | -32768 to 32767 | °C | 1 | F002 | 0 |
| **Ohm Input Values (Read Only) (2 modules)** | | | | | | |
| 3520 | Ohm Inputs 1 Value | 0 to 65535 | Ohm | 1 | F001 | 0 |
| 3521 | Ohm Inputs 2 Value | 0 to 65535 | Ohm | 1 | F001 | 0 |
| **RADIUS Configuration (Read/Write Setting)** | | | | | | |
| 3735 | Primary RADIUS IP Address | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 3737 | Primary Authentication Port | 1 to 65535 | --- | 1 | F001 | 1812 |
| 3738 | Primary Accounting Port | 1 to 65535 | --- | 1 | F001 | 1813 |
| 3739 | Secondary RADIUS IP Address | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 373B | Secondary Authentication Port | 0 to 65535 | --- | 1 | F001 | 1812 |
| 373D | Secondary Accounting Port | 0 to 65535 | --- | 1 | F001 | 1813 |
| 373F | RADIUS Authentication Method | --- | --- | 1 | F619 | 0 (EAP-TTLS) |
| 3740 | RADIUS Vendor ID | 1 to 65535 | --- | 1 | F001 | 2910 |
| 3741 | Authentication Timeout | 0 to 9999 | sec | 1 | F001 | 10 |
| 3742 | Authentication Retries | 0 to 9999 | --- | 1 | F001 | 3 |
| 3743 | RADIUS Authentication Shared Secret | --- | --- | --- | F202 | (none) |
| **PTP Basic Configuration (Read/Write Setting)** | | | | | | |
| 3750 | PTP Strict Power Profile | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 3751 | PTP Domain Number | 0 to 255 | --- | 1 | F001 | 0 |
| 3752 | PTP VLAN Priority | 0 to 7 | --- | 1 | F001 | 4 |
| 3753 | PTP VLAN ID | 0 to 4095 | --- | 1 | F001 | 0 |
| 3754 | Undefined (2 items) | 0 to 1 | --- | 1 | F001 | 0 |
| **PTP Port Configuration (Read/Write Setting) (3 modules)** | | | | | | |
| 3756 | PTP Port 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |

### Table B–10: MODBUS MEMORY MAP (Sheet 17 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 3757 | PTP Port 1 Path Delay Adder | 0 to 60000 | ns | 1 | F001 | 0 |
| 3758 | PTP Port 1 Path Delay Asymmetry | -1000 to 1000 | ns | 1 | F002 | 0 |
| 3759 | ...Repeated for PTP Port 2 | | | | | |
| 375C | ...Repeated for PTP Port 3 | | | | | |
| **Real Time Clock Synchronizing Actual Values (Read Only)** | | | | | | |
| 375F | RTC Sync Source | 0 to 5 | --- | 1 | F624 | 0 (None) |
| 3760 | PTP GrandMaster ID | 0 to 100 | -- | 1 | F073 | 0 |
| 3764 | Real Time Clock Accuracy | 0 to 999999999 | ns | 1 | F003 | 0 |
| 3766 | PTP Port 1 State (3 items) | 0 to 4 | -- | 1 | F625 | 0 (Disabled) |
| 3769 | RTC Offset | 0 to 999999999 | ns | 1 | F004 | 0 |
| 376B | PTP - IRIG-B Delta | -500000000 to 500000000 | ns | 1 | F004 | 0 |
| **Real Time Clock Synchronizing FlexAnalogs (Read Only)** | | | | | | |
| 376D | PTP - IRIG-B Delta FlexAnalog | -262143 to 262143 | --- | 1 | F004 | 0 |
| **Field Units (Read/Write Setting) (8 modules)** | | | | | | |
| 3800 | Field Unit 1 ID | 0 to 1 | --- | 1 | F205 | "U1" |
| 3806 | Field Unit 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 3807 | Field Unit 1 Type | 0 to 3 | --- | 1 | F243 | 0 (CC-05) |
| 3808 | Field Unit 1 Serial Number | 1 to 1 | --- | 1 | F205 | "000000000000" |
| 380E | Field Unit 1 Port | 1 to 4 | --- | 1 | F001 | 1 |
| 380F | ...Repeated for Field Unit 2 | | | | | |
| 381E | ...Repeated for Field Unit 3 | | | | | |
| 382D | ...Repeated for Field Unit 4 | | | | | |
| 383C | ...Repeated for Field Unit 5 | | | | | |
| 384B | ...Repeated for Field Unit 6 | | | | | |
| 385A | ...Repeated for Field Unit 7 | | | | | |
| 3869 | ...Repeated for Field Unit 8 | | | | | |
| **Field Unit Process Card Ports (Read/Write Setting)** | | | | | | |
| 3878 | Field Unit 1 Process Card Port | 0 to 7 | --- | 1 | F244 | 6 (H1a) |
| 3879 | Field Unit 2 Process Card Port | 0 to 7 | --- | 1 | F244 | 4 (H2a) |
| 387A | Field Unit3 Process Card Port | 0 to 7 | --- | 1 | F244 | 2 (H3a) |
| 387B | Field Unit 4 Process Card Port | 0 to 7 | --- | 1 | F244 | 0 (H4a) |
| 387C | Field Unit 5 Process Card Port | 0 to 7 | --- | 1 | F244 | 7 (H1b) |
| 387D | Field Unit 6 Process Card Port | 0 to 7 | --- | 1 | F244 | 5 (H2b) |
| 387E | Field Unit 7 Process Card Port | 0 to 7 | --- | 1 | F244 | 3 (H3b) |
| 387F | Field Unit 8 Process Card Port | 0 to 7 | --- | 1 | F244 | 1 (H4b) |
| **Field Unit CT VT Settings (Read/Write Setting) (6 modules)** | | | | | | |
| 3890 | Remote Phase CT x Origin 1 | 0 to 16 | --- | 1 | F247 | 0 (None) |
| 3891 | Remote Phase CT x Origin 2 | 0 to 16 | --- | 1 | F247 | 0 (None) |
| 3892 | Remote Ground CT x Origin 1 | 0 to 16 | --- | 1 | F248 | 0 (None) |
| 3893 | Remote Ground CT x Origin 2 | 0 to 16 | --- | 1 | F248 | 0 (None) |
| 3894 | AC Bank Redundancy Type | 0 to 2 | --- | 1 | F261 | 1 (Dependability Biased) |
| 3895 | Remote Phase CT 1 Primary | 1 to 65000 | --- | 1 | F001 | 1 |
| 3896 | Remote Phase CT 1 Secondary | 0 to 1 | --- | 1 | F123 | 0 (1 A) |
| 3897 | Remote Ground CT 1 Primary | 1 to 65000 | --- | 1 | F001 | 1 |
| 3898 | Remote Ground CT 1 Secondary | 0 to 1 | --- | 1 | F123 | 0 (1 A) |
| 3899 | Remote Phase VT 1 Connection | 0 to 1 | --- | 1 | F100 | 0 (Wye) |
| 389A | Remote Phase VT 1 Secondary | 25 to 240 | --- | 0.1 | F001 | 664 |
| 389B | Remote Phase VT 1 Ratio | 1 to 24000 | --- | 1 | F060 | 1 |
| 389D | Remote Auxiliary VT 1 Connection | 0 to 6 | --- | 1 | F166 | 1 (Vag) |
| 389E | Remote Auxiliary VT 1 Secondary | 25 to 240 | --- | 0.1 | F001 | 664 |
| 389F | Remote Auxiliary VT 1 Ratio | 1 to 24000 | --- | 1 | F060 | 1 |
| 38A1 | ...Repeated for Field Unit 2 | | | | | |
| 38B2 | ...Repeated for Field Unit 3 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 18 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 38C3 | ...Repeated for Field Unit 4 | | | | | |
| 38D4 | ...Repeated for Field Unit 5 | | | | | |
| 38E5 | ...Repeated for Field Unit 6 | | | | | |
| **Field Unit Contact Inputs (Read/Write Setting) (40 modules)** | | | | | | |
| 3900 | Field Contact Input 1 ID | --- | --- | --- | F205 | "FCI 1" |
| 3906 | Field Contact Input 1 Origin | 0 to 8 | --- | 1 | F256 | 0 (None) |
| 3907 | Field Contact Input 1 Input | 1 to 18 | --- | 1 | F001 | 1 |
| 3908 | Field Contact Input 1 Failsafe Value | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 3909 | Field Contact Input 1 Debounce Time | 0 to 16 | ms | 0.5 | F001 | 20 |
| 390A | Field Contact Input 1 Events | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 390B | ...Repeated for Field Contact Input 2 | | | | | |
| 3916 | ...Repeated for Field Contact Input 3 | | | | | |
| 3921 | ...Repeated for Field Contact Input 4 | | | | | |
| 392C | ...Repeated for Field Contact Input 5 | | | | | |
| 3937 | ...Repeated for Field Contact Input 6 | | | | | |
| 3942 | ...Repeated for Field Contact Input 7 | | | | | |
| 394D | ...Repeated for Field Contact Input 8 | | | | | |
| 3958 | ...Repeated for Field Contact Input9 | | | | | |
| 3963 | ...Repeated for Field Contact Input 10 | | | | | |
| 396E | ...Repeated for Field Contact Input 11 | | | | | |
| 3979 | ...Repeated for Field Contact Input 12 | | | | | |
| 3984 | ...Repeated for Field Contact Input 13 | | | | | |
| 398F | ...Repeated for Field Contact Input 14 | | | | | |
| 399A | ...Repeated for Field Contact Input 15 | | | | | |
| 39A5 | ...Repeated for Field Contact Input 16 | | | | | |
| 39B0 | ...Repeated for Field Contact Input 17 | | | | | |
| 39BB | ...Repeated for Field Contact Input 18 | | | | | |
| 39C6 | ...Repeated for Field Contact Input 19 | | | | | |
| 39D1 | ...Repeated for Field Contact Input 20 | | | | | |
| 39DC | ...Repeated for Field Contact Input 21 | | | | | |
| 39E7 | ...Repeated for Field Contact Input 22 | | | | | |
| 39F2 | ...Repeated for Field Contact Input 23 | | | | | |
| 39FD | ...Repeated for Field Contact Input 24 | | | | | |
| 3A08 | ...Repeated for Field Contact Input 25 | | | | | |
| 3A13 | ...Repeated for Field Contact Input 26 | | | | | |
| 3A1E | ...Repeated for Field Contact Input 27 | | | | | |
| 3A29 | ...Repeated for Field Contact Input 28 | | | | | |
| 3A34 | ...Repeated for Field Contact Input 29 | | | | | |
| 3A3F | ...Repeated for Field Contact Input 30 | | | | | |
| 3A4A | ...Repeated for Field Contact Input 31 | | | | | |
| 3A55 | ...Repeated for Field Contact Input 32 | | | | | |
| 3A60 | ...Repeated for Field Contact Input 33 | | | | | |
| 3A6B | ...Repeated for Field Contact Input 34 | | | | | |
| 3A76 | ...Repeated for Field Contact Input 35 | | | | | |
| 3A81 | ...Repeated for Field Contact Input 36 | | | | | |
| 3A8C | ...Repeated for Field Contact Input 37 | | | | | |
| 3A97 | ...Repeated for Field Contact Input 38 | | | | | |
| 3AA2 | ...Repeated for Field Contact Input 39 | | | | | |
| 3AAD | ...Repeated for Field Contact Input 40 | | | | | |
| **Field Unit Shared Inputs (Read/Write Setting) (16 modules)** | | | | | | |
| 3B00 | Field Shared Input 1 ID | 0 to 65535 | --- | 1 | F205 | "SI 1" |
| 3B06 | Field Shared Input 1 Unit Origin 1 | 0 to 8 | --- | 1 | F256 | 0 (None) |
| 3B07 | Field Shared Input 1 Channel Origin 1 | 1 to 15 | --- | 1 | F001 | 1 |
| 3B08 | Field Shared Input 1 Events | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |

**Table B–10: MODBUS MEMORY MAP (Sheet 19 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 3B09 | ...Repeated for Field Shared Input 2 | | | | | |
| 3B12 | ...Repeated for Field Shared Input 3 | | | | | |
| 3B1B | ...Repeated for Field Shared Input 4 | | | | | |
| 3B24 | ...Repeated for Field Shared Input 5 | | | | | |
| 3B2D | ...Repeated for Field Shared Input 6 | | | | | |
| 3B36 | ...Repeated for Field Shared Input 7 | | | | | |
| 3B3F | ...Repeated for Field Shared Input 8 | | | | | |
| 3B48 | ...Repeated for Field Shared Input 9 | | | | | |
| 3B51 | ...Repeated for Field Shared Input 10 | | | | | |
| 3B5A | ...Repeated for Field Shared Input 11 | | | | | |
| 3B63 | ...Repeated for Field Shared Input 12 | | | | | |
| 3B6C | ...Repeated for Field Shared Input 13 | | | | | |
| 3B75 | ...Repeated for Field Shared Input 14 | | | | | |
| 3B7E | ...Repeated for Field Shared Input 15 | | | | | |
| 3B87 | ...Repeated for Field Shared Input 16 | | | | | |
| **Field Unit Contact Outputs (Read/Write Setting) (8 modules)** | | | | | | |
| 3B90 | Field Contact Output 1 ID (6 items) | --- | --- | --- | F205 | "FCO U /OUT" |
| 3BB4 | Field Output 1 Operate (6 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 3BC0 | Field Output 1 Seal In (6 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 3BCC | Field Output 1 Events (6 items) | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 3BD2 | ...Repeated for Field Contact Output 2 | | | | | |
| 3C14 | ...Repeated for Field Contact Output 3 | | | | | |
| 3C56 | ...Repeated for Field Contact Output 4 | | | | | |
| 3C98 | ...Repeated for Field Contact Output 5 | | | | | |
| 3CDA | ...Repeated for Field Contact Output 6 | | | | | |
| 3D1C | ...Repeated for Field Contact Output 7 | | | | | |
| 3D5E | ...Repeated for Field Contact Output 8 | | | | | |
| **Field Unit Latching Outputs (Read/Write Setting) (8 modules)** | | | | | | |
| 3DC7 | Field Latching Output 1 ID | 0 to 1 | --- | 1 | F205 | "FLO Ux /LO" |
| 3DCD | Field Latching Output 1 Open | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 3DCF | Field Latching Output 1 Close | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 3DD1 | Field Latching Output 1 Events | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 3DD2 | Reserved (2 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 3DD4 | ...Repeated for Field Latching Output 2 | | | | | |
| 3DE1 | ...Repeated for Field Latching Output 3 | | | | | |
| 3DEE | ...Repeated for Field Latching Output 4 | | | | | |
| 3DFB | ...Repeated for Field Latching Output 5 | | | | | |
| 3E08 | ...Repeated for Field Latching Output 6 | | | | | |
| 3E15 | ...Repeated for Field Latching Output 7 | | | | | |
| 3E22 | ...Repeated for Field Latching Output 8 | | | | | |
| **Field Unit Shared Outputs (Read/Write Setting) (16 modules)** | | | | | | |
| 3E30 | Field Shared Output 1 ID | 0 to 65535 | --- | 1 | F205 | "SO 1" |
| 3E36 | Field Shared Output 1 Operate | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 3E38 | Field Shared Output 1 Unit Dest 1 | 0 to 8 | --- | 1 | F256 | 0 (None) |
| 3E39 | Field Shared Output 1 Channel Dest 1 | 1 to 15 | --- | 1 | F001 | 1 |
| 3E3A | Field Shared Output 1 Unit Dest 2 | 0 to 8 | --- | 1 | F256 | 0 (None) |
| 3E3B | Field Shared Output 1 Channel Dest 2 | 1 to 15 | --- | 1 | F001 | 1 |
| 3E3C | Field Shared Output 1 Events | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 3E3D | ...Repeated for Field Shared Output 2 | | | | | |
| 3E4A | ...Repeated for Field Shared Output 3 | | | | | |
| 3E57 | ...Repeated for Field Shared Output 4 | | | | | |
| 3E64 | ...Repeated for Field Shared Output 5 | | | | | |
| 3E71 | ...Repeated for Field Shared Output 6 | | | | | |
| 3E7E | ...Repeated for Field Shared Output 7 | | | | | |

**Table B–10: MODBUS MEMORY MAP (Sheet 20 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 3E8B | ...Repeated for Field Shared Output 8 | | | | | |
| 3E98 | ...Repeated for Field Shared Output 9 | | | | | |
| 3EA5 | ...Repeated for Field Shared Output 10 | | | | | |
| 3EB2 | ...Repeated for Field Shared Output 11 | | | | | |
| 3EBF | ...Repeated for Field Shared Output 12 | | | | | |
| 3ECC | ...Repeated for Field Shared Output 13 | | | | | |
| 3ED9 | ...Repeated for Field Shared Output 14 | | | | | |
| 3EE6 | ...Repeated for Field Shared Output 15 | | | | | |
| 3EF3 | ...Repeated for Field Shared Output 16 | | | | | |
| **Field Unit RTDs (Read/Write Setting) (8 modules)** | | | | | | |
| 3F00 | Field Unit RTD 1Name | 0 to 1 | --- | 1 | F205 | "RTD 1" |
| 3F06 | Field Unit RTD 1 Origin | 0 to 24 | --- | 1 | F253 | 0 (None) |
| 3F07 | Field Unit RTD 1 Type | 0 to 2 | --- | 1 | F259 | 0 (100 Ohm Nickel) |
| 3F08 | ...Repeated for Field Unit RTD 2 | | | | | |
| 3F10 | ...Repeated for Field Unit RTD 3 | | | | | |
| 3F18 | ...Repeated for Field Unit RTD 4 | | | | | |
| 3F20 | ...Repeated for Field Unit RTD 5 | | | | | |
| 3F28 | ...Repeated for Field Unit RTD 6 | | | | | |
| 3F30 | ...Repeated for Field Unit RTD 7 | | | | | |
| 3F38 | ...Repeated for Field Unit RTD 8 | | | | | |
| **Field Unit Transducers (Read/Write Setting) (8 modules)** | | | | | | |
| 3F40 | Field Unit Transducer 1 Name | 0 to 1 | --- | 1 | F205 | "TRD 1" |
| 3F46 | Field Unit Transducer 1 Origin | 0 to 24 | --- | 1 | F253 | 0 (None) |
| 3F47 | Field Unit Transducer 1 Range | 0 to 9 | --- | 1 | F246 | 6 (0...20mA) |
| 3F48 | Field Unit Transducer 1 Min Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 0 |
| 3F4A | Field Unit Transducer 1 Max Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 100000 |
| 3F4C | Field Unit Transducer 1 Units | --- | --- | --- | F206 | (none) |
| 3F4F | ...Repeated for Field Unit Transducer 2 | | | | | |
| 3F5E | ...Repeated for Field Unit Transducer 3 | | | | | |
| 3F6D | ...Repeated for Field Unit Transducer 4 | | | | | |
| 3F7C | ...Repeated for Field Unit Transducer 5 | | | | | |
| 3F8B | ...Repeated for Field Unit Transducer 6 | | | | | |
| 3F9A | ...Repeated for Field Unit Transducer 7 | | | | | |
| 3FA9 | ...Repeated for Field Unit Transducer 8 | | | | | |
| **Field Unit Identifiers (Read Only) (8 modules)** | | | | | | |
| 3FB8 | Attached Field Unit 1 Serial Number | --- | --- | 1 | F205 | (none) |
| 3FBE | Attached Filed Unit 1 Port Number | --- | --- | 1 | F001 | 0 |
| 3FBF | Attached Field Unit 1 Type | 0 to 3 | --- | 1 | F243 | 0 (CC-05) |
| 3FC0 | Field Unit 1 Status | 0 to 4 | --- | 1 | F262 | 0 (Disabled) |
| 3FC1 | ...Repeated for Field Unit 2 | | | | | |
| 3FCA | ...Repeated for Field Unit 3 | | | | | |
| 3FD3 | ...Repeated for Field Unit 4 | | | | | |
| 3FDC | ...Repeated for Field Unit 5 | | | | | |
| 3FE5 | ...Repeated for Field Unit 6 | | | | | |
| 3FEE | ...Repeated for Field Unit 7 | | | | | |
| 3FF7 | ...Repeated for Field Unit 8 | | | | | |
| **Passwords (Read/Write Command)** | | | | | | |
| 4000 | Command Password Setting | 0 to 4294967295 | --- | 1 | F202 | (none) |
| **Passwords (Read/Write Setting)** | | | | | | |
| 400A | Setting Password Setting | 0 to 4294967295 | --- | 1 | F202 | (none) |
| **Passwords (Read/Write)** | | | | | | |
| 4014 | Command Password Entry | 0 to 4294967295 | --- | 1 | F202 | (none) |
| 401E | Setting Password Entry | 0 to 4294967295 | --- | 1 | F202 | (none) |

### Table B–10: MODBUS MEMORY MAP (Sheet 21 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| **Passwords (Read Only)** | | | | | | |
| 4028 | Command Password Status | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 4029 | Setting Password Status | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Passwords (Read/Write Setting)** | | | | | | |
| 402A | Command Password Access Timeout | 5 to 480 | min | 1 | F001 | 5 |
| 402B | Setting Password Access Timeout | 5 to 480 | min | 1 | F001 | 30 |
| 402C | Invalid Password Attempts (before lockout) | 2 to 5 | --- | 1 | F001 | 3 |
| 402D | Password Lockout Duration | 5 to 60 | min | 1 | F001 | 5 |
| **Passwords (Read/Write)** | | | | | | |
| 402E | Password Access Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Passwords (Read/Write Setting)** | | | | | | |
| 402F | Local Setting Auth | 1 to 4294967295 | --- | 1 | F300 | 1 |
| 4031 | Remote Setting Auth | 0 to 4294967295 | --- | 1 | F300 | 1 |
| 4033 | Access Auth Timeout | 5 to 480 | min | 1 | F001 | 30 |
| **User Display Invoke (Read/Write Setting)** | | | | | | |
| 4040 | Invoke and Scroll Through User Display Menu Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| **LED Test (Read/Write Setting)** | | | | | | |
| 4048 | LED Test Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 4049 | LED Test Control | 0 to 4294967295 | --- | 1 | F300 | 0 |
| **Preferences (Read/Write Setting)** | | | | | | |
| 404F | Language | 0 to 5 | --- | 1 | F531 | 0 (English) |
| 4050 | Flash Message Time | 0.5 to 10 | s | 0.1 | F001 | 10 |
| 4051 | Default Message Timeout | 10 to 900 | s | 1 | F001 | 300 |
| 4052 | Default Message Intensity | 0 to 3 | --- | 1 | F101 | 0 (25%) |
| 4053 | Screen Saver Feature | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 4054 | Screen Saver Wait Time | 1 to 65535 | min | 1 | F001 | 30 |
| 4055 | Current Cutoff Level | 0.002 to 0.02 | pu | 0.001 | F001 | 20 |
| 4056 | Voltage Cutoff Level | 0.1 to 1 | V | 0.1 | F001 | 10 |
| **87L Channel Status (Read Only)** | | | | | | |
| 4059 | Channel 1 Local Loopback Status | 0 to 2 | --- | 1 | F134 | 2 (n/a) |
| 405A | Channel 1 Loop Delay | 0 to 200 | ms | 0.1 | F001 | 0 |
| 405B | Channel 1 Number of Lost Packets | 0 to 65535 | --- | 1 | F001 | 0 |
| 405C | Channel 1 Remote Loopback Status | 0 to 2 | --- | 1 | F134 | 2 (n/a) |
| 405D | Channel 1 Status | 0 to 2 | --- | 1 | F134 | 1 (OK) |
| 405E | Channel 2 Local Loopback Status | 0 to 2 | --- | 1 | F134 | 2 (n/a) |
| 405F | Channel 2 Loop Delay | 0 to 200 | ms | 0.1 | F001 | 0 |
| 4060 | Channel 2 Number of Lost Packets | 0 to 65535 | --- | 1 | F001 | 0 |
| 4061 | Channel 2 Remote Loopback Status | 0 to 2 | --- | 1 | F134 | 2 (n/a) |
| 4062 | Channel 2 Status | 0 to 2 | --- | 1 | F134 | 2 (n/a) |
| 4063 | Channel PFLL Status | 0 to 2 | --- | 1 | F134 | 1 (OK) |
| 4064 | 87L Network Status | 0 to 2 | --- | 1 | F134 | 2 (n/a) |
| **87L Channel Status (Read/Write Command)** | | | | | | |
| 4065 | Channel Status Clear | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **87L Power System (Read/Write Setting)** | | | | | | |
| 4068 | Block GPS Time Reference | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 406A | Channel Asymmetry Compensation | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 406C | Charging Current Compensation | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 406D | Local Relay ID | 0 to 255 | --- | 1 | F001 | 0 |
| 406E | Maximum Channel Asymmetry | 0 to 10 | ms | 0.1 | F001 | 15 |
| 406F | Number of Channels | 1 to 2 | --- | 1 | F001 | 1 |
| 4070 | Number of Terminals | 2 to 3 | --- | 1 | F001 | 2 |
| 4071 | Positive Sequence Reactance | 0.1 to 65.535 | kohms | 0.001 | F001 | 100 |
| 4072 | Round Trip Time | 0 to 10 | ms | 0.1 | F001 | 15 |
| 4073 | Terminal 1 ID | 0 to 255 | --- | 1 | F001 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 22 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 4074 | Terminal 2 ID | 0 to 255 | --- | 1 | F001 | 0 |
| 4075 | Zero-Sequence Current Removal | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 4076 | Zero Sequence Reactance | 0.1 to 65.535 | kohms | 0.001 | F001 | 100 |
| **Communications (Read/Write Setting)** | | | | | | |
| 407D | COM2 Selection | 0 to 3 | --- | 1 | F601 | 0 (RS485) |
| 407E | COM1 Minimum Response Time | 0 to 1000 | ms | 10 | F001 | 0 |
| 407F | COM2 Minimum Response Time | 0 to 1000 | ms | 10 | F001 | 0 |
| 4080 | Modbus Slave Address | 1 to 254 | --- | 1 | F001 | 254 |
| 4083 | RS485 Com1 Baud Rate | 0 to 11 | --- | 1 | F112 | 8 (115200) |
| 4084 | RS485 Com1 Parity | 0 to 2 | --- | 1 | F113 | 0 (None) |
| 4085 | RS485 Com2 Baud Rate | 0 to 11 | --- | 1 | F112 | 8 (115200) |
| 4086 | RS485 Com2 Parity | 0 to 2 | --- | 1 | F113 | 2 (Even) |
| 4087 | Port 1 IP Address | 0 to 4294967295 | --- | 1 | F003 | 2130706433 |
| 4089 | Port 1 IP Subnet Mask | 0 to 4294967295 | --- | 1 | F003 | 4278190080 |
| 408B | Port 1 Gateway IP Address | 0 to 4294967295 | --- | 1 | F003 | 56554497 |
| 408D | Network Address NSAP | --- | --- | --- | F074 | 0 |
| 4097 | Port 1 Link Loss Alert | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 4098 | Port 2 Link Loss Alert | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 4099 | Port 3 Link Loss Alert | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 409A | DNP Channel 1 Port | 0 to 5 | --- | 1 | F177 | 0 (None) |
| 409B | DNP Channel 2 Port | 0 to 5 | --- | 1 | F177 | 0 (None) |
| 409C | DNP Address | 0 to 65519 | --- | 1 | F001 | 1 |
| 409E | DNP Client Addresses (2 items) | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 40A3 | TCP Port Number for the Modbus protocol | 0 to 65535 | --- | 1 | F001 | 502 |
| 40A4 | TCP/UDP Port Number for the DNP Protocol | 0 to 65535 | --- | 1 | F001 | 20000 |
| 40A5 | TCP Port Number for the HTTP (Web Server) Protocol | 0 to 65535 | --- | 1 | F001 | 80 |
| 40A6 | Main UDP Port Number for the TFTP Protocol | 0 to 65535 | --- | 1 | F001 | 69 |
| 40A7 | Data Transfer UDP Port Numbers for the TFTP Protocol (zero means “automatic”) (2 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| 40A9 | DNP Unsolicited Responses Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 40AA | DNP Unsolicited Responses Timeout | 0 to 60 | s | 1 | F001 | 5 |
| 40AB | DNP Unsolicited Responses Maximum Retries | 1 to 255 | --- | 1 | F001 | 10 |
| 40AC | DNP Unsolicited Responses Destination Address | 0 to 65519 | --- | 1 | F001 | 1 |
| 40AD | Ethernet Operation Mode | 0 to 1 | --- | 1 | F192 | 1 (Full-Duplex) |
| 40AE | DNP Current Scale Factor | 0 to 8 | --- | 1 | F194 | 2 (1) |
| 40AF | DNP Voltage Scale Factor | 0 to 8 | --- | 1 | F194 | 2 (1) |
| 40B0 | DNP Power Scale Factor | 0 to 8 | --- | 1 | F194 | 2 (1) |
| 40B1 | DNP Energy Scale Factor | 0 to 8 | --- | 1 | F194 | 2 (1) |
| 40B2 | DNP Power Scale Factor | 0 to 8 | --- | 1 | F194 | 2 (1) |
| 40B3 | DNP Other Scale Factor | 0 to 8 | --- | 1 | F194 | 2 (1) |
| 40B4 | DNP Current Default Deadband | 0 to 100000000 | --- | 1 | F003 | 30000 |
| 40B6 | DNP Voltage Default Deadband | 0 to 100000000 | --- | 1 | F003 | 30000 |
| 40B8 | DNP Power Default Deadband | 0 to 100000000 | --- | 1 | F003 | 30000 |
| 40BA | DNP Energy Default Deadband | 0 to 100000000 | --- | 1 | F003 | 30000 |
| 40BC | DNP Power Factor Default Deadband | 0 to 100000000 | -- | 1 | F003 | 30000 |
| 40BE | DNP Other Default Deadband | 0 to 100000000 | --- | 1 | F003 | 30000 |
| 40C0 | DNP IIN Time Synchronization Bit Period | 1 to 10080 | min | 1 | F001 | 1440 |
| 40C1 | DNP Message Fragment Size | 30 to 2048 | --- | 1 | F001 | 240 |
| 40C2 | DNP Client Address 3 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 40C4 | DNP Client Address 4 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 40C6 | DNP Client Address 5 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 40C8 | DNP Number of Paired Binary Output Control Points | 0 to 32 | --- | 1 | F001 | 0 |
| 40C9 | DNP TCP Connection Timeout | 10 to 7200 | s | 1 | F001 | 120 |
| 40CA | DNP Communications Reserved (22 items) | 0 to 1 | --- | 1 | F001 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 23 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 40E0 | TCP Port Number for the IEC 60870-5-104 Protocol | 0 to 65535 | --- | 1 | F001 | 2404 |
| 40E1 | IEC 60870-5-104 Protocol Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 40E2 | IEC 60870-5-104 Protocol Common Address of ASDU | 0 to 65535 | --- | 1 | F001 | 0 |
| 40E3 | IEC 60870-5-104 Protocol Cyclic Data Transmit Period | 1 to 65535 | s | 1 | F001 | 60 |
| 40E4 | IEC 60870-5-104 Current Default Threshold | 0 to 100000000 | --- | 1 | F003 | 30000 |
| 40E6 | IEC 60870-5-104 Voltage Default Threshold | 0 to 100000000 | --- | 1 | F003 | 30000 |
| 40E8 | IEC 60870-5-104 Power Default Threshold | 0 to 100000000 | --- | 1 | F003 | 30000 |
| 40EA | IEC 60870-5-104 Energy Default Threshold | 0 to 100000000 | --- | 1 | F003 | 30000 |
| 40EC | IEC 60870-5-104 Power Default Threshold | 0 to1 | --- | 0.01 | F001 | 100 |
| 40EE | IEC 60870-5-104 Other Default Threshold | 0 to 100000000 | --- | 1 | F003 | 30000 |
| 40F0 | IEC 60870-5-104 Client Address (5 items) | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 4104 | IEC 60870-5-104 Redundancy Port Enabled/Disabled | 0 to 1 | --- | 1 | F126 | 0 (No) |
| 4105 | Port 2 IP Address | 0 to 4294967295 | --- | 1 | F003 | 2130706433 |
| 4107 | Port 2 IP Subnet Mask | 0 to 4294967295 | --- | 1 | F003 | 4278190080 |
| 4109 | Port 2 Gateway IP Address | 0 to 4294967295 | --- | 1 | F003 | 56554497 |
| 410B | PRT2 Ethernet Operation Mode | 0 to 1 | --- | 1 | F192 | 1 (Full-Duplex) |
| 410C | PRT2 Redundancy Enabled | 0 to 2 | --- | 1 | F627 | 0 (None) |
| 410D | Port 3 IP Address | 0 to 4294967295 | --- | 1 | F003 | 2130706433 |
| 410F | Port 3 IP Subnet Mask | 0 to 4294967295 | --- | 1 | F003 | 4278190080 |
| 4111 | Port 3 Gateway IP Address | 0 to 4294967295 | --- | 1 | F003 | 56554497 |
| 4113 | Port 3 Ethernet Operation Mode | 0 to 1 | --- | 1 | F192 | 1 (Full-Duplex) |
| 4114 | PRT1 GOOSE Enabled | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 4115 | PRT2 GOOSE Enabled | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 4116 | PRT3 GOOSE Enabled | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 4117 | Default IPv4 Route | 0 to 4294967295 | --- | 1 | F003 | 2130706433 |
| 4119 | PRT2 PRP Mcst Addr | --- | --- | --- | F072 | 0 |
| 411C | IEC Communications Reserved (33 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 413E | High Enet Traffic Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 413F | High Enet Traffic Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 4140 | DNP Object 1 Default Variation | 1 to 2 | --- | 1 | F001 | 2 |
| 4141 | DNP Object 2 Default Variation | 1 to 3 | --- | 1 | F001 | 2 |
| 4142 | DNP Object 20 Default Variation | 0 to 3 | --- | 1 | F523 | 0 (1) |
| 4143 | DNP Object 21 Default Variation | 0 to 3 | --- | 1 | F524 | 0 (1) |
| 4144 | DNP Object 22 Default Variation | 0 to 3 | --- | 1 | F523 | 0 (1) |
| 4145 | DNP Object 23 Default Variation | 0 to 3 | --- | 1 | F523 | 0 (1) |
| 4146 | DNP Object 30 Default Variation | 1 to 5 | --- | 1 | F001 | 1 |
| 4147 | DNP Object 32 Default Variation | 0 to 5 | --- | 1 | F525 | 0 (1) |
| 4148 | SCADA Protocol | 0 to 2 | --- | 1 | F629 | 0 (DNP 3.0) |
| **Communications Actual Values (Read Only)** | | | | | | |
| 4160 | Modbus Available TCP/IP Connections | 0 to 4 | --- | 1 | F001 | 4 |
| 4161 | DNP Available TCP/IP Connections | 0 to 2 | --- | 1 | F001 | 2 |
| 4162 | IEC Available TCP/IP Connections | 0 to 2 | --- | 1 | F001 | 2 |
| 4163 | MMS Available TCP/IP Connections | 0 to 5 | --- | 1 | F001 | 5 |
| 4164 | PMU Available TCP/IP Connections | 0 to 4 | --- | 1 | F001 | 4 |
| **Simple Network Time Protocol (Read/Write Setting)** | | | | | | |
| 4168 | Simple Network Time Protocol (SNTP) Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 4169 | Simple Network Time Protocol (SNTP) Server IP Address | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 416B | Simple Network Time Protocol (SNTP) UDP Port Number | 1 to 65535 | --- | 1 | F001 | 123 |
| **Data Logger Commands (Read/Write Command)** | | | | | | |
| 4170 | Data Logger Clear | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **Data Logger (Read/Write Setting)** | | | | | | |
| 4181 | Data Logger Channel Settings (16 items) | --- | --- | --- | F600 | 0 |
| 4191 | Data Logger Mode | 0 to 1 | --- | 1 | F260 | 0 (Continuous) |
| 4192 | Data Logger Trigger | 0 to 4294967295 | --- | 1 | F300 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 24 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 4194 | Data Logger Rate | 15 to 3600000 | ms | 1 | F003 | 60000 |
| **Clock (Read/Write Setting)** | | | | | | |
| 419F | Synchronizing Source | 0 to 3 | --- | 1 | F623 | 0 (None) |
| **Clock (Read/Write Command)** | | | | | | |
| 41A0 | Real Time Clock Set Time | 0 to 235959 | --- | 1 | F050 | 0 |
| **Clock (Read/Write Setting)** | | | | | | |
| 41A2 | SR Date Format | 0 to 4294967295 | --- | 1 | F051 | 0 |
| 41A4 | SR Time Format | 0 to 4294967295 | --- | 1 | F052 | 0 |
| 41A6 | IRIG-B Signal Type | 0 to 2 | --- | 1 | F114 | 0 (None) |
| 41A7 | Clock Events Enable / Disable | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 41A8 | Time Zone Offset from UTC | –24 to 24 | hours | 0.5 | F002 | 0 |
| 41A9 | Daylight Savings Time (DST) Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 41AA | Daylight Savings Time (DST) Start Month | 0 to 11 | --- | 1 | F237 | 0 (January) |
| 41AB | Daylight Savings Time (DST) Start Day | 0 to 6 | --- | 1 | F238 | 0 (Sunday) |
| 41AC | Daylight Savings Time (DST) Start Day Instance | 0 to 4 | --- | 1 | F239 | 0 (First) |
| 41AD | Daylight Savings Time (DST) Start Hour | 0 to 23 | --- | 1 | F001 | 2 |
| 41AE | Daylight Savings Time (DST) Stop Month | 0 to 11 | --- | 1 | F237 | 0 (January) |
| 41AF | Daylight Savings Time (DST) Stop Day | 0 to 6 | --- | 1 | F238 | 0 (Sunday) |
| 41B0 | Daylight Savings Time (DST) Stop Day Instance | 0 to 4 | --- | 1 | F239 | 0 (First) |
| 41B1 | Daylight Savings Time (DST) Stop Hour | 0 to 23 | --- | 1 | F001 | 2 |
| **Fault Report Commands (Read/Write Command)** | | | | | | |
| 41B2 | Fault Reports Clear Data Command | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **Oscillography (Read/Write Setting)** | | | | | | |
| 41C0 | Oscillography Number of Records | 3 to 64 | --- | 1 | F001 | 15 |
| 41C1 | Oscillography Trigger Mode | 0 to 1 | --- | 1 | F118 | 0 (Auto. Overwrite) |
| 41C2 | Oscillography Trigger Position | 0 to 100 | % | 1 | F001 | 50 |
| 41C3 | Oscillography Trigger Source | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 41C5 | Oscillography AC Input Waveforms | 0 to 4 | --- | 1 | F183 | 2 (16 samples/ cycle) |
| 41D0 | Oscillography Analog Channel *n* (16 items) | 0 to 65535 | --- | 1 | F600 | 0 |
| 4200 | Oscillography Digital Channel *n* (63 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| **Trip and Alarm LEDs (Read/Write Setting)** | | | | | | |
| 42B0 | Trip LED Input FlexLogic Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 42B2 | Alarm LED Input FlexLogic Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| **User Programmable LEDs (Read/Write Setting) (48 modules)** | | | | | | |
| 42C0 | FlexLogic Operand to Activate LED | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 42C2 | User LED type (latched or self-resetting) | 0 to 1 | --- | 1 | F127 | 1 (Self-Reset) |
| 42C3 | ...Repeated for User-Programmable LED 2 | | | | | |
| 42C6 | ...Repeated for User-Programmable LED 3 | | | | | |
| 42C9 | ...Repeated for User-Programmable LED 4 | | | | | |
| 42CC | ...Repeated for User-Programmable LED 5 | | | | | |
| 42CF | ...Repeated for User-Programmable LED 6 | | | | | |
| 42D2 | ...Repeated for User-Programmable LED 7 | | | | | |
| 42D5 | ...Repeated for User-Programmable LED 8 | | | | | |
| 42D8 | ...Repeated for User-Programmable LED 9 | | | | | |
| 42DB | ...Repeated for User-Programmable LED 10 | | | | | |
| 42DE | ...Repeated for User-Programmable LED 11 | | | | | |
| 42E1 | ...Repeated for User-Programmable LED 12 | | | | | |
| 42E4 | ...Repeated for User-Programmable LED 13 | | | | | |
| 42E7 | ...Repeated for User-Programmable LED 14 | | | | | |
| 42EA | ...Repeated for User-Programmable LED 15 | | | | | |
| 42ED | ...Repeated for User-Programmable LED 16 | | | | | |
| 42F0 | ...Repeated for User-Programmable LED 17 | | | | | |
| 42F3 | ...Repeated for User-Programmable LED 18 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 25 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 42F6 | ...Repeated for User-Programmable LED 19 | | | | | |
| 42F9 | ...Repeated for User-Programmable LED 20 | | | | | |
| 42FC | ...Repeated for User-Programmable LED 21 | | | | | |
| 42FF | ...Repeated for User-Programmable LED 22 | | | | | |
| 4302 | ...Repeated for User-Programmable LED 23 | | | | | |
| 4305 | ...Repeated for User-Programmable LED 24 | | | | | |
| 4308 | ...Repeated for User-Programmable LED 25 | | | | | |
| 430B | ...Repeated for User-Programmable LED 26 | | | | | |
| 430E | ...Repeated for User-Programmable LED 27 | | | | | |
| 4311 | ...Repeated for User-Programmable LED 28 | | | | | |
| 4314 | ...Repeated for User-Programmable LED 29 | | | | | |
| 4317 | ...Repeated for User-Programmable LED 30 | | | | | |
| 431A | ...Repeated for User-Programmable LED 31 | | | | | |
| 431D | ...Repeated for User-Programmable LED 32 | | | | | |
| 4320 | ...Repeated for User-Programmable LED 33 | | | | | |
| 4323 | ...Repeated for User-Programmable LED 34 | | | | | |
| 4326 | ...Repeated for User-Programmable LED 35 | | | | | |
| 4329 | ...Repeated for User-Programmable LED 36 | | | | | |
| 432C | ...Repeated for User-Programmable LED 37 | | | | | |
| 432F | ...Repeated for User-Programmable LED 38 | | | | | |
| 4332 | ...Repeated for User-Programmable LED 39 | | | | | |
| 4335 | ...Repeated for User-Programmable LED 40 | | | | | |
| 4338 | ...Repeated for User-Programmable LED 41 | | | | | |
| 433B | ...Repeated for User-Programmable LED 42 | | | | | |
| 433E | ...Repeated for User-Programmable LED 43 | | | | | |
| 4341 | ...Repeated for User-Programmable LED 44 | | | | | |
| 4344 | ...Repeated for User-Programmable LED 45 | | | | | |
| 4347 | ...Repeated for User-Programmable LED 46 | | | | | |
| 434A | ...Repeated for User-Programmable LED 47 | | | | | |
| 434D | ...Repeated for User-Programmable LED 48 | | | | | |
| **PRP Status (Read Only)** | | | | | | |
| 4363 | Total Received Port A | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 4365 | Total Received Port B | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 4367 | Total Mismatches Port A | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 4369 | Total Mismatches Port B | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 436B | Total Errors | 0 to 4294967295 | --- | 1 | F003 | 0 |
| **IPv4 Route Table (Read/Write Setting) (6 modules)** | | | | | | |
| 4370 | IPv4 Network Route 1 Destination | 0 to 4294967295 | --- | 1 | F003 | 2130706433 |
| 4372 | IPv4 Network Route 1 Netmask | 0 to 4294967295 | --- | 1 | F003 | 4278190080 |
| 4374 | IPv4 Network Route 1 Gateway | 0 to 4294967295 | --- | 1 | F003 | 2130706433 |
| 4376 | ...Repeated for Route 2 | | | | | |
| 437C | ...Repeated for Route 3 | | | | | |
| 4382 | ...Repeated for Route 4 | | | | | |
| 4388 | ...Repeated for Route 5 | | | | | |
| 438E | ...Repeated for Route 6 | | | | | |
| **Installation (Read/Write Setting)** | | | | | | |
| 43E0 | Relay Programmed State | 0 to 1 | --- | 1 | F133 | 0 (Not Programmed) |
| 43E1 | Relay Name | --- | --- | --- | F202 | “Relay-1” |
| **User Programmable Self Tests (Read/Write Setting)** | | | | | | |
| 4441 | User Programmable Detect Ring Break Function | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 4442 | User Programmable Direct Device Off Function | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 4443 | User Programmable Remote Device Off Function | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 4444 | User Programmable First Ethernet Fail Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |

### Table B–10: MODBUS MEMORY MAP (Sheet 26 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 4445 | User Programmable Secondary Ethernet Fail Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 4446 | User Programmable Battery Fail Function | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 4447 | User Programmable SNTP Fail Function | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 4448 | User Programmable IRIG-B Fail Function | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 4449 | User Programmable Ethernet Switch Fail Function | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 444A | Process Bus Failure Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 444C | PTP Fail Function | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 444D | User Programmable Third Ethernet Fail Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 444E | User Programmable SFP Fail Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **CT Settings (Read/Write Setting) (6 modules)** | | | | | | |
| 4480 | Phase CT 1 Primary | 1 to 65000 | A | 1 | F001 | 1 |
| 4481 | Phase CT 1 Secondary | 0 to 1 | --- | 1 | F123 | 0 (1 A) |
| 4482 | Ground CT 1 Primary | 1 to 65000 | A | 1 | F001 | 1 |
| 4483 | Ground CT 1 Secondary | 0 to 1 | --- | 1 | F123 | 0 (1 A) |
| 4484 | ...Repeated for CT Bank 2 | | | | | |
| 4488 | ...Repeated for CT Bank 3 | | | | | |
| 448C | ...Repeated for CT Bank 4 | | | | | |
| 4490 | ...Repeated for CT Bank 5 | | | | | |
| 4494 | ...Repeated for CT Bank 6 | | | | | |
| **VT Settings (Read/Write Setting) (6 modules)** | | | | | | |
| 4500 | Phase VT 1 Connection | 0 to 1 | --- | 1 | F100 | 0 (Wye) |
| 4501 | Phase VT 1 Secondary | 25 to 240 | V | 0.1 | F001 | 664 |
| 4502 | Phase VT 1 Ratio | 1 to 24000 | :1 | 1 | F060 | 1 |
| 4504 | Auxiliary VT 1 Connection | 0 to 6 | --- | 1 | F166 | 1 (Vag) |
| 4505 | Auxiliary VT 1 Secondary | 25 to 240 | V | 0.1 | F001 | 664 |
| 4506 | Auxiliary VT 1 Ratio | 1 to 24000 | :1 | 1 | F060 | 1 |
| 4508 | ...Repeated for VT Bank 2 | | | | | |
| 4510 | ...Repeated for VT Bank 3 | | | | | |
| 4518 | ...Repeated for VT Bank 4 | | | | | |
| 4520 | ...Repeated for VT Bank 5 | | | | | |
| 4528 | ...Repeated for VT Bank 6 | | | | | |
| **Source Settings (Read/Write Setting) (2 modules)** | | | | | | |
| 4580 | Source 1 Name | 0 to 1 | --- | 1 | F206 | “SRC 1" |
| 4583 | Source 1 Phase CT | 0 to 63 | --- | 1 | F400 | 0 |
| 4584 | Source 1 Ground CT | 0 to 63 | --- | 1 | F400 | 0 |
| 4585 | Source 1 Phase VT | 0 to 63 | --- | 1 | F400 | 0 |
| 4586 | Source 1 Auxiliary VT | 0 to 63 | --- | 1 | F400 | 0 |
| 4587 | ...Repeated for Source 2 | | | | | |
| **Power System (Read/Write Setting)** | | | | | | |
| 4600 | Nominal Frequency | 25 to 60 | Hz | 1 | F001 | 60 |
| 4601 | Phase Rotation | 0 to 1 | --- | 1 | F106 | 0 (ABC) |
| 4602 | Frequency and Phase Reference | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 4603 | Frequency Tracking Function | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| **87L Power System In-Zone Transformer (Read/Write Setting)** | | | | | | |
| 4606 | In-Zone Transformer Connection | 0 to 12 | --- | 1 | F560 | 0 (None) |
| 4607 | 87L In-Zone Transformer Location | 0 to 2 | --- | 1 | F562 | 0 (Local-Tap) |
| **Breaker Control (Read/Write Settings) (2 modules)** | | | | | | |
| 47D0 | Breaker 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 47D1 | Breaker 1 Name | --- | --- | --- | F206 | “Bkr 1" |
| 47D4 | Breaker 1 Mode | 0 to 1 | --- | 1 | F157 | 0 (3-Pole) |
| 47D5 | Breaker 1 Open | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47D7 | Breaker 1 Close | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47D9 | Breaker 1 Phase A / Three-pole Closed | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47DB | Breaker 1 Phase B Closed | 0 to 4294967295 | --- | 1 | F300 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 27 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 47DD | Breaker 1 Phase C Closed | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47DF | Breaker 1 External Alarm | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47E1 | Breaker 1 Alarm Delay | 0 to 65.535 | s | 0.001 | F003 | 0 |
| 47E3 | Breaker 1 Pushbutton Control | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 47E4 | Breaker 1 Manual Close Recall Time | 0 to 65.535 | s | 0.001 | F003 | 0 |
| 47E6 | Breaker 1 Out of Service | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47E8 | Breaker 1 Block Open | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47EA | Breaker 1 Block Close | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47EC | Breaker 1 Phase A / Three-pole Opened | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47EE | Breaker 1 Phase B Opened | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47F0 | Breaker 1 Phase C Opened | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 47F2 | Breaker 1 Operate Time | 0 to 65.535 | s | 0.001 | F001 | 70 |
| 47F3 | Breaker 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 47F4 | Reserved | 0 to 65535 | s | 1 | F001 | 0 |
| 47F5 | ...Repeated for Breaker 2 | | | | | |
| **FlexCurves A and B (Read/Write Settings)** | | | | | | |
| 4910 | FlexCurve A (120 items) | 0 to 65535 | ms | 1 | F011 | 0 |
| 4988 | FlexCurve B (120 items) | 0 to 65535 | ms | 1 | F011 | 0 |
| **Modbus User Map (Read/Write Setting)** | | | | | | |
| 4A00 | Modbus Address Settings for User Map (256 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| **User Displays Settings (Read/Write Setting) (16 modules)** | | | | | | |
| 4C00 | User-Definable Display 1 Top Line Text | --- | --- | --- | F202 | " " |
| 4C0A | User-Definable Display 1 Bottom Line Text | --- | --- | --- | F202 | " " |
| 4C14 | Modbus Addresses of Display 1 Items (5 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| 4C19 | Reserved (7 items) | --- | --- | --- | F001 | 0 |
| 4C20 | ...Repeated for User-Definable Display 2 | | | | | |
| 4C40 | ...Repeated for User-Definable Display 3 | | | | | |
| 4C60 | ...Repeated for User-Definable Display 4 | | | | | |
| 4C80 | ...Repeated for User-Definable Display 5 | | | | | |
| 4CA0 | ...Repeated for User-Definable Display 6 | | | | | |
| 4CC0 | ...Repeated for User-Definable Display 7 | | | | | |
| 4CE0 | ...Repeated for User-Definable Display 8 | | | | | |
| 4D00 | ...Repeated for User-Definable Display 9 | | | | | |
| 4D20 | ...Repeated for User-Definable Display 10 | | | | | |
| 4D40 | ...Repeated for User-Definable Display 11 | | | | | |
| 4D60 | ...Repeated for User-Definable Display 12 | | | | | |
| 4D80 | ...Repeated for User-Definable Display 13 | | | | | |
| 4DA0 | ...Repeated for User-Definable Display 14 | | | | | |
| 4DC0 | ...Repeated for User-Definable Display 15 | | | | | |
| 4DE0 | ...Repeated for User-Definable Display 16 | | | | | |
| **Field Unit Raw Data Actuals (Read Only) (8 modules)** | | | | | | |
| 4E00 | Raw Field Data AC1 Mag | 0 to 0.001 | A | 0.001 | F003 | 0 |
| 4E02 | Raw Field Data AC1 Angle | 0 to 0.1 | degree | 0.1 | F002 | 0 |
| 4E03 | Raw Field Data AC2 Mag | 0 to 0.001 | A | 0.001 | F003 | 0 |
| 4E05 | Raw Field Data AC2 Angle | 0 to 0.1 | degree | 0.1 | F002 | 0 |
| 4E06 | Raw Field Data AC3 Mag | 0 to 0.001 | A | 0.001 | F003 | 0 |
| 4E08 | Raw Field Data AC3 Angle | 0 to 0.1 | degree | 0.1 | F002 | 0 |
| 4E09 | Raw Field Data AC4 Mag | 0 to 0.001 | A | 0.001 | F003 | 0 |
| 4E0B | Raw Field Data AC4 Angle | 0 to 0.1 | degree | 0.1 | F002 | 0 |
| 4E0C | Raw Field Data AC5 Mag | 0 to 0.001 | A/V | 0.001 | F003 | 0 |
| 4E0E | Raw Field Data AC5 Angle | 0 to 0.1 | degree | 0.1 | F002 | 0 |
| 4E0F | Raw Field Data AC6 Mag | 0 to 0.001 | A/V | 0.001 | F003 | 0 |
| 4E11 | Raw Field Data AC6 Angle | 0 to 0.1 | degree | 0.1 | F002 | 0 |
| 4E12 | Raw Field Data AC7 Mag | 0 to 0.001 | A/V | 0.001 | F003 | 0 |

**Table B–10: MODBUS MEMORY MAP (Sheet 28 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 4E14 | Raw Field Data AC7 Angle | 0 to 0.1 | degree | 0.1 | F002 | 0 |
| 4E15 | Raw Field Data AC8 Mag | 0 to 0.001 | A/V | 0.001 | F003 | 0 |
| 4E17 | Raw Field Data AC8 Angle | 0 to 0.1 | degree | 0.1 | F002 | 0 |
| 4E18 | Raw Field Data DC1 | 0 to 0.001 | V | 0.001 | F002 | 0 |
| 4E19 | Raw Field Data DC2 | 0 to 0.001 | V | 0.001 | F002 | 0 |
| 4E1A | Raw Field Data DC3 | 0 to 0.001 | V | 0.001 | F002 | 0 |
| 4E1B | Raw Field Data FCI States (2 items) | 0 to 1 | --- | 1 | F500 | 0 |
| 4E1D | Raw Field Data SI States | 0 to 1 | --- | 1 | F500 | 0 |
| 4E1E | Raw Field Data SI Test States | 0 to 1 | --- | 1 | F500 | 0 |
| 4E1F | Raw Field Data Brick ADC Temperature | 0 to 1 | degree | 1 | F002 | 0 |
| 4E20 | Raw Field Data Brick Transceiver Temperature | 0 to 1 | degree | 1 | F002 | 0 |
| 4E21 | Raw Field Data Brick Transceiver Voltage | 0 to 0.01 | V | 0.01 | F001 | 0 |
| 4E22 | Raw Field Data Brick Transceiver Current | 0 to 1 | mA | 1 | F001 | 0 |
| 4E23 | Raw Field Data Brick Tx Power | 0 to 0.1 | dBm | 0.1 | F002 | 0 |
| 4E24 | Raw Field Data Brick Rx Power | 0 to 0.1 | dBm | 0.1 | F002 | 0 |
| 4E25 | Raw Field Data Brick Diagnostics (2 items) | 0 to 65535 | --- | 1 | F500 | 0 |
| 4E27 | Raw Field Data Local Transceiver Temperature | 0 to 1 | degree | 1 | F002 | 0 |
| 4E28 | Raw Field Data Local Transceiver Voltage | 0 to 0.01 | V | 0.01 | F001 | 0 |
| 4E29 | Raw Field Data Local Transceiver Current | 0 to 1 | mA | 1 | F001 | 0 |
| 4E2A | Raw Field Data Local Tx Power | 0 to 0.1 | dBm | 0.1 | F002 | 0 |
| 4E2B | Raw Field Data Local Rx Power | 0 to 0.1 | dBm | 0.1 | F002 | 0 |
| 4E2C | Repeated for Field Unit 2 | | | | | |
| 4E58 | Repeated for Field Unit 3 | | | | | |
| 4E84 | Repeated for Field Unit 4 | | | | | |
| 4EB0 | Repeated for Field Unit 5 | | | | | |
| 4EDC | Repeated for Field Unit 6 | | | | | |
| 4F08 | Repeated for Field Unit 7 | | | | | |
| 4F34 | Repeated for Field Unit 8 | | | | | |
| **FlexLogic (Read/Write Setting)** | | | | | | |
| 5000 | FlexLogic Entry (512 items) | 0 to 4294967295 | --- | 1 | F300 | 2097152 |
| **RTD Inputs (Read/Write Setting) (48 modules)** | | | | | | |
| 5400 | RTD Input 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5401 | RTD Input 1 ID | --- | --- | --- | F205 | “RTD Ip 1“ |
| 5407 | RTD Input 1 Type | 0 to 3 | --- | 1 | F174 | 0 (100 ohm Platinum) |
| 5414 | ...Repeated for RTD Input 2 | | | | | |
| 5428 | ...Repeated for RTD Input 3 | | | | | |
| 543C | ...Repeated for RTD Input 4 | | | | | |
| 5450 | ...Repeated for RTD Input 5 | | | | | |
| 5464 | ...Repeated for RTD Input 6 | | | | | |
| 5478 | ...Repeated for RTD Input 7 | | | | | |
| 548C | ...Repeated for RTD Input 8 | | | | | |
| 54A0 | ...Repeated for RTD Input 9 | | | | | |
| 54B4 | ...Repeated for RTD Input 10 | | | | | |
| 54C8 | ...Repeated for RTD Input 11 | | | | | |
| 54DC | ...Repeated for RTD Input 12 | | | | | |
| 54F0 | ...Repeated for RTD Input 13 | | | | | |
| 5504 | ...Repeated for RTD Input 14 | | | | | |
| 5518 | ...Repeated for RTD Input 15 | | | | | |
| 552C | ...Repeated for RTD Input 16 | | | | | |
| 5540 | ...Repeated for RTD Input 17 | | | | | |
| 5554 | ...Repeated for RTD Input 18 | | | | | |
| 5568 | ...Repeated for RTD Input 19 | | | | | |
| 557C | ...Repeated for RTD Input 20 | | | | | |

**Table B–10: MODBUS MEMORY MAP (Sheet 29 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 5590 | ...Repeated for RTD Input 21 | | | | | |
| 55A4 | ...Repeated for RTD Input 22 | | | | | |
| 55B8 | ...Repeated for RTD Input 23 | | | | | |
| 55CC | ...Repeated for RTD Input 24 | | | | | |
| 55E0 | ...Repeated for RTD Input 25 | | | | | |
| 55F4 | ...Repeated for RTD Input 26 | | | | | |
| 5608 | ...Repeated for RTD Input 27 | | | | | |
| 561C | ...Repeated for RTD Input 28 | | | | | |
| 5630 | ...Repeated for RTD Input 29 | | | | | |
| 5644 | ...Repeated for RTD Input 30 | | | | | |
| 5658 | ...Repeated for RTD Input 31 | | | | | |
| 566C | ...Repeated for RTD Input 32 | | | | | |
| 5680 | ...Repeated for RTD Input 33 | | | | | |
| 5694 | ...Repeated for RTD Input 34 | | | | | |
| 56A8 | ...Repeated for RTD Input 35 | | | | | |
| 56BC | ...Repeated for RTD Input 36 | | | | | |
| 56D0 | ...Repeated for RTD Input 37 | | | | | |
| 56E4 | ...Repeated for RTD Input 38 | | | | | |
| 56F8 | ...Repeated for RTD Input 39 | | | | | |
| 570C | ...Repeated for RTD Input 40 | | | | | |
| 5720 | ...Repeated for RTD Input 41 | | | | | |
| 5734 | ...Repeated for RTD Input 42 | | | | | |
| 5748 | ...Repeated for RTD Input 43 | | | | | |
| 575C | ...Repeated for RTD Input 44 | | | | | |
| 5770 | ...Repeated for RTD Input 45 | | | | | |
| 5784 | ...Repeated for RTD Input 46 | | | | | |
| 5798 | ...Repeated for RTD Input 47 | | | | | |
| 57AC | ...Repeated for RTD Input 48 | | | | | |
| **FlexLogic Timers (Read/Write Setting) (32 modules)** | | | | | | |
| 5800 | FlexLogic Timer 1 Type | 0 to 2 | --- | 1 | F129 | 0 (millisecond) |
| 5801 | FlexLogic Timer 1 Pickup Delay | 0 to 60000 | --- | 1 | F001 | 0 |
| 5802 | FlexLogic Timer 1 Dropout Delay | 0 to 60000 | --- | 1 | F001 | 0 |
| 5803 | Reserved (5 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| 5808 | ...Repeated for FlexLogic Timer 2 | | | | | |
| 5810 | ...Repeated for FlexLogic Timer 3 | | | | | |
| 5818 | ...Repeated for FlexLogic Timer 4 | | | | | |
| 5820 | ...Repeated for FlexLogic Timer 5 | | | | | |
| 5828 | ...Repeated for FlexLogic Timer 6 | | | | | |
| 5830 | ...Repeated for FlexLogic Timer 7 | | | | | |
| 5838 | ...Repeated for FlexLogic Timer 8 | | | | | |
| 5840 | ...Repeated for FlexLogic Timer 9 | | | | | |
| 5848 | ...Repeated for FlexLogic Timer 10 | | | | | |
| 5850 | ...Repeated for FlexLogic Timer 11 | | | | | |
| 5858 | ...Repeated for FlexLogic Timer 12 | | | | | |
| 5860 | ...Repeated for FlexLogic Timer 13 | | | | | |
| 5868 | ...Repeated for FlexLogic Timer 14 | | | | | |
| 5870 | ...Repeated for FlexLogic Timer 15 | | | | | |
| 5878 | ...Repeated for FlexLogic Timer 16 | | | | | |
| 5880 | ...Repeated for FlexLogic Timer 17 | | | | | |
| 5888 | ...Repeated for FlexLogic Timer 18 | | | | | |
| 5890 | ...Repeated for FlexLogic Timer 19 | | | | | |
| 5898 | ...Repeated for FlexLogic Timer 20 | | | | | |
| 58A0 | ...Repeated for FlexLogic Timer 21 | | | | | |
| 58A8 | ...Repeated for FlexLogic Timer 22 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 30 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 58B0 | ...Repeated for FlexLogic Timer 23 | | | | | |
| 58B8 | ...Repeated for FlexLogic Timer 24 | | | | | |
| 58C0 | ...Repeated for FlexLogic Timer 25 | | | | | |
| 58C8 | ...Repeated for FlexLogic Timer 26 | | | | | |
| 58D0 | ...Repeated for FlexLogic Timer 27 | | | | | |
| 58D8 | ...Repeated for FlexLogic Timer 28 | | | | | |
| 58E0 | ...Repeated for FlexLogic Timer 29 | | | | | |
| 58E8 | ...Repeated for FlexLogic Timer 30 | | | | | |
| 58F0 | ...Repeated for FlexLogic Timer 31 | | | | | |
| 58F8 | ...Repeated for FlexLogic Timer 32 | | | | | |
| **Phase Time Overcurrent (Read/Write Grouped Setting) (2 modules)** | | | | | | |
| 5900 | Phase Time Overcurrent 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5901 | Phase Time Overcurrent 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 5902 | Phase Time Overcurrent 1 Input | 0 to 1 | --- | 1 | F122 | 0 (Phasor) |
| 5903 | Phase Time Overcurrent 1 Pickup | 0 to 30 | pu | 0.001 | F001 | 1000 |
| 5904 | Phase Time Overcurrent 1 Curve | 0 to 16 | --- | 1 | F103 | 0 (IEEE Mod Inv) |
| 5905 | Phase Time Overcurrent 1 Multiplier | 0 to 600 | --- | 0.01 | F001 | 100 |
| 5906 | Phase Time Overcurrent 1 Reset | 0 to 1 | --- | 1 | F104 | 0 (Instantaneous) |
| 5907 | Phase Time Overcurrent 1 Voltage Restraint | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5908 | Phase TOC 1 Block For Each Phase (3 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 590F | Phase Time Overcurrent 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 5910 | Phase Time Overcurrent 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5911 | Reserved (3 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 5914 | ...Repeated for Phase Time Overcurrent 2 | | | | | |
| **Phase Instantaneous Overcurrent (Read/Write Grouped Setting) (4 modules)** | | | | | | |
| 5A00 | Phase Instantaneous Overcurrent 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5A01 | Phase Instantaneous Overcurrent 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 5A02 | Phase Instantaneous Overcurrent 1 Pickup | 0 to 30 | pu | 0.001 | F001 | 1000 |
| 5A03 | Phase Instantaneous Overcurrent 1 Delay | 0 to 600 | s | 0.01 | F001 | 0 |
| 5A04 | Phase Instantaneous Overcurrent 1 Reset Delay | 0 to 600 | s | 0.01 | F001 | 0 |
| 5A05 | Phase IOC1 Block For Each Phase (3 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5A0B | Phase Instantaneous Overcurrent 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 5A0C | Phase Instantaneous Overcurrent 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5A0D | Reserved (6 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 5A13 | ...Repeated for Phase Instantaneous Overcurrent 2 | | | | | |
| 5A26 | ...Repeated for Phase Instantaneous Overcurrent 3 | | | | | |
| 5A39 | ...Repeated for Phase Instantaneous Overcurrent 4 | | | | | |
| **Neutral Time Overcurrent (Read/Write Grouped Setting) (2 modules)** | | | | | | |
| 5B00 | Neutral Time Overcurrent 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5B01 | Neutral Time Overcurrent 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 5B02 | Neutral Time Overcurrent 1 Input | 0 to 1 | --- | 1 | F122 | 0 (Phasor) |
| 5B03 | Neutral Time Overcurrent 1 Pickup | 0 to 30 | pu | 0.001 | F001 | 1000 |
| 5B04 | Neutral Time Overcurrent 1 Curve | 0 to 16 | --- | 1 | F103 | 0 (IEEE Mod Inv) |
| 5B05 | Neutral Time Overcurrent 1 Multiplier | 0 to 600 | --- | 0.01 | F001 | 100 |
| 5B06 | Neutral Time Overcurrent 1 Reset | 0 to 1 | --- | 1 | F104 | 0 (Instantaneous) |
| 5B07 | Neutral Time Overcurrent 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5B09 | Neutral Time Overcurrent 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 5B0A | Neutral Time Overcurrent 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5B0B | Reserved (6 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 5B11 | ...Repeated for Neutral Time Overcurrent 2 | | | | | |
| **Neutral Instantaneous Overcurrent (Read/Write Grouped Setting) (4 modules)** | | | | | | |
| 5C00 | Neutral Instantaneous Overcurrent 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5C01 | Neutral Instantaneous Overcurrent 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 5C02 | Neutral Instantaneous Overcurrent 1 Pickup | 0 to 30 | pu | 0.001 | F001 | 1000 |

### Table B–10: MODBUS MEMORY MAP (Sheet 31 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 5C03 | Neutral Instantaneous Overcurrent 1 Delay | 0 to 600 | s | 0.01 | F001 | 0 |
| 5C04 | Neutral Instantaneous Overcurrent 1 Reset Delay | 0 to 600 | s | 0.01 | F001 | 0 |
| 5C05 | Neutral Instantaneous Overcurrent 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5C07 | Neutral Instantaneous Overcurrent 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 5C08 | Neutral Instantaneous Overcurrent 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5C09 | Reserved (8 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 5C11 | ...Repeated for Neutral Instantaneous Overcurrent 2 | | | | | |
| 5C22 | ...Repeated for Neutral Instantaneous Overcurrent 3 | | | | | |
| 5C33 | ...Repeated for Neutral Instantaneous Overcurrent 4 | | | | | |
| **Ground Time Overcurrent (Read/Write Grouped Setting) (2 modules)** | | | | | | |
| 5D00 | Ground Time Overcurrent 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5D01 | Ground Time Overcurrent 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 5D02 | Ground Time Overcurrent 1 Input | 0 to 1 | --- | 1 | F122 | 0 (Phasor) |
| 5D03 | Ground Time Overcurrent 1 Pickup | 0 to 30 | pu | 0.001 | F001 | 1000 |
| 5D04 | Ground Time Overcurrent 1 Curve | 0 to 16 | --- | 1 | F103 | 0 (IEEE Mod Inv) |
| 5D05 | Ground Time Overcurrent 1 Multiplier | 0 to 600 | --- | 0.01 | F001 | 100 |
| 5D06 | Ground Time Overcurrent 1 Reset | 0 to 1 | --- | 1 | F104 | 0 (Instantaneous) |
| 5D07 | Ground Time Overcurrent 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5D09 | Ground Time Overcurrent 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 5D0A | Ground Time Overcurrent 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5D0B | Reserved (6 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 5D11 | ...Repeated for Ground Time Overcurrent 2 | | | | | |
| **Ground Instantaneous Overcurrent (Read/Write Grouped Setting) (4 modules)** | | | | | | |
| 5DA0 | Ground Instantaneous Overcurrent 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5DA1 | Ground Instantaneous Overcurrent 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 5DA2 | Ground Instantaneous Overcurrent 1 Pickup | 0 to 30 | pu | 0.001 | F001 | 1000 |
| 5DA3 | Ground Instantaneous Overcurrent 1 Delay | 0 to 600 | s | 0.01 | F001 | 0 |
| 5DA4 | Ground Instantaneous Overcurrent 1 Reset Delay | 0 to 600 | s | 0.01 | F001 | 0 |
| 5DA5 | Ground Instantaneous Overcurrent 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5DA7 | Ground Instantaneous Overcurrent 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 5DA8 | Ground Instantaneous Overcurrent 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5DA9 | Reserved (8 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 5DB1 | ...Repeated for Ground Instantaneous Overcurrent 2 | | | | | |
| 5DC2 | ...Repeated for Ground Instantaneous Overcurrent 3 | | | | | |
| 5DD3 | ...Repeated for Ground Instantaneous Overcurrent 4 | | | | | |
| **CT Fail (Read/Write Setting) (2 modules)** | | | | | | |
| 5E6C | CT Fail 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5E6D | CT Fail 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5E6F | CT Fail 1 Current Source 1 | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 5E70 | CT Fail 1 Current Pickup 1 | 0 to 2 | pu | 0.1 | F001 | 2 |
| 5E71 | CT Fail 1 Current Source 2 | 0 to 5 | --- | 1 | F167 | 1 (SRC 2) |
| 5E72 | CT Fail 1 Current Pickup 2 | 0 to 2 | pu | 0.1 | F001 | 2 |
| 5E73 | CT Fail 1 Voltage Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 5E74 | CT Fail 1 Voltage Pickup | 0 to 2 | pu | 0.01 | F001 | 20 |
| 5E75 | CT Fail 1 Pickup Delay | 0 to 65.535 | s | 0.001 | F001 | 1000 |
| 5E76 | CT Fail 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 5E77 | CT Fail 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5E78 | ...Repeated for CT Fail 2 | | | | | |
| **Stub Bus (Read/Write Grouped Setting)** | | | | | | |
| 5F10 | Stub Bus Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5F11 | Stub Bus Disconnect | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5F13 | Stub Bus Trigger | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5F15 | Stub Bus Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 5F17 | Stub Bus Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |

### Table B–10: MODBUS MEMORY MAP (Sheet 32 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| **50DD Disturbance Detection (Read/Write Grouped Setting)** | | | | | | |
| 5F20 | 50DD Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5F21 | 50DD Non Current Supervision | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5F23 | 50DD Control Logic | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5F25 | 50DD Logic Seal In | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5F27 | 50DD Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Setting Groups (Read/Write Setting)** | | | | | | |
| 5F70 | Setting Group for Modbus Comms (0 means group 1) | 0 to 5 | --- | 1 | F001 | 0 |
| 5F71 | Setting Groups Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5F73 | FlexLogic Operands to Activate Groups 2 through 6 (5 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 5F7D | Setting Group Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 5F7E | Setting Group Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Setting Groups (Read Only)** | | | | | | |
| 5F7F | Current Setting Group | 0 to 5 | --- | 1 | F001 | 0 |
| **Setting Group Names (Read/Write Setting)** | | | | | | |
| 5F8C | Setting Group 1 Name | --- | --- | --- | F203 | (none) |
| 5F94 | Setting Group 2 Name | --- | --- | --- | F203 | (none) |
| 5F9C | Setting Group 3 Name | --- | --- | --- | F203 | (none) |
| 5FA4 | Setting Group 4 Name | --- | --- | --- | F203 | (none) |
| 5FAC | Setting Group 5 Name | --- | --- | --- | F203 | (none) |
| 5FB4 | Setting Group 6 Name | --- | --- | --- | F203 | (none) |
| **Current Differential 87L (Read/Write Grouped Setting)** | | | | | | |
| 6000 | 87L Current Differential Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 6001 | 87L Current Differential Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 6003 | 87L Current Differential Signal Source 1 | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 6004 | 87L Minimum Phase Current Sensitivity | 0.1 to 4 | pu | 0.01 | F001 | 20 |
| 6005 | 87L Current Differential Tap Setting | 0.2 to 5 | --- | 0.01 | F001 | 100 |
| 6006 | 87L Current Differential Phase Percent Restraint 1 | 1 to 50 | % | 1 | F001 | 30 |
| 6007 | 87L Current Differential Phase Percent Restraint 2 | 1 to 70 | % | 1 | F001 | 50 |
| 6008 | 87L Current Differential Phase Dual Slope Breakpoint | 0 to 20 | pu | 0.1 | F001 | 10 |
| 6009 | 87L Current Differential Ground Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 600A | 87L Current Differential Ground Pickup | 0.05 to 1 | pu | 0.01 | F001 | 10 |
| 600B | 87L Current Differential Ground Restraint | 1 to 50 | % | 1 | F001 | 25 |
| 600C | 87L Current Differential Ground Delay | 0 to 5 | seconds | 0.01 | F001 | 10 |
| 600D | 87L Current Differential Key DTT | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 600E | 87L Current Differential External Key DTT | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 6010 | 87L Current Differential Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 6011 | 87L Current Differential Event | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 6012 | 87L Current Differential Tap 2 Setting | 0.2 to 5 | --- | 0.01 | F001 | 100 |
| **Current Differential 87L In-Zone Transformer (Read/Write Grouped Setting)** | | | | | | |
| 601E | 87L Inrush Inhibit Mode | 0 to 3 | --- | 1 | F561 | 0 (Disabled) |
| 601F | 87L Inrush Inhibit Level | 1 to 40 | %$f_0$ | 0.1 | F001 | 200 |
| **Autoreclose (Read/Write Setting) (2 modules)** | | | | | | |
| 6200 | Autoreclose 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 6201 | Autoreclose 1 Initiate | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 6203 | Autoreclose 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 6205 | Autoreclose 1 Max Number of Shots | 1 to 4 | --- | 1 | F001 | 1 |
| 6206 | Autoreclose 1 Manual Close | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 6208 | Autoreclose 1 Manual Reset from LO | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 620A | Autoreclose 1 Reset Lockout if Breaker Closed | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 620B | Autoreclose 1 Reset Lockout On Manual Close | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| 620C | Autoreclose 1 Breaker Closed | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 620E | Autoreclose 1 Breaker Open | 0 to 4294967295 | --- | 1 | F300 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 33 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 6210 | Autoreclose 1 Block Time Upon Manual Close | 0 to 655.35 | s | 0.01 | F001 | 1000 |
| 6211 | Autoreclose 1 Dead Time Shot 1 | 0 to 655.35 | s | 0.01 | F001 | 100 |
| 6212 | Autoreclose 1 Dead Time Shot 2 | 0 to 655.35 | s | 0.01 | F001 | 200 |
| 6213 | Autoreclose 1 Dead Time Shot 3 | 0 to 655.35 | s | 0.01 | F001 | 300 |
| 6214 | Autoreclose 1 Dead Time Shot 4 | 0 to 655.35 | s | 0.01 | F001 | 400 |
| 6215 | Autoreclose 1 Reset Lockout Delay | 0 to 655.35 | s | 0.01 | F001 | 6000 |
| 6216 | Autoreclose 1 Reset Time | 0 to 655.35 | s | 0.01 | F001 | 6000 |
| 6217 | Autoreclose 1 Incomplete Sequence Time | 0 to 655.35 | s | 0.01 | F001 | 500 |
| 6218 | Autoreclose 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 6219 | Autoreclose 1 Reduce Max 1 | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 621B | Autoreclose 1 Reduce Max 2 | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 621D | Autoreclose 1 Reduce Max 3 | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 621F | Autoreclose 1 Add Delay 1 | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 6221 | Autoreclose 1 Delay 1 | 0 to 655.35 | s | 0.01 | F001 | 0 |
| 6222 | Autoreclose 1 Add Delay 2 | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 6224 | Autoreclose 1 Delay 2 | 0 to 655.35 | s | 0.01 | F001 | 0 |
| 6225 | Reserved (4 items) | 0 to 0.001 | --- | 0.001 | F001 | 0 |
| 6229 | ...Repeated for Autoreclose 2 | | | | | |
| **Negative Sequence Time Overcurrent (Read/Write Grouped Setting) (2 modules)** | | | | | | |
| 6300 | Negative Sequence Time Overcurrent 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 6301 | Negative Sequence Time Overcurrent 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 6302 | Negative Sequence Time Overcurrent 1 Pickup | 0 to 30 | pu | 0.001 | F001 | 1000 |
| 6303 | Negative Sequence Time Overcurrent 1 Curve | 0 to 16 | --- | 1 | F103 | 0 (IEEE Mod Inv) |
| 6304 | Negative Sequence Time Overcurrent 1 Multiplier | 0 to 600 | --- | 0.01 | F001 | 100 |
| 6305 | Negative Sequence Time Overcurrent 1 Reset | 0 to 1 | --- | 1 | F104 | 0 (Instantaneous) |
| 6306 | Negative Sequence Time Overcurrent 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 6308 | Negative Sequence Time Overcurrent 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 6309 | Negative Sequence Time Overcurrent 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 630A | Reserved (7 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 6311 | ...Repeated for Negative Sequence Time Overcurrent 2 | | | | | |
| **Negative Sequence Instantaneous Overcurrent (Read/Write Grouped Setting) (2 modules)** | | | | | | |
| 63C0 | Negative Sequence Instantaneous OC 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 63C1 | Negative Sequence Instantaneous OC 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 63C2 | Negative Sequence Instantaneous Overcurrent 1 Pickup | 0 to 30 | pu | 0.001 | F001 | 1000 |
| 63C3 | Negative Sequence Instantaneous Overcurrent 1 Delay | 0 to 600 | s | 0.01 | F001 | 0 |
| 63C4 | Negative Sequence Instantaneous OC 1 Reset Delay | 0 to 600 | s | 0.01 | F001 | 0 |
| 63C5 | Negative Sequence Instantaneous Overcurrent 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 63C7 | Negative Sequence Instantaneous Overcurrent 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 63C8 | Negative Sequence Instantaneous Overcurrent 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 63C9 | Reserved (8 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 63D1 | ...Repeated for Negative Sequence Instantaneous OC 2 | | | | | |
| **Negative Sequence Overvoltage (Read/Write Grouped Setting) (3 modules)** | | | | | | |
| 6440 | Negative Sequence Overvoltage 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 6441 | Negative Sequence Overvoltage 1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 6442 | Negative Sequence Overvoltage 1 Pickup | 0 to 1.25 | pu | 0.001 | F001 | 300 |
| 6443 | Negative Sequence Overvoltage 1 Pickup Delay | 0 to 600 | s | 0.01 | F001 | 50 |
| 6444 | Negative Sequence Overvoltage 1 Reset Delay | 0 to 600 | s | 0.01 | F001 | 50 |
| 6445 | Negative Sequence Overvoltage 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 6447 | Negative Sequence Overvoltage 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 6448 | Negative Sequence Overvoltage 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 6449 | ...Repeated for Negative Sequence Overvoltage 2 | | | | | |
| 6452 | ...Repeated for Negative Sequence Overvoltage 3 | | | | | |
| **Phase Undervoltage (Read/Write Grouped Setting) (3 modules)** | | | | | | |
| 7000 | Phase Undervoltage 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |

### Table B–10: MODBUS MEMORY MAP (Sheet 34 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 7001 | Phase Undervoltage 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 7002 | Phase Undervoltage 1 Pickup | 0 to 3 | pu | 0.001 | F001 | 1000 |
| 7003 | Phase Undervoltage 1 Curve | 0 to 1 | --- | 1 | F111 | 0 (Definite Time) |
| 7004 | Phase Undervoltage 1 Delay | 0 to 600 | s | 0.01 | F001 | 100 |
| 7005 | Phase Undervoltage 1 Minimum Voltage | 0 to 3 | pu | 0.001 | F001 | 100 |
| 7006 | Phase Undervoltage 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7008 | Phase Undervoltage 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 7009 | Phase Undervoltage 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 700A | Phase Undervoltage 1 Measurement Mode | 0 to 1 | --- | 1 | F186 | 0 (Phase to Ground) |
| 700B | Reserved (6 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 7013 | ...Repeated for Phase Undervoltage 2 | | | | | |
| 7022 | ...Repeated for Phase Undervoltage 3 | | | | | |
| **Phase Overvoltage (Read/Write Grouped Setting) (3 modules)** | | | | | | |
| 7040 | Phase Overvoltage 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7041 | Phase Overvoltage 1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 7042 | Phase Overvoltage 1 Pickup | 0 to 3 | pu | 0.001 | F001 | 1000 |
| 7043 | Phase Overvoltage 1 Delay | 0 to 600 | s | 0.01 | F001 | 100 |
| 7044 | Phase Overvoltage 1 Reset Delay | 0 to 600 | s | 0.01 | F001 | 100 |
| 7045 | Phase Overvoltage 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7047 | Phase Overvoltage 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 7048 | Phase Overvoltage 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7049 | ...Repeated for Phase Overvoltage 2 | | | | | |
| 7052 | ...Repeated for Phase Overvoltage 3 | | | | | |
| **Phase Directional Overcurrent (Read/Write Grouped Setting) (2 modules)** | | | | | | |
| 7200 | Phase Directional Overcurrent 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7201 | Phase Directional Overcurrent 1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 7202 | Phase Directional Overcurrent 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7204 | Phase Directional Overcurrent 1 ECA | 0 to 359 | --- | 1 | F001 | 30 |
| 7205 | Phase Directional Overcurrent 1 Pol V Threshold | 0 to 3 | pu | 0.001 | F001 | 700 |
| 7206 | Phase Directional Overcurrent 1 Block Overcurrent | 0 to 1 | --- | 1 | F126 | 0 (No) |
| 7207 | Phase Directional Overcurrent 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 7208 | Phase Directional Overcurrent 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7209 | Reserved (8 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 7211 | ...Repeated for Phase Directional Overcurrent 2 | | | | | |
| **Neutral Directional Overcurrent (Read/Write Grouped Setting) (2 modules)** | | | | | | |
| 7230 | Neutral Directional Overcurrent 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7231 | Neutral Directional Overcurrent 1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 7232 | Neutral Directional Overcurrent 1 Polarizing | 0 to 4 | --- | 1 | F230 | 0 (Voltage) |
| 7233 | Neutral Directional Overcurrent 1 Forward ECA | -90 to 90 | ° Lag | 1 | F002 | 75 |
| 7234 | Neutral Directional Overcurrent 1 Forward Limit Angle | 40 to 90 | degrees | 1 | F001 | 90 |
| 7235 | Neutral Directional Overcurrent 1 Forward Pickup | 0.006 to 30 | pu | 0.001 | F001 | 50 |
| 7236 | Neutral Directional Overcurrent 1 Reverse Limit Angle | 40 to 90 | degrees | 1 | F001 | 90 |
| 7237 | Neutral Directional Overcurrent 1 Reverse Pickup | 0.006 to 30 | pu | 0.001 | F001 | 50 |
| 7238 | Neutral Directional Overcurrent 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 7239 | Neutral Directional Overcurrent 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 723B | Neutral Directional Overcurrent 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 723C | Neutral Directional Overcurrent 1 Polarizing Voltage | 0 to 1 | --- | 1 | F231 | 0 (Calculated V0) |
| 723D | Neutral Directional Overcurrent 1 Op Current | 0 to 1 | --- | 1 | F196 | 0 (Calculated 3I0) |
| 723E | Neutral Directional Overcurrent 1 Offset | 0 to 250 | ohms | 0.01 | F001 | 0 |
| 723F | Neutral Directional Overcurrent 1 Pos Seq Restraint | 0 to 0.5 | --- | 0.001 | F001 | 63 |
| 7240 | Reserved | 0 to 1 | --- | 1 | F001 | 0 |
| 7241 | ...Repeated for Neutral Directional Overcurrent 2 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 35 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| **Breaker Arcing Current Settings (Read/Write Setting) (2 modules)** | | | | | | |
| 7290 | Breaker 1 Arcing Amp Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7291 | Breaker 1 Arcing Amp Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 7292 | Breaker 1 Arcing Amp Init | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7294 | Breaker 1 Arcing Amp Init B | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7296 | Breaker 1 Arcing Amp Init C | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7298 | Breaker 1 Arcing Amp Delay | 0 to 65.535 | s | 0.001 | F001 | 0 |
| 7299 | Breaker 1 Arcing Amp Limit | 0 to 50000 | kA2-cyc | 1 | F001 | 1000 |
| 729A | Breaker 1 Arcing Amp Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 729C | Breaker 1 Arcing Amp Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 729D | Breaker 1 Arcing Amp Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 729E | ...Repeated for Breaker 2 Arcing Amp | | | | | |
| **Disconnect (Breaker) Switch (Read/Write Setting) (8 modules)** | | | | | | |
| 74A0 | Disconnect Switch 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 74A1 | Disconnect Switch 1 Name | --- | --- | --- | F206 | "SW 1" |
| 74A4 | Disconnect Switch 1 Mode | 0 to 1 | --- | 1 | F157 | 0 (3-Pole) |
| 74A5 | Disconnect Switch 1 Open | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 74A7 | Disconnect Switch 1 Block Open | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 74A9 | Disconnect Switch 1 Close | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 74AB | Disconnect Switch 1 Block Close | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 74AD | Disconnect Switch 1 Phase A / Three-pole Closed | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 74AF | Disconnect Switch 1 Phase A / Three-pole Opened | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 74B1 | Disconnect Switch 1 Phase B Closed | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 74B3 | Disconnect Switch 1 Phase B Opened | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 74B5 | Disconnect Switch 1 Phase C Closed | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 74B7 | Disconnect Switch 1 Phase C Opened | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 74B9 | Disconnect Switch 1 Operate Time | 0 to 65.535 | s | 0.001 | F001 | 70 |
| 74BA | Disconnect Switch 1 Alarm Delay | 0 to 65.535 | s | 0.001 | F003 | 0 |
| 74BC | Disconnect Switch 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 74BD | Reserved (2 items) | --- | --- | --- | F001 | 0 |
| 74BF | ...Repeated for Disconnect Switch 2 | | | | | |
| 74DE | ...Repeated for Disconnect Switch 3 | | | | | |
| 74FD | ...Repeated for Disconnect Switch 4 | | | | | |
| 751C | ...Repeated for Disconnect Switch 5 | | | | | |
| 753B | ...Repeated for Disconnect Switch 6 | | | | | |
| 755A | ...Repeated for Disconnect Switch 7 | | | | | |
| 7579 | ...Repeated for Disconnect Switch 8 | | | | | |
| **Thermal Overload Protection (Read/Write Settings) (2 modules)** | | | | | | |
| 7788 | Thermal Protection 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7789 | Thermal Protection 1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 778A | Thermal Protection 1 Base Current | 0.2 to 3 | pu | 0.01 | F001 | 80 |
| 778B | Thermal Protection 1 K Factor | 1 to 1.2 | --- | 0.05 | F001 | 110 |
| 778C | Thermal Protection 1 Trip Time Constant | 0 to 1000 | min. | 1 | F001 | 45 |
| 778D | Thermal Protection 1 Reset Time Constant | 0 to 1000 | min. | 1 | F001 | 45 |
| 778E | Thermal Protection 1 Minimum Reset Time | 0 to 1000 | min. | 1 | F001 | 20 |
| 778F | Thermal Protection 1 Reset | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7791 | Thermal Protection 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7793 | Thermal Protection 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 7794 | Thermal Protection 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7795 | Reserved (2 items) | --- | --- | --- | F001 | 0 |
| 7797 | Repeated for Thermal Protection 2 | | | | | |
| **Broken Conductor Detection (Read/Write Settings) (2 modules)** | | | | | | |
| 77AA | Broken Conductor 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 77AB | Broken Conductor 1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |

### Table B–10: MODBUS MEMORY MAP (Sheet 36 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 77AC | Broken Conductor 1 I2/I1 Ratio | 20 to 100 | % | 0.1 | F001 | 200 |
| 77AD | Broken Conductor 1 I1 Minimum | 0.05 to 1 | pu | 0.01 | F001 | 10 |
| 77AE | Broken Conductor 1 I1 Maximum | 0.05 to 5 | pu | 0.01 | F001 | 150 |
| 77AF | Broken Conductor 1 Pickup Delay | 0 to 65.535 | s | 0.001 | F001 | 20000 |
| 77B0 | Broken Conductor 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 77B2 | Broken Conductor 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 77B3 | Broken Conductor 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 77B4 | Reserved (2 items) | --- | --- | --- | F001 | 0 |
| 77B6 | ...Repeated for Broken Conductor 2 | | | | | |
| **Ohm Inputs (Read/Write Setting) (2 modules)** | | | | | | |
| 77F8 | Ohm Inputs 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 77F9 | Ohm Inputs 1 ID | --- | --- | --- | F205 | "Ohm Ip 1 " |
| 77FF | Reserved (9 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| 7808 | ...Repeated for Ohm Inputs 2 | | | | | |
| **Phasor Measurement Unit Recorder Config Counter Command (Read/Write Command)** | | | | | | |
| 781A | PMU 1 Recorder Clear Config Counter | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **Phasor Measurement Unit One-shot Command (Read/Write Setting)** | | | | | | |
| 788C | PMU One-shot Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 788D | PMU One-shot Sequence Number | 0 to 99 | --- | 1 | F001 | 1 |
| 788E | PMU One-shot Time | 0 to 235959 | --- | 1 | F050 | 0 |
| **Phasor Measurement Unit Recording Values (Read Only)** | | | | | | |
| 7890 | PMU 1 Available Records | 0 to 65535 | --- | 1 | F001 | 0 |
| 7891 | PMU 1 Second Per Record | 0 to 6553.5 | --- | 0.1 | F003 | 0 |
| 7893 | PMU 1 Last Cleared Date | 0 to 400000000 | --- | 1 | F050 | 0 |
| **Phasor Measurement Unit Test Values (Read/Write Setting)** | | | | | | |
| 78AE | PMU 1 Test Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 78AF | PMU 1 Phase A Voltage Test Magnitude | 0 to 700 | kV | 0.01 | F003 | 50000 |
| 78B1 | PMU 1 Page A Voltage Test Angle | -180 to 180 | ° | 0.05 | F002 | 0 |
| 78B2 | PMU 1 Phase B Voltage Test Magnitude | 0 to 700 | kV | 0.01 | F003 | 50000 |
| 78B4 | PMU 1 Phase B Voltage Test Angle | -180 to 180 | ° | 0.05 | F002 | -12000 |
| 78B5 | PMU 1 Phase C Voltage Test Magnitude | 0 to 700 | kV | 0.01 | F003 | 50000 |
| 78B7 | PMU 1 Phase C Voltage Test Angle | -180 to 180 | ° | 0.05 | F002 | 12000 |
| 78B8 | PMU 1 Auxiliary Voltage Test Magnitude | 0 to 700 | kV | 0.01 | F003 | 50000 |
| 78BA | PMU 1 Auxiliary Voltage Test Angle | -180 to 180 | ° | 0.05 | F002 | 0 |
| 78BB | PMU 1 Phase A Current Test Magnitude | 0 to 9.999 | kA | 0.001 | F004 | 1000 |
| 78BD | PMU 1 Phase A Current Test Angle | -180 to 180 | ° | 0.05 | F002 | -1000 |
| 78BE | PMU 1 Phase B Current Test Magnitude | 0 to 9.999 | kA | 0.001 | F004 | 1000 |
| 78C0 | PMU 1 Phase B Current Test Angle | -180 to 180 | ° | 0.05 | F002 | -13000 |
| 78C1 | PMU 1 Phase C Current Test Magnitude | 0 to 9.999 | kA | 0.001 | F003 | 1000 |
| 78C3 | PMU 1 Phase C Current Test Angle | -180 to 180 | ° | 0.05 | F002 | 11000 |
| 78C4 | PMU 1 Ground Current Test Magnitude | 0 to 9.999 | kA | 0.001 | F004 | 0 |
| 78C6 | PMU 1 Ground Current Test Angle | -180 to 180 | ° | 0.05 | F002 | 0 |
| 78C7 | PMU 1 Test Frequency | 20 to 70 | Hz | 0.001 | F003 | 60000 |
| 78C9 | PMU 1 Test df/dt | -10 to 10 | Hz/s | 0.01 | F002 | 0 |
| **Underfrequency (Read/Write Setting) (6 modules)** | | | | | | |
| 7A80 | Underfrequency 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7A81 | Underfrequency 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7A83 | Underfrequency 1 Min Current | 0.1 to 1.25 | pu | 0.01 | F001 | 10 |
| 7A84 | Underfrequency 1 Pickup | 20 to 65 | Hz | 0.01 | F001 | 5950 |
| 7A85 | Underfrequency 1 Pickup Delay | 0 to 65.535 | s | 0.001 | F001 | 2000 |
| 7A86 | Underfrequency 1 Reset Delay | 0 to 65.535 | s | 0.001 | F001 | 2000 |
| 7A87 | Underfrequency 1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 7A88 | Underfrequency 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7A89 | Underfrequency 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |

**Table B–10: MODBUS MEMORY MAP (Sheet 37 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 7A8A | Reserved (5 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 7A8F | ...Repeated for Underfrequency 2 | | | | | |
| 7A9E | ...Repeated for Underfrequency 3 | | | | | |
| 7AAD | ...Repeated for Underfrequency 4 | | | | | |
| 7ABC | ...Repeated for Underfrequency 5 | | | | | |
| 7ACB | ...Repeated for Underfrequency 6 | | | | | |
| **User Programmable Pushbuttons (Read/Write Setting) (16 modules)** | | | | | | |
| 7B60 | User Programmable Pushbutton 1 Function | 0 to 2 | --- | 1 | F137 | 0 (Disabled) |
| 7B61 | User Programmable Pushbutton 1 Top Line | --- | --- | --- | F202 | (none) |
| 7B6B | User Programmable Pushbutton 1 On Text | --- | --- | --- | F202 | (none) |
| 7B75 | User Programmable Pushbutton 1 Off Text | --- | --- | --- | F202 | (none) |
| 7B7F | User Programmable Pushbutton 1 Drop-Out Time | 0 to 60 | s | 0.05 | F001 | 0 |
| 7B80 | User Programmable Pushbutton 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 7B81 | User Programmable Pushbutton 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7B82 | User Programmable Pushbutton 1 LED Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7B84 | User Programmable Pushbutton 1 Autoreset Delay | 0.2 to 600 | s | 0.1 | F001 | 10 |
| 7B85 | User Programmable Pushbutton 1 Autoreset Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7B86 | User Programmable Pushbutton 1 Local Lock Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7B88 | User Programmable Pushbutton 1 Message Priority | 0 to 2 | --- | 1 | F220 | 0 (Disabled) |
| 7B89 | User Programmable Pushbutton 1 Remote Lock Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7B8B | User Programmable Pushbutton 1 Reset Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7B8D | User Programmable Pushbutton 1 Set Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7B8F | User Programmable Pushbutton 1 Hold | 0 to 10 | s | 0.1 | F001 | 1 |
| 7B90 | ...Repeated for User Programmable Pushbutton 2 | | | | | |
| 7BC0 | ...Repeated for User Programmable Pushbutton 3 | | | | | |
| 7BF0 | ...Repeated for User Programmable Pushbutton 4 | | | | | |
| 7C20 | ...Repeated for User Programmable Pushbutton 5 | | | | | |
| 7C50 | ...Repeated for User Programmable Pushbutton 6 | | | | | |
| 7C80 | ...Repeated for User Programmable Pushbutton 7 | | | | | |
| 7CB0 | ...Repeated for User Programmable Pushbutton 8 | | | | | |
| 7DE0 | ...Repeated for User Programmable Pushbutton 9 | | | | | |
| 7D10 | ...Repeated for User Programmable Pushbutton 10 | | | | | |
| 7D40 | ...Repeated for User Programmable Pushbutton 11 | | | | | |
| 7D70 | ...Repeated for User Programmable Pushbutton 12 | | | | | |
| 7DA0 | ...Repeated for User Programmable Pushbutton 13 | | | | | |
| 7DD0 | ...Repeated for User Programmable Pushbutton 14 | | | | | |
| 7E00 | ...Repeated for User Programmable Pushbutton 15 | | | | | |
| 7E30 | ...Repeated for User Programmable Pushbutton 16 | | | | | |
| **Auxiliary Undervoltage (Read/Write Grouped Setting** | | | | | | |
| 7F60 | Auxiliary Undervoltage 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7F61 | Auxiliary Undervoltage 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 7F62 | Auxiliary Undervoltage 1 Pickup | 0 to 3 | pu | 0.001 | F001 | 700 |
| 7F63 | Auxiliary Undervoltage 1 Delay | 0 to 600 | s | 0.01 | F001 | 100 |
| 7F64 | Auxiliary Undervoltage 1 Curve | 0 to 1 | --- | 1 | F111 | 0 (Definite Time) |
| 7F65 | Auxiliary Undervoltage 1 Minimum Voltage | 0 to 3 | pu | 0.001 | F001 | 100 |
| 7F66 | Auxiliary Undervoltage 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7F68 | Auxiliary Undervoltage 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 7F69 | Auxiliary Undervoltage 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7F6A | Reserved (7 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| **Auxiliary Overvoltage (Read/Write Grouped Setting)** | | | | | | |
| 7FA0 | Auxiliary Overvoltage 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7FA1 | Auxiliary Overvoltage 1 Signal Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 7FA2 | Auxiliary Overvoltage 1 Pickup | 0 to 3 | pu | 0.001 | F001 | 300 |
| 7FA3 | Auxiliary Overvoltage 1 Pickup Delay | 0 to 600 | s | 0.01 | F001 | 100 |

### Table B–10: MODBUS MEMORY MAP (Sheet 38 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 7FA4 | Auxiliary Overvoltage 1 Reset Delay | 0 to 600 | s | 0.01 | F001 | 100 |
| 7FA5 | Auxiliary Overvoltage 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 7FA7 | Auxiliary Overvoltage 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 7FA8 | Auxiliary Overvoltage 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 7FA9 | Reserved (8 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| **Frequency (Read Only)** | | | | | | |
| 8000 | Tracking Frequency | 2 to 90 | Hz | 0.01 | F001 | 0 |
| **Temp Monitor Actual Values (Read Only Non-Volatile)** | | | | | | |
| 81C0 | Reserved Register T1 | -55 to 125 | C | 1 | F002 | -55 |
| 81C1 | Reserved Register T2 | -55 to 125 | C | 1 | F002 | 125 |
| 81C2 | Reserved Register T3 | -2147483647 to 2147483647 | --- | 1 | F004 | 0 |
| 81C4 | Reserved Register T4 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 81C6 | Reserved Register T5 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 81C8 | Reserved Register T6 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 81CA | Reserved Register T7 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| 81CC | Reserved Register T8 | 0 to 4294967295 | --- | 1 | F003 | 0 |
| **Breaker Failure (Read/Write Grouped Setting) (2 modules)** | | | | | | |
| 8600 | Breaker Failure 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 8601 | Breaker Failure 1 Mode | 0 to 1 | --- | 1 | F157 | 0 (3-Pole) |
| 8602 | Breaker Failure 1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 8603 | Breaker Failure 1 Amp Supervision | 0 to 1 | --- | 1 | F126 | 1 (Yes) |
| 8604 | Breaker Failure 1 Use Seal-In | 0 to 1 | --- | 1 | F126 | 1 (Yes) |
| 8605 | Breaker Failure 1 Three Pole Initiate | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8607 | Breaker Failure 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8609 | Breaker Failure 1 Phase Amp Supv Pickup | 0.001 to 30 | pu | 0.001 | F001 | 1050 |
| 860A | Breaker Failure 1 Neutral Amp Supv Pickup | 0.001 to 30 | pu | 0.001 | F001 | 1050 |
| 860B | Breaker Failure 1 Use Timer 1 | 0 to 1 | --- | 1 | F126 | 1 (Yes) |
| 860C | Breaker Failure 1 Timer 1 Pickup | 0 to 65.535 | s | 0.001 | F001 | 0 |
| 860D | Breaker Failure 1 Use Timer 2 | 0 to 1 | --- | 1 | F126 | 1 (Yes) |
| 860E | Breaker Failure 1 Timer 2 Pickup | 0 to 65.535 | s | 0.001 | F001 | 0 |
| 860F | Breaker Failure 1 Use Timer 3 | 0 to 1 | --- | 1 | F126 | 1 (Yes) |
| 8610 | Breaker Failure 1 Timer 3 Pickup | 0 to 65.535 | s | 0.001 | F001 | 0 |
| 8611 | Breaker Failure 1 Breaker Status 1 Phase A/3P | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8613 | Breaker Failure 1 Breaker Status 2 Phase A/3P | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8615 | Breaker Failure 1 Breaker Test On | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8617 | Breaker Failure 1 Phase Amp Hiset Pickup | 0.001 to 30 | pu | 0.001 | F001 | 1050 |
| 8618 | Breaker Failure 1 Neutral Amp Hiset Pickup | 0.001 to 30 | pu | 0.001 | F001 | 1050 |
| 8619 | Breaker Failure 1 Phase Amp Loset Pickup | 0.001 to 30 | pu | 0.001 | F001 | 1050 |
| 861A | Breaker Failure 1 Neutral Amp Loset Pickup | 0.001 to 30 | pu | 0.001 | F001 | 1050 |
| 861B | Breaker Failure 1 Loset Time | 0 to 65.535 | s | 0.001 | F001 | 0 |
| 861C | Breaker Failure 1 Trip Dropout Delay | 0 to 65.535 | s | 0.001 | F001 | 0 |
| 861D | Breaker Failure 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 861E | Breaker Failure 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 861F | Breaker Failure 1 Phase A Initiate | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8621 | Breaker Failure 1 Phase B Initiate | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8623 | Breaker Failure 1 Phase C Initiate | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8625 | Breaker Failure 1 Breaker Status 1 Phase B | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8627 | Breaker Failure 1 Breaker Status 1 Phase C | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8629 | Breaker Failure 1 Breaker Status 2 Phase B | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 862B | Breaker Failure 1 Breaker Status 2 Phase C | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 862D | ...Repeated for Breaker Failure 2 | | | | | |
| **FlexState Settings (Read/Write Setting)** | | | | | | |
| 8800 | FlexState Parameters (256 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 39 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| **Digital Elements (Read/Write Setting) (48 modules)** | | | | | | |
| 8A00 | Digital Element 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 8A01 | Digital Element 1 Name | --- | --- | --- | F203 | “Dig Element 1“ |
| 8A09 | Digital Element 1 Input | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8A0B | Digital Element 1 Pickup Delay | 0 to 999999.999 | s | 0.001 | F003 | 0 |
| 8A0D | Digital Element 1 Reset Delay | 0 to 999999.999 | s | 0.001 | F003 | 0 |
| 8A0F | Digital Element 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8A11 | Digital Element 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 8A12 | Digital Element 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 8A13 | Digital Element 1 Pickup LED | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| 8A14 | Reserved (2 items) | --- | --- | --- | F001 | 0 |
| 8A16 | ...Repeated for Digital Element 2 | | | | | |
| 8A2C | ...Repeated for Digital Element 3 | | | | | |
| 8A42 | ...Repeated for Digital Element 4 | | | | | |
| 8A58 | ...Repeated for Digital Element 5 | | | | | |
| 8A6E | ...Repeated for Digital Element 6 | | | | | |
| 8A84 | ...Repeated for Digital Element 7 | | | | | |
| 8A9A | ...Repeated for Digital Element 8 | | | | | |
| 8AB0 | ...Repeated for Digital Element 9 | | | | | |
| 8AC6 | ...Repeated for Digital Element 10 | | | | | |
| 8ADC | ...Repeated for Digital Element 11 | | | | | |
| 8AF2 | ...Repeated for Digital Element 12 | | | | | |
| 8B08 | ...Repeated for Digital Element 13 | | | | | |
| 8B1E | ...Repeated for Digital Element 14 | | | | | |
| 8B34 | ...Repeated for Digital Element 15 | | | | | |
| 8B4A | ...Repeated for Digital Element 16 | | | | | |
| 8B60 | ...Repeated for Digital Element 17 | | | | | |
| 8B76 | ...Repeated for Digital Element 18 | | | | | |
| 8B8C | ...Repeated for Digital Element 19 | | | | | |
| 8BA2 | ...Repeated for Digital Element 20 | | | | | |
| 8BB8 | ...Repeated for Digital Element 21 | | | | | |
| 8BCE | ...Repeated for Digital Element 22 | | | | | |
| 8BE4 | ...Repeated for Digital Element 23 | | | | | |
| 8BFA | ...Repeated for Digital Element 24 | | | | | |
| 8C10 | ...Repeated for Digital Element 25 | | | | | |
| 8C26 | ...Repeated for Digital Element 26 | | | | | |
| 8C3C | ...Repeated for Digital Element 27 | | | | | |
| 8C52 | ...Repeated for Digital Element 28 | | | | | |
| 8C68 | ...Repeated for Digital Element 29 | | | | | |
| 8C7E | ...Repeated for Digital Element 30 | | | | | |
| 8C94 | ...Repeated for Digital Element 31 | | | | | |
| 8CAA | ...Repeated for Digital Element 32 | | | | | |
| 8CC0 | ...Repeated for Digital Element 33 | | | | | |
| 8CD6 | ...Repeated for Digital Element 34 | | | | | |
| 8CEC | ...Repeated for Digital Element 35 | | | | | |
| 8D02 | ...Repeated for Digital Element 36 | | | | | |
| 8D18 | ...Repeated for Digital Element 37 | | | | | |
| 8D2E | ...Repeated for Digital Element 38 | | | | | |
| 8D44 | ...Repeated for Digital Element 39 | | | | | |
| 8D5A | ...Repeated for Digital Element 40 | | | | | |
| 8D70 | ...Repeated for Digital Element 41 | | | | | |
| 8D86 | ...Repeated for Digital Element 42 | | | | | |
| 8D9C | ...Repeated for Digital Element 43 | | | | | |
| 8DB2 | ...Repeated for Digital Element 44 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 40 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 8DC8 | ...Repeated for Digital Element 45 | | | | | |
| 8DDE | ...Repeated for Digital Element 46 | | | | | |
| 8DF4 | ...Repeated for Digital Element 47 | | | | | |
| 8E0A | ...Repeated for Digital Element 48 | | | | | |
| **Trip Bus (Read/Write Setting) (6 modules)** | | | | | | |
| 8ED0 | Trip Bus 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 8ED1 | Trip Bus 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8ED3 | Trip Bus 1 Pickup Delay | 0 to 600 | s | 0.01 | F001 | 0 |
| 8ED4 | Trip Bus 1 Reset Delay | 0 to 600 | s | 0.01 | F001 | 0 |
| 8ED5 | Trip Bus 1 Input (16 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8EF5 | Trip Bus 1 Latching | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 8EF6 | Trip Bus 1 Reset | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 8EF8 | Trip Bus 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 8EF9 | Trip Bus 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 8EFA | Reserved (8 items) | 0 to 1 | --- | 1 | F001 | 0 |
| 8F02 | ...Repeated for Trip Bus 2 | | | | | |
| 8F34 | ...Repeated for Trip Bus 3 | | | | | |
| 8F66 | ...Repeated for Trip Bus 4 | | | | | |
| 8F98 | ...Repeated for Trip Bus 5 | | | | | |
| 8FCA | ...Repeated for Trip Bus 6 | | | | | |
| **FlexElement (Read/Write Setting) (8 modules)** | | | | | | |
| 9000 | FlexElement 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 9001 | FlexElement 1 Name | --- | --- | --- | F206 | “FxE 1” |
| 9004 | FlexElement 1 InputP | 0 to 65535 | --- | 1 | F600 | 0 |
| 9005 | FlexElement 1 InputM | 0 to 65535 | --- | 1 | F600 | 0 |
| 9006 | FlexElement 1 Compare | 0 to 1 | --- | 1 | F516 | 0 (LEVEL) |
| 9007 | FlexElement 1 Input | 0 to 1 | --- | 1 | F515 | 0 (SIGNED) |
| 9008 | FlexElement 1 Direction | 0 to 1 | --- | 1 | F517 | 0 (OVER) |
| 9009 | FlexElement 1 Hysteresis | 0.1 to 50 | % | 0.1 | F001 | 30 |
| 900A | FlexElement 1 Pickup | -90 to 90 | pu | 0.001 | F004 | 1000 |
| 900C | FlexElement 1 DeltaT Units | 0 to 2 | --- | 1 | F518 | 0 (Milliseconds) |
| 900D | FlexElement 1 DeltaT | 20 to 86400 | --- | 1 | F003 | 20 |
| 900F | FlexElement 1 Pickup Delay | 0 to 65.535 | s | 0.001 | F001 | 0 |
| 9010 | FlexElement 1 Reset Delay | 0 to 65.535 | s | 0.001 | F001 | 0 |
| 9011 | FlexElement 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 9013 | FlexElement 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| 9014 | FlexElement 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| 9015 | ...Repeated for FlexElement 2 | | | | | |
| 902A | ...Repeated for FlexElement 3 | | | | | |
| 903F | ...Repeated for FlexElement 4 | | | | | |
| 9054 | ...Repeated for FlexElement 5 | | | | | |
| 9069 | ...Repeated for FlexElement 6 | | | | | |
| 907E | ...Repeated for FlexElement 7 | | | | | |
| 9093 | ...Repeated for FlexElement 8 | | | | | |
| **Fault Report Settings (Read/Write Setting)** | | | | | | |
| 9200 | Fault Report 1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| 9201 | Fault Report 1 Trigger | 0 to 4294967295 | --- | 1 | F300 | 0 |
| 9203 | Fault Report 1 Z1 Magnitude | 0.01 to 250 | ohms | 0.01 | F001 | 300 |
| 9204 | Fault Report 1 Z1 Angle | 25 to 90 | degrees | 1 | F001 | 75 |
| 9205 | Fault Report 1 Z0 Magnitude | 0.01 to 650 | ohms | 0.01 | F001 | 900 |
| 9206 | Fault Report 1 Z0 Angle | 25 to 90 | degrees | 1 | F001 | 75 |
| 9207 | Fault Report 1 Line Length Units | 0 to 1 | --- | 1 | F147 | 0 (km) |
| 9208 | Fault Report 1 Line Length | 0 to 2000 | --- | 0.1 | F001 | 1000 |
| 9209 | Fault Report 1 VT Substitution | 0 to 2 | --- | 1 | F270 | 0 (None) |

### Table B–10: MODBUS MEMORY MAP (Sheet 41 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 920A | Fault Report 1 System Z0 Magnitude | 0.01 to 650 | ohms | 0.01 | F001 | 200 |
| 920B | Fault Report 1 System Z0 Angle | 25 to 90 | degrees | 1 | F001 | 75 |
| 920C | Fault REM1-TAP Z1 Magnitude | 0.01 to 250 | ohms | 0.01 | F001 | 300 |
| 920D | Fault REM1-TAP Z1 Angle | 25 to 90 | degrees | 1 | F001 | 75 |
| 920E | Fault REM1-TAP Length | 0 to 2000 | --- | 0.1 | F001 | 1000 |
| 920F | Fault REM2-TAP Z1 Magnitude | 0.01 to 250 | ohms | 0.01 | F001 | 300 |
| 9210 | Fault REM2-TAP Z1 Angle | 25 to 90 | degrees | 1 | F001 | 75 |
| 9211 | Fault REM2-TAP Length | 0 to 2000 | --- | 0.1 | F001 | 1000 |
| **DCmA Outputs (Read/Write Setting) (24 modules)** | | | | | | |
| 9360 | DCmA Output 1 Source | 0 to 65535 | --- | 1 | F600 | 0 |
| 9361 | DCmA Output 1 Range | 0 to 2 | --- | 1 | F522 | 0 (–1 to 1 mA) |
| 9362 | DCmA Output 1 Minimum | –90 to 90 | pu | 0.001 | F004 | 0 |
| 9364 | DCmA Output 1 Maximum | –90 to 90 | pu | 0.001 | F004 | 1000 |
| 9366 | ...Repeated for DCmA Output 2 | | | | | |
| 936C | ...Repeated for DCmA Output 3 | | | | | |
| 9372 | ...Repeated for DCmA Output 4 | | | | | |
| 9378 | ...Repeated for DCmA Output 5 | | | | | |
| 937E | ...Repeated for DCmA Output 6 | | | | | |
| 9384 | ...Repeated for DCmA Output 7 | | | | | |
| 938A | ...Repeated for DCmA Output 8 | | | | | |
| 9390 | ...Repeated for DCmA Output 9 | | | | | |
| 9396 | ...Repeated for DCmA Output 10 | | | | | |
| 939C | ...Repeated for DCmA Output 11 | | | | | |
| 93A2 | ...Repeated for DCmA Output 12 | | | | | |
| 93A8 | ...Repeated for DCmA Output 13 | | | | | |
| 93AE | ...Repeated for DCmA Output 14 | | | | | |
| 93B4 | ...Repeated for DCmA Output 15 | | | | | |
| 93BA | ...Repeated for DCmA Output 16 | | | | | |
| 93C0 | ...Repeated for DCmA Output 17 | | | | | |
| 93C6 | ...Repeated for DCmA Output 18 | | | | | |
| 93CC | ...Repeated for DCmA Output 19 | | | | | |
| 93D2 | ...Repeated for DCmA Output 20 | | | | | |
| 93D8 | ...Repeated for DCmA Output 21 | | | | | |
| 93DE | ...Repeated for DCmA Output 22 | | | | | |
| 93E4 | ...Repeated for DCmA Output 23 | | | | | |
| 93EA | ...Repeated for DCmA Output 24 | | | | | |
| **IEC 61850 Received Integers (Read/Write Setting) (16 modules)** | | | | | | |
| 98A0 | IEC 61850 GOOSE uinteger 1 Default Value | 0 to 429496295 | --- | 1 | F003 | 1000 |
| 98A2 | IEC 61850 GOOSE uinteger Input 1 Mode | 0 to 1 | --- | 1 | F491 | 0 (Default Value) |
| 98A3 | ...Repeated for IEC61850 GOOSE uinteger 2 | | | | | |
| 98A6 | ...Repeated for IEC61850 GOOSE uinteger 3 | | | | | |
| 98A9 | ...Repeated for IEC61850 GOOSE uinteger 4 | | | | | |
| 98AC | ...Repeated for IEC61850 GOOSE uinteger 5 | | | | | |
| 98AF | ...Repeated for IEC61850 GOOSE uinteger 6 | | | | | |
| 98B2 | ...Repeated for IEC61850 GOOSE uinteger 7 | | | | | |
| 98B5 | ...Repeated for IEC61850 GOOSE uinteger 8 | | | | | |
| 98B8 | ...Repeated for IEC61850 GOOSE uinteger 9 | | | | | |
| 98BB | ...Repeated for IEC61850 GOOSE uinteger 10 | | | | | |
| 98BE | ...Repeated for IEC61850 GOOSE uinteger 11 | | | | | |
| 98C1 | ...Repeated for IEC61850 GOOSE uinteger 12 | | | | | |
| 98C4 | ...Repeated for IEC61850 GOOSE uinteger 13 | | | | | |
| 98C7 | ...Repeated for IEC61850 GOOSE uinteger 14 | | | | | |
| 98CA | ...Repeated for IEC61850 GOOSE uinteger 15 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 42 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| 98CD | ...Repeated for IEC61850 GOOSE uinteger 16 | | | | | |
| **FlexElement Actual Values (Read Only) (8 modules)** | | | | | | |
| 9900 | FlexElement 1 Actual | -2147483.647 to 2147483.647 | --- | 0.001 | F004 | 0 |
| 9902 | FlexElement 2 Actual | -2147483.647 to 2147483.647 | --- | 0.001 | F004 | 0 |
| 9904 | FlexElement 3 Actual | -2147483.647 to 2147483.647 | --- | 0.001 | F004 | 0 |
| 9906 | FlexElement 4 Actual | -2147483.647 to 2147483.647 | --- | 0.001 | F004 | 0 |
| 9908 | FlexElement 5 Actual | -2147483.647 to 2147483.647 | --- | 0.001 | F004 | 0 |
| 990A | FlexElement 6 Actual | -2147483.647 to 2147483.647 | --- | 0.001 | F004 | 0 |
| 990C | FlexElement 7 Actual | -2147483.647 to 2147483.647 | --- | 0.001 | F004 | 0 |
| 990E | FlexElement 8 Actual | -2147483.647 to 2147483.647 | --- | 0.001 | F004 | 0 |
| **VT Fuse Failure (Read/Write Setting) (2 modules)** | | | | | | |
| A09A | VT Fuse Failure1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| A09B | VT Fuse Failure Neutral Wire Open1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| A09C | VT Fuse Failure Neutral Wire Open 1 3rd Harmonic Pickup | 0 to 3 | pu | 0.001 | F001 | 100 |
| A09D | ...Repeated for module number 2 | | | | | |
| **VT Fuse Failure Actuals (Read Only) (2 modules)** | | | | | | |
| A0AC | VT Fuse Failure 1 V0 3rd Harmonic | 0 to 999999.999 | V | 0.001 | F060 | 0 |
| A0AE | ...Repeated for module number 2 | | | | | |
| **Selector Switch Actual Values (Read Only)** | | | | | | |
| A210 | Selector Switch 1 Position | 1 to 7 | --- | 1 | F001 | 0 |
| A211 | Selector Switch 2 Position | 1 to 7 | --- | 1 | F001 | 1 |
| **Selector Switch Settings (Read/Write) (2 modules)** | | | | | | |
| A280 | Selector 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| A281 | Selector 1 Range | 1 to 7 | --- | 1 | F001 | 7 |
| A282 | Selector 1 Timeout | 3 to 60 | s | 0.1 | F001 | 50 |
| A283 | Selector 1 Step Up | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A285 | Selector 1 Step Mode | 0 to 1 | --- | 1 | F083 | 0 (Time-out) |
| A286 | Selector 1 Acknowledge | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A288 | Selector 1 Bit0 | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A28A | Selector 1 Bit1 | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A28C | Selector 1 Bit2 | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A28E | Selector 1 Bit Mode | 0 to 1 | --- | 1 | F083 | 0 (Time-out) |
| A28F | Selector 1 Bit Acknowledge | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A291 | Selector 1 Power Up Mode | 0 to 2 | --- | 1 | F084 | 0 (Restore) |
| A292 | Selector 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| A293 | Selector 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| A294 | Reserved (10 items) | --- | --- | 1 | F001 | 0 |
| A29E | ...Repeated for Selector 2 | | | | | |
| **Digital Counter (Read/Write Setting) (8 modules)** | | | | | | |
| A300 | Digital Counter 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| A301 | Digital Counter 1 Name | --- | --- | --- | F205 | “Counter 1" |
| A307 | Digital Counter 1 Units | --- | --- | --- | F206 | (none) |
| A30A | Digital Counter 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A30C | Digital Counter 1 Up | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A30E | Digital Counter 1 Down | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A311 | Digital Counter 1 Preset | –2147483647 to 2147483647 | --- | 1 | F004 | 0 |
| A313 | Digital Counter 1 Compare | –2147483647 to 2147483647 | --- | 1 | F004 | 0 |
| A315 | Digital Counter 1 Reset | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A317 | Digital Counter 1 Freeze/Reset | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A319 | Digital Counter 1 Freeze/Count | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A31B | Digital Counter 1 Set To Preset | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A31D | Reserved (11 items) | --- | --- | --- | F001 | 0 |
| A328 | ...Repeated for Digital Counter 2 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 43 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| A350 | ...Repeated for Digital Counter 3 | | | | | |
| A378 | ...Repeated for Digital Counter 4 | | | | | |
| A3A0 | ...Repeated for Digital Counter 5 | | | | | |
| A3C8 | ...Repeated for Digital Counter 6 | | | | | |
| A3F0 | ...Repeated for Digital Counter 7 | | | | | |
| A418 | ...Repeated for Digital Counter 8 | | | | | |
| **FlexCurves C and D (Read/Write Setting)** | | | | | | |
| A600 | FlexCurve C (120 items) | 0 to 65535 | ms | 1 | F011 | 0 |
| A680 | FlexCurve D (120 items) | 0 to 65535 | ms | 1 | F011 | 0 |
| **Non Volatile Latches (Read/Write Setting) (16 modules)** | | | | | | |
| A700 | Non-Volatile Latch 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| A701 | Non-Volatile Latch 1 Type | 0 to 1 | --- | 1 | F519 | 0 (Reset Dominant) |
| A702 | Non-Volatile Latch 1 Set | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A704 | Non-Volatile Latch 1 Reset | 0 to 4294967295 | --- | 1 | F300 | 0 |
| A706 | Non-Volatile Latch 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| A707 | Non-Volatile Latch 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| A708 | Reserved (4 items) | --- | --- | --- | F001 | 0 |
| A70C | ...Repeated for Non-Volatile Latch 2 | | | | | |
| A718 | ...Repeated for Non-Volatile Latch 3 | | | | | |
| A724 | ...Repeated for Non-Volatile Latch 4 | | | | | |
| A730 | ...Repeated for Non-Volatile Latch 5 | | | | | |
| A73C | ...Repeated for Non-Volatile Latch 6 | | | | | |
| A748 | ...Repeated for Non-Volatile Latch 7 | | | | | |
| A754 | ...Repeated for Non-Volatile Latch 8 | | | | | |
| A760 | ...Repeated for Non-Volatile Latch 9 | | | | | |
| A76C | ...Repeated for Non-Volatile Latch 10 | | | | | |
| A778 | ...Repeated for Non-Volatile Latch 11 | | | | | |
| A784 | ...Repeated for Non-Volatile Latch 12 | | | | | |
| A790 | ...Repeated for Non-Volatile Latch 13 | | | | | |
| A79C | ...Repeated for Non-Volatile Latch 14 | | | | | |
| A7A8 | ...Repeated for Non-Volatile Latch 15 | | | | | |
| A7B4 | ...Repeated for Non-Volatile Latch 16 | | | | | |
| **IEC 61850 Received Analog Settings (Read/Write Setting) (32 modules)** | | | | | | |
| AA00 | IEC 61850 GOOSE Analog 1 Default Value | –1000000 to 1000000 | --- | 0.001 | F060 | 1000 |
| AA02 | IEC 61850 GOOSE Analog Input 1 Mode | 0 to 1 | --- | 1 | F491 | 0 (Default Value) |
| AA03 | IEC 61850 GOOSE Analog Input 1 Units | --- | --- | --- | F207 | (none) |
| AA05 | IEC 61850 GOOSE Analog Input 1 Per-Unit Base | 0 to 999999999.999 | --- | 0.001 | F060 | 1 |
| AA07 | ...Repeated for IEC 61850 GOOSE Analog Input 2 | | | | | |
| AA0E | ...Repeated for IEC 61850 GOOSE Analog Input 3 | | | | | |
| AA15 | ...Repeated for IEC 61850 GOOSE Analog Input 4 | | | | | |
| AA1C | ...Repeated for IEC 61850 GOOSE Analog Input 5 | | | | | |
| AA23 | ...Repeated for IEC 61850 GOOSE Analog Input 6 | | | | | |
| AA2A | ...Repeated for IEC 61850 GOOSE Analog Input 7 | | | | | |
| AA31 | ...Repeated for IEC 61850 GOOSE Analog Input 8 | | | | | |
| AA38 | ...Repeated for IEC 61850 GOOSE Analog Input 9 | | | | | |
| AA3F | ...Repeated for IEC 61850 GOOSE Analog Input 10 | | | | | |
| AA46 | ...Repeated for IEC 61850 GOOSE Analog Input 11 | | | | | |
| AA4D | ...Repeated for IEC 61850 GOOSE Analog Input 12 | | | | | |
| AA54 | ...Repeated for IEC 61850 GOOSE Analog Input 13 | | | | | |
| AA5B | ...Repeated for IEC 61850 GOOSE Analog Input 14 | | | | | |
| AA62 | ...Repeated for IEC 61850 GOOSE Analog Input 15 | | | | | |
| AA69 | ...Repeated for IEC 61850 GOOSE Analog Input 16 | | | | | |
| AA70 | ...Repeated for IEC 61850 GOOSE Analog Input 17 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 44 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| AA77 | ...Repeated for IEC 61850 GOOSE Analog Input 18 | | | | | |
| AA7E | ...Repeated for IEC 61850 GOOSE Analog Input 19 | | | | | |
| AA85 | ...Repeated for IEC 61850 GOOSE Analog Input 20 | | | | | |
| AA8C | ...Repeated for IEC 61850 GOOSE Analog Input 21 | | | | | |
| AA93 | ...Repeated for IEC 61850 GOOSE Analog Input 22 | | | | | |
| AA9A | ...Repeated for IEC 61850 GOOSE Analog Input 23 | | | | | |
| AAA1 | ...Repeated for IEC 61850 GOOSE Analog Input 24 | | | | | |
| AAA8 | ...Repeated for IEC 61850 GOOSE Analog Input 25 | | | | | |
| AAAF | ...Repeated for IEC 61850 GOOSE Analog Input 26 | | | | | |
| AAB6 | ...Repeated for IEC 61850 GOOSE Analog Input 27 | | | | | |
| AABD | ...Repeated for IEC 61850 GOOSE Analog Input 28 | | | | | |
| AAC4 | ...Repeated for IEC 61850 GOOSE Analog Input 29 | | | | | |
| AACB | ...Repeated for IEC 61850 GOOSE Analog Input 30 | | | | | |
| AAD2 | ...Repeated for IEC 61850 GOOSE Analog Input 31 | | | | | |
| AAD9 | ...Repeated for IEC 61850 GOOSE Analog Input 32 | | | | | |
| **IEC 61850 XCBR Configuration (Read/Write Settings and Commands) (6 modules)** | | | | | | |
| AB00 | FlexLogic Operand for IEC 61850 XCBR1.ST.Loc status | 0 to 4294967295 | --- | 1 | F300 | 0 |
| AB02 | Command to Clear XCBR1 OpCnt (Operation Counter | 0 to 1 | --- | 1 | F126 | 0 (No) |
| AB03 | FlexLogic Operand for IEC 61850 XCBR Check Sync Release | 0 to 4294967295 | --- | 1 | F300 | 0 |
| AB05 | FlexLogic Operand for IEC 61850 XCBR Open Interlock | 0 to 4294967295 | --- | 1 | F300 | 0 |
| AB07 | FlexLogic Operand for IEC 61850 XCBR Close Interlock | 0 to 4294967295 | --- | 1 | F300 | 0 |
| AB09 | FlexLogic Operand for IEC 61850 XCBR Pos ct1Model | 0 to 4 | --- | 1 | F001 | 2 |
| AB0A | FlexLogic Operand for IEC 61850 XCBR Pos sboTimeout | 2 to 60 | s | 1 | F001 | 30 |
| AB0B | ...Repeated for Module 2 | | | | | |
| AB16 | ...Repeated for Module 3 | | | | | |
| AB21 | ...Repeated for Module 4 | | | | | |
| AB2C | ...Repeated for Module 5 | | | | | |
| AB37 | ...Repeated for Module 6 | | | | | |
| **IEC 61850 LN Name Prefixes (Read/Write Settings)** | | | | | | |
| AB48 | IEC 61850 Logical Node LPHD1 Name Prefix | 0 to 65534 | --- | 1 | F206 | (none) |
| AB4B | IEC 61850 Logical Node PIOCx Name Prefix (72 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AC23 | IEC 61850 Logical Node PTOCx Name Prefix (24 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AC6B | IEC 61850 Logical Node PTUVx Name Prefix (13 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AC92 | IEC 61850 Logical Node PTOVx Name Prefix (10 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| ACB6 | IEC 61850 Logical Node PDISx Name Prefix (10 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| ACD4 | IEC 61850 Logical Node RBRFx Name Prefix (24 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AD1C | IEC 61850 Logical Node RPSBx Name Prefix | 0 to 65534 | --- | 1 | F206 | (none) |
| AD1F | IEC 61850 Logical Node RRECx Name Prefix (6 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AD31 | IEC 61850 Logical Node MMXUx Name Prefix (6 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AD43 | IEC 61850 Logical Node GGIOx Name Prefix (5 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AD52 | IEC 61850 Logical Node RFLOx Name Prefix (5 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AD61 | IEC 61850 Logical Node XCBRx Name Prefix (6 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AD73 | IEC 61850 Logical Node PTRCx Name Prefix (6 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AD85 | IEC 61850 Logical Node PDIFx Name Prefix (4 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AD91 | IEC 61850 Logical Node MMXNx Name Prefix (37 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AE00 | IEC 61850 Logical Node CSWIx Name Prefix (30 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| AE5A | IEC 61850 Logical Node XSWIx Name Prefix (24 items) | 0 to 65534 | --- | 1 | F206 | (none) |
| **IEC 61850 GGIO4 General Analog Configuration Settings (Read/Write)** | | | | | | |
| AF00 | Number of Analog Input Points in GGIO4 | 4 to 32 | --- | 4 | F001 | 4 |
| **IEC 61850 GGIO4 Analog Input Points Configuration Settings (Read/Write Setting) (32 modules)** | | | | | | |
| AF10 | IEC 61850 GGIO4 Analog Input 1 Value | --- | --- | --- | F600 | 0 |
| AF11 | IEC 61850 GGIO4 Analog Input 1 Deadband | 0.001 to 100 | % | 0.001 | F003 | 100000 |

### Table B–10: MODBUS MEMORY MAP (Sheet 45 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| AF13 | IEC 61850 GGIO4 Analog Input 1 Minimum | –1000000000000 to 1000000000000 | --- | 0.001 | F060 | 0 |
| AF15 | IEC 61850 GGIO4 Analog Input 1 Maximum | –1000000000000 to 1000000000000 | --- | 0.001 | F060 | 1000000 |
| AF17 | ...Repeated for IEC 61850 GGIO4 Analog Input 2 | | | | | |
| AF1E | ...Repeated for IEC 61850 GGIO4 Analog Input 3 | | | | | |
| AF25 | ...Repeated for IEC 61850 GGIO4 Analog Input 4 | | | | | |
| AF2C | ...Repeated for IEC 61850 GGIO4 Analog Input 5 | | | | | |
| AF33 | ...Repeated for IEC 61850 GGIO4 Analog Input 6 | | | | | |
| AF3A | ...Repeated for IEC 61850 GGIO4 Analog Input 7 | | | | | |
| AF41 | ...Repeated for IEC 61850 GGIO4 Analog Input 8 | | | | | |
| AF48 | ...Repeated for IEC 61850 GGIO4 Analog Input 9 | | | | | |
| AF4F | ...Repeated for IEC 61850 GGIO4 Analog Input 10 | | | | | |
| AF56 | ...Repeated for IEC 61850 GGIO4 Analog Input 11 | | | | | |
| AF5D | ...Repeated for IEC 61850 GGIO4 Analog Input 12 | | | | | |
| AF64 | ...Repeated for IEC 61850 GGIO4 Analog Input 13 | | | | | |
| AF6B | ...Repeated for IEC 61850 GGIO4 Analog Input 14 | | | | | |
| AF72 | ...Repeated for IEC 61850 GGIO4 Analog Input 15 | | | | | |
| AF79 | ...Repeated for IEC 61850 GGIO4 Analog Input 16 | | | | | |
| AF80 | ...Repeated for IEC 61850 GGIO4 Analog Input 17 | | | | | |
| AF87 | ...Repeated for IEC 61850 GGIO4 Analog Input 18 | | | | | |
| AF8E | ...Repeated for IEC 61850 GGIO4 Analog Input 19 | | | | | |
| AF95 | ...Repeated for IEC 61850 GGIO4 Analog Input 20 | | | | | |
| AF9C | ...Repeated for IEC 61850 GGIO4 Analog Input 21 | | | | | |
| AFA3 | ...Repeated for IEC 61850 GGIO4 Analog Input 22 | | | | | |
| AFAA | ...Repeated for IEC 61850 GGIO4 Analog Input 23 | | | | | |
| AFB1 | ...Repeated for IEC 61850 GGIO4 Analog Input 24 | | | | | |
| AFB8 | ...Repeated for IEC 61850 GGIO4 Analog Input 25 | | | | | |
| AFBF | ...Repeated for IEC 61850 GGIO4 Analog Input 26 | | | | | |
| AFC6 | ...Repeated for IEC 61850 GGIO4 Analog Input 27 | | | | | |
| AFCD | ...Repeated for IEC 61850 GGIO4 Analog Input 28 | | | | | |
| AFD4 | ...Repeated for IEC 61850 GGIO4 Analog Input 29 | | | | | |
| AFDB | ...Repeated for IEC 61850 GGIO4 Analog Input 30 | | | | | |
| AFE2 | ...Repeated for IEC 61850 GGIO4 Analog Input 31 | | | | | |
| AFE9 | ...Repeated for IEC 61850 GGIO4 Analog Input 32 | | | | | |
| **IEC 61850 GOOSE/GSSE Configuration (Read/Write Setting)** | | | | | | |
| B01C | Default GOOSE/GSSE Update Time | 1 to 60 | s | 1 | F001 | 60 |
| B01D | IEC 61850 GSSE Function (GsEna) | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| B01E | IEC 61850 GSSE ID | --- | --- | --- | F209 | “GSSEOut” |
| B03F | IEC 61850 GOOSE Function (GoEna) | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| B040 | IEC 61850 GSSE Destination MAC Address | --- | --- | --- | F072 | 0 |
| B043 | IEC 61850 Standard GOOSE ID | --- | --- | --- | F209 | “GOOSEOut” |
| B064 | IEC 61850 Standard GOOSE Destination MAC Address | --- | --- | --- | F072 | 0 |
| B067 | IEC 61850 GOOSE VLAN Transmit Priority | 0 to 7 | --- | 1 | F001 | 4 |
| B068 | IEC 61850 GOOSE VLAN ID | 0 to 4095 | --- | 1 | F001 | 0 |
| B069 | IEC 61850 GOOSE ETYPE APPID | 0 to 16383 | --- | 1 | F001 | 0 |
| B06A | Reserved (2 items) | 0 to 1 | --- | 1 | F001 | 0 |
| **IEC 61850 Server Configuration (Read/Write Settings/Commands)** | | | | | | |
| B06C | TCP Port Number for the IEC 61850 / MMS Protocol | 0 to 65535 | --- | 1 | F001 | 102 |
| B06D | IEC 61850 Logical Device Name | --- | --- | --- | F213 | “IEDName” |
| B07D | IEC 61850 Logical Device Instance | --- | --- | --- | F213 | “LDInst” |
| B08D | IEC 61850 LPHD Location | 0 to 65534 | --- | 1 | F204 | “Location” |
| B0B5 | Include non-IEC 61850 Data | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| B0B6 | IEC 61850 Server Data Scanning Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| B0B7 | IEC 61850 LPHD Latitude | -90 to 90 | degrees | 0.001 | F004 | 0 |

### Table B–10: MODBUS MEMORY MAP (Sheet 46 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| B0B9 | IEC 61850 LPHD DC PhyNam Longitude | -180 to 180 | degrees | 0.001 | F004 | 0 |
| B9BB | IEC 61850 LPHD DC PhyNam Altitude | 0 to 10000 | m | 1 | F003 | 0 |
| B0BD | Reserved (3 items) | 0 to 1 | --- | 1 | F001 | 0 |
| **IEC 61850 MMXU Deadbands (Read/Write Setting) (6 modules)** | | | | | | |
| B0C0 | IEC 61850 MMXU TotW Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0C2 | IEC 61850 MMXU TotVAr Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0C4 | IEC 61850 MMXU TotVA Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0C6 | IEC 61850 MMXU TotPF Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0C8 | IEC 61850 MMXU Hz Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0CA | IEC 61850 MMXU PPV.phsAB Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0CC | IEC 61850 MMXU PPV.phsBC Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0CE | IEC 61850 MMXU PPV.phsCA Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0D0 | IEC 61850 MMXU PhV.phsA Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0D2 | IEC 61850 MMXU PhV.phsB Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0D4 | IEC 61850 MMXU PhV.phsC Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0D6 | IEC 61850 MMXU A.phsA Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0D8 | IEC 61850 MMXU A.phsB Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0DA | IEC 61850 MMXU A.phsC Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0DC | IEC 61850 MMXU A.neut Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0DE | IEC 61850 MMXU W.phsA Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0E0 | IEC 61850 MMXU W.phsB Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0E2 | IEC 61850 MMXU W.phsC Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0E4 | IEC 61850 MMXU VAr.phsA Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0E6 | IEC 61850 MMXU VAr.phsB Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0E8 | IEC 61850 MMXU VAr.phsC Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0EA | IEC 61850 MMXU VA.phsA Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0EC | IEC 61850 MMXU VA.phsB Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0EE | IEC 61850 MMXU VA.phsC Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0F0 | IEC 61850 MMXU PF.phsA Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0F2 | IEC 61850 MMXU PF.phsB Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0F4 | IEC 61850 MMXU PF.phsC Deadband 1 | 0.001 to 100 | % | 0.001 | F003 | 10000 |
| B0F6 | ...Repeated for Deadband 2 | | | | | |
| B12C | ...Repeated for Deadband 3 | | | | | |
| B162 | ...Repeated for Deadband 4 | | | | | |
| B198 | ...Repeated for Deadband 5 | | | | | |
| B1CE | ...Repeated for Deadband 6 | | | | | |
| **IEC 61850 Received Analogs (Read Only) (32 modules)** | | | | | | |
| B210 | IEC 61850 Received Analog 1 | -1000000000000 to 1000000000000 | --- | 0.001 | F060 | 0 |
| B212 | ...Repeated for Received Analog 2 | | | | | |
| B214 | ...Repeated for Received Analog 3 | | | | | |
| B216 | ...Repeated for Received Analog 4 | | | | | |
| B218 | ...Repeated for Received Analog 5 | | | | | |
| B21A | ...Repeated for Received Analog 6 | | | | | |
| B21C | ...Repeated for Received Analog 7 | | | | | |
| B21E | ...Repeated for Received Analog 8 | | | | | |
| B220 | ...Repeated for Received Analog 9 | | | | | |
| B222 | ...Repeated for Received Analog 10 | | | | | |
| B224 | ...Repeated for Received Analog 11 | | | | | |
| B226 | ...Repeated for Received Analog 12 | | | | | |
| B228 | ...Repeated for Received Analog 13 | | | | | |
| B22A | ...Repeated for Received Analog 14 | | | | | |
| B22C | ...Repeated for Received Analog 15 | | | | | |
| B22E | ...Repeated for Received Analog 16 | | | | | |

**Table B–10: MODBUS MEMORY MAP (Sheet 47 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| B230 | ...Repeated for Received Analog 17 | | | | | |
| B232 | ...Repeated for Received Analog 18 | | | | | |
| B234 | ...Repeated for Received Analog 19 | | | | | |
| B236 | ...Repeated for Received Analog 20 | | | | | |
| B238 | ...Repeated for Received Analog 21 | | | | | |
| B23A | ...Repeated for Received Analog 22 | | | | | |
| B23C | ...Repeated for Received Analog 23 | | | | | |
| B23E | ...Repeated for Received Analog 24 | | | | | |
| B240 | ...Repeated for Received Analog 25 | | | | | |
| B242 | ...Repeated for Received Analog 26 | | | | | |
| B244 | ...Repeated for Received Analog 27 | | | | | |
| B246 | ...Repeated for Received Analog 28 | | | | | |
| B248 | ...Repeated for Received Analog 29 | | | | | |
| B24A | ...Repeated for Received Analog 30 | | | | | |
| B24C | ...Repeated for Received Analog 31 | | | | | |
| B24E | ...Repeated for Received Analog 32 | | | | | |
| **IEC 61850 Configurable Report Settings (Read/Write Setting)** | | | | | | |
| B290 | IEC 61850 Configurable Reports Dataset Items (64 items) | 0 to 848 | --- | 1 | F615 | 0 (None) |
| **IEC 61850 XSWI Configuration (Read/Write Setting) (24 modules)** | | | | | | |
| B370 | FlexLogic Operand for IEC 61850 XSWI.ST.Loc Status | 0 to 4294967295 | --- | 1 | F300 | 0 |
| B373 | ...Repeated for module number 2 | | | | | |
| B376 | ...Repeated for module number 3 | | | | | |
| B379 | ...Repeated for module number 4 | | | | | |
| B37C | ...Repeated for module number 5 | | | | | |
| B37F | ...Repeated for module number 6 | | | | | |
| B382 | ...Repeated for module number 7 | | | | | |
| B385 | ...Repeated for module number 8 | | | | | |
| B388 | ...Repeated for module number 9 | | | | | |
| B38B | ...Repeated for module number 10 | | | | | |
| B38E | ...Repeated for module number 11 | | | | | |
| B391 | ...Repeated for module number 12 | | | | | |
| B394 | ...Repeated for module number 13 | | | | | |
| B397 | ...Repeated for module number 14 | | | | | |
| B39A | ...Repeated for module number 15 | | | | | |
| B39D | ...Repeated for module number 16 | | | | | |
| B3A0 | ...Repeated for module number 17 | | | | | |
| B3A3 | ...Repeated for module number 18 | | | | | |
| B3A6 | ...Repeated for module number 19 | | | | | |
| B3A9 | ...Repeated for module number 20 | | | | | |
| B3AC | ...Repeated for module number 21 | | | | | |
| B3AF | ...Repeated for module number 22 | | | | | |
| B3B2 | ...Repeated for module number 23 | | | | | |
| B3B5 | ...Repeated for module number 24 | | | | | |
| **IEC 61850 XSWI Configuration (Read/Write Command) (24 modules)** | | | | | | |
| B372 | Command to Clear XSWI OpCnt (Operation Counter) | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **IEC 61850 GGIO1 Configuration Settings (Read/Write Setting)** | | | | | | |
| B400 | Number of Status Indications in GGIO1 | 8 to 128 | --- | 8 | F001 | 8 |
| B402 | IEC 61850 GGIO1 Indication FlexLogic operands (128 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| **IEC 61850 Configurable GOOSE Transmission (Read/Write Setting) (8 modules)** | | | | | | |
| B5A0 | IEC 61850 Configurable GOOSE Function (GoEna) | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| B5A1 | IEC 61850 Configurable GOOSE ID | --- | --- | --- | F209 | "GOOSEOut_x_" |
| B5C2 | Configurable GOOSE Destination MAC Address | --- | --- | --- | F072 | 0 |
| B5C5 | IEC 61850 Configurable GOOSE VLAN Transmit Priority | 0 to 7 | --- | 1 | F001 | 4 |

### Table B–10: MODBUS MEMORY MAP (Sheet 48 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| B5C6 | IEC 61850 Configurable GOOSE VLAN ID | 0 to 4095 | --- | 1 | F001 | 0 |
| B5C7 | IEC 61850 Configurable GOOSE ETYPE APPID | 0 to 16383 | --- | 1 | F001 | 0 |
| B5C8 | IEC 61850 Configurable GOOSE ConfRev (Configuration Revision) | 1 to 4294967295 | --- | 1 | F003 | 1 |
| B5CA | IEC 61850 Configurable GOOSE Retransmission Curve | 0 to 3 | --- | 1 | F611 | 3 (Relaxed) |
| B5CB | Configurable GOOSE Dataset Items for Transmission (64 items) | 0 to 1008 | --- | 1 | F616 | 0 (None) |
| B60B | ...Repeated for module number 2 | | | | | |
| B676 | ...Repeated for module number 3 | | | | | |
| B6E1 | ...Repeated for module number 4 | | | | | |
| B74C | ...Repeated for module number 5 | | | | | |
| B7B7 | ...Repeated for module number 6 | | | | | |
| B822 | ...Repeated for module number 7 | | | | | |
| B88D | ...Repeated for module number 8 | | | | | |
| **IEC 61850 Configurable GOOSE Reception (Read/Write Setting) (16 modules)** | | | | | | |
| B900 | Configurable GOOSE Dataset Items for Reception (32 items) | 0 to 197 | --- | 1 | F233 | 0 (None) |
| B920 | ...Repeated for module number 2 | | | | | |
| B940 | ...Repeated for module number 3 | | | | | |
| B960 | ...Repeated for module number 4 | | | | | |
| B980 | ...Repeated for module number 5 | | | | | |
| B9A0 | ...Repeated for module number 6 | | | | | |
| B9C0 | ...Repeated for module number 7 | | | | | |
| B9E0 | ...Repeated for module number 8 | | | | | |
| BA00 | ...Repeated for module number 9 | | | | | |
| BA20 | ...Repeated for module number 10 | | | | | |
| BA40 | ...Repeated for module number 11 | | | | | |
| BA60 | ...Repeated for module number 12 | | | | | |
| BA80 | ...Repeated for module number 13 | | | | | |
| BAA0 | ...Repeated for module number 14 | | | | | |
| BAC0 | ...Repeated for module number 15 | | | | | |
| BAE0 | ...Repeated for module number 16 | | | | | |
| **Contact Inputs (Read/Write Setting) (96 modules)** | | | | | | |
| BB00 | Contact Input 1 Name | --- | --- | --- | F205 | “Cont Ip 1“ |
| BB06 | Contact Input 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| BB07 | Contact Input 1 Debounce Time | 0 to 16 | ms | 0.5 | F001 | 20 |
| BB08 | ...Repeated for Contact Input 2 | | | | | |
| BB10 | ...Repeated for Contact Input 3 | | | | | |
| BB18 | ...Repeated for Contact Input 4 | | | | | |
| BB20 | ...Repeated for Contact Input 5 | | | | | |
| BB28 | ...Repeated for Contact Input 6 | | | | | |
| BB30 | ...Repeated for Contact Input 7 | | | | | |
| BB38 | ...Repeated for Contact Input 8 | | | | | |
| BB40 | ...Repeated for Contact Input 9 | | | | | |
| BB48 | ...Repeated for Contact Input 10 | | | | | |
| BB50 | ...Repeated for Contact Input 11 | | | | | |
| BB58 | ...Repeated for Contact Input 12 | | | | | |
| BB60 | ...Repeated for Contact Input 13 | | | | | |
| BB68 | ...Repeated for Contact Input 14 | | | | | |
| BB70 | ...Repeated for Contact Input 15 | | | | | |
| BB78 | ...Repeated for Contact Input 16 | | | | | |
| BB80 | ...Repeated for Contact Input 17 | | | | | |
| BB88 | ...Repeated for Contact Input 18 | | | | | |
| BB90 | ...Repeated for Contact Input 19 | | | | | |
| BB98 | ...Repeated for Contact Input 20 | | | | | |

**Table B–10: MODBUS MEMORY MAP (Sheet 49 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| BBA0 | ...Repeated for Contact Input 21 | | | | | |
| BBA8 | ...Repeated for Contact Input 22 | | | | | |
| BBB0 | ...Repeated for Contact Input 23 | | | | | |
| BBB8 | ...Repeated for Contact Input 24 | | | | | |
| BBC0 | ...Repeated for Contact Input 25 | | | | | |
| BBC8 | ...Repeated for Contact Input 26 | | | | | |
| BBD0 | ...Repeated for Contact Input 27 | | | | | |
| BBD8 | ...Repeated for Contact Input 28 | | | | | |
| BBE0 | ...Repeated for Contact Input 29 | | | | | |
| BBE8 | ...Repeated for Contact Input 30 | | | | | |
| BBF0 | ...Repeated for Contact Input 31 | | | | | |
| BBF8 | ...Repeated for Contact Input 32 | | | | | |
| BC00 | ...Repeated for Contact Input 33 | | | | | |
| BC08 | ...Repeated for Contact Input 34 | | | | | |
| BC10 | ...Repeated for Contact Input 35 | | | | | |
| BC18 | ...Repeated for Contact Input 36 | | | | | |
| BC20 | ...Repeated for Contact Input 37 | | | | | |
| BC28 | ...Repeated for Contact Input 38 | | | | | |
| BC30 | ...Repeated for Contact Input 39 | | | | | |
| BC38 | ...Repeated for Contact Input 40 | | | | | |
| BC40 | ...Repeated for Contact Input 41 | | | | | |
| BC48 | ...Repeated for Contact Input 42 | | | | | |
| BC50 | ...Repeated for Contact Input 43 | | | | | |
| BC58 | ...Repeated for Contact Input 44 | | | | | |
| BC60 | ...Repeated for Contact Input 45 | | | | | |
| BC68 | ...Repeated for Contact Input 46 | | | | | |
| BC70 | ...Repeated for Contact Input 47 | | | | | |
| BC78 | ...Repeated for Contact Input 48 | | | | | |
| BC80 | ...Repeated for Contact Input 49 | | | | | |
| BC88 | ...Repeated for Contact Input 50 | | | | | |
| BC90 | ...Repeated for Contact Input 51 | | | | | |
| BC98 | ...Repeated for Contact Input 52 | | | | | |
| BCA0 | ...Repeated for Contact Input 53 | | | | | |
| BCA8 | ...Repeated for Contact Input 54 | | | | | |
| BCB0 | ...Repeated for Contact Input 55 | | | | | |
| BCB8 | ...Repeated for Contact Input 56 | | | | | |
| BCC0 | ...Repeated for Contact Input 57 | | | | | |
| BCC8 | ...Repeated for Contact Input 58 | | | | | |
| BCD0 | ...Repeated for Contact Input 59 | | | | | |
| BCD8 | ...Repeated for Contact Input 60 | | | | | |
| BCE0 | ...Repeated for Contact Input 61 | | | | | |
| BCE8 | ...Repeated for Contact Input 62 | | | | | |
| BCF0 | ...Repeated for Contact Input 63 | | | | | |
| BCF8 | ...Repeated for Contact Input 64 | | | | | |
| BD00 | ...Repeated for Contact Input 65 | | | | | |
| BD08 | ...Repeated for Contact Input 66 | | | | | |
| BD10 | ...Repeated for Contact Input 67 | | | | | |
| BD18 | ...Repeated for Contact Input 68 | | | | | |
| BD20 | ...Repeated for Contact Input 69 | | | | | |
| BD28 | ...Repeated for Contact Input 70 | | | | | |
| BD30 | ...Repeated for Contact Input 71 | | | | | |
| BD38 | ...Repeated for Contact Input 72 | | | | | |
| BD40 | ...Repeated for Contact Input 73 | | | | | |
| BD48 | ...Repeated for Contact Input 74 | | | | | |

**Table B–10: MODBUS MEMORY MAP (Sheet 50 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| BD50 | ...Repeated for Contact Input 75 | | | | | |
| BD58 | ...Repeated for Contact Input 76 | | | | | |
| BD60 | ...Repeated for Contact Input 77 | | | | | |
| BD68 | ...Repeated for Contact Input 78 | | | | | |
| BD70 | ...Repeated for Contact Input 79 | | | | | |
| BD78 | ...Repeated for Contact Input 80 | | | | | |
| BD80 | ...Repeated for Contact Input 81 | | | | | |
| BD88 | ...Repeated for Contact Input 82 | | | | | |
| BD90 | ...Repeated for Contact Input 83 | | | | | |
| BD98 | ...Repeated for Contact Input 84 | | | | | |
| BDA0 | ...Repeated for Contact Input 85 | | | | | |
| BDA8 | ...Repeated for Contact Input 86 | | | | | |
| BDB0 | ...Repeated for Contact Input 87 | | | | | |
| BDB8 | ...Repeated for Contact Input 88 | | | | | |
| BDC0 | ...Repeated for Contact Input 89 | | | | | |
| BDC8 | ...Repeated for Contact Input 90 | | | | | |
| BDD0 | ...Repeated for Contact Input 91 | | | | | |
| BDD8 | ...Repeated for Contact Input 92 | | | | | |
| BDE0 | ...Repeated for Contact Input 93 | | | | | |
| BDE8 | ...Repeated for Contact Input 94 | | | | | |
| BDF0 | ...Repeated for Contact Input 95 | | | | | |
| BDF8 | ...Repeated for Contact Input 96 | | | | | |
| **Contact Input Thresholds (Read/Write Setting)** | | | | | | |
| BE00 | Contact Input *n* Threshold, *n* = 1 to 48 (48 items) | 0 to 3 | --- | 1 | F128 | 1 (33 Vdc) |
| **Virtual Inputs (Read/Write Setting) (64 modules)** | | | | | | |
| BE30 | Virtual Input 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| BE31 | Virtual Input 1 Name | --- | --- | --- | F205 | “Virt Ip 1“ |
| BE37 | Virtual Input 1 Programmed Type | 0 to 1 | --- | 1 | F127 | 0 (Latched) |
| BE38 | Virtual Input 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| BE39 | Reserved (3 items) | --- | --- | --- | F001 | 0 |
| BE3C | ...Repeated for Virtual Input 2 | | | | | |
| BE48 | ...Repeated for Virtual Input 3 | | | | | |
| BE54 | ...Repeated for Virtual Input 4 | | | | | |
| BE60 | ...Repeated for Virtual Input 5 | | | | | |
| BE6C | ...Repeated for Virtual Input 6 | | | | | |
| BE78 | ...Repeated for Virtual Input 7 | | | | | |
| BE84 | ...Repeated for Virtual Input 8 | | | | | |
| BE90 | ...Repeated for Virtual Input 9 | | | | | |
| BE9C | ...Repeated for Virtual Input 10 | | | | | |
| BEA8 | ...Repeated for Virtual Input 11 | | | | | |
| BEB4 | ...Repeated for Virtual Input 12 | | | | | |
| BEC0 | ...Repeated for Virtual Input 13 | | | | | |
| BECC | ...Repeated for Virtual Input 14 | | | | | |
| BED8 | ...Repeated for Virtual Input 15 | | | | | |
| BEE4 | ...Repeated for Virtual Input 16 | | | | | |
| BEF0 | ...Repeated for Virtual Input 17 | | | | | |
| BEFC | ...Repeated for Virtual Input 18 | | | | | |
| BF08 | ...Repeated for Virtual Input 19 | | | | | |
| BF14 | ...Repeated for Virtual Input 20 | | | | | |
| BF20 | ...Repeated for Virtual Input 21 | | | | | |
| BF2C | ...Repeated for Virtual Input 22 | | | | | |
| BF38 | ...Repeated for Virtual Input 23 | | | | | |
| BF44 | ...Repeated for Virtual Input 24 | | | | | |
| BF50 | ...Repeated for Virtual Input 25 | | | | | |

**Table B–10: MODBUS MEMORY MAP (Sheet 51 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| BF5C | ...Repeated for Virtual Input 26 | | | | | |
| BF68 | ...Repeated for Virtual Input 27 | | | | | |
| BF74 | ...Repeated for Virtual Input 28 | | | | | |
| BF80 | ...Repeated for Virtual Input 29 | | | | | |
| BF8C | ...Repeated for Virtual Input 30 | | | | | |
| BF98 | ...Repeated for Virtual Input 31 | | | | | |
| BFA4 | ...Repeated for Virtual Input 32 | | | | | |
| BFB0 | ...Repeated for Virtual Input 33 | | | | | |
| BFBC | ...Repeated for Virtual Input 34 | | | | | |
| BFC8 | ...Repeated for Virtual Input 35 | | | | | |
| BFD4 | ...Repeated for Virtual Input 36 | | | | | |
| BFE0 | ...Repeated for Virtual Input 37 | | | | | |
| BFEC | ...Repeated for Virtual Input 38 | | | | | |
| BFF8 | ...Repeated for Virtual Input 39 | | | | | |
| C004 | ...Repeated for Virtual Input 40 | | | | | |
| C010 | ...Repeated for Virtual Input 41 | | | | | |
| C01C | ...Repeated for Virtual Input 42 | | | | | |
| C028 | ...Repeated for Virtual Input 43 | | | | | |
| C034 | ...Repeated for Virtual Input 44 | | | | | |
| C040 | ...Repeated for Virtual Input 45 | | | | | |
| C04C | ...Repeated for Virtual Input 46 | | | | | |
| C058 | ...Repeated for Virtual Input 47 | | | | | |
| C064 | ...Repeated for Virtual Input 48 | | | | | |
| C070 | ...Repeated for Virtual Input 49 | | | | | |
| C07C | ...Repeated for Virtual Input 50 | | | | | |
| C088 | ...Repeated for Virtual Input 51 | | | | | |
| C094 | ...Repeated for Virtual Input 52 | | | | | |
| C0A0 | ...Repeated for Virtual Input 53 | | | | | |
| C0AC | ...Repeated for Virtual Input 54 | | | | | |
| C0B8 | ...Repeated for Virtual Input 55 | | | | | |
| C0C4 | ...Repeated for Virtual Input 56 | | | | | |
| C0D0 | ...Repeated for Virtual Input 57 | | | | | |
| C0DC | ...Repeated for Virtual Input 58 | | | | | |
| C0E8 | ...Repeated for Virtual Input 59 | | | | | |
| C0F4 | ...Repeated for Virtual Input 60 | | | | | |
| C100 | ...Repeated for Virtual Input 61 | | | | | |
| C10C | ...Repeated for Virtual Input 62 | | | | | |
| C118 | ...Repeated for Virtual Input 63 | | | | | |
| C124 | ...Repeated for Virtual Input 64 | | | | | |
| **Virtual Outputs (Read/Write Setting) (96 modules)** | | | | | | |
| C130 | Virtual Output 1 Name | --- | --- | --- | F205 | “Virt Op 1 “ |
| C136 | Virtual Output 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| C137 | Reserved | --- | --- | --- | F001 | 0 |
| C138 | ...Repeated for Virtual Output 2 | | | | | |
| C140 | ...Repeated for Virtual Output 3 | | | | | |
| C148 | ...Repeated for Virtual Output 4 | | | | | |
| C150 | ...Repeated for Virtual Output 5 | | | | | |
| C158 | ...Repeated for Virtual Output 6 | | | | | |
| C160 | ...Repeated for Virtual Output 7 | | | | | |
| C168 | ...Repeated for Virtual Output 8 | | | | | |
| C170 | ...Repeated for Virtual Output 9 | | | | | |
| C178 | ...Repeated for Virtual Output 10 | | | | | |
| C180 | ...Repeated for Virtual Output 11 | | | | | |
| C188 | ...Repeated for Virtual Output 12 | | | | | |

**Table B–10: MODBUS MEMORY MAP (Sheet 52 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| C190 | ...Repeated for Virtual Output 13 | | | | | |
| C198 | ...Repeated for Virtual Output 14 | | | | | |
| C1A0 | ...Repeated for Virtual Output 15 | | | | | |
| C1A8 | ...Repeated for Virtual Output 16 | | | | | |
| C1B0 | ...Repeated for Virtual Output 17 | | | | | |
| C1B8 | ...Repeated for Virtual Output 18 | | | | | |
| C1C0 | ...Repeated for Virtual Output 19 | | | | | |
| C1C8 | ...Repeated for Virtual Output 20 | | | | | |
| C1D0 | ...Repeated for Virtual Output 21 | | | | | |
| C1D8 | ...Repeated for Virtual Output 22 | | | | | |
| C1E0 | ...Repeated for Virtual Output 23 | | | | | |
| C1E8 | ...Repeated for Virtual Output 24 | | | | | |
| C1F0 | ...Repeated for Virtual Output 25 | | | | | |
| C1F8 | ...Repeated for Virtual Output 26 | | | | | |
| C200 | ...Repeated for Virtual Output 27 | | | | | |
| C208 | ...Repeated for Virtual Output 28 | | | | | |
| C210 | ...Repeated for Virtual Output 29 | | | | | |
| C218 | ...Repeated for Virtual Output 30 | | | | | |
| C220 | ...Repeated for Virtual Output 31 | | | | | |
| C228 | ...Repeated for Virtual Output 32 | | | | | |
| C230 | ...Repeated for Virtual Output 33 | | | | | |
| C238 | ...Repeated for Virtual Output 34 | | | | | |
| C240 | ...Repeated for Virtual Output 35 | | | | | |
| C248 | ...Repeated for Virtual Output 36 | | | | | |
| C250 | ...Repeated for Virtual Output 37 | | | | | |
| C258 | ...Repeated for Virtual Output 38 | | | | | |
| C260 | ...Repeated for Virtual Output 39 | | | | | |
| C268 | ...Repeated for Virtual Output 40 | | | | | |
| C270 | ...Repeated for Virtual Output 41 | | | | | |
| C278 | ...Repeated for Virtual Output 42 | | | | | |
| C280 | ...Repeated for Virtual Output 43 | | | | | |
| C288 | ...Repeated for Virtual Output 44 | | | | | |
| C290 | ...Repeated for Virtual Output 45 | | | | | |
| C298 | ...Repeated for Virtual Output 46 | | | | | |
| C2A0 | ...Repeated for Virtual Output 47 | | | | | |
| C2A8 | ...Repeated for Virtual Output 48 | | | | | |
| C2B0 | ...Repeated for Virtual Output 49 | | | | | |
| C2B8 | ...Repeated for Virtual Output 50 | | | | | |
| C2C0 | ...Repeated for Virtual Output 51 | | | | | |
| C2C8 | ...Repeated for Virtual Output 52 | | | | | |
| C2D0 | ...Repeated for Virtual Output 53 | | | | | |
| C2D8 | ...Repeated for Virtual Output 54 | | | | | |
| C2E0 | ...Repeated for Virtual Output 55 | | | | | |
| C2E8 | ...Repeated for Virtual Output 56 | | | | | |
| C2F0 | ...Repeated for Virtual Output 57 | | | | | |
| C2F8 | ...Repeated for Virtual Output 58 | | | | | |
| C300 | ...Repeated for Virtual Output 59 | | | | | |
| C308 | ...Repeated for Virtual Output 60 | | | | | |
| C310 | ...Repeated for Virtual Output 61 | | | | | |
| C318 | ...Repeated for Virtual Output 62 | | | | | |
| C320 | ...Repeated for Virtual Output 63 | | | | | |
| C328 | ...Repeated for Virtual Output 64 | | | | | |
| C330 | ...Repeated for Virtual Output 65 | | | | | |
| C338 | ...Repeated for Virtual Output 66 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 53 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| C340 | ...Repeated for Virtual Output 67 | | | | | |
| C348 | ...Repeated for Virtual Output 68 | | | | | |
| C350 | ...Repeated for Virtual Output 69 | | | | | |
| C358 | ...Repeated for Virtual Output 70 | | | | | |
| C360 | ...Repeated for Virtual Output 71 | | | | | |
| C368 | ...Repeated for Virtual Output 72 | | | | | |
| C370 | ...Repeated for Virtual Output 73 | | | | | |
| C378 | ...Repeated for Virtual Output 74 | | | | | |
| C380 | ...Repeated for Virtual Output 75 | | | | | |
| C388 | ...Repeated for Virtual Output 76 | | | | | |
| C390 | ...Repeated for Virtual Output 77 | | | | | |
| C398 | ...Repeated for Virtual Output 78 | | | | | |
| C3A0 | ...Repeated for Virtual Output 79 | | | | | |
| C3A8 | ...Repeated for Virtual Output 80 | | | | | |
| C3B0 | ...Repeated for Virtual Output 81 | | | | | |
| C3B8 | ...Repeated for Virtual Output 82 | | | | | |
| C3C0 | ...Repeated for Virtual Output 83 | | | | | |
| C3C8 | ...Repeated for Virtual Output 84 | | | | | |
| C3D0 | ...Repeated for Virtual Output 85 | | | | | |
| C3D8 | ...Repeated for Virtual Output 86 | | | | | |
| C3E0 | ...Repeated for Virtual Output 87 | | | | | |
| C3E8 | ...Repeated for Virtual Output 88 | | | | | |
| C3F0 | ...Repeated for Virtual Output 89 | | | | | |
| C3F8 | ...Repeated for Virtual Output 90 | | | | | |
| C400 | ...Repeated for Virtual Output 91 | | | | | |
| C408 | ...Repeated for Virtual Output 92 | | | | | |
| C410 | ...Repeated for Virtual Output 93 | | | | | |
| C418 | ...Repeated for Virtual Output 94 | | | | | |
| C420 | ...Repeated for Virtual Output 95 | | | | | |
| C428 | ...Repeated for Virtual Output 96 | | | | | |
| **Mandatory (Read/Write Setting or Command)** | | | | | | |
| C430 | Test Mode Function | 0 to 2 | --- | 1 | F245 | 0 (Disabled) |
| C431 | Force VFD and LED | 0 to 1 | --- | 1 | F126 | 0 (No) |
| C432 | Test Mode Initiate (Forcing) | 0 to 4294967295 | --- | 1 | F300 | 1 |
| **Clear Commands (Read/Write)** | | | | | | |
| C434 | Clear All Relay Records Command | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **Mandatory (Read Only)** | | | | | | |
| C435 | DSP Advanced Diagnostics Active | 0 to 1 | -- | 1 | F126 | 0 (No) |
| C436 | Synchrophasor Feature Active | 0 to 1 | -- | 1 | F126 | 0 (No) |
| **Mandatory (Read/Write Command)** | | | | | | |
| C437 | Relay Reboot Command | 0 to 1 | --- | 1 | F126 | 0 (No) |
| C438 | Save Volatile Data | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **Clear Records (Read/Write Setting)** | | | | | | |
| C450 | Clear Fault Reports Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| C454 | Clear Event Records Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| C456 | Clear Oscillography Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| C458 | Clear Data Logger Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| C45A | Clear Breaker 1 Arcing Current Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| C45C | Clear Breaker 2 Arcing Current Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| C466 | Clear Channel Tests Status Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| C46C | Clear Unauthorized Access Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| C472 | Reserved (13 items) | --- | --- | --- | F001 | 0 |
| **Direct Input/Output Settings (Read/Write Setting)** | | | | | | |
| C500 | Direct Input Default States (8 items) | 0 to 1 | --- | 1 | F108 | 0 (Off) |

### Table B–10: MODBUS MEMORY MAP (Sheet 54 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| C508 | Direct Input Default States (8 items) | 0 to 1 | --- | 1 | F108 | 0 (Off) |
| C510 | Direct Output x 1 Operand (8 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| C520 | Direct Output x 2 Operand (8 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| **Reset (Read/Write Setting)** | | | | | | |
| C750 | FlexLogic operand which initiates a reset | 0 to 4294967295 | --- | 1 | F300 | 0 |
| **Control Pushbuttons (Read/Write Setting) (7 modules)** | | | | | | |
| C760 | Control Pushbutton 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| C761 | Control Pushbutton 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| C762 | ...Repeated for Control Pushbutton 2 | | | | | |
| C764 | ...Repeated for Control Pushbutton 3 | | | | | |
| C766 | ...Repeated for Control Pushbutton 4 | | | | | |
| C768 | ...Repeated for Control Pushbutton 5 | | | | | |
| C76A | ...Repeated for Control Pushbutton 6 | | | | | |
| C76C | ...Repeated for Control Pushbutton 7 | | | | | |
| **Force Contact Inputs/Outputs (Read/Write Settings)** | | | | | | |
| C7A0 | Force Contact Input *x* State (96 items) | 0 to 2 | --- | 1 | F144 | 0 (Disabled) |
| C800 | Force Contact Output *x* State (64 items) | 0 to 3 | --- | 1 | F131 | 0 (Disabled) |
| **87L Channel Tests (Read/Write)** | | | | | | |
| C840 | Local Loopback Function | 0 to 1 | --- | 1 | F126 | 0 (No) |
| C841 | Local Loopback Channel | 1 to 2 | --- | 1 | F001 | 1 |
| C842 | Remote Loopback Function | 0 to 1 | --- | 1 | F126 | 0 (No) |
| C843 | Remote Loopback Channel | 1 to 2 | --- | 1 | F001 | 1 |
| C844 | Remote Diagnostics Transmit | 0 to 2 | --- | 1 | F223 | 0 (NO TEST) |
| **Remote Devices (Read/Write Setting) (16 modules)** | | | | | | |
| CB00 | Remote Device 1 GSSE/GOOSE Application ID (GOID) | --- | --- | --- | F209 | “Remote Device 1“ |
| CB21 | Remote Device 1 GOOSE Ethernet APPID | 0 to 16383 | --- | 1 | F001 | 0 |
| CB22 | Remote Device 1 GOOSE Dataset | 0 to 16 | --- | 1 | F184 | 0 (Fixed) |
| CB23 | Remote Device 1 in PMU Scheme | 0 to 1 | --- | 1 | F126 | 0 (No) |
| CB24 | Reserved | 0 to 3 | --- | 1 | F626 | 0 (None) |
| CB25 | ...Repeated for Device 2 | | | | | |
| CB4A | ...Repeated for Device 3 | | | | | |
| CB6F | ...Repeated for Device 4 | | | | | |
| CB94 | ...Repeated for Device 5 | | | | | |
| CBB9 | ...Repeated for Device 6 | | | | | |
| CBDE | ...Repeated for Device 7 | | | | | |
| CC03 | ...Repeated for Device 8 | | | | | |
| CC28 | ...Repeated for Device 9 | | | | | |
| CC4D | ...Repeated for Device 10 | | | | | |
| CC72 | ...Repeated for Device 11 | | | | | |
| CC97 | ...Repeated for Device 12 | | | | | |
| CCBC | ...Repeated for Device 13 | | | | | |
| CCE1 | ...Repeated for Device 14 | | | | | |
| CD06 | ...Repeated for Device 15 | | | | | |
| CD2B | ...Repeated for Device 16 | | | | | |
| **Remote Inputs (Read/Write Setting) (32 modules)** | | | | | | |
| CFA0 | Remote Input 1 Device | 1 to 32 | --- | 1 | F001 | 1 |
| CFA1 | Remote Input 1 Bit Pair | 0 to 96 | --- | 1 | F156 | 0 (None) |
| CFA2 | Remote Input 1 Default State | 0 to 3 | --- | 1 | F086 | 0 (Off) |
| CFA3 | Remote Input 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| CFA4 | Remote Input 1 Name | 1 to 64 | --- | 1 | F205 | “Rem Ip 1” |
| CFAA | ...Repeated for Remote Input 2 | | | | | |
| CFB4 | ...Repeated for Remote Input 3 | | | | | |
| CFBE | ...Repeated for Remote Input 4 | | | | | |

**Table B–10: MODBUS MEMORY MAP (Sheet 55 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| CFC8 | ...Repeated for Remote Input 5 | | | | | |
| CFD2 | ...Repeated for Remote Input 6 | | | | | |
| CFDC | ...Repeated for Remote Input 7 | | | | | |
| CFE6 | ...Repeated for Remote Input 8 | | | | | |
| CFF0 | ...Repeated for Remote Input 9 | | | | | |
| CFFA | ...Repeated for Remote Input 10 | | | | | |
| D004 | ...Repeated for Remote Input 11 | | | | | |
| D00E | ...Repeated for Remote Input 12 | | | | | |
| D018 | ...Repeated for Remote Input 13 | | | | | |
| D022 | ...Repeated for Remote Input 14 | | | | | |
| D02C | ...Repeated for Remote Input 15 | | | | | |
| D036 | ...Repeated for Remote Input 16 | | | | | |
| D040 | ...Repeated for Remote Input 17 | | | | | |
| D04A | ...Repeated for Remote Input 18 | | | | | |
| D054 | ...Repeated for Remote Input 19 | | | | | |
| D05E | ...Repeated for Remote Input 20 | | | | | |
| D068 | ...Repeated for Remote Input 21 | | | | | |
| D072 | ...Repeated for Remote Input 22 | | | | | |
| D07C | ...Repeated for Remote Input 23 | | | | | |
| D086 | ...Repeated for Remote Input 24 | | | | | |
| D090 | ...Repeated for Remote Input 25 | | | | | |
| D09A | ...Repeated for Remote Input 26 | | | | | |
| D0A4 | ...Repeated for Remote Input 27 | | | | | |
| D0AE | ...Repeated for Remote Input 28 | | | | | |
| D0B8 | ...Repeated for Remote Input 29 | | | | | |
| D0C2 | ...Repeated for Remote Input 30 | | | | | |
| D0CC | ...Repeated for Remote Input 31 | | | | | |
| D0D6 | ...Repeated for Remote Input 32 | | | | | |
| **Remote Output DNA Pairs (Read/Write Setting) (32 modules)** | | | | | | |
| D220 | Remote Output DNA 1 Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| D222 | Remote Output DNA 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| D223 | Reserved | 0 to 1 | --- | 1 | F001 | 0 |
| D224 | ...Repeated for Remote Output 2 | | | | | |
| D228 | ...Repeated for Remote Output 3 | | | | | |
| D22C | ...Repeated for Remote Output 4 | | | | | |
| D230 | ...Repeated for Remote Output 5 | | | | | |
| D234 | ...Repeated for Remote Output 6 | | | | | |
| D238 | ...Repeated for Remote Output 7 | | | | | |
| D23C | ...Repeated for Remote Output 8 | | | | | |
| D240 | ...Repeated for Remote Output 9 | | | | | |
| D244 | ...Repeated for Remote Output 10 | | | | | |
| D248 | ...Repeated for Remote Output 11 | | | | | |
| D24C | ...Repeated for Remote Output 12 | | | | | |
| D250 | ...Repeated for Remote Output 13 | | | | | |
| D254 | ...Repeated for Remote Output 14 | | | | | |
| D258 | ...Repeated for Remote Output 15 | | | | | |
| D25C | ...Repeated for Remote Output 16 | | | | | |
| D260 | ...Repeated for Remote Output 17 | | | | | |
| D264 | ...Repeated for Remote Output 18 | | | | | |
| D268 | ...Repeated for Remote Output 19 | | | | | |
| D26C | ...Repeated for Remote Output 20 | | | | | |
| D270 | ...Repeated for Remote Output 21 | | | | | |
| D274 | ...Repeated for Remote Output 22 | | | | | |
| D278 | ...Repeated for Remote Output 23 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 56 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| D27C | ...Repeated for Remote Output 24 | | | | | |
| D280 | ...Repeated for Remote Output 25 | | | | | |
| D284 | ...Repeated for Remote Output 26 | | | | | |
| D288 | ...Repeated for Remote Output 27 | | | | | |
| D28C | ...Repeated for Remote Output 28 | | | | | |
| D290 | ...Repeated for Remote Output 29 | | | | | |
| D294 | ...Repeated for Remote Output 30 | | | | | |
| D298 | ...Repeated for Remote Output 31 | | | | | |
| D29C | ...Repeated for Remote Output 32 | | | | | |
| **Remote Output UserSt Pairs (Read/Write Setting) (32 modules)** | | | | | | |
| D2A0 | Remote Output UserSt 1 Operand | 0 to 4294967295 | --- | 1 | F300 | 0 |
| D2A2 | Remote Output UserSt 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| D2A3 | Reserved | 0 to 1 | --- | 1 | F001 | 0 |
| D2A4 | ...Repeated for Remote Output 2 | | | | | |
| D2A8 | ...Repeated for Remote Output 3 | | | | | |
| D2AC | ...Repeated for Remote Output 4 | | | | | |
| D2B0 | ...Repeated for Remote Output 5 | | | | | |
| D2B4 | ...Repeated for Remote Output 6 | | | | | |
| D2B8 | ...Repeated for Remote Output 7 | | | | | |
| D2BC | ...Repeated for Remote Output 8 | | | | | |
| D2C0 | ...Repeated for Remote Output 9 | | | | | |
| D2C4 | ...Repeated for Remote Output 10 | | | | | |
| D2C8 | ...Repeated for Remote Output 11 | | | | | |
| D2CC | ...Repeated for Remote Output 12 | | | | | |
| D2D0 | ...Repeated for Remote Output 13 | | | | | |
| D2D4 | ...Repeated for Remote Output 14 | | | | | |
| D2D8 | ...Repeated for Remote Output 15 | | | | | |
| D2DC | ...Repeated for Remote Output 16 | | | | | |
| D2E0 | ...Repeated for Remote Output 17 | | | | | |
| D2E4 | ...Repeated for Remote Output 18 | | | | | |
| D2E8 | ...Repeated for Remote Output 19 | | | | | |
| D2EC | ...Repeated for Remote Output 20 | | | | | |
| D2F0 | ...Repeated for Remote Output 21 | | | | | |
| D2F4 | ...Repeated for Remote Output 22 | | | | | |
| D2F8 | ...Repeated for Remote Output 23 | | | | | |
| D2FC | ...Repeated for Remote Output 24 | | | | | |
| D300 | ...Repeated for Remote Output 25 | | | | | |
| D304 | ...Repeated for Remote Output 26 | | | | | |
| D308 | ...Repeated for Remote Output 27 | | | | | |
| D30C | ...Repeated for Remote Output 28 | | | | | |
| D310 | ...Repeated for Remote Output 29 | | | | | |
| D314 | ...Repeated for Remote Output 30 | | | | | |
| D318 | ...Repeated for Remote Output 31 | | | | | |
| D31C | ...Repeated for Remote Output 32 | | | | | |
| **IEC 61850 GGIO2 Control Configuration (Read/Write Setting) (64 modules)** | | | | | | |
| D320 | IEC 61850 GGIO2.CF.SPCSO1.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D321 | IEC 61850 GGIO2.CF.SPCSO2.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D322 | IEC 61850 GGIO2.CF.SPCSO3.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D323 | IEC 61850 GGIO2.CF.SPCSO4.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D324 | IEC 61850 GGIO2.CF.SPCSO5.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D325 | IEC 61850 GGIO2.CF.SPCSO6.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D326 | IEC 61850 GGIO2.CF.SPCSO7.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D327 | IEC 61850 GGIO2.CF.SPCSO8.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D328 | IEC 61850 GGIO2.CF.SPCSO9.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |

**Table B–10: MODBUS MEMORY MAP (Sheet 57 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| D329 | IEC 61850 GGIO2.CF.SPCSO10.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D32A | IEC 61850 GGIO2.CF.SPCSO11.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D32B | IEC 61850 GGIO2.CF.SPCSO12.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D32C | IEC 61850 GGIO2.CF.SPCSO13.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D32D | IEC 61850 GGIO2.CF.SPCSO14.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D32E | IEC 61850 GGIO2.CF.SPCSO15.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D32F | IEC 61850 GGIO2.CF.SPCSO16.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D330 | IEC 61850 GGIO2.CF.SPCSO17.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D331 | IEC 61850 GGIO2.CF.SPCSO18.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D332 | IEC 61850 GGIO2.CF.SPCSO19.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D333 | IEC 61850 GGIO2.CF.SPCSO20.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D334 | IEC 61850 GGIO2.CF.SPCSO21.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D335 | IEC 61850 GGIO2.CF.SPCSO22.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D336 | IEC 61850 GGIO2.CF.SPCSO23.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D337 | IEC 61850 GGIO2.CF.SPCSO24.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D338 | IEC 61850 GGIO2.CF.SPCSO25.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D339 | IEC 61850 GGIO2.CF.SPCSO26.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D33A | IEC 61850 GGIO2.CF.SPCSO27.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D33B | IEC 61850 GGIO2.CF.SPCSO28.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D33C | IEC 61850 GGIO2.CF.SPCSO29.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D33D | IEC 61850 GGIO2.CF.SPCSO30.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D33E | IEC 61850 GGIO2.CF.SPCSO31.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D33F | IEC 61850 GGIO2.CF.SPCSO32.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D340 | IEC 61850 GGIO2.CF.SPCSO33.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D341 | IEC 61850 GGIO2.CF.SPCSO34.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D342 | IEC 61850 GGIO2.CF.SPCSO35.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D343 | IEC 61850 GGIO2.CF.SPCSO36.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D344 | IEC 61850 GGIO2.CF.SPCSO37.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D345 | IEC 61850 GGIO2.CF.SPCSO38.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D346 | IEC 61850 GGIO2.CF.SPCSO39.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D347 | IEC 61850 GGIO2.CF.SPCSO40.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D348 | IEC 61850 GGIO2.CF.SPCSO41.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D349 | IEC 61850 GGIO2.CF.SPCSO42.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D34A | IEC 61850 GGIO2.CF.SPCSO43.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D34B | IEC 61850 GGIO2.CF.SPCSO44.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D34C | IEC 61850 GGIO2.CF.SPCSO45.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D34D | IEC 61850 GGIO2.CF.SPCSO46.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D34E | IEC 61850 GGIO2.CF.SPCSO47.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D34F | IEC 61850 GGIO2.CF.SPCSO48.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D350 | IEC 61850 GGIO2.CF.SPCSO49.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D351 | IEC 61850 GGIO2.CF.SPCSO50.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D352 | IEC 61850 GGIO2.CF.SPCSO51.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D353 | IEC 61850 GGIO2.CF.SPCSO52.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D354 | IEC 61850 GGIO2.CF.SPCSO53.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D355 | IEC 61850 GGIO2.CF.SPCSO54.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D356 | IEC 61850 GGIO2.CF.SPCSO55.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D357 | IEC 61850 GGIO2.CF.SPCSO56.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D358 | IEC 61850 GGIO2.CF.SPCSO57.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D359 | IEC 61850 GGIO2.CF.SPCSO58.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D35A | IEC 61850 GGIO2.CF.SPCSO59.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D35B | IEC 61850 GGIO2.CF.SPCSO60.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D35C | IEC 61850 GGIO2.CF.SPCSO61.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D35D | IEC 61850 GGIO2.CF.SPCSO62.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| D35E | IEC 61850 GGIO2.CF.SPCSO63.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |

### Table B–10: MODBUS MEMORY MAP (Sheet 58 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| D35F | IEC 61850 GGIO2.CF.SPCSO64.ctlModel Value | 0 to 2 | --- | 1 | F001 | 1 |
| **Remote Device Status (Read Only) (16 modules)** | | | | | | |
| D360 | Remote Device 1 StNum | 0 to 4294967295 | --- | 1 | F003 | 0 |
| D362 | Remote Device 1 SqNum | 0 to 4294967295 | --- | 1 | F003 | 0 |
| D364 | ...Repeated for Remote Device 2 | | | | | |
| D368 | ...Repeated for Remote Device 3 | | | | | |
| D36C | ...Repeated for Remote Device 4 | | | | | |
| D370 | ...Repeated for Remote Device 5 | | | | | |
| D374 | ...Repeated for Remote Device 6 | | | | | |
| D378 | ...Repeated for Remote Device 7 | | | | | |
| D37C | ...Repeated for Remote Device 8 | | | | | |
| D380 | ...Repeated for Remote Device 9 | | | | | |
| D384 | ...Repeated for Remote Device 10 | | | | | |
| D388 | ...Repeated for Remote Device 11 | | | | | |
| D38C | ...Repeated for Remote Device 12 | | | | | |
| D390 | ...Repeated for Remote Device 13 | | | | | |
| D394 | ...Repeated for Remote Device 14 | | | | | |
| D398 | ...Repeated for Remote Device 15 | | | | | |
| D39C | ...Repeated for Remote Device 16 | | | | | |
| **Contact Outputs (Read/Write Setting) (64 modules)** | | | | | | |
| D3E0 | Contact Output 1 Name | --- | --- | --- | F205 | "Cont Op 1" |
| D3E6 | Contact Output 1 Operation | 0 to 4294967295 | --- | 1 | F300 | 0 |
| D3E8 | Contact Output 1 Seal In | 0 to 4294967295 | --- | 1 | F300 | 0 |
| D3EA | Latching Output 1 Reset | 0 to 4294967295 | --- | 1 | F300 | 0 |
| D3EC | Contact Output 1 Events | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| D3ED | Latching Output 1 Type | 0 to 1 | --- | 1 | F090 | 0 (Operate-dominant) |
| D3EE | Reserved | --- | --- | --- | F001 | 0 |
| D3EF | ...Repeated for Contact Output 2 | | | | | |
| D3FE | ...Repeated for Contact Output 3 | | | | | |
| D40D | ...Repeated for Contact Output 4 | | | | | |
| D41C | ...Repeated for Contact Output 5 | | | | | |
| D42B | ...Repeated for Contact Output 6 | | | | | |
| D43A | ...Repeated for Contact Output 7 | | | | | |
| D449 | ...Repeated for Contact Output 8 | | | | | |
| D458 | ...Repeated for Contact Output 9 | | | | | |
| D467 | ...Repeated for Contact Output 10 | | | | | |
| D476 | ...Repeated for Contact Output 11 | | | | | |
| D485 | ...Repeated for Contact Output 12 | | | | | |
| D494 | ...Repeated for Contact Output 13 | | | | | |
| D4A3 | ...Repeated for Contact Output 14 | | | | | |
| D4B2 | ...Repeated for Contact Output 15 | | | | | |
| D4C1 | ...Repeated for Contact Output 16 | | | | | |
| D4D0 | ...Repeated for Contact Output 17 | | | | | |
| D4DF | ...Repeated for Contact Output 18 | | | | | |
| D4EE | ...Repeated for Contact Output 19 | | | | | |
| D4FD | ...Repeated for Contact Output 20 | | | | | |
| D50C | ...Repeated for Contact Output 21 | | | | | |
| D51B | ...Repeated for Contact Output 22 | | | | | |
| D52A | ...Repeated for Contact Output 23 | | | | | |
| D539 | ...Repeated for Contact Output 24 | | | | | |
| D548 | ...Repeated for Contact Output 25 | | | | | |
| D557 | ...Repeated for Contact Output 26 | | | | | |
| D566 | ...Repeated for Contact Output 27 | | | | | |

**Table B–10: MODBUS MEMORY MAP (Sheet 59 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| D575 | ...Repeated for Contact Output 28 | | | | | |
| D584 | ...Repeated for Contact Output 29 | | | | | |
| D593 | ...Repeated for Contact Output 30 | | | | | |
| D5A2 | ...Repeated for Contact Output 31 | | | | | |
| D5B1 | ...Repeated for Contact Output 32 | | | | | |
| D5C0 | ...Repeated for Contact Output 33 | | | | | |
| D5CF | ...Repeated for Contact Output 34 | | | | | |
| D5DE | ...Repeated for Contact Output 35 | | | | | |
| D5ED | ...Repeated for Contact Output 36 | | | | | |
| D5FC | ...Repeated for Contact Output 37 | | | | | |
| D60B | ...Repeated for Contact Output 38 | | | | | |
| D61A | ...Repeated for Contact Output 39 | | | | | |
| D629 | ...Repeated for Contact Output 40 | | | | | |
| D638 | ...Repeated for Contact Output 41 | | | | | |
| D647 | ...Repeated for Contact Output 42 | | | | | |
| D656 | ...Repeated for Contact Output 43 | | | | | |
| D665 | ...Repeated for Contact Output 44 | | | | | |
| D674 | ...Repeated for Contact Output 45 | | | | | |
| D683 | ...Repeated for Contact Output 46 | | | | | |
| D692 | ...Repeated for Contact Output 47 | | | | | |
| D6A1 | ...Repeated for Contact Output 48 | | | | | |
| D6B0 | ...Repeated for Contact Output 49 | | | | | |
| D6BF | ...Repeated for Contact Output 50 | | | | | |
| D6CE | ...Repeated for Contact Output 51 | | | | | |
| D6DD | ...Repeated for Contact Output 52 | | | | | |
| D6EC | ...Repeated for Contact Output 53 | | | | | |
| D6FB | ...Repeated for Contact Output 54 | | | | | |
| D70A | ...Repeated for Contact Output 55 | | | | | |
| D719 | ...Repeated for Contact Output 56 | | | | | |
| D728 | ...Repeated for Contact Output 57 | | | | | |
| D737 | ...Repeated for Contact Output 58 | | | | | |
| D746 | ...Repeated for Contact Output 59 | | | | | |
| D755 | ...Repeated for Contact Output 60 | | | | | |
| D764 | ...Repeated for Contact Output 61 | | | | | |
| D773 | ...Repeated for Contact Output 62 | | | | | |
| D782 | ...Repeated for Contact Output 63 | | | | | |
| D791 | ...Repeated for Contact Output 64 | | | | | |
| **DCmA Inputs (Read/Write Setting) (24 modules)** | | | | | | |
| D7A0 | DCmA Inputs 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| D7A1 | DCmA Inputs 1 ID | --- | --- | --- | F205 | "DCMA Ip 1" |
| D7A7 | Reserved 1 (4 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| D7AB | DCmA Inputs 1 Units | --- | --- | --- | F206 | "mA" |
| D7AE | DCmA Inputs 1 Range | 0 to 6 | --- | 1 | F173 | 6 (4 to 20 mA) |
| D7AF | DCmA Inputs 1 Minimum Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 4000 |
| D7B1 | DCmA Inputs 1 Maximum Value | -9999.999 to 9999.999 | --- | 0.001 | F004 | 20000 |
| D7B3 | ...Repeated for DCmA Inputs 2 | | | | | |
| D7C6 | ...Repeated for DCmA Inputs 3 | | | | | |
| D7D9 | ...Repeated for DCmA Inputs 4 | | | | | |
| D7EC | ...Repeated for DCmA Inputs 5 | | | | | |
| D7FF | ...Repeated for DCmA Inputs 6 | | | | | |
| D812 | ...Repeated for DCmA Inputs 7 | | | | | |
| D825 | ...Repeated for DCmA Inputs 8 | | | | | |
| D838 | ...Repeated for DCmA Inputs 9 | | | | | |
| D84B | ...Repeated for DCmA Inputs 10 | | | | | |

### Table B–10: MODBUS MEMORY MAP (Sheet 60 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| D85E | ...Repeated for DCmA Inputs 11 | | | | | |
| D871 | ...Repeated for DCmA Inputs 12 | | | | | |
| D884 | ...Repeated for DCmA Inputs 13 | | | | | |
| D897 | ...Repeated for DCmA Inputs 14 | | | | | |
| D8AA | ...Repeated for DCmA Inputs 15 | | | | | |
| D8BD | ...Repeated for DCmA Inputs 16 | | | | | |
| D8D0 | ...Repeated for DCmA Inputs 17 | | | | | |
| D8E3 | ...Repeated for DCmA Inputs 18 | | | | | |
| D8F6 | ...Repeated for DCmA Inputs 19 | | | | | |
| D909 | ...Repeated for DCmA Inputs 20 | | | | | |
| D91C | ...Repeated for DCmA Inputs 21 | | | | | |
| D92F | ...Repeated for DCmA Inputs 22 | | | | | |
| D942 | ...Repeated for DCmA Inputs 23 | | | | | |
| D955 | ...Repeated for DCmA Inputs 24 | | | | | |
| **DNP/IEC Points (Read/Write Setting)** | | | | | | |
| D968 | DNP/IEC 60870-5-104 Binary Input Points (256 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| DB68 | DNP/IEC 60870-5-104 Analog Input Points (256 items) | 0 to 65535 | --- | 1 | F600 | 0 |
| **Synchrocheck (Read/Write Setting) (4 modules)** | | | | | | |
| DC70 | Synchrocheck 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| DC71 | Synchrocheck 1 V1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| DC72 | Synchrocheck 1 V2 Source | 0 to 5 | --- | 1 | F167 | 1 (SRC 2) |
| DC73 | Synchrocheck 1 Maximum Voltage Difference | 0 to 400000 | V | 1 | F060 | 10000 |
| DC75 | Synchrocheck 1 Maximum Angle Difference | 0 to 100 | degrees | 1 | F001 | 30 |
| DC76 | Synchrocheck 1 Maximum Frequency Difference | 0 to 2 | Hz | 0.01 | F001 | 100 |
| DC77 | Synchrocheck 1 Dead Source Select | 0 to 5 | --- | 1 | F176 | 1 (LV1 and DV2) |
| DC78 | Synchrocheck 1 Dead V1 Maximum Voltage | 0 to 1.25 | pu | 0.01 | F001 | 30 |
| DC79 | Synchrocheck 1 Dead V2 Maximum Voltage | 0 to 1.25 | pu | 0.01 | F001 | 30 |
| DC7A | Synchrocheck 1 Live V1 Minimum Voltage | 0 to 1.25 | pu | 0.01 | F001 | 70 |
| DC7B | Synchrocheck 1 Live V2 Minimum Voltage | 0 to 1.25 | pu | 0.01 | F001 | 70 |
| DC7C | Synchrocheck 1 Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| DC7D | Synchrocheck 1 Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| DC7E | Synchrocheck 1 Block | 0 to 4294967295 | --- | 1 | F300 | 0 |
| DC80 | Synchrocheck 1 Frequency Hysteresis | 0 to 0.1 | Hz | 0.01 | F001 | 6 |
| DC81 | ...Repeated for Synchrocheck 2 | | | | | |
| DC92 | ...Repeated for Synchrocheck 3 | | | | | |
| DCA3 | ...Repeated for Synchrocheck 4 | | | | | |
| **Phasor Measurement Unit Basic Configuration (Read/Write Setting)** | | | | | | |
| DCB4 | PMU 1 Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| DCB5 | PMU 1 LDInst | --- | --- | --- | F214 | "PMUx" |
| DCD6 | PMU 1 IDCode | 1 to 65534 | --- | 1 | F001 | 1 |
| DCD7 | PMU 1 STN | --- | --- | --- | F203 | "GE-UR-PMU" |
| DCDF | PMU 1 Source | 0 to 5 | --- | 1 | F167 | 0 (SRC 1) |
| DCE0 | PMU 1 Class | 0 to 2 | --- | 1 | F549 | 1 (M-CLASS) |
| DCE1 | PMU 1 Format | 0 to 1 | --- | 1 | F547 | 0 (Integer) |
| DCE2 | PMU 1 Style | 0 to 1 | --- | 1 | F546 | 0 (Polar) |
| DCE3 | PMU 1 Rate | 0 to 13 | --- | 1 | F544 | 4 (10/sec) |
| DCE4 | PMU 1 PHS-x (14 items) | 0 to 14 | --- | 1 | F543 | 1 (Va) |
| DCF2 | PMU 1 PHS-x Name (14 items) | --- | --- | --- | F203 | "GE-UR-PMU-PHS 1 " |
| DD62 | PMU 1 A-CH-x (16 items) | 0 to 65535 | --- | 1 | F600 | 0 |
| DD72 | PMU 1 A-CH-x (16 items) | --- | --- | --- | F203 | "AnalogChannel 1 " |
| DDF2 | PMU 1 D-CH-x (16 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| DE12 | PMU 1 D-CH-x Name (16 items) | --- | --- | --- | F203 | "Dig Channel 1 " |
| DE92 | PMU 1 D-CH-x Normal State (16 items) | 0 to 1 | --- | 1 | F108 | 0 (Off) |

### Table B–10: MODBUS MEMORY MAP (Sheet 61 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| DEA2 | Reserved (16 items) | 0 to 1 | --- | 1 | F001 | 0 |
| **Phasor Measurement Unit Aggregator (Read/Write Setting)** | | | | | | |
| E8A8 | PMU Aggregator 1 Name | --- | --- | 1 | F209 | "MSVID 1 " |
| E8C9 | Aggregator 1 IDcode | 1 to 65534 | --- | 1 | F001 | 1 |
| E8CA | Aggregator 1 Protocol | 0 to 2 | --- | 1 | F548 | 0 (NONE) |
| E8CB | Aggregator 1 TCP Port | 0 to 65534 | --- | 1 | F001 | 4712 |
| E8CC | Aggregator 1 UDP Port | 0 to 65534 | --- | 1 | F001 | 4713 |
| E8CD | PMU Aggregator 1 90-5 UDP Port | 0 to 65534 | --- | 1 | F001 | 102 |
| E8CE | PMU Aggregator 1 PDC Network Control | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| E8CF | Aggregator 1 Include PMU1 | 0 to 1 | --- | 1 | F126 | 0 (No) |
| E8D0 | Aggregator 1 Include PMU2 | 0 to 1 | --- | 1 | F126 | 0 (No) |
| E8D1 | Aggregator 1 Include PMU3 | 0 to 1 | --- | 1 | F126 | 0 (No) |
| E8D2 | Aggregator 1 Include PMU4 | 0 to 1 | --- | 1 | F126 | 0 (No) |
| E8D3 | Aggregator 1 Include PMU5 | 0 to 1 | --- | 1 | F126 | 0 (No) |
| E8D4 | Aggregator 1 Include PMU6 | 0 to 1 | --- | 1 | F126 | 0 (No) |
| E8D5 | PMU Aggregator 1 ASDUS | 1 to 4 | --- | 1 | F001 | 1 |
| E8D6 | PMU Aggregator 1 Port | 1 to 3 | --- | 1 | F001 | 1 |
| E8D7 | Reserved (3 items) | 0 to 1 | --- | 1 | F001 | 0 |
| **Phasor Measurement Unit Aggregator Control Block (Read/Write Setting)** | | | | | | |
| E9C8 | PMU Aggregator 1 Control Block SvEna | 0 to 4294967295 | --- | 1 | F300 | 0 |
| E9CA | PMU Aggregator 1 Control Block Client Control | 0 to 4294967295 | --- | 1 | F300 | 0 |
| E9CC | PMU Aggregator 1 CB SvEna Default | 0 to 4294967295 | --- | 1 | F300 | 0 |
| E9CE | PMU Aggregator 1 Control Block ConfRev | 1 to 4294967295 | --- | 1 | F003 | 1 |
| E9D0 | PMU Aggregator 1 Control Block Priority | 0 to 7 | --- | 1 | F001 | 4 |
| E9D1 | PMU Aggregator 1 Control Block IPClass | 0 to 1 | --- | 1 | F563 | 1 (Expedited Forwarding) |
| E9D2 | PMU Aggregator 1 Control Block VID | 0 to 4095 | --- | 1 | F001 | 0 |
| E9D3 | PMU Aggregator 1 Control Block APPID | 0 to 16383 | --- | 1 | F001 | 0 |
| E9D4 | PMU Aggregator 1 Control Block IP Address | 0 to 4294967295 | --- | 1 | F003 | 0 |
| E9D6 | PMU Aggregator 1 Control Block Security | 0 to 2 | --- | 1 | F001 | 0 |
| **Phasor Measurement Unit Recording Command (Read/Write Command)** | | | | | | |
| EA22 | PMU 1 Recording Clear Command | 0 to 1 | --- | 1 | F126 | 0 (No) |
| EA23 | PMU 1 Recording Force Trigger | 0 to 1 | --- | 1 | F126 | 0 (No) |
| **Phasor Measurement Unit Recording (Read/Write Setting)** | | | | | | |
| EA2E | PMU 1 Record Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| EA2F | PMU 1 No of Timed Records | 2 to 128 | --- | 1 | F001 | 10 |
| EA30 | PMU 1 Trigger Mode | 0 to 1 | --- | 1 | F542 | 0 (Auto Overwrite) |
| EA31 | .PMU 1 Timed Trigger Position | 1 to 50 | % | 1 | F001 | 10 |
| **Phasor Measurement Unit Recording Ex (Read/Write Setting)** | | | | | | |
| **Phasor Measurement Unit Triggering (Read/Write Setting)** | | | | | | |
| EA4A | PMU 1 User Trigger | 0 to 4294967295 | --- | 1 | F300 | 0 |
| **Phasor Measurement Unit Voltage Trigger (Read/Write Setting)** | | | | | | |
| EA56 | PMU 1 Volt Trigger Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| EA57 | PMU 1 Voltage Trigger Low Volt | 0.25 to 1.25 | pu | 0.001 | F001 | 800 |
| EA58 | PMU 1 Voltage Trigger High Volt | 0.75 to 1.75 | pu | 0.001 | F001 | 1200 |
| EA59 | PMU 1 Voltage Trigger Pkp Time | 0 to 600 | s | 0.01 | F001 | 10 |
| EA5A | PMU 1 Voltage Trigger Dpo Time | 0 to 600 | s | 0.01 | F001 | 100 |
| EA5B | PMU 1 Voltage Trigger Block (3 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| EA61 | PMU 1 Voltage Trigger Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| EA62 | PMU 1 Voltage Trigger Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Phasor Measurement Unit Current Trigger (Read/Write Setting** | | | | | | |
| EAA4 | PMU 1 Current Trigger Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| EAA5 | PMU 1 Current Trigger Pickup | 0.1 to 30 | pu | 0.001 | F001 | 1800 |
| EAA6 | PMU 1 Current Trigger Pkp Time | 0 to 600 | s | 0.01 | F001 | 10 |

### Table B–10: MODBUS MEMORY MAP (Sheet 62 of 63)

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| EAA7 | PMU 1 Current Trigger Dpo Time | 0 to 600 | s | 0.01 | F001 | 100 |
| EAA8 | PMU 1 Current Trigger Block (3 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| EAAE | PMU 1 Current Trigger Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| EAAF | PMU 1 Current Trigger Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Phasor Measurement Unit Frequency Trigger (Read/Write Setting)** | | | | | | |
| EAEC | PMU 1 Frequency Trigger Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| EAED | PMU 1 Frequency Trigger Low Frequency | 20 to 70 | Hz | 0.01 | F001 | 4900 |
| EAEE | PMU 1 Frequency Trigger High Frequency | 20 to 70 | Hz | 0.01 | F001 | 6100 |
| EAEF | PMU 1 Frequency Trigger Pickup Time | 0 to 600 | s | 0.01 | F001 | 10 |
| EAF0 | PMU 1 Frequency Trigger Dropout Time | 0 to 600 | s | 0.01 | F001 | 100 |
| EAF1 | PMU 1 Frequency Trigger Block (3 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| EAF7 | PMU 1 Frequency Trigger Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| EAF8 | PMU 1 Frequency Trigger Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Phasor Measurement Unit df/dt Trigger (Read/Write Setting)** | | | | | | |
| EB3A | PMU 1 df/dt Trigger Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| EB3B | PMU 1 df/dt Trigger Raise | 0.1 to 15 | Hz/s | 0.01 | F001 | 25 |
| EB3C | PMU 1 df/dt Trigger Fall | 0.1 to 15 | Hz/s | 0.01 | F001 | 25 |
| EB3D | PMU 1 df/dt Trigger Pkp Time | 0 to 600 | s | 0.01 | F001 | 10 |
| EB3E | PMU 1 df/dt Trigger Dpo Time | 0 to 600 | s | 0.01 | F001 | 100 |
| EB3F | PMU 1 df/dt Trigger Block (3 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| EB45 | PMU 1 df/dt Trigger Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| EB46 | PMU 1 df/dt Trigger Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Phasor Measurement Unit Power Trigger (Read/Write Setting)** | | | | | | |
| EB88 | PMU 1 Power Trigger Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| EB89 | PMU 1 Power Trigger Active | 0.25 to 3 | pu | 0.001 | F001 | 1250 |
| EB8A | PMU 1 Power Trigger Reactive | 0.25 to 3 | pu | 0.001 | F001 | 1250 |
| EB8B | PMU 1 Power Trigger Apparent | 0.25 to 3 | pu | 0.001 | F001 | 1250 |
| EB8C | PMU 1 Power Trigger Pkp Time | 0 to 600 | s | 0.01 | F001 | 10 |
| EB8D | PMU 1 Power Trigger Dpo Time | 0 to 600 | s | 0.01 | F001 | 100 |
| EB8E | PMU 1 Power Trigger Block (3 items) | 0 to 4294967295 | --- | 1 | F300 | 0 |
| EB94 | PMU 1 Power Trigger Target | 0 to 2 | --- | 1 | F109 | 0 (Self-reset) |
| EB95 | PMU 1 Power Trigger Events | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| **Phasor Measurement Unit Calibration (Read/Write Setting)** | | | | | | |
| EBDC | PMU 1 Va Calibration Angle | -5 to 5 | ° | 0.05 | F002 | 0 |
| EBDD | PMU 1 Va Calibration Magnitude | 95 to 105 | % | 0.1 | F002 | 1000 |
| EBDE | PMU 1 Vb Calibration Angle | -5 to 5 | ° | 0.05 | F002 | 0 |
| EBDF | PMU 1 Vb Calibration Magnitude | 95 to 105 | % | 0.1 | F002 | 1000 |
| EBE0 | PMU 1 Vc Calibration Angle | -5 to 5 | ° | 0.05 | F002 | 0 |
| EBE1 | PMU 1 Vc Calibration Magnitude | 95 to 105 | % | 0.1 | F002 | 1000 |
| EBE2 | PMU 1 Vx Calibration Angle | -5 to 5 | ° | 0.05 | F002 | 0 |
| EBE3 | PMU 1 Vx Calibration Magnitude | 95 to 105 | % | 0.1 | F002 | 1000 |
| EBE4 | PMU 1 Ia Calibration Angle | -5 to 5 | ° | 0.05 | F002 | 0 |
| EBE5 | PMU 1 Ia Calibration Magnitude | 95 to 105 | % | 0.1 | F002 | 1000 |
| EBE6 | PMU 1 Ib Calibration Angle | -5 to 5 | ° | 0.05 | F002 | 0 |
| EBE7 | PMU 1 Ib Calibration Magnitude | 95 to 105 | % | 0.1 | F002 | 1000 |
| EBE8 | PMU 1 Ic Calibration Angle | -5 to 5 | ° | 0.05 | F002 | 0 |
| EBE9 | PMU 1 Ic Calibration Magnitude | 95 to 105 | % | 0.1 | F002 | 1000 |
| EBEA | PMU 1 Ig Calibration Angle | -5 to 5 | ° | 0.05 | F002 | 0 |
| EBEB | PMU 1 Ig Calibration Magnitude | 95 to 105 | % | 0.1 | F002 | 1000 |
| EBEC | PMU 1 Sequence Voltage Shift Angle | -180 to 180 | ° | 30 | F002 | 0 |
| EBED | PMU 1 Sequence Current Shift Angle | -180 to 180 | ° | 30 | F002 | 0 |
| **Phasor Measurement Unit Network Reporting Configuration (Read/Write Setting)** | | | | | | |
| EC48 | PMU Network Reporting Function | 0 to 1 | --- | 1 | F102 | 0 (Disabled) |
| EC49 | PMU Network Reporting ID Code | 1 to 65534 | --- | 1 | F001 | 1 |

**Table B–10: MODBUS MEMORY MAP (Sheet 63 of 63)**

| ADDR | REGISTER NAME | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|---|---|---|---|---|---|---|
| EC4A | PMU TCP Port Number | 1 to 65535 | --- | 1 | F001 | 4712 |
| EC4B | PMU UDP Port Number 1 | 1 to 65535 | --- | 1 | F001 | 4713 |
| EC4C | PMU UDP Port Number 2 | 1 to 65535 | --- | 1 | F001 | 4714 |
| **Settings File Template (Read/Write Setting)** | | | | | | |
| ED00 | FlexLogic Displays Active | 0 to 1 | --- | 1 | F102 | 1 (Enabled) |
| ED01 | Template Access | --- | --- | --- | F205 | (none) |
| **Setting File Template (Read Only Non-Volatile)** | | | | | | |
| ED07 | Last Settings Change Date | 0 to 4294967295 | --- | 1 | F050 | 0 |
| **Settings File Template (Read/Write Setting)** | | | | | | |
| ED09 | Template Bitmask (750 items) | 0 to 65535 | --- | 1 | F001 | 0 |
| **Phasor Measurement Unit Records (Read Only)** | | | | | | |
| EFFF | PMU Recording Number of Triggers | 0 to 65535 | --- | 1 | F001 | 0 |

**F001**
**UR_UINT16 UNSIGNED 16 BIT INTEGER**

**F002**
**UR_SINT16 SIGNED 16 BIT INTEGER**

**F003**
**UR_UINT32 UNSIGNED 32 BIT INTEGER (2 registers)**

High order word is stored in the first register.
Low order word is stored in the second register.

**F004**
**UR_SINT32 SIGNED 32 BIT INTEGER (2 registers)**

High order word is stored in the first register.
Low order word is stored in the second register.

**F011**
**UR_UINT16 FLEXCURVE DATA (120 points)**

A FlexCurve is an array of 120 consecutive data points (x, y) that are interpolated to generate a smooth curve. The y-axis is the user-defined trip or operation time setting; the x-axis is the pickup ratio and is pre-defined. See format F119 for a listing of the pickup ratios; the enumeration value for the pickup ratio indicates the off-set into the FlexCurve base address where the corresponding time value is stored.

**F013**
**POWER_FACTOR (SIGNED 16 BIT INTEGER)**

Positive values indicate lagging power factor; negative values indicate leading.

**F050**
**UR_UINT32 TIME and DATE (UNSIGNED 32 BIT INTEGER)**

Gives the current time in seconds elapsed since 00:00:00 January 1, 1970.

**F051**
**UR_UINT32 DATE in SR format (alternate format for F050)**

First 16 bits are Month/Day (MM/DD/xxxx).
Month: 1=January, 2=February,...,12=December.
Day: 1 to 31 in steps of 1.
Last 16 bits are Year (xx/xx/YYYY): 1970 to 2106 in steps of 1.

**F052**
**UR_UINT32 TIME in SR format (alternate format for F050)**

First 16 bits are Hours/Minutes (HH:MM:xx.xxx).
Hours: 0=12am, 1=1am,...,12=12pm,...23=11pm.
Minutes: 0 to 59 in steps of 1.
Last 16 bits are Seconds (xx:xx:.SS.SSS): (0=00.000s, 1=00.001,...,59999=59.999s).

**F060**
**FLOATING_POINT IEEE FLOATING POINT (32 bits)**

**F072**
**HEX6 6 BYTES - 12 ASCII DIGITS**

**F073**
**HEX8 8 BYTES - 16 ASCII DIGITS**

**F074**
**HEX20 20 BYTES - 40 ASCII DIGITS**

**F083**
**ENUMERATION: SELECTOR MODES**

0 = Time-Out, 1 = Acknowledge

**F084**
**ENUMERATION: SELECTOR POWER UP**

0 = Restore, 1 = Synchronize, 2 = Sync/Restore

**F086**
**ENUMERATION: CONTACT INPUT DEFAULT STATE**

0 = Off, 1 = On, 2= Latest/Off, 3 = Latest/On

**F090**
**ENUMERATION: LATCHING OUTPUT TYPE**

0 = Operate-dominant, 1 = Reset-dominant

**F100**
**ENUMERATION: VT CONNECTION TYPE**

0 = Wye, 1 = Delta

**F101**
**ENUMERATION: MESSAGE DISPLAY INTENSITY**

0 = 25%, 1 = 50%, 2 = 75%, 3 = 100%

**F102**
**ENUMERATION: DISABLED/ENABLED**

0 = Disabled, 1 = Enabled

**F103**
**ENUMERATION: CURVE SHAPES**

| Bitmask | Curve shape |
|---|---|
| 0 | IEEE Mod Inv |
| 1 | IEEE Very Inv |
| 2 | IEEE Ext Inv |
| 3 | IEC Curve A |
| 4 | IEC Curve B |
| 5 | IEC Curve C |
| 6 | IEC Short Inv |
| 7 | IAC Ext Inv |
| 8 | IAC Very Inv |

| Bitmask | Curve shape |
|---|---|
| 9 | IAC Inverse |
| 10 | IAC Short Inv |
| 11 | I2t |
| 12 | Definite Time |
| 13 | FlexCurve A |
| 14 | FlexCurve B |
| 15 | FlexCurve C |
| 16 | FlexCurve D |

**F104**
**ENUMERATION: RESET TYPE**

0 = Instantaneous, 1 = Timed

**F106**
**ENUMERATION: PHASE ROTATION**

0 = ABC, 1 = ACB

**F108**
**ENUMERATION: OFF/ON**

0 = Off, 1 = On

**F109**
**ENUMERATION: CONTACT OUTPUT OPERATION**

0 = Self-reset, 1 = Latched, 2 = Disabled

**F111**
**ENUMERATION: UNDERVOLTAGE CURVE SHAPES**

0 = Definite Time, 1 = Inverse Time

**F112**
**ENUMERATION: RS485 BAUD RATES**

| Bitmask | Value |
|---|---|
| 0 | 300 |
| 1 | 1200 |
| 2 | 2400 |
| 3 | 4800 |

| Bitmask | Value |
|---|---|
| 4 | 9600 |
| 5 | 19200 |
| 6 | 38400 |
| 7 | 57600 |

| Bitmask | Value |
|---|---|
| 8 | 115200 |
| 9 | 14400 |
| 10 | 28800 |
| 11 | 33600 |

**F113**
**ENUMERATION: PARITY**

0 = None, 1 = Odd, 2 = Even

**F114**
**ENUMERATION: IRIG-B SIGNAL TYPE**

0 = None, 1 = DC Shift, 2 = Amplitude Modulated

**F118**
**ENUMERATION: OSCILLOGRAPHY MODE**

0 = Automatic Overwrite, 1 = Protected

**F122**
**ENUMERATION: ELEMENT INPUT SIGNAL TYPE**

0 = Phasor, 1 = RMS

**F123**
**ENUMERATION: CT SECONDARY**

0 = 1 A, 1 = 5 A

**F124**
**ENUMERATION: LIST OF ELEMENTS**

| Bitmask | Element |
|---|---|
| 0 | Phase Instantaneous Overcurrent 1 |
| 1 | Phase Instantaneous Overcurrent 2 |
| 2 | Phase Instantaneous Overcurrent 3 |
| 3 | Phase Instantaneous Overcurrent 4 |
| 16 | Phase Time Overcurrent 1 |
| 17 | Phase Time Overcurrent 2 |
| 24 | Phase Directional Overcurrent 1 |
| 25 | Phase Directional Overcurrent 2 |
| 32 | Neutral Instantaneous Overcurrent 1 |
| 33 | Neutral Instantaneous Overcurrent 2 |
| 34 | Neutral Instantaneous Overcurrent 3 |
| 35 | Neutral Instantaneous Overcurrent 4 |
| 48 | Neutral Time Overcurrent 1 |
| 49 | Neutral Time Overcurrent 2 |
| 56 | Neutral Directional Overcurrent 1 |
| 57 | Neutral Directional Overcurrent 2 |
| 64 | Ground Instantaneous Overcurrent 1 |
| 65 | Ground Instantaneous Overcurrent 2 |
| 66 | Ground Instantaneous Overcurrent 3 |
| 67 | Ground Instantaneous Overcurrent 4 |
| 80 | Ground Time Overcurrent 1 |
| 81 | Ground Time Overcurrent 2 |
| 96 | Negative Sequence Instantaneous Overcurrent 1 |
| 97 | Negative Sequence Instantaneous Overcurrent 2 |
| 112 | Negative Sequence Time Overcurrent 1 |
| 113 | Negative Sequence Time Overcurrent 2 |
| 120 | Negative Sequence Overvoltage 1 |
| 121 | Negative Sequence Overvoltage 2 |
| 122 | Negative Sequence Overvoltage 3 |
| 140 | Auxiliary Undervoltage 1 |
| 144 | Phase Undervoltage 1 |

| Bitmask | Element |
|---|---|
| 145 | Phase Undervoltage 2 |
| 146 | Phase Undervoltage 3 |
| 148 | Auxiliary Overvoltage 1 |
| 151 | Phase Overvoltage 1 |
| 152 | Phase Overvoltage 2 |
| 153 | Phase Overvoltage 3 |
| 224 | SRC1 VT Fuse Failure |
| 225 | SRC2 VT Fuse Failure |
| 232 | SRC1 50DD (Disturbance Detection) |
| 233 | SRC2 50DD (Disturbance Detection) |
| 240 | 87L Current Differential |
| 241 | 87L Current Differential |
| 244 | 50DD Disturbance Detector |
| 255 | Stub Bus |
| 272 | CT Fail 1 |
| 273 | CT Fail 2 |
| 280 | Breaker Failure 1 |
| 281 | Breaker Failure 2 |
| 288 | Breaker Arcing Current 1 |
| 289 | Breaker Arcing Current 2 |
| 304 | Autoreclose 1 |
| 305 | Autoreclose 2 |
| 311 | Phasor measurement unit one-shot |
| 312 | Synchrocheck 1 |
| 313 | Synchrocheck 2 |
| 314 | Synchrocheck 3 |
| 315 | Synchrocheck 4 |
| 336 | Setting Group |
| 337 | Reset |
| 352 | Underfrequency 1 |
| 353 | Underfrequency 2 |
| 354 | Underfrequency 3 |
| 355 | Underfrequency 4 |
| 356 | Underfrequency 5 |
| 357 | Underfrequency 6 |
| 388 | Selector switch 1 |
| 389 | Selector switch 2 |
| 390 | Control pushbutton 1 |
| 391 | Control pushbutton 2 |
| 392 | Control pushbutton 3 |
| 393 | Control pushbutton 4 |
| 394 | Control pushbutton 5 |
| 395 | Control pushbutton 6 |
| 396 | Control pushbutton 7 |
| 400 | FlexElement 1 |
| 401 | FlexElement 2 |
| 402 | FlexElement 3 |
| 403 | FlexElement 4 |
| 404 | FlexElement 5 |
| 405 | FlexElement 6 |
| 406 | FlexElement 7 |
| 407 | FlexElement 8 |
| 420 | Non-volatile Latch 1 |

| Bitmask | Element |
|---|---|
| 421 | Non-volatile Latch 2 |
| 422 | Non-volatile Latch 3 |
| 423 | Non-volatile Latch 4 |
| 424 | Non-volatile Latch 5 |
| 425 | Non-volatile Latch 6 |
| 426 | Non-volatile Latch 7 |
| 427 | Non-volatile Latch 8 |
| 428 | Non-volatile Latch 9 |
| 429 | Non-volatile Latch 10 |
| 430 | Non-volatile Latch 11 |
| 431 | Non-volatile Latch 12 |
| 432 | Non-volatile Latch 13 |
| 433 | Non-volatile Latch 14 |
| 434 | Non-volatile Latch 15 |
| 435 | Non-volatile Latch 16 |
| 544 | Digital Counter 1 |
| 545 | Digital Counter 2 |
| 546 | Digital Counter 3 |
| 547 | Digital Counter 4 |
| 548 | Digital Counter 5 |
| 549 | Digital Counter 6 |
| 550 | Digital Counter 7 |
| 551 | Digital Counter 8 |
| 692 | Digital Element 1 |
| 693 | Digital Element 2 |
| 694 | Digital Element 3 |
| 695 | Digital Element 4 |
| 696 | Digital Element 5 |
| 697 | Digital Element 6 |
| 698 | Digital Element 7 |
| 699 | Digital Element 8 |
| 700 | Digital Element 9 |
| 701 | Digital Element 10 |
| 702 | Digital Element 11 |
| 703 | Digital Element 12 |
| 704 | Digital Element 13 |
| 705 | Digital Element 14 |
| 706 | Digital Element 15 |
| 707 | Digital Element 16 |
| 708 | Digital Element 17 |
| 709 | Digital Element 18 |
| 710 | Digital Element 19 |
| 711 | Digital Element 20 |
| 712 | Digital Element 21 |
| 713 | Digital Element 22 |
| 714 | Digital Element 23 |
| 715 | Digital Element 24 |
| 716 | Digital Element 25 |
| 717 | Digital Element 26 |
| 718 | Digital Element 27 |
| 719 | Digital Element 28 |
| 720 | Digital Element 29 |
| 721 | Digital Element 30 |

| Bitmask | Element |
|---|---|
| 722 | Digital Element 31 |
| 723 | Digital Element 32 |
| 724 | Digital Element 33 |
| 725 | Digital Element 34 |
| 726 | Digital Element 35 |
| 727 | Digital Element 36 |
| 728 | Digital Element 37 |
| 729 | Digital Element 38 |
| 730 | Digital Element 39 |
| 731 | Digital Element 40 |
| 732 | Digital Element 41 |
| 733 | Digital Element 42 |
| 734 | Digital Element 43 |
| 735 | Digital Element 44 |
| 736 | Digital Element 45 |
| 737 | Digital Element 46 |
| 738 | Digital Element 47 |
| 739 | Digital Element 48 |
| 740 | Phasor Measurement Unit 1 Frequency |
| 746 | Phasor Measurement Unit 1 Voltage |
| 752 | Phasor Measurement Unit 1 Current |
| 758 | Phasor Measurement Unit 1 Power |
| 764 | PMU 1 Rate of Change of Frequency |
| 823 | Phasor Measurement Unit 1 |
| 842 | Trip Bus 1 |
| 843 | Trip Bus 2 |
| 844 | Trip Bus 3 |
| 845 | Trip Bus 4 |
| 846 | Trip Bus 5 |
| 847 | Trip Bus 6 |
| 849 | RTD Input 1 |
| 850 | RTD Input 2 |
| 851 | RTD Input 3 |
| 852 | RTD Input 4 |
| 853 | RTD Input 5 |
| 854 | RTD Input 6 |
| 855 | RTD Input 7 |
| 856 | RTD Input 8 |
| 857 | RTD Input 9 |
| 858 | RTD Input 10 |
| 859 | RTD Input 11 |
| 860 | RTD Input 12 |
| 861 | RTD Input 13 |
| 862 | RTD Input 14 |
| 863 | RTD Input 15 |
| 864 | RTD Input 16 |
| 865 | RTD Input 17 |
| 866 | RTD Input 18 |
| 867 | RTD Input 19 |
| 868 | RTD Input 20 |
| 869 | RTD Input 21 |
| 870 | RTD Input 22 |
| 871 | RTD Input 23 |

| Bitmask | Element |
|---|---|
| 872 | RTD Input 24 |
| 873 | RTD Input 25 |
| 874 | RTD Input 26 |
| 875 | RTD Input 27 |
| 876 | RTD Input 28 |
| 877 | RTD Input 29 |
| 878 | RTD Input 30 |
| 879 | RTD Input 31 |
| 880 | RTD Input 32 |
| 881 | RTD Input 33 |
| 882 | RTD Input 34 |
| 883 | RTD Input 35 |
| 884 | RTD Input 36 |
| 885 | RTD Input 37 |
| 886 | RTD Input 38 |
| 887 | RTD Input 39 |
| 888 | RTD Input 40 |
| 889 | RTD Input 41 |
| 890 | RTD Input 42 |
| 891 | RTD Input 43 |
| 892 | RTD Input 44 |
| 893 | RTD Input 45 |
| 894 | RTD Input 46 |
| 895 | RTD Input 47 |
| 896 | RTD Input 48 |
| 900 | User-Programmable Pushbutton 1 |
| 901 | User-Programmable Pushbutton 2 |
| 902 | User-Programmable Pushbutton 3 |
| 903 | User-Programmable Pushbutton 4 |
| 904 | User-Programmable Pushbutton 5 |
| 905 | User-Programmable Pushbutton 6 |
| 906 | User-Programmable Pushbutton 7 |
| 907 | User-Programmable Pushbutton 8 |
| 908 | User-Programmable Pushbutton 9 |
| 909 | User-Programmable Pushbutton 10 |
| 910 | User-Programmable Pushbutton 11 |
| 911 | User-Programmable Pushbutton 12 |
| 912 | User-Programmable Pushbutton 13 |
| 913 | User-Programmable Pushbutton 14 |
| 914 | User-Programmable Pushbutton 15 |
| 915 | User-Programmable Pushbutton 16 |
| 920 | Disconnect switch 1 |
| 921 | Disconnect switch 2 |
| 922 | Disconnect switch 3 |
| 923 | Disconnect switch 4 |
| 924 | Disconnect switch 5 |
| 925 | Disconnect switch 6 |
| 926 | Disconnect switch 7 |
| 927 | Disconnect switch 8 |
| 968 | Breaker 1 |
| 969 | Breaker 2 |
| 974 | Breaker 1 |
| 975 | Breaker 2 |

| Bitmask | Element |
|---|---|
| 1003 | 87L Diff |
| 1012 | Thermal overload protection 1 |
| 1013 | Thermal overload protection 2 |
| 1014 | Broken conductor detection 1 |
| 1015 | Broken conductor detection 2 |

**F126**
**ENUMERATION: NO/YES CHOICE**

0 = No, 1 = Yes

**F127**
**ENUMERATION: LATCHED OR SELF-RESETTING**

0 = Latched, 1 = Self-Reset

**F128**
**ENUMERATION: CONTACT INPUT THRESHOLD**

0 = 17 V DC, 1 = 33 V DC, 2 = 84 V DC, 3 = 166 V DC

**F129**
**ENUMERATION: FLEXLOGIC TIMER TYPE**

0 = millisecond, 1 = second, 2 = minute

**F131**
**ENUMERATION: FORCED CONTACT OUTPUT STATE**

0 = Disabled, 1 = Energized, 2 = De-energized, 3 = Freeze

**F133**
**ENUMERATION: PROGRAM STATE**

0 = Not Programmed, 1 = Programmed

**F134**
**ENUMERATION: PASS/FAIL**

0 = Fail, 1 = OK, 2 = n/a

**F137**
**ENUMERATION: USER-PROGRAMMABLE PUSHBUTTON FUNCTION**

0 = Disabled, 1 = Self-Reset, 2 = Latched

**F141**
**ENUMERATION: SELF TEST ERRORS**

| Bitmask | Error |
|---|---|
| 0 | Any Self Tests |
| 1 | IRIG-B Failure |
| 2 | Port 1 Offline |
| 3 | Port 2 Offline |
| 4 | Port 3 Offline |
| 5 | Port 4 Offline |
| 6 | Port 5 Offline |
| 7 | Port 6 Offline |
| 8 | RRTD Communications Failure |
| 9 | Voltage Monitor |
| 10 | FlexLogic Error Token |
| 11 | Equipment Mismatch |
| 12 | Process Bus Failure |
| 13 | Unit Not Programmed |
| 14 | System Exception |
| 15 | Latching Output Discrepancy |
| 17 | Maintenance Alert 01 |
| 18 | SNTP Failure |
| 19 | Maintenance Alert |
| 20 | Maintenance Alert |
| 21 | Maintenance Alert |
| 22 | Temperature Monitor |
| 23 | Process Bus Trouble |
| 24 | Brick Trouble |
| 25 | Field RTD Trouble |
| 26 | Field TDR Trouble |
| 27 | Remote Device Offline |
| 28 | Direct Device Offline |
| 29 | Maintenance Alert |
| 30 | Any Minor Error |
| 31 | Any Major Error |
| 33 | Maintenance Alert |
| 64 | Maintenance Alert |
| 65 | IEC 61850 Data Set |
| 66 | Aggregator Error |
| 67 | Unit Not Calibrated |
| 68 | Settings Save Error |
| 69 | SRAM Data Error |
| 70 | Program Memory |
| 71 | Watchdog Error |
| 72 | Low On Memory |
| 73 | Prototype Firmware |
| 74 | Module Failure 01 |
| 75 | Module Failure 02 |
| 76 | Module Failure 03 |
| 77 | Module Failure 04 |
| 78 | Module Failure 05 |
| 79 | Module Failure 06 |
| 80 | Module Failure 07 |
| 81 | Module Failure 08 |
| 82 | Module Failure 09 |
| 83 | Incompatible H/W |
| 84 | Module Failure 10 |
| 85 | Module Failure 11 |
| 86 | Module Failure 12 |
| 87 | High ENET Traffic |
| 89 | Relay Restart |
| 90 | FGM Failure |

| Bitmask | Error |
|---|---|
| 91 | FGM Failure |
| 92 | FGM Failure |
| 93 | FGM Failure |
| 94 | FGM Failure |
| 95 | FGM Error |
| 96 | Maintenance Alert |
| 97 | PHY Monitor |
| 98 | Storage Media Alarm |
| 99 | Wrong Transceiver |
| 100 | Power Supply Warning |

**F143**
**UR_UINT32: 32 BIT ERROR CODE (F141 specifies bit number)**

A bit value of 0 = no error, 1 = error

**F144**
**ENUMERATION: FORCED CONTACT INPUT STATE**

0 = Disabled, 1 = Open, 2 = Closed

**F146**
**ENUMERATION: MISCELLANEOUS EVENT CAUSES**

| Bitmask | Definition |
|---|---|
| 0 | Events Cleared |
| 1 | Oscillography Triggered |
| 2 | Date/time Changed |
| 3 | Default Settings Loaded |
| 4 | Test Mode Forcing On |
| 5 | Test Mode Forcing Off |
| 6 | Power On |
| 7 | Power Off |
| 8 | Relay In Service |
| 9 | Relay Out Of Service |
| 10 | Watchdog Reset |
| 11 | Oscillography Clear |
| 12 | Reboot Command |
| 13 | LED Test Initiated |
| 14 | Flash Programming |
| 15 | Fault Report Trigger |
| 16 | User Programmable Fault Report Trigger |
| 17 | --- |
| 18 | Reload CT/VT module Settings |
| 19 | --- |
| 20 | Ethernet Port 1 Offline |
| 21 | Ethernet Port 2 Offline |
| 22 | Ethernet Port 3 Offline |
| 23 | Ethernet Port 4 Offline |
| 24 | Ethernet Port 5 Offline |
| 25 | Ethernet Port 6 Offline |
| 26 | Test-Blocked Mode |
| 27 | Test Mode Test |
| 28 | Test Mode Disabled |
| 29 | Temperature Warning On |
| 30 | Temperature Warning Off |
| 31 | Unauthorized Access |
| 32 | System Integrity Recovery |
| 33 | System Integrity Recovery 06 |
| 34 | System Integrity Recovery 07 |

**F147**
**ENUMERATION: LINE LENGTH UNITS**

0 = km, 1 = miles

**F148**
**ENUMERATION: FAULT TYPE**

| Bitmask | Fault type |
|---|---|
| 0 | NA |
| 1 | AG |
| 2 | BG |
| 3 | CG |
| 4 | AB |
| 5 | BC |

| Bitmask | Fault type |
|---|---|
| 6 | AC |
| 7 | ABG |
| 8 | BCG |
| 9 | ACG |
| 10 | ABC |
| 11 | ABCG |

**F152**
**ENUMERATION: SETTING GROUP**

0 = Active Group, 1 = Group 1, 2 = Group 2, 3 = Group 3
4 = Group 4, 5 = Group 5, 6 = Group 6

**F155**
**ENUMERATION: REMOTE DEVICE STATE**

0 = Offline, 1 = Online

B

**F156**
**ENUMERATION: REMOTE INPUT BIT PAIRS**

| Bitmask | Value | Bitmask | Value |
|---|---|---|---|
| 0 | None | 35 | UserSt-3 |
| 1 | DNA-1 | 36 | UserSt-4 |
| 2 | DNA-2 | 37 | UserSt-5 |
| 3 | DNA-3 | 38 | UserSt-6 |
| 4 | DNA-4 | 39 | UserSt-7 |
| 5 | DNA-5 | 40 | UserSt-8 |
| 6 | DNA-6 | 41 | UserSt-9 |
| 7 | DNA-7 | 42 | UserSt-10 |
| 8 | DNA-8 | 43 | UserSt-11 |
| 9 | DNA-9 | 44 | UserSt-12 |
| 10 | DNA-10 | 45 | UserSt-13 |
| 11 | DNA-11 | 46 | UserSt-14 |
| 12 | DNA-12 | 47 | UserSt-15 |
| 13 | DNA-13 | 48 | UserSt-16 |
| 14 | DNA-14 | 49 | UserSt-17 |
| 15 | DNA-15 | 50 | UserSt-18 |
| 16 | DNA-16 | 51 | UserSt-19 |
| 17 | DNA-17 | 52 | UserSt-20 |
| 18 | DNA-18 | 53 | UserSt-21 |
| 19 | DNA-19 | 54 | UserSt-22 |
| 20 | DNA-20 | 55 | UserSt-23 |
| 21 | DNA-21 | 56 | UserSt-24 |
| 22 | DNA-22 | 57 | UserSt-25 |
| 23 | DNA-23 | 58 | UserSt-26 |
| 24 | DNA-24 | 59 | UserSt-27 |
| 25 | DNA-25 | 60 | UserSt-28 |
| 26 | DNA-26 | 61 | UserSt-29 |
| 27 | DNA-27 | 62 | UserSt-30 |
| 28 | DNA-28 | 63 | UserSt-31 |
| 29 | DNA-29 | 64 | UserSt-32 |
| 30 | DNA-30 | 65 | Dataset Item 1 |
| 31 | DNA-31 | 66 | Dataset Item 2 |
| 32 | DNA-32 | 67 | Dataset Item 3 |
| 33 | UserSt-1 | ↓ | ↓ |
| 34 | UserSt-2 | 96 | Dataset Item 32 |

**F157**
**ENUMERATION: BREAKER MODE**

0 = 3-Pole, 1 = 1-Pole

**F166**
**ENUMERATION: AUXILIARY VT CONNECTION TYPE**

0 = Vn, 1 = Vag, 2 = Vbg, 3 = Vcg, 4 = Vab, 5 = Vbc, 6 = Vca

**F167**
**ENUMERATION: SIGNAL SOURCE**

0 = SRC 1, 1 = SRC 2, 2 = SRC 3, 3 = SRC 4,
4 = SRC 5, 5 = SRC 6

**F172**
**ENUMERATION: SLOT LETTERS**

| Bitmask | Slot | Bitmask | Slot | Bitmask | Slot | Bitmask | Slot |
|---|---|---|---|---|---|---|---|
| 0 | F | 4 | K | 8 | P | 12 | U |
| 1 | G | 5 | L | 9 | R | 13 | V |
| 2 | H | 6 | M | 10 | S | 14 | W |
| 3 | J | 7 | N | 11 | T | 15 | X |

**F173**
**ENUMERATION: DCmA INPUT/OUTPUT RANGE**

| Bitmask | DCmA input/output range |
|---|---|
| 0 | 0 to –1 mA |
| 1 | 0 to 1 mA |
| 2 | –1 to 1 mA |
| 3 | 0 to 5 mA |
| 4 | 0 to 10 mA |
| 5 | 0 to 20 mA |
| 6 | 4 to 20 mA |

**F174**
**ENUMERATION: TRANSDUCER RTD INPUT TYPE**

0 = 100 Ohm Platinum, 1 = 120 Ohm Nickel,
2 = 100 Ohm Nickel, 3 = 10 Ohm Copper

**F176**
**ENUMERATION: SYNCHROCHECK DEAD SOURCE SELECT**

| Bitmask | Synchrocheck dead source |
|---|---|
| 0 | None |
| 1 | LV1 and DV2 |
| 2 | DV1 and LV2 |
| 3 | DV1 or DV2 |
| 4 | DV1 Xor DV2 |
| 5 | DV1 and DV2 |

**F177**
**ENUMERATION: COMMUNICATION PORT**

0 = None, 1 = COM1-RS485 (not applicable to UR firmware 7.00),
2 = COM2-RS485, 3 = Front Panel-RS232, 4 = Network - TCP,
5 = Network - UDP

**F183**
**ENUMERATION: AC INPUT WAVEFORMS**

| Bitmask | Definition |
|---|---|
| 0 | Off |
| 1 | 8 samples/cycle |
| 2 | 16 samples/cycle |
| 3 | 32 samples/cycle |
| 4 | 64 samples/cycle |

**F184**
**ENUMERATION: IEC GOOSE DATASET**

| Value | IEC 61850 dataset |
|---|---|
| 0 | Fixed |
| 1 | GooseIn 1 |
| 2 | GooseIn 2 |
| 3 | GooseIn 3 |
| 4 | GooseIn 4 |
| 5 | GooseIn 5 |
| 6 | GooseIn 6 |
| 7 | GooseIn 7 |
| 8 | GooseIn 8 |
| 9 | GooseIn 9 |
| 10 | GooseIn 10 |
| 11 | GooseIn 11 |
| 12 | GooseIn 12 |
| 13 | GooseIn 13 |
| 14 | GooseIn 14 |
| 15 | GooseIn 15 |
| 16 | GooseIn 16 |

**F186**
**ENUMERATION: MEASUREMENT MODE**

0 = Phase to Ground, 1 = Phase to Phase

**F190**
**ENUMERATION: SIMULATED KEYPRESS**

| Bitmask | Keypress | Bitmask | Keypress |
|---|---|---|---|
| 0 | No key --- use between real keys | 23 | Reset |
| 1 | 1 | 24 | User 1 |
| 2 | 2 | 25 | User 2 |
| 3 | 3 | 26 | User 3 |
| 4 | 4 | 27 | User-programmable key 1 |
| 5 | 5 | 28 | User-programmable key 2 |
| 6 | 6 | 29 | User-programmable key 3 |
| 7 | 7 | 30 | User-programmable key 4 |
| 8 | 8 | 31 | User-programmable key 5 |
| 9 | 9 | 32 | User-programmable key 6 |
| 10 | 0 | 33 | User-programmable key 7 |
| 11 | Decimal Point | 34 | User-programmable key 8 |
| 12 | Plus/Minus | 35 | User-programmable key 9 |
| 13 | Value Up | 36 | User-programmable key 10 |
| 14 | Value Down | 37 | User-programmable key 11 |
| 15 | Message Up | 38 | User-programmable key 12 |
| 16 | Message Down | 39 | User 4 (control pushbutton) |
| 17 | Message Left | 40 | User 5 (control pushbutton) |
| 18 | Message Right | 41 | User 6 (control pushbutton) |
| 19 | Menu | 42 | User 7 (control pushbutton) |
| 20 | Help | 43 | User-programmable key 13 |
| 21 | Escape | 44 | User-programmable key 14 |
| 22 | Enter | 45 | User-programmable key 15 |
| | | 46 | User-programmable key 16 |

**F192**
**ENUMERATION: ETHERNET OPERATION MODE**

0 = Half-Duplex, 1 = Full-Duplex

**F194**
**ENUMERATION: DNP SCALE**

0 = 0.01, 1 = 0.1, 2 = 1, 3 = 10, 4 = 100, 5 = 1000, 6 = 10000, 7 = 100000, 8 = 0.001

**F196**
**ENUMERATION: NEUTRAL DIRECTIONAL OVERCURRENT OPERATING CURRENT**

0 = Calculated 3I0, 1 = Measured IG

**F200**
**TEXT40: 40-CHARACTER ASCII TEXT**

20 registers, 16 Bits: 1st Char MSB, 2nd Char LSB

**F202**
**TEXT20: 20-CHARACTER ASCII TEXT**

10 registers, 16 Bits: 1st Char MSB, 2nd Char LSB

B

**F203**
**TEXT16: 16-CHARACTER ASCII TEXT**

**F204**
**TEXT80: 80-CHARACTER ASCII TEXT**

**F205**
**TEXT12: 12-CHARACTER ASCII TEXT**

**F206**
**TEXT6: 6-CHARACTER ASCII TEXT**

**F207**
**TEXT4: 4-CHARACTER ASCII TEXT**

**F209**
**TEXT65: 65-CHARACTER ASCII TEXT**

**F213**
**TEXT32: 32-CHARACTER ASCII TEXT**

**F214**
**TEXT64: 64-CHARACTER ASCII TEXTF220**
**ENUMERATION: PUSHBUTTON MESSAGE PRIORITY**

| Value | Priority |
|---|---|
| 0 | Disabled |
| 1 | Normal |
| 2 | High Priority |

**F223**
**ENUMERATION: DIAGNOSTIC TEST**

0 = NO TEST, 1 = RUN TEST, 2 = END TEST

**F230**
**ENUMERATION: DIRECTIONAL POLARIZING**

0 = Voltage, 1 = Current, 2 = Dual, 3 = Dual-V, 4 = Dual-I

**F231**
**ENUMERATION: POLARIZING VOLTAGE**

0 = Calculated V0, 1 = Measured VX**F232**
**ENUMERATION: CONFIGURABLE GOOSE Tx DATASET ITEMS**

| Value | IEC 61850 Tx dataset item |
|---|---|
| 0 | None |
| 1 | GGIO1.ST.Ind1.q |
| 2 | GGIO1.ST.Ind1.stVal |
| 3 | GGIO1.ST.Ind2.q |
| 4 | GGIO1.ST.Ind2.stVal |
| ↓ | ↓ |
| 255 | GGIO1.ST.Ind128.q |
| 256 | GGIO1.ST.Ind128.stVal |
| 257 | MMXU1.MX.TotW.mag.f |
| 258 | MMXU1.MX.TotVAr.mag.f |
| 259 | MMXU1.MX.TotVA.mag.f |
| 260 | MMXU1.MX.TotPF.mag.f |
| 261 | MMXU1.MX.Hz.mag.f |
| 262 | MMXU1.MX.PPV.phsAB.cVal.mag.f |
| 263 | MMXU1.MX.PPV.phsAB.cVal.ang.f |
| 264 | MMXU1.MX.PPV.phsBC.cVal.mag.f |
| 265 | MMXU1.MX.PPV.phsBC.cVal.ang.f |
| 266 | MMXU1.MX.PPV.phsCA.cVal.mag.f |
| 267 | MMXU1.MX.PPV.phsCA.cVal.ang.f |
| 268 | MMXU1.MX.PhV.phsA.cVal.mag.f |
| 269 | MMXU1.MX.PhV.phsA.cVal.ang.f |
| 270 | MMXU1.MX.PhV.phsB.cVal.mag.f |
| 271 | MMXU1.MX.PhV.phsB.cVal.ang.f |
| 272 | MMXU1.MX.PhV.phsC.cVal.mag.f |
| 273 | MMXU1.MX.PhV.phsC.cVal.ang.f |
| 274 | MMXU1.MX.A.phsA.cVal.mag.f |
| 275 | MMXU1.MX.A.phsA.cVal.ang.f |
| 276 | MMXU1.MX.A.phsB.cVal.mag.f |
| 277 | MMXU1.MX.A.phsB.cVal.ang.f |
| 278 | MMXU1.MX.A.phsC.cVal.mag.f |
| 279 | MMXU1.MX.A.phsC.cVal.ang.f |
| 280 | MMXU1.MX.A.neut.cVal.mag.f |
| 281 | MMXU1.MX.A.neut.cVal.ang.f |
| 282 | MMXU1.MX.W.phsA.cVal.mag.f |
| 283 | MMXU1.MX.W.phsB.cVal.mag.f |
| 284 | MMXU1.MX.W.phsC.cVal.mag.f |
| 285 | MMXU1.MX.VAr.phsA.cVal.mag.f |
| 286 | MMXU1.MX.VAr.phsB.cVal.mag.f |
| 287 | MMXU1.MX.VAr.phsC.cVal.mag.f |
| 288 | MMXU1.MX.VA.phsA.cVal.mag.f |
| 289 | MMXU1.MX.VA.phsB.cVal.mag.f |
| 290 | MMXU1.MX.VA.phsC.cVal.mag.f |
| 291 | MMXU1.MX.PF.phsA.cVal.mag.f |
| 292 | MMXU1.MX.PF.phsB.cVal.mag.f |
| 293 | MMXU1.MX.PF.phsC.cVal.mag.f |
| 294 | MMXU2.MX.TotW.mag.f |
| 295 | MMXU2.MX.TotVAr.mag.f |
| 296 | MMXU2.MX.TotVA.mag.f |
| 297 | MMXU2.MX.TotPF.mag.f |
| 298 | MMXU2.MX.Hz.mag.f |
| 299 | MMXU2.MX.PPV.phsAB.cVal.mag.f |
| 300 | MMXU2.MX.PPV.phsAB.cVal.ang.f |
| 301 | MMXU2.MX.PPV.phsBC.cVal.mag.f |
| 302 | MMXU2.MX.PPV.phsBC.cVal.ang.f |
| 303 | MMXU2.MX.PPV.phsCA.cVal.mag.f |
| 304 | MMXU2.MX.PPV.phsCA.cVal.ang.f |
| 305 | MMXU2.MX.PhV.phsA.cVal.mag.f |

| Value | IEC 61850 Tx dataset item |
|---|---|
| 306 | MMXU2.MX.PhV.phsA.cVal.ang.f |
| 307 | MMXU2.MX.PhV.phsB.cVal.mag.f |
| 308 | MMXU2.MX.PhV.phsB.cVal.ang.f |
| 309 | MMXU2.MX.PhV.phsC.cVal.mag.f |
| 310 | MMXU2.MX.PhV.phsC.cVal.ang.f |
| 311 | MMXU2.MX.A.phsA.cVal.mag.f |
| 312 | MMXU2.MX.A.phsA.cVal.ang.f |
| 313 | MMXU2.MX.A.phsB.cVal.mag.f |
| 314 | MMXU2.MX.A.phsB.cVal.ang.f |
| 315 | MMXU2.MX.A.phsC.cVal.mag.f |
| 316 | MMXU2.MX.A.phsC.cVal.ang.f |
| 317 | MMXU2.MX.A.neut.cVal.mag.f |
| 318 | MMXU2.MX.A.neut.cVal.ang.f |
| 319 | MMXU2.MX.W.phsA.cVal.mag.f |
| 320 | MMXU2.MX.W.phsB.cVal.mag.f |
| 321 | MMXU2.MX.W.phsC.cVal.mag.f |
| 322 | MMXU2.MX.VAr.phsA.cVal.mag.f |
| 323 | MMXU2.MX.VAr.phsB.cVal.mag.f |
| 324 | MMXU2.MX.VAr.phsC.cVal.mag.f |
| 325 | MMXU2.MX.VA.phsA.cVal.mag.f |
| 326 | MMXU2.MX.VA.phsB.cVal.mag.f |
| 327 | MMXU2.MX.VA.phsC.cVal.mag.f |
| 328 | MMXU2.MX.PF.phsA.cVal.mag.f |
| 329 | MMXU2.MX.PF.phsB.cVal.mag.f |
| 330 | MMXU2.MX.PF.phsC.cVal.mag.f |
| 331 | MMXU3.MX.TotW.mag.f |
| 332 | MMXU3.MX.TotVAr.mag.f |
| 333 | MMXU3.MX.TotVA.mag.f |
| 334 | MMXU3.MX.TotPF.mag.f |
| 335 | MMXU3.MX.Hz.mag.f |
| 336 | MMXU3.MX.PPV.phsAB.cVal.mag.f |
| 337 | MMXU3.MX.PPV.phsAB.cVal.ang.f |
| 338 | MMXU3.MX.PPV.phsBC.cVal.mag.f |
| 339 | MMXU3.MX.PPV.phsBC.cVal.ang.f |
| 340 | MMXU3.MX.PPV.phsCA.cVal.mag.f |
| 341 | MMXU3.MX.PPV.phsCA.cVal.ang.f |
| 342 | MMXU3.MX.PhV.phsA.cVal.mag.f |
| 343 | MMXU3.MX.PhV.phsA.cVal.ang.f |
| 344 | MMXU3.MX.PhV.phsB.cVal.mag.f |
| 345 | MMXU3.MX.PhV.phsB.cVal.ang.f |
| 346 | MMXU3.MX.PhV.phsC.cVal.mag.f |
| 347 | MMXU3.MX.PhV.phsC.cVal.ang.f |
| 348 | MMXU3.MX.A.phsA.cVal.mag.f |
| 349 | MMXU3.MX.A.phsA.cVal.ang.f |
| 350 | MMXU3.MX.A.phsB.cVal.mag.f |
| 351 | MMXU3.MX.A.phsB.cVal.ang.f |
| 352 | MMXU3.MX.A.phsC.cVal.mag.f |
| 353 | MMXU3.MX.A.phsC.cVal.ang.f |
| 354 | MMXU3.MX.A.neut.cVal.mag.f |
| 355 | MMXU3.MX.A.neut.cVal.ang.f |
| 356 | MMXU3.MX.W.phsA.cVal.mag.f |
| 357 | MMXU3.MX.W.phsB.cVal.mag.f |
| 358 | MMXU3.MX.W.phsC.cVal.mag.f |

| Value | IEC 61850 Tx dataset item |
|---|---|
| 359 | MMXU3.MX.VAr.phsA.cVal.mag.f |
| 360 | MMXU3.MX.VAr.phsB.cVal.mag.f |
| 361 | MMXU3.MX.VAr.phsC.cVal.mag.f |
| 362 | MMXU3.MX.VA.phsA.cVal.mag.f |
| 363 | MMXU3.MX.VA.phsB.cVal.mag.f |
| 364 | MMXU3.MX.VA.phsC.cVal.mag.f |
| 365 | MMXU3.MX.PF.phsA.cVal.mag.f |
| 366 | MMXU3.MX.PF.phsB.cVal.mag.f |
| 367 | MMXU3.MX.PF.phsC.cVal.mag.f |
| 368 | MMXU4.MX.TotW.mag.f |
| 369 | MMXU4.MX.TotVAr.mag.f |
| 370 | MMXU4.MX.TotVA.mag.f |
| 371 | MMXU4.MX.TotPF.mag.f |
| 372 | MMXU4.MX.Hz.mag.f |
| 373 | MMXU4.MX.PPV.phsAB.cVal.mag.f |
| 374 | MMXU4.MX.PPV.phsAB.cVal.ang.f |
| 375 | MMXU4.MX.PPV.phsBC.cVal.mag.f |
| 376 | MMXU4.MX.PPV.phsBC.cVal.ang.f |
| 377 | MMXU4.MX.PPV.phsCA.cVal.mag.f |
| 378 | MMXU4.MX.PPV.phsCA.cVal.ang.f |
| 379 | MMXU4.MX.PhV.phsA.cVal.mag.f |
| 380 | MMXU4.MX.PhV.phsA.cVal.ang.f |
| 381 | MMXU4.MX.PhV.phsB.cVal.mag.f |
| 382 | MMXU4.MX.PhV.phsB.cVal.ang.f |
| 383 | MMXU4.MX.PhV.phsC.cVal.mag.f |
| 384 | MMXU4.MX.PhV.phsC.cVal.ang.f |
| 385 | MMXU4.MX.A.phsA.cVal.mag.f |
| 386 | MMXU4.MX.A.phsA.cVal.ang.f |
| 387 | MMXU4.MX.A.phsB.cVal.mag.f |
| 388 | MMXU4.MX.A.phsB.cVal.ang.f |
| 389 | MMXU4.MX.A.phsC.cVal.mag.f |
| 390 | MMXU4.MX.A.phsC.cVal.ang.f |
| 391 | MMXU4.MX.A.neut.cVal.mag.f |
| 392 | MMXU4.MX.A.neut.cVal.ang.f |
| 393 | MMXU4.MX.W.phsA.cVal.mag.f |
| 394 | MMXU4.MX.W.phsB.cVal.mag.f |
| 395 | MMXU4.MX.W.phsC.cVal.mag.f |
| 396 | MMXU4.MX.VAr.phsA.cVal.mag.f |
| 397 | MMXU4.MX.VAr.phsB.cVal.mag.f |
| 398 | MMXU4.MX.VAr.phsC.cVal.mag.f |
| 399 | MMXU4.MX.VA.phsA.cVal.mag.f |
| 400 | MMXU4.MX.VA.phsB.cVal.mag.f |
| 401 | MMXU4.MX.VA.phsC.cVal.mag.f |
| 402 | MMXU4.MX.PF.phsA.cVal.mag.f |
| 403 | MMXU4.MX.PF.phsB.cVal.mag.f |
| 404 | MMXU4.MX.PF.phsC.cVal.mag.f |
| 405 | MMXU5.MX.TotW.mag.f |
| 406 | MMXU5.MX.TotVAr.mag.f |
| 407 | MMXU5.MX.TotVA.mag.f |
| 408 | MMXU5.MX.TotPF.mag.f |
| 409 | MMXU5.MX.Hz.mag.f |
| 410 | MMXU5.MX.PPV.phsAB.cVal.mag.f |
| 411 | MMXU5.MX.PPV.phsAB.cVal.ang.f |

| Value | IEC 61850 Tx dataset item |
|---|---|
| 412 | MMXU5.MX.PPV.phsBC.cVal.mag.f |
| 413 | MMXU5.MX.PPV.phsBC.cVal.ang.f |
| 414 | MMXU5.MX.PPV.phsCA.cVal.mag.f |
| 415 | MMXU5.MX.PPV.phsCA.cVal.ang.f |
| 416 | MMXU5.MX.PhV.phsA.cVal.mag.f |
| 417 | MMXU5.MX.PhV.phsA.cVal.ang.f |
| 418 | MMXU5.MX.PhV.phsB.cVal.mag.f |
| 419 | MMXU5.MX.PhV.phsB.cVal.ang.f |
| 420 | MMXU5.MX.PhV.phsC.cVal.mag.f |
| 421 | MMXU5.MX.PhV.phsC.cVal.ang.f |
| 422 | MMXU5.MX.A.phsA.cVal.mag.f |
| 423 | MMXU5.MX.A.phsA.cVal.ang.f |
| 424 | MMXU5.MX.A.phsB.cVal.mag.f |
| 425 | MMXU5.MX.A.phsB.cVal.ang.f |
| 426 | MMXU5.MX.A.phsC.cVal.mag.f |
| 427 | MMXU5.MX.A.phsC.cVal.ang.f |
| 428 | MMXU5.MX.A.neut.cVal.mag.f |
| 429 | MMXU5.MX.A.neut.cVal.ang.f |
| 430 | MMXU5.MX.W.phsA.cVal.mag.f |
| 431 | MMXU5.MX.W.phsB.cVal.mag.f |
| 432 | MMXU5.MX.W.phsC.cVal.mag.f |
| 433 | MMXU5.MX.VAr.phsA.cVal.mag.f |
| 434 | MMXU5.MX.VAr.phsB.cVal.mag.f |
| 435 | MMXU5.MX.VAr.phsC.cVal.mag.f |
| 436 | MMXU5.MX.VA.phsA.cVal.mag.f |
| 437 | MMXU5.MX.VA.phsB.cVal.mag.f |
| 438 | MMXU5.MX.VA.phsC.cVal.mag.f |
| 439 | MMXU5.MX.PF.phsA.cVal.mag.f |
| 440 | MMXU5.MX.PF.phsB.cVal.mag.f |
| 441 | MMXU5.MX.PF.phsC.cVal.mag.f |
| 442 | MMXU6.MX.TotW.mag.f |
| 443 | MMXU6.MX.TotVAr.mag.f |
| 444 | MMXU6.MX.TotVA.mag.f |
| 445 | MMXU6.MX.TotPF.mag.f |
| 446 | MMXU6.MX.Hz.mag.f |
| 447 | MMXU6.MX.PPV.phsAB.cVal.mag.f |
| 448 | MMXU6.MX.PPV.phsAB.cVal.ang.f |
| 449 | MMXU6.MX.PPV.phsBC.cVal.mag.f |
| 450 | MMXU6.MX.PPV.phsBC.cVal.ang.f |
| 451 | MMXU6.MX.PPV.phsCA.cVal.mag.f |
| 452 | MMXU6.MX.PPV.phsCA.cVal.ang.f |
| 453 | MMXU6.MX.PhV.phsA.cVal.mag.f |
| 454 | MMXU6.MX.PhV.phsA.cVal.ang.f |
| 455 | MMXU6.MX.PhV.phsB.cVal.mag.f |
| 456 | MMXU6.MX.PhV.phsB.cVal.ang.f |
| 457 | MMXU6.MX.PhV.phsC.cVal.mag.f |
| 458 | MMXU6.MX.PhV.phsC.cVal.ang.f |
| 459 | MMXU6.MX.A.phsA.cVal.mag.f |
| 460 | MMXU6.MX.A.phsA.cVal.ang.f |
| 461 | MMXU6.MX.A.phsB.cVal.mag.f |
| 462 | MMXU6.MX.A.phsB.cVal.ang.f |
| 463 | MMXU6.MX.A.phsC.cVal.mag.f |
| 464 | MMXU6.MX.A.phsC.cVal.ang.f |

| Value | IEC 61850 Tx dataset item |
|---|---|
| 465 | MMXU6.MX.A.neut.cVal.mag.f |
| 466 | MMXU6.MX.A.neut.cVal.ang.f |
| 467 | MMXU6.MX.W.phsA.cVal.mag.f |
| 468 | MMXU6.MX.W.phsB.cVal.mag.f |
| 469 | MMXU6.MX.W.phsC.cVal.mag.f |
| 470 | MMXU6.MX.VAr.phsA.cVal.mag.f |
| 471 | MMXU6.MX.VAr.phsB.cVal.mag.f |
| 472 | MMXU6.MX.VAr.phsC.cVal.mag.f |
| 473 | MMXU6.MX.VA.phsA.cVal.mag.f |
| 474 | MMXU6.MX.VA.phsB.cVal.mag.f |
| 475 | MMXU6.MX.VA.phsC.cVal.mag.f |
| 476 | MMXU6.MX.PF.phsA.cVal.mag.f |
| 477 | MMXU6.MX.PF.phsB.cVal.mag.f |
| 478 | MMXU6.MX.PF.phsC.cVal.mag.f |
| 479 | GGIO4.MX.AnIn1.mag.f |
| 480 | GGIO4.MX.AnIn2.mag.f |
| 481 | GGIO4.MX.AnIn3.mag.f |
| 482 | GGIO4.MX.AnIn4.mag.f |
| 483 | GGIO4.MX.AnIn5.mag.f |
| 484 | GGIO4.MX.AnIn6.mag.f |
| 485 | GGIO4.MX.AnIn7.mag.f |
| 486 | GGIO4.MX.AnIn8.mag.f |
| 487 | GGIO4.MX.AnIn9.mag.f |
| 488 | GGIO4.MX.AnIn10.mag.f |
| 489 | GGIO4.MX.AnIn11.mag.f |
| 490 | GGIO4.MX.AnIn12.mag.f |
| 491 | GGIO4.MX.AnIn13.mag.f |
| 492 | GGIO4.MX.AnIn14.mag.f |
| 493 | GGIO4.MX.AnIn15.mag.f |
| 494 | GGIO4.MX.AnIn16.mag.f |
| 495 | GGIO4.MX.AnIn17.mag.f |
| 496 | GGIO4.MX.AnIn18.mag.f |
| 497 | GGIO4.MX.AnIn19.mag.f |
| 498 | GGIO4.MX.AnIn20.mag.f |
| 499 | GGIO4.MX.AnIn21.mag.f |
| 500 | GGIO4.MX.AnIn22.mag.f |
| 501 | GGIO4.MX.AnIn23.mag.f |
| 502 | GGIO4.MX.AnIn24.mag.f |
| 503 | GGIO4.MX.AnIn25.mag.f |
| 504 | GGIO4.MX.AnIn26.mag.f |
| 505 | GGIO4.MX.AnIn27.mag.f |
| 506 | GGIO4.MX.AnIn28.mag.f |
| 507 | GGIO4.MX.AnIn29.mag.f |
| 508 | GGIO4.MX.AnIn30.mag.f |
| 509 | GGIO4.MX.AnIn31.mag.f |
| 510 | GGIO4.MX.AnIn32.mag.f |
| 511 | GGIO5.ST.UIntIn1.q |
| 512 | GGIO5.ST.UIntIn1.stVal |
| 513 | GGIO5.ST.UIntIn2.q |
| 514 | GGIO5.ST.UIntIn2.stVal |
| 515 | GGIO5.ST.UIntIn3.q |
| 516 | GGIO5.ST.UIntIn3.stVal |
| 517 | GGIO5.ST.UIntIn4.q |

| Value | IEC 61850 Tx dataset item |
|---|---|
| 518 | GGIO5.ST.UIntIn4.stVal |
| 519 | GGIO5.ST.UIntIn5.q |
| 520 | GGIO5.ST.UIntIn5.stVal |
| 521 | GGIO5.ST.UIntIn6.q |
| 522 | GGIO5.ST.UIntIn6.stVal |
| 523 | GGIO5.ST.UIntIn7.q |
| 524 | GGIO5.ST.UIntIn7.stVal |
| 525 | GGIO5.ST.UIntIn8.q |
| 526 | GGIO5.ST.UIntIn8.stVal |
| 527 | GGIO5.ST.UIntIn9.q |
| 528 | GGIO5.ST.UIntIn9.stVal |
| 529 | GGIO5.ST.UIntIn10.q |
| 530 | GGIO5.ST.UIntIn10.stVal |
| 531 | GGIO5.ST.UIntIn11.q |
| 532 | GGIO5.ST.UIntIn11.stVal |
| 533 | GGIO5.ST.UIntIn12.q |
| 534 | GGIO5.ST.UIntIn12.stVal |
| 535 | GGIO5.ST.UIntIn13.q |
| 536 | GGIO5.ST.UIntIn13.stVal |
| 537 | GGIO5.ST.UIntIn14.q |
| 538 | GGIO5.ST.UIntIn14.stVal |
| 539 | GGIO5.ST.UIntIn15.q |
| 540 | GGIO5.ST.UIntIn15.stVal |
| 541 | GGIO5.ST.UIntIn16.q |
| 542 | GGIO5.ST.UIntIn16.stVal |

**F233**
**ENUMERATION: CONFIGURABLE GOOSE Rx DATASET ITEMS**

| Value | IEC 61850 GOOSE Rx dataset item |
|---|---|
| 0 | None |
| 1 | GGIO3.ST.Ind1.q |
| 2 | GGIO3.ST.Ind1.stVal |
| 3 | GGIO3.ST.Ind2.q |
| 4 | GGIO3.ST.Ind2.stVal |
| ↓ | ↓ |
| 127 | GGIO3.ST.Ind64q |
| 128 | GGIO3.ST.Ind64.stVal |
| 129 | GGIO3.MX.AnIn1.mag.f |
| 130 | GGIO3.MX.AnIn2.mag.f |
| 131 | GGIO3.MX.AnIn3.mag.f |
| 132 | GGIO3.MX.AnIn4.mag.f |
| 133 | GGIO3.MX.AnIn5.mag.f |
| 134 | GGIO3.MX.AnIn6.mag.f |
| 135 | GGIO3.MX.AnIn7.mag.f |
| 136 | GGIO3.MX.AnIn8.mag.f |
| 137 | GGIO3.MX.AnIn9.mag.f |
| 138 | GGIO3.MX.AnIn10.mag.f |
| 139 | GGIO3.MX.AnIn11.mag.f |
| 140 | GGIO3.MX.AnIn12.mag.f |
| 141 | GGIO3.MX.AnIn13.mag.f |
| 142 | GGIO3.MX.AnIn14.mag.f |
| 143 | GGIO3.MX.AnIn15.mag.f |
| 144 | GGIO3.MX.AnIn16.mag.f |
| 145 | GGIO3.MX.AnIn17.mag.f |
| 146 | GGIO3.MX.AnIn18.mag.f |
| 147 | GGIO3.MX.AnIn19.mag.f |
| 148 | GGIO3.MX.AnIn20.mag.f |
| 149 | GGIO3.MX.AnIn21.mag.f |
| 150 | GGIO3.MX.AnIn22.mag.f |
| 151 | GGIO3.MX.AnIn23.mag.f |
| 152 | GGIO3.MX.AnIn24.mag.f |
| 153 | GGIO3.MX.AnIn25.mag.f |
| 154 | GGIO3.MX.AnIn26.mag.f |
| 155 | GGIO3.MX.AnIn27.mag.f |
| 156 | GGIO3.MX.AnIn28.mag.f |
| 157 | GGIO3.MX.AnIn29.mag.f |
| 158 | GGIO3.MX.AnIn30.mag.f |
| 159 | GGIO3.MX.AnIn31.mag.f |
| 160 | GGIO3.MX.AnIn32.mag.f |
| 161 | GGIO3.ST.IndPos1.stVal |
| 162 | GGIO3.ST.IndPos2.stVal |
| 163 | GGIO3.ST.IndPos3.stVal |
| 164 | GGIO3.ST.IndPos4.stVal |
| 165 | GGIO3.ST.IndPos5.stVal |
| 166 | GGIO3.ST.UIntIn1.q |
| 167 | GGIO3.ST.UIntIn1.stVal |
| 168 | GGIO3.ST.UIntIn2.q |
| 169 | GGIO3.ST.UIntIn2.stVal |
| 170 | GGIO3.ST.UIntIn3.q |
| 171 | GGIO3.ST.UIntIn3.stVal |
| 172 | GGIO3.ST.UIntIn4.q |
| 173 | GGIO3.ST.UIntIn4.stVal |
| 174 | GGIO3.ST.UIntIn5.q |
| 175 | GGIO3.ST.UIntIn5.stVal |
| 176 | GGIO3.ST.UIntIn6.q |
| 177 | GGIO3.ST.UIntIn6.stVal |
| 178 | GGIO3.ST.UIntIn7.q |
| 179 | GGIO3.ST.UIntIn7.stVal |
| 180 | GGIO3.ST.UIntIn8.q |
| 181 | GGIO3.ST.UIntIn8.stVal |
| 182 | GGIO3.ST.UIntIn9.q |
| 183 | GGIO3.ST.UIntIn9.stVal |
| 184 | GGIO3.ST.UIntIn10.q |
| 185 | GGIO3.ST.UIntIn10.stVal |
| 186 | GGIO3.ST.UIntIn11.q |
| 187 | GGIO3.ST.UIntIn11.stVal |
| 188 | GGIO3.ST.UIntIn12.q |
| 189 | GGIO3.ST.UIntIn12.stVal |
| 190 | GGIO3.ST.UIntIn13.q |
| 191 | GGIO3.ST.UIntIn13.stVal |
| 192 | GGIO3.ST.UIntIn14.q |
| 193 | GGIO3.ST.UIntIn14.stVal |

| Value | IEC 61850 GOOSE Rx dataset item |
|---|---|
| 194 | GGIO3.ST.UIntIn15.q |
| 195 | GGIO3.ST.UIntIn15.stVal |
| 196 | GGIO3.ST.UIntIn16.q |
| 197 | GGIO3.ST.UIntIn16.stVal |

**F237**
**ENUMERATION: REAL TIME CLOCK MONTH (FOR EXAMPLE, DAYLIGHT SAVINGS TIME)**

| Value | Month |
|---|---|
| 0 | January |
| 1 | February |
| 2 | March |
| 3 | April |
| 4 | May |
| 5 | June |
| 6 | July |
| 7 | August |
| 8 | September |
| 9 | October |
| 10 | November |
| 11 | December |

**F238**
**ENUMERATION: REAL TIME CLOCK DAY (FOR EXAMPLE, DAYLIGHT SAVINGS TIME)**

| Value | Day |
|---|---|
| 0 | Sunday |
| 1 | Monday |
| 2 | Tuesday |
| 3 | Wednesday |
| 4 | Thursday |
| 5 | Friday |
| 6 | Saturday |

**F239**
**ENUMERATION: REAL TIME CLOCK DAYLIGHT SAVINGS TIME START DAY INSTANCE**

| Value | Instance |
|---|---|
| 0 | First |
| 1 | Second |
| 2 | Third |
| 3 | Fourth |
| 4 | Last |

**F243**
**ENUMERATION: FIELD UNIT TYPE**

0 = CC-05, 1 = CV-05, 2 = CC-01, 3 = CV-01

**F244**
**ENUMERATION: FIELD UNIT PROCESS CARD PORT**

0 = H4a, 1 = H4b, 2 = H3a, 3 = H3b, 4 = H2a, 5 = H2b, 6 = H1a, 7 = H1b

**F245**
**ENUMERATION: TEST MODE FUNCTION**

| Value | Instance |
|---|---|
| 0 | Disabled |
| 1 | Isolated |
| 2 | Forcible |

**F246**
**ENUMERATION: BRICK TRANSDUCER RANGE**

| Value | Description |
|---|---|
| 0 | -5...5V |
| 1 | -1...1mA |
| 2 | 0...1mA |
| 3 | 0...-1mA |
| 4 | 0...5mA |
| 5 | 0...10mA |
| 6 | 0...20mA |
| 7 | 4...20mA |
| 8 | potentiometer |
| 9 | tap position |

**F247**
**ENUMERATION: BRICK AC BANK ORIGIN**

| Value | Description |
|---|---|
| 0 | None |
| 1 | U1/AC1..3 |
| 2 | U1/AC5..7 |
| 3 | U2/AC1..3 |
| 4 | U2/AC5..7 |
| 5 | U3/AC1..3 |
| 6 | U3/AC5..7 |
| 7 | U4/AC1..3 |
| 8 | U4/AC5..7 |
| 9 | U5/AC1..3 |
| 10 | U5/AC5..7 |
| 11 | U6/AC1..3 |
| 12 | U6/AC5..7 |
| 13 | U7/AC1..3 |
| 14 | U7/AC5..7 |
| 15 | U8/AC1..3 |
| 16 | U8/AC5..7 |

**F248**
**ENUMERATION: BRICK AUX BANK ORIGIN**

| Value | Description |
|---|---|
| 0 | None |
| 1 | U1/AC4 |
| 2 | U1/AC8 |
| 3 | U2/AC4 |
| 4 | U2/AC8 |
| 5 | U3/AC4 |
| 6 | U3/AC8 |
| 7 | U4/AC4 |
| 8 | U4/AC8 |
| 9 | U5/AC4 |
| 10 | U5/AC8 |
| 11 | U6/AC4 |
| 12 | U6/AC8 |
| 13 | U7/AC5 |
| 14 | U7/AC8 |
| 15 | U8/AC5 |
| 16 | U8/AC8 |

**F253**
**ENUMERATION: BRICK TRANSDUCER ORIGIN**

| Value | Description |
|---|---|
| 0 | None |
| 1 | U1/DC1 |
| 2 | U1/DC2 |
| 3 | U1/DC3 |
| 4 | U2/DC1 |
| 5 | U2/DC2 |
| 6 | U2/DC3 |
| ... | ... |
| 24 | U8/DC3 |

**F256**
**ENUMERATION: BRICK ORIGIN/DESTINATION**

| Value | Description |
|---|---|
| 0 | None |
| 1 | U1 |
| 2 | U2 |
| 3 | U3 |
| 4 | U4 |
| 5 | U5 |
| 6 | U6 |
| 7 | U7 |
| 8 | U8 |

**F259**
**ENUMERATION: BRICK RTD TYPE**

0 = 100 Ohm Nickel, 1 = 120 Ohm Nickel, 2 = 100 Ohm Platinum

**F260**
**ENUMERATION: DATA LOGGER MODE**

0 = Continuous, 1 = Trigger

**F261**
**ENUMERATION: BANK REDUNDANCY TYPE**

0 = None, 1 = Dependability Biased, 2 = Security Biased

**F262**
**ENUMERATION: BRICK STATUS**

0 = Disabled, 1 = OK, 2 = Communications Trouble, 3 = Equipment Mismatch, 4 = Brick Trouble

**F270**
**ENUMERATION: FAULT REPORT VT SUBSTITUTION**

| Value | Description |
|---|---|
| 0 | None |
| 1 | I0 |
| 2 | V0 |

**F300**
**UR_UINT32: FLEXLOGIC BASE TYPE (15-bit type)**

The FlexLogic BASE type is 7 bits and is combined with a 8-bit descriptor and 1 bit for the protection element to form a 16-bit value. The combined bits are of the form: PTTTTTTTDDDDDDDD, where P bit if set indicates that the FlexLogic type is associated with a protection element state and D represents bits for the type in F124 format. If P bit is not set, then the T represents bits for the type and D represents range.

The values in square brackets indicate the base type with P prefix [PTTTTTTT] and the values in round brackets indicate the descriptor range. The left-most D bit indicates whether the type is an ON or OFF type. There can be a total 64 type elements. There can be a total of 256 descriptors of each type.

[0] Off (0) – This is boolean FALSE value
[1] On (1) – This is boolean TRUE value
[2] CONTACT INPUTS (1 to 96)
[3] CONTACT INPUTS OFF (1 to 96)
[4] VIRTUAL INPUTS (1 to 32)
[6] VIRTUAL OUTPUTS (1 to 64)
[8] CONTACT OUTPUTS
[10] CONTACT OUTPUTS VOLTAGE DETECTED (1 to 64)
[11] CONTACT OUTPUTS VOLTAGE OFF DETECTED (1 to 64)
[12] CONTACT OUTPUTS CURRENT DETECTED (1 to 64)
[13] CONTACT OUTPUTS CURRENT OFF DETECTED (1 to 64)
[14] REMOTE INPUTS (1 to 32)
[16] DIRECT INPUTS (1 to 96
[18] REMOTE OUTPUT DNA BIT PAIRS (1 to 32)
[20] REMOTE OUTPUT UserSt BIT PAIRS (1 to 32)
[22] REMOTE DEVICE ONLINE (1 to 16)
[24] MISCELLANEOUS EQUATION
[26] TELEPROTECTION INPUTS
[28] INSERT (via keypad only)
[30] DELETE (via keypad only)
[32] END

[34] NOT (1 INPUT)
[36] 2 INPUT XOR (0)
[38] LATCH SET/RESET (2 inputs)
[40] OR (2 to 16 inputs)
[42] AND (2 to 16 inputs)
[44] NOR (2 to 16 inputs)
[46] NAND (2 to 16 inputs)
[48] TIMER (1 to 32)
[50] ASSIGN VIRTUAL OUTPUT (1 to 64)
[52] ONE SHOT
[54] SELF-TEST ERROR (see F141 for range)
[56] PLATFORM DIRECT INPUT (1 to 96)
[58] PLATFORM DIRECT OUTPUT (1 to 96)
[60] PLATFORM DIRECT DEVICE (1 to 8)
[62] MISCELLANEOUS EVENTS (see F146 for range)
[64] PDC NETWORK CONTROL
[66] PMU RECORDER OUT OF MEMORY
[68] PMU RECORDER STOPPED
[128 to 255] ELEMENT STATES (see the Element States section in the Modbus memory map)

**F400**
**UR_UINT16: CT/VT BANK SELECTION**

| Bitmask | Bank selection |
|---|---|
| 0 | Card 1 Contact 1 to 4 |
| 1 | Card 1 Contact 5 to 8 |
| 2 | Card 2 Contact 1 to 4 |
| 3 | Card 2 Contact 5 to 8 |
| 4 | Card 3 Contact 1 to 4 |
| 5 | Card 3 Contact 5 to 8 |

**F491**
**ENUMERATION: ANALOG INPUT MODE**

0 = Default Value, 1 = Last Known

**F500**
**UR_UINT16: PACKED BITFIELD**

First register indicates input/output state with bits 0 (MSB) to 15 (LSB) corresponding to input/output state 1 to 16. The second register indicates input/output state with bits 0 to 15 corresponding to input/output state 17 to 32 (if required). The third register indicates input/output state with bits 0 to 15 corresponding to input/output state 33 to 48 (if required). The fourth register indicates input/output state with bits 0 to 15 corresponding to input/output state 49 to 64 (if required).

The number of registers required is determined by the specific data item. A bit value of 0 = Off and 1 = On.

**F501**
**UR_UINT16: LED STATUS**

Low byte of register indicates LED status with bit 0 representing the top LED and bit 7 the bottom LED. A bit value of 1 indicates the LED is on, 0 indicates the LED is off.

0 = Off, 1 = On

**F502**
**BITFIELD: ELEMENT OPERATE STATES**

Each bit contains the operate state for an element. See the F124 format code for a list of element IDs. The operate bit for element ID X is bit [X mod 16] in register [X/16].

**F515**
**ENUMERATION ELEMENT INPUT MODE**

0 = Signed, 1 = Absolute

**F516**
**ENUMERATION ELEMENT COMPARE MODE**

0 = Level, 1 = Delta

**F517**
**ENUMERATION: ELEMENT DIRECTION OPERATION**

0 = Over, 1 = Under

**F518**
**ENUMERATION: FLEXELEMENT UNITS**

0 = Milliseconds, 1 = Seconds, 2 = Minutes

**F519**
**ENUMERATION: NON-VOLATILE LATCH**

0 = Reset-Dominant, 1 = Set-Dominant

**F522**
**ENUMERATION: TRANSDUCER DCmA OUTPUT RANGE**

0 = –1 to 1 mA, 1 = 0 to 1 mA, 2 = 4 to 20 mA

**F523**
**ENUMERATION: DNP OBJECTS 20, 22, AND 23 DEFAULT VARIATION**

| Bitmask | Default variation |
|---|---|
| 0 | 1 |
| 1 | 2 |
| 2 | 5 |
| 3 | 6 |

**F524**
**ENUMERATION: DNP OBJECT 21 DEFAULT VARIATION**

| Bitmask | Default variation |
|---|---|
| 0 | 1 |
| 1 | 2 |
| 2 | 9 |
| 3 | 10 |

**F525**
**ENUMERATION: DNP OBJECT 32 DEFAULT VARIATION**

| Bitmask | Default variation |
|---|---|
| 0 | 1 |
| 1 | 2 |
| 2 | 3 |
| 3 | 4 |
| 4 | 5 |
| 5 | 7 |

**F530**
**ENUMERATION: FRONT PANEL INTERFACE KEYPRESS**

| Value | Keypress |
|---|---|
| 0 | None |
| 1 | Menu |
| 2 | Message Up |
| 3 | 7 |
| 4 | 8 |
| 5 | 9 |
| 6 | Help |
| 7 | Message Left |
| 8 | 4 |
| 9 | 5 |
| 10 | 6 |
| 11 | Escape |
| 12 | Message Right |
| 13 | 1 |
| 14 | 2 |

| Value | Keypress |
|---|---|
| 15 | 3 |
| 16 | Enter |
| 17 | Message Down |
| 18 | 0 |
| 19 | Decimal |
| 20 | +/– |
| 21 | Value Up |
| 22 | Value Down |
| 23 | Reset |
| 24 | User 1 |
| 25 | User 2 |
| 26 | User 3 |
| 31 | User PB 1 |
| 32 | User PB 2 |

| Value | Keypress |
|---|---|
| 33 | User PB 3 |
| 34 | User PB 4 |
| 35 | User PB 5 |
| 36 | User PB 6 |
| 37 | User PB 7 |
| 38 | User PB 8 |
| 39 | User PB 9 |
| 40 | User PB 10 |
| 41 | User PB 11 |
| 42 | User PB 12 |
| 44 | User 4 |
| 45 | User 5 |
| 46 | User 6 |
| 47 | User 7 |

**F531**
**ENUMERATION: LANGUAGE**

0 = English, 1 = French, 2 = Chinese, 3 = Russian, 4 = Turkish, 5 = German

**F542**
**ENUMERATION: PMU TRIGGERING MODE**

0 = Automatic Overwrite, 1 = Protected

**F543**
**ENUMERATION: PMU PHASORS**

| Value | Phasor |
|---|---|
| 0 | Off |
| 1 | Va |
| 2 | Vb |
| 3 | Vc |
| 4 | Vx |
| 5 | Ia |
| 6 | Ib |
| 7 | Ic |

| Value | Phasor |
|---|---|
| 8 | Ig |
| 9 | V1 |
| 10 | V2 |
| 11 | V0 |
| 12 | I1 |
| 13 | I2 |
| 14 | I0 |

**F544**
**ENUMERATION: PMU RECORDING/REPORTING RATE**

| Value | Rate |
|---|---|
| 0 | 1/second |
| 1 | 2/second |
| 2 | 4/second |
| 3 | 5/second |
| 4 | 10/second |
| 5 | 12/second |
| 6 | 15/second |

| Value | Rate |
|---|---|
| 7 | 20second |
| 8 | 25/second |
| 9 | 30/second |
| 10 | 50/second |
| 11 | 60/second |
| 12 | 100/second |
| 13 | 120/second |

**F546**
**ENUMERATION: PMU REPORTING STYLE**

0 = Polar, 1 = Rectangular

**F547**
**ENUMERATION: PMU REPORTING FORMAT**

0 = Integer, 1 = Floating

**F548**
**ENUMERATION: PMU COM PROTOCOL**

0 = NONE, 1 = 37.118, 2 = 61850-90-5

**F549**
**ENUMERATION: PMU PERFORMANCE CLASS**

0 = None, 1 = M-CLASS, 2 = P-CLASS

**F560**
**ENUMERATION: IN-ZONE TRANSFORMER CONNECTION**

| Enumeration | In-zone transformer connnection |
|---|---|
| 0 | None |
| 1 | 0° lag |
| 2 | 30° lag |
| 3 | 60° lag |
| 4 | 90° lag |
| 5 | 120° lag |
| 6 | 150° lag |
| 7 | 180° lag |
| 8 | 210° lag |
| 9 | 240° lag |
| 10 | 270° lag |
| 11 | 300° lag |
| 12 | 330° lag |

B

**F561**
**ENUMERATION: 87L INRUSH INHIBIT MODE**

| Enumeration | Inrush inhibit mode |
|---|---|
| 0 | Disabled |
| 1 | Per phase |
| 2 | Two out of three |
| 3 | Average |

**F562**
**ENUMERATION: 87L IN-ZONE TRANSFORMER LOCATION**

| Enumeration | In-zone transformer location |
|---|---|
| 0 | Local-Tap |
| 1 | Rem1-Tap |
| 2 | Rem2-Tap |

**F563**
**ENUMERATION: DSCP TYPE**

| Enumeration | DSCP type |
|---|---|
| 0 | None |
| 1 | Expedited Forwarding |

**F600**
**UR_UINT16: FLEXANALOG PARAMETER**

Corresponds to the Modbus address of the value used when this parameter is selected. Only certain values can be used as FlexAnalogs (basically all metering quantities used in protection).

**F601**
**ENUMERATION: COM2 PORT USAGE**

| Enumeration | COM2 port usage |
|---|---|
| 0 | RS485 |
| 1 | RRTD |
| 2 | GPM-F |
| 3 | RRTD and GPM-F |

**F605**
**ENUMERATION: REMOTE DOUBLE-POINT STATUS INPUT STATUS**

| Enumeration | Remote DPS input status |
|---|---|
| 0 | Intermediate |
| 1 | Off |
| 2 | On |
| 3 | Bad |

**F606**
**ENUMERATION: REMOTE DOUBLE-POINT STATUS INPUT**

| Enumeration | Remote double-point status input |
|---|---|
| 0 | None |
| 1 | Remote input 1 |
| 2 | Remote input 2 |
| 3 | Remote input 3 |
| ↓ | ↓ |
| 64 | Remote input 64 |

**F611**
**ENUMERATION: GOOSE RETRANSMISSION CURVE**

| Enumeration | Configurable GOOSE retransmission scheme |
|---|---|
| 0 | Heartbeat |
| 1 | Aggressive |
| 2 | Medium |
| 3 | Relaxed |

**F612**
**UR_UINT16: FLEXINTEGER PARAMETER**

This 16-bit value corresponds to the Modbus address of the selected FlexInteger parameter. Only certain values can be used as FlexIntegers. There is no operation executed even though they are called FlexIntegers.

**F615**
**ENUMERATION: IEC 61850 REPORT DATASET ITEMS**

| Enumeration | IEC 61850 report dataset items |
|---|---|
| 0 | None |
| 1 | PDIF1.ST.Str.general |
| 2 | PDIF1.ST.Op.general |
| 3 | PDIF2.ST.Str.general |
| 4 | PDIF2.ST.Op.general |
| 5 | PDIF3.ST.Str.general |
| 6 | PDIF3.ST.Op.general |
| 7 | PDIF4.ST.Str.general |
| 8 | PDIF4.ST.Op.general |
| 9 | PDIS1.ST.Str.general |
| 10 | PDIS1.ST.Op.general |
| 11 | PDIS2.ST.Str.general |
| 12 | PDIS2.ST.Op.general |
| 13 | PDIS3.ST.Str.general |
| 14 | PDIS3.ST.Op.general |
| 15 | PDIS4.ST.Str.general |
| 16 | PDIS4.ST.Op.general |
| 17 | PDIS5.ST.Str.general |
| 18 | PDIS5.ST.Op.general |
| 19 | PDIS6.ST.Str.general |
| 20 | PDIS6.ST.Op.general |
| 21 | PDIS7.ST.Str.general |
| 22 | PDIS7.ST.Op.general |

| Enumeration | IEC 61850 report dataset items |
|---|---|
| 23 | PDIS8.ST.Str.general |
| 24 | PDIS8.ST.Op.general |
| 25 | PDIS9.ST.Str.general |
| 26 | PDIS9.ST.Op.general |
| 27 | PDIS10.ST.Str.general |
| 28 | PDIS10.ST.Op.general |
| 29 | PIOC1.ST.Str.general |
| 30 | PIOC1.ST.Op.general |
| 31 | PIOC2.ST.Str.general |
| 32 | PIOC2.ST.Op.general |
| 33 | PIOC3.ST.Str.general |
| 34 | PIOC3.ST.Op.general |
| 35 | PIOC4.ST.Str.general |
| 36 | PIOC4.ST.Op.general |
| 37 | PIOC5.ST.Str.general |
| 38 | PIOC5.ST.Op.general |
| 39 | PIOC6.ST.Str.general |
| 40 | PIOC6.ST.Op.general |
| 41 | PIOC7.ST.Str.general |
| 42 | PIOC7.ST.Op.general |
| 43 | PIOC8.ST.Str.general |
| 44 | PIOC8.ST.Op.general |
| 45 | PIOC9.ST.Str.general |
| 46 | PIOC9.ST.Op.general |
| 47 | PIOC10.ST.Str.general |
| 48 | PIOC10.ST.Op.general |
| 49 | PIOC11.ST.Str.general |
| 50 | PIOC11.ST.Op.general |
| 51 | PIOC12.ST.Str.general |
| 52 | PIOC12.ST.Op.general |
| 53 | PIOC13.ST.Str.general |
| 54 | PIOC13.ST.Op.general |
| 55 | PIOC14.ST.Str.general |
| 56 | PIOC14.ST.Op.general |
| 57 | PIOC15.ST.Str.general |
| 58 | PIOC15.ST.Op.general |
| 59 | PIOC16.ST.Str.general |
| 60 | PIOC16.ST.Op.general |
| 61 | PIOC17.ST.Str.general |
| 62 | PIOC17.ST.Op.general |
| 63 | PIOC18.ST.Str.general |
| 64 | PIOC18.ST.Op.general |
| 65 | PIOC19.ST.Str.general |
| 66 | PIOC19.ST.Op.general |
| 67 | PIOC20.ST.Str.general |
| 68 | PIOC20.ST.Op.general |
| 69 | PIOC21.ST.Str.general |
| 70 | PIOC21.ST.Op.general |
| 71 | PIOC22.ST.Str.general |
| 72 | PIOC22.ST.Op.general |
| 73 | PIOC23.ST.Str.general |
| 74 | PIOC23.ST.Op.general |
| 75 | PIOC24.ST.Str.general |

| Enumeration | IEC 61850 report dataset items |
|---|---|
| 76 | PIOC24.ST.Op.general |
| 77 | PIOC25.ST.Str.general |
| 78 | PIOC25.ST.Op.general |
| 79 | PIOC26.ST.Str.general |
| 80 | PIOC26.ST.Op.general |
| 81 | PIOC27.ST.Str.general |
| 82 | PIOC27.ST.Op.general |
| 83 | PIOC28.ST.Str.general |
| 84 | PIOC28.ST.Op.general |
| 85 | PIOC29.ST.Str.general |
| 86 | PIOC29.ST.Op.general |
| 87 | PIOC30.ST.Str.general |
| 88 | PIOC30.ST.Op.general |
| 89 | PIOC31.ST.Str.general |
| 90 | PIOC31.ST.Op.general |
| 91 | PIOC32.ST.Str.general |
| 92 | PIOC32.ST.Op.general |
| 93 | PIOC33.ST.Str.general |
| 94 | PIOC33.ST.Op.general |
| 95 | PIOC34.ST.Str.general |
| 96 | PIOC34.ST.Op.general |
| 97 | PIOC35.ST.Str.general |
| 98 | PIOC35.ST.Op.general |
| 99 | PIOC36.ST.Str.general |
| 100 | PIOC36.ST.Op.general |
| 101 | PIOC37.ST.Str.general |
| 102 | PIOC37.ST.Op.general |
| 103 | PIOC38.ST.Str.general |
| 104 | PIOC38.ST.Op.general |
| 105 | PIOC39.ST.Str.general |
| 106 | PIOC39.ST.Op.general |
| 107 | PIOC40.ST.Str.general |
| 108 | PIOC40.ST.Op.general |
| 109 | PIOC41.ST.Str.general |
| 110 | PIOC41.ST.Op.general |
| 111 | PIOC42.ST.Str.general |
| 112 | PIOC42.ST.Op.general |
| 113 | PIOC43.ST.Str.general |
| 114 | PIOC43.ST.Op.general |
| 115 | PIOC44.ST.Str.general |
| 116 | PIOC44.ST.Op.general |
| 117 | PIOC45.ST.Str.general |
| 118 | PIOC45.ST.Op.general |
| 119 | PIOC46.ST.Str.general |
| 120 | PIOC46.ST.Op.general |
| 121 | PIOC47.ST.Str.general |
| 122 | PIOC47.ST.Op.general |
| 123 | PIOC48.ST.Str.general |
| 124 | PIOC48.ST.Op.general |
| 125 | PIOC49.ST.Str.general |
| 126 | PIOC49.ST.Op.general |
| 127 | PIOC50.ST.Str.general |
| 128 | PIOC50.ST.Op.general |

| Enumeration | IEC 61850 report dataset items |
|---|---|
| 129 | PIOC51.ST.Str.general |
| 130 | PIOC51.ST.Op.general |
| 131 | PIOC52.ST.Str.general |
| 132 | PIOC52.ST.Op.general |
| 133 | PIOC53.ST.Str.general |
| 134 | PIOC53.ST.Op.general |
| 135 | PIOC54.ST.Str.general |
| 136 | PIOC54.ST.Op.general |
| 137 | PIOC55.ST.Str.general |
| 138 | PIOC55.ST.Op.general |
| 139 | PIOC56.ST.Str.general |
| 140 | PIOC56.ST.Op.general |
| 141 | PIOC57.ST.Str.general |
| 142 | PIOC57.ST.Op.general |
| 143 | PIOC58.ST.Str.general |
| 144 | PIOC58.ST.Op.general |
| 145 | PIOC59.ST.Str.general |
| 146 | PIOC59.ST.Op.general |
| 147 | PIOC60.ST.Str.general |
| 148 | PIOC60.ST.Op.general |
| 149 | PIOC61.ST.Str.general |
| 150 | PIOC61.ST.Op.general |
| 151 | PIOC62.ST.Str.general |
| 152 | PIOC62.ST.Op.general |
| 153 | PIOC63.ST.Str.general |
| 154 | PIOC63.ST.Op.general |
| 155 | PIOC64.ST.Str.general |
| 156 | PIOC64.ST.Op.general |
| 157 | PIOC65.ST.Str.general |
| 158 | PIOC65.ST.Op.general |
| 159 | PIOC66.ST.Str.general |
| 160 | PIOC66.ST.Op.general |
| 161 | PIOC67.ST.Str.general |
| 162 | PIOC67.ST.Op.general |
| 163 | PIOC68.ST.Str.general |
| 164 | PIOC68.ST.Op.general |
| 165 | PIOC69.ST.Str.general |
| 166 | PIOC69.ST.Op.general |
| 167 | PIOC70.ST.Str.general |
| 168 | PIOC70.ST.Op.general |
| 169 | PIOC71.ST.Str.general |
| 170 | PIOC71.ST.Op.general |
| 171 | PIOC72.ST.Str.general |
| 172 | PIOC72.ST.Op.general |
| 173 | PTOC1.ST.Str.general |
| 174 | PTOC1.ST.Op.general |
| 175 | PTOC2.ST.Str.general |
| 176 | PTOC2.ST.Op.general |
| 177 | PTOC3.ST.Str.general |
| 178 | PTOC3.ST.Op.general |
| 179 | PTOC4.ST.Str.general |
| 180 | PTOC4.ST.Op.general |
| 181 | PTOC5.ST.Str.general |

| Enumeration | IEC 61850 report dataset items |
|---|---|
| 182 | PTOC5.ST.Op.general |
| 183 | PTOC6.ST.Str.general |
| 184 | PTOC6.ST.Op.general |
| 185 | PTOC7.ST.Str.general |
| 186 | PTOC7.ST.Op.general |
| 187 | PTOC8.ST.Str.general |
| 188 | PTOC8.ST.Op.general |
| 189 | PTOC9.ST.Str.general |
| 190 | PTOC9.ST.Op.general |
| 191 | PTOC10.ST.Str.general |
| 192 | PTOC10.ST.Op.general |
| 193 | PTOC11.ST.Str.general |
| 194 | PTOC11.ST.Op.general |
| 195 | PTOC12.ST.Str.general |
| 196 | PTOC12.ST.Op.general |
| 197 | PTOC13.ST.Str.general |
| 198 | PTOC13.ST.Op.general |
| 199 | PTOC14.ST.Str.general |
| 200 | PTOC14.ST.Op.general |
| 201 | PTOC15.ST.Str.general |
| 202 | PTOC15.ST.Op.general |
| 203 | PTOC16.ST.Str.general |
| 204 | PTOC16.ST.Op.general |
| 205 | PTOC17.ST.Str.general |
| 206 | PTOC17.ST.Op.general |
| 207 | PTOC18.ST.Str.general |
| 208 | PTOC18.ST.Op.general |
| 209 | PTOC19.ST.Str.general |
| 210 | PTOC19.ST.Op.general |
| 211 | PTOC20.ST.Str.general |
| 212 | PTOC20.ST.Op.general |
| 213 | PTOC21.ST.Str.general |
| 214 | PTOC21.ST.Op.general |
| 215 | PTOC22.ST.Str.general |
| 216 | PTOC22.ST.Op.general |
| 217 | PTOC23.ST.Str.general |
| 218 | PTOC23.ST.Op.general |
| 219 | PTOC24.ST.Str.general |
| 220 | PTOC24.ST.Op.general |
| 221 | PTOV1.ST.Str.general |
| 222 | PTOV1.ST.Op.general |
| 223 | PTOV2.ST.Str.general |
| 224 | PTOV2.ST.Op.general |
| 225 | PTOV3.ST.Str.general |
| 226 | PTOV3.ST.Op.general |
| 227 | PTOV4.ST.Str.general |
| 228 | PTOV4.ST.Op.general |
| 229 | PTOV5.ST.Str.general |
| 230 | PTOV5.ST.Op.general |
| 231 | PTOV6.ST.Str.general |
| 232 | PTOV6.ST.Op.general |
| 233 | PTOV7.ST.Str.general |
| 234 | PTOV7.ST.Op.general |

| Enumeration | IEC 61850 report dataset items |
|---|---|
| 235 | PTOV8.ST.Str.general |
| 236 | PTOV8.ST.Op.general |
| 237 | PTOV9.ST.Str.general |
| 238 | PTOV9.ST.Op.general |
| 239 | PTOV10.ST.Str.general |
| 240 | PTOV10.ST.Op.general |
| 241 | PTRC1.ST.Tr.general |
| 242 | PTRC1.ST.Op.general |
| 243 | PTRC2.ST.Tr.general |
| 244 | PTRC2.ST.Op.general |
| 245 | PTRC3.ST.Tr.general |
| 246 | PTRC3.ST.Op.general |
| 247 | PTRC4.ST.Tr.general |
| 248 | PTRC4.ST.Op.general |
| 249 | PTRC5.ST.Tr.general |
| 250 | PTRC5.ST.Op.general |
| 251 | PTRC6.ST.Tr.general |
| 252 | PTRC6.ST.Op.general |
| 253 | PTUV1.ST.Str.general |
| 254 | PTUV1.ST.Op.general |
| 255 | PTUV2.ST.Str.general |
| 256 | PTUV2.ST.Op.general |
| 257 | PTUV3.ST.Str.general |
| 258 | PTUV3.ST.Op.general |
| 259 | PTUV4.ST.Str.general |
| 260 | PTUV4.ST.Op.general |
| 261 | PTUV5.ST.Str.general |
| 262 | PTUV5.ST.Op.general |
| 263 | PTUV6.ST.Str.general |
| 264 | PTUV6.ST.Op.general |
| 265 | PTUV7.ST.Str.general |
| 266 | PTUV7.ST.Op.general |
| 267 | PTUV8.ST.Str.general |
| 268 | PTUV8.ST.Op.general |
| 269 | PTUV9.ST.Str.general |
| 270 | PTUV9.ST.Op.general |
| 271 | PTUV10.ST.Str.general |
| 272 | PTUV10.ST.Op.general |
| 273 | PTUV11.ST.Str.general |
| 274 | PTUV11.ST.Op.general |
| 275 | PTUV12.ST.Str.general |
| 276 | PTUV12.ST.Op.general |
| 277 | PTUV13.ST.Str.general |
| 278 | PTUV13.ST.Op.general |
| 279 | RBRF1.ST.OpEx.general |
| 280 | RBRF1.ST.OpIn.general |
| 281 | RBRF2.ST.OpEx.general |
| 282 | RBRF2.ST.OpIn.general |
| 283 | RBRF3.ST.OpEx.general |
| 284 | RBRF3.ST.OpIn.general |
| 285 | RBRF4.ST.OpEx.general |
| 286 | RBRF4.ST.OpIn.general |
| 287 | RBRF5.ST.OpEx.general |

| Enumeration | IEC 61850 report dataset items |
|---|---|
| 288 | RBRF5.ST.OpIn.general |
| 289 | RBRF6.ST.OpEx.general |
| 290 | RBRF6.ST.OpIn.general |
| 291 | RBRF7.ST.OpEx.general |
| 292 | RBRF7.ST.OpIn.general |
| 293 | RBRF8.ST.OpEx.general |
| 294 | RBRF8.ST.OpIn.general |
| 295 | RBRF9.ST.OpEx.general |
| 296 | RBRF9.ST.OpIn.general |
| 297 | RBRF10.ST.OpEx.general |
| 298 | RBRF10.ST.OpIn.general |
| 299 | RBRF11.ST.OpEx.general |
| 300 | RBRF11.ST.OpIn.general |
| 301 | RBRF12.ST.OpEx.general |
| 302 | RBRF12.ST.OpIn.general |
| 303 | RBRF13.ST.OpEx.general |
| 304 | RBRF13.ST.OpIn.general |
| 305 | RBRF14.ST.OpEx.general |
| 306 | RBRF14.ST.OpIn.general |
| 307 | RBRF15.ST.OpEx.general |
| 308 | RBRF15.ST.OpIn.general |
| 309 | RBRF16.ST.OpEx.general |
| 310 | RBRF16.ST.OpIn.general |
| 311 | RBRF17.ST.OpEx.general |
| 312 | RBRF17.ST.OpIn.general |
| 313 | RBRF18.ST.OpEx.general |
| 314 | RBRF18.ST.OpIn.general |
| 315 | RBRF19.ST.OpEx.general |
| 316 | RBRF19.ST.OpIn.general |
| 317 | RBRF20.ST.OpEx.general |
| 318 | RBRF20.ST.OpIn.general |
| 319 | RBRF21.ST.OpEx.general |
| 320 | RBRF21.ST.OpIn.general |
| 321 | RBRF22.ST.OpEx.general |
| 322 | RBRF22.ST.OpIn.general |
| 323 | RBRF23.ST.OpEx.general |
| 324 | RBRF23.ST.OpIn.general |
| 325 | RBRF24.ST.OpEx.general |
| 326 | RBRF24.ST.OpIn.general |
| 327 | RFLO1.MX.FltDiskm.mag.f |
| 328 | RFLO2.MX.FltDiskm.mag.f |
| 329 | RFLO3.MX.FltDiskm.mag.f |
| 330 | RFLO4.MX.FltDiskm.mag.f |
| 331 | RFLO5.MX.FltDiskm.mag.f |
| 332 | RPSB1.ST.Str.general |
| 333 | RPSB1.ST.Op.general |
| 334 | RPSB1.ST.BlkZn.stVal |
| 335 | RREC1.ST.Op.general |
| 336 | RREC1.ST.AutoRecSt.stVal |
| 337 | RREC2.ST.Op.general |
| 338 | RREC2.ST.AutoRecSt.stVal |
| 339 | RREC3.ST.Op.general |
| 340 | RREC3.ST.AutoRecSt.stVal |

| Enumeration | IEC 61850 report dataset items |
|---|---|
| 341 | RREC4.ST.Op.general |
| 342 | RREC4.ST.AutoRecSt.stVal |
| 343 | RREC5.ST.Op.general |
| 344 | RREC5.ST.AutoRecSt.stVal |
| 345 | RREC6.ST.Op.general |
| 346 | RREC6.ST.AutoRecSt.stVal |
| 347 | CSWI1.ST.Loc.stVal |
| 348 | CSWI1.ST.Pos.stVal |
| 349 | CSWI2.ST.Loc.stVal |
| 350 | CSWI2.ST.Pos.stVal |
| 351 | CSWI3.ST.Loc.stVal |
| 352 | CSWI3.ST.Pos.stVal |
| 353 | CSWI4.ST.Loc.stVal |
| 354 | CSWI4.ST.Pos.stVal |
| 355 | CSWI5.ST.Loc.stVal |
| 356 | CSWI5.ST.Pos.stVal |
| 357 | CSWI6.ST.Loc.stVal |
| 358 | CSWI6.ST.Pos.stVal |
| 359 | CSWI7.ST.Loc.stVal |
| 360 | CSWI7.ST.Pos.stVal |
| 361 | CSWI8.ST.Loc.stVal |
| 362 | CSWI8.ST.Pos.stVal |
| 363 | CSWI9.ST.Loc.stVal |
| 364 | CSWI9.ST.Pos.stVal |
| 365 | CSWI10.ST.Loc.stVal |
| 366 | CSWI10.ST.Pos.stVal |
| 367 | CSWI11.ST.Loc.stVal |
| 368 | CSWI11.ST.Pos.stVal |
| 369 | CSWI12.ST.Loc.stVal |
| 370 | CSWI12.ST.Pos.stVal |
| 371 | CSWI13.ST.Loc.stVal |
| 372 | CSWI13.ST.Pos.stVal |
| 373 | CSWI14.ST.Loc.stVal |
| 374 | CSWI14.ST.Pos.stVal |
| 375 | CSWI15.ST.Loc.stVal |
| 376 | CSWI15.ST.Pos.stVal |
| 377 | CSWI16.ST.Loc.stVal |
| 378 | CSWI16.ST.Pos.stVal |
| 379 | CSWI17.ST.Loc.stVal |
| 380 | CSWI17.ST.Pos.stVal |
| 381 | CSWI18.ST.Loc.stVal |
| 382 | CSWI18.ST.Pos.stVal |
| 383 | CSWI19.ST.Loc.stVal |
| 384 | CSWI19.ST.Pos.stVal |
| 385 | CSWI20.ST.Loc.stVal |
| 386 | CSWI20.ST.Pos.stVal |
| 387 | CSWI21.ST.Loc.stVal |
| 388 | CSWI21.ST.Pos.stVal |
| 389 | CSWI22.ST.Loc.stVal |
| 390 | CSWI22.ST.Pos.stVal |
| 391 | CSWI23.ST.Loc.stVal |
| 392 | CSWI23.ST.Pos.stVal |
| 393 | CSWI24.ST.Loc.stVal |

| Enumeration | IEC 61850 report dataset items |
|---|---|
| 394 | CSWI24.ST.Pos.stVal |
| 395 | CSWI25.ST.Loc.stVal |
| 396 | CSWI25.ST.Pos.stVal |
| 397 | CSWI26.ST.Loc.stVal |
| 398 | CSWI26.ST.Pos.stVal |
| 399 | CSWI27.ST.Loc.stVal |
| 400 | CSWI27.ST.Pos.stVal |
| 401 | CSWI28.ST.Loc.stVal |
| 402 | CSWI28.ST.Pos.stVal |
| 403 | CSWI29.ST.Loc.stVal |
| 404 | CSWI29.ST.Pos.stVal |
| 405 | CSWI30.ST.Loc.stVal |
| 406 | CSWI30.ST.Pos.stVal |
| 407 | GGIO1.ST.Ind1.stVal |
| 408 | GGIO1.ST.Ind2.stVal |
| 409 | GGIO1.ST.Ind3.stVal |
| 410 | GGIO1.ST.Ind4.stVal |
| 411 | GGIO1.ST.Ind5.stVal |
| 412 | GGIO1.ST.Ind6.stVal |
| 413 | GGIO1.ST.Ind7.stVal |
| 414 | GGIO1.ST.Ind8.stVal |
| 415 | GGIO1.ST.Ind9.stVal |
| 416 | GGIO1.ST.Ind10.stVal |
| 417 | GGIO1.ST.Ind11.stVal |
| 418 | GGIO1.ST.Ind12.stVal |
| 419 | GGIO1.ST.Ind13.stVal |
| 420 | GGIO1.ST.Ind14.stVal |
| 421 | GGIO1.ST.Ind15.stVal |
| 422 | GGIO1.ST.Ind16.stVal |
| 423 | GGIO1.ST.Ind17.stVal |
| 424 | GGIO1.ST.Ind18.stVal |
| 425 | GGIO1.ST.Ind19.stVal |
| 426 | GGIO1.ST.Ind20.stVal |
| 427 | GGIO1.ST.Ind21.stVal |
| 428 | GGIO1.ST.Ind22.stVal |
| 429 | GGIO1.ST.Ind23.stVal |
| 430 | GGIO1.ST.Ind24.stVal |
| 431 | GGIO1.ST.Ind25.stVal |
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| 433 | GGIO1.ST.Ind27.stVal |
| 434 | GGIO1.ST.Ind28.stVal |
| 435 | GGIO1.ST.Ind29.stVal |
| 436 | GGIO1.ST.Ind30.stVal |
| 437 | GGIO1.ST.Ind31.stVal |
| 438 | GGIO1.ST.Ind32.stVal |
| 439 | GGIO1.ST.Ind33.stVal |
| 440 | GGIO1.ST.Ind34.stVal |
| 441 | GGIO1.ST.Ind35.stVal |
| 442 | GGIO1.ST.Ind36.stVal |
| 443 | GGIO1.ST.Ind37.stVal |
| 444 | GGIO1.ST.Ind38.stVal |
| 445 | GGIO1.ST.Ind39.stVal |
| 446 | GGIO1.ST.Ind40.stVal |

| Enumeration | IEC 61850 report dataset items |
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| 448 | GGIO1.ST.Ind42.stVal |
| 449 | GGIO1.ST.Ind43.stVal |
| 450 | GGIO1.ST.Ind44.stVal |
| 451 | GGIO1.ST.Ind45.stVal |
| 452 | GGIO1.ST.Ind46.stVal |
| 453 | GGIO1.ST.Ind47.stVal |
| 454 | GGIO1.ST.Ind48.stVal |
| 455 | GGIO1.ST.Ind49.stVal |
| 456 | GGIO1.ST.Ind50.stVal |
| 457 | GGIO1.ST.Ind51.stVal |
| 458 | GGIO1.ST.Ind52.stVal |
| 459 | GGIO1.ST.Ind53.stVal |
| 460 | GGIO1.ST.Ind54.stVal |
| 461 | GGIO1.ST.Ind55.stVal |
| 462 | GGIO1.ST.Ind56.stVal |
| 463 | GGIO1.ST.Ind57.stVal |
| 464 | GGIO1.ST.Ind58.stVal |
| 465 | GGIO1.ST.Ind59.stVal |
| 466 | GGIO1.ST.Ind60.stVal |
| 467 | GGIO1.ST.Ind61.stVal |
| 468 | GGIO1.ST.Ind62.stVal |
| 469 | GGIO1.ST.Ind63.stVal |
| 470 | GGIO1.ST.Ind64.stVal |
| 471 | GGIO1.ST.Ind65.stVal |
| 472 | GGIO1.ST.Ind66.stVal |
| 473 | GGIO1.ST.Ind67.stVal |
| 474 | GGIO1.ST.Ind68.stVal |
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| 486 | GGIO1.ST.Ind80.stVal |
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| 498 | GGIO1.ST.Ind92.stVal |
| 499 | GGIO1.ST.Ind93.stVal |

| Enumeration | IEC 61850 report dataset items |
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| 502 | GGIO1.ST.Ind96.stVal |
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| 504 | GGIO1.ST.Ind98.stVal |
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| 509 | GGIO1.ST.Ind103.stVal |
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| 523 | GGIO1.ST.Ind117.stVal |
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| 526 | GGIO1.ST.Ind120.stVal |
| 527 | GGIO1.ST.Ind121.stVal |
| 528 | GGIO1.ST.Ind122.stVal |
| 529 | GGIO1.ST.Ind123.stVal |
| 530 | GGIO1.ST.Ind124.stVal |
| 531 | GGIO1.ST.Ind125.stVal |
| 532 | GGIO1.ST.Ind126.stVal |
| 533 | GGIO1.ST.Ind127.stVal |
| 534 | GGIO1.ST.Ind128.stVal |
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| 536 | MMXU1.MX.TotVAr.mag.f |
| 537 | MMXU1.MX.TotVA.mag.f |
| 538 | MMXU1.MX.TotPF.mag.f |
| 539 | MMXU1.MX.Hz.mag.f |
| 540 | MMXU1.MX.PPV.phsAB.cVal.mag.f |
| 541 | MMXU1.MX.PPV.phsAB.cVal.ang.f |
| 542 | MMXU1.MX.PPV.phsBC.cVal.mag.f |
| 543 | MMXU1.MX.PPV.phsBC.cVal.ang.f |
| 544 | MMXU1.MX.PPV.phsCA.cVal.mag.f |
| 545 | MMXU1.MX.PPV.phsCA.cVal.ang.f |
| 546 | MMXU1.MX.PhV.phsA.cVal.mag.f |
| 547 | MMXU1.MX.PhV.phsA.cVal.ang.f |
| 548 | MMXU1.MX.PhV.phsB.cVal.mag.f |
| 549 | MMXU1.MX.PhV.phsB.cVal.ang.f |
| 550 | MMXU1.MX.PhV.phsC.cVal.mag.f |
| 551 | MMXU1.MX.PhV.phsC.cVal.ang.f |
| 552 | MMXU1.MX.A.phsA.cVal.mag.f |

| Enumeration | IEC 61850 report dataset items |
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| 554 | MMXU1.MX.A.phsB.cVal.mag.f |
| 555 | MMXU1.MX.A.phsB.cVal.ang.f |
| 556 | MMXU1.MX.A.phsC.cVal.mag.f |
| 557 | MMXU1.MX.A.phsC.cVal.ang.f |
| 558 | MMXU1.MX.A.neut.cVal.mag.f |
| 559 | MMXU1.MX.A.neut.cVal.ang.f |
| 560 | MMXU1.MX.W.phsA.cVal.mag.f |
| 561 | MMXU1.MX.W.phsB.cVal.mag.f |
| 562 | MMXU1.MX.W.phsC.cVal.mag.f |
| 563 | MMXU1.MX.VAr.phsA.cVal.mag.f |
| 564 | MMXU1.MX.VAr.phsB.cVal.mag.f |
| 565 | MMXU1.MX.VAr.phsC.cVal.mag.f |
| 566 | MMXU1.MX.VA.phsA.cVal.mag.f |
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| 568 | MMXU1.MX.VA.phsC.cVal.mag.f |
| 569 | MMXU1.MX.PF.phsA.cVal.mag.f |
| 570 | MMXU1.MX.PF.phsB.cVal.mag.f |
| 571 | MMXU1.MX.PF.phsC.cVal.mag.f |
| 572 | MMXU2.MX.TotW.mag.f |
| 573 | MMXU2.MX.TotVAr.mag.f |
| 574 | MMXU2.MX.TotVA.mag.f |
| 575 | MMXU2.MX.TotPF.mag.f |
| 576 | MMXU2.MX.Hz.mag.f |
| 577 | MMXU2.MX.PPV.phsAB.cVal.mag.f |
| 578 | MMXU2.MX.PPV.phsAB.cVal.ang.f |
| 579 | MMXU2.MX.PPV.phsBC.cVal.mag.f |
| 580 | MMXU2.MX.PPV.phsBC.cVal.ang.f |
| 581 | MMXU2.MX.PPV.phsCA.cVal.mag.f |
| 582 | MMXU2.MX.PPV.phsCA.cVal.ang.f |
| 583 | MMXU2.MX.PhV.phsA.cVal.mag.f |
| 584 | MMXU2.MX.PhV.phsA.cVal.ang.f |
| 585 | MMXU2.MX.PhV.phsB.cVal.mag.f |
| 586 | MMXU2.MX.PhV.phsB.cVal.ang.f |
| 587 | MMXU2.MX.PhV.phsC.cVal.mag.f |
| 588 | MMXU2.MX.PhV.phsC.cVal.ang.f |
| 589 | MMXU2.MX.A.phsA.cVal.mag.f |
| 590 | MMXU2.MX.A.phsA.cVal.ang.f |
| 591 | MMXU2.MX.A.phsB.cVal.mag.f |
| 592 | MMXU2.MX.A.phsB.cVal.ang.f |
| 593 | MMXU2.MX.A.phsC.cVal.mag.f |
| 594 | MMXU2.MX.A.phsC.cVal.ang.f |
| 595 | MMXU2.MX.A.neut.cVal.mag.f |
| 596 | MMXU2.MX.A.neut.cVal.ang.f |
| 597 | MMXU2.MX.W.phsA.cVal.mag.f |
| 598 | MMXU2.MX.W.phsB.cVal.mag.f |
| 599 | MMXU2.MX.W.phsC.cVal.mag.f |
| 600 | MMXU2.MX.VAr.phsA.cVal.mag.f |
| 601 | MMXU2.MX.VAr.phsB.cVal.mag.f |
| 602 | MMXU2.MX.VAr.phsC.cVal.mag.f |
| 603 | MMXU2.MX.VA.phsA.cVal.mag.f |
| 604 | MMXU2.MX.VA.phsB.cVal.mag.f |
| 605 | MMXU2.MX.VA.phsC.cVal.mag.f |

| Enumeration | IEC 61850 report dataset items |
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| 606 | MMXU2.MX.PF.phsA.cVal.mag.f |
| 607 | MMXU2.MX.PF.phsB.cVal.mag.f |
| 608 | MMXU2.MX.PF.phsC.cVal.mag.f |
| 609 | MMXU3.MX.TotW.mag.f |
| 610 | MMXU3.MX.TotVAr.mag.f |
| 611 | MMXU3.MX.TotVA.mag.f |
| 612 | MMXU3.MX.TotPF.mag.f |
| 613 | MMXU3.MX.Hz.mag.f |
| 614 | MMXU3.MX.PPV.phsAB.cVal.mag.f |
| 615 | MMXU3.MX.PPV.phsAB.cVal.ang.f |
| 616 | MMXU3.MX.PPV.phsBC.cVal.mag.f |
| 617 | MMXU3.MX.PPV.phsBC.cVal.ang.f |
| 618 | MMXU3.MX.PPV.phsCA.cVal.mag.f |
| 619 | MMXU3.MX.PPV.phsCA.cVal.ang.f |
| 620 | MMXU3.MX.PhV.phsA.cVal.mag.f |
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| 624 | MMXU3.MX.PhV.phsC.cVal.mag.f |
| 625 | MMXU3.MX.PhV.phsC.cVal.ang.f |
| 626 | MMXU3.MX.A.phsA.cVal.mag.f |
| 627 | MMXU3.MX.A.phsA.cVal.ang.f |
| 628 | MMXU3.MX.A.phsB.cVal.mag.f |
| 629 | MMXU3.MX.A.phsB.cVal.ang.f |
| 630 | MMXU3.MX.A.phsC.cVal.mag.f |
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| 632 | MMXU3.MX.A.neut.cVal.mag.f |
| 633 | MMXU3.MX.A.neut.cVal.ang.f |
| 634 | MMXU3.MX.W.phsA.cVal.mag.f |
| 635 | MMXU3.MX.W.phsB.cVal.mag.f |
| 636 | MMXU3.MX.W.phsC.cVal.mag.f |
| 637 | MMXU3.MX.VAr.phsA.cVal.mag.f |
| 638 | MMXU3.MX.VAr.phsB.cVal.mag.f |
| 639 | MMXU3.MX.VAr.phsC.cVal.mag.f |
| 640 | MMXU3.MX.VA.phsA.cVal.mag.f |
| 641 | MMXU3.MX.VA.phsB.cVal.mag.f |
| 642 | MMXU3.MX.VA.phsC.cVal.mag.f |
| 643 | MMXU3.MX.PF.phsA.cVal.mag.f |
| 644 | MMXU3.MX.PF.phsB.cVal.mag.f |
| 645 | MMXU3.MX.PF.phsC.cVal.mag.f |
| 646 | MMXU4.MX.TotW.mag.f |
| 647 | MMXU4.MX.TotVAr.mag.f |
| 648 | MMXU4.MX.TotVA.mag.f |
| 649 | MMXU4.MX.TotPF.mag.f |
| 650 | MMXU4.MX.Hz.mag.f |
| 651 | MMXU4.MX.PPV.phsAB.cVal.mag.f |
| 652 | MMXU4.MX.PPV.phsAB.cVal.ang.f |
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| 655 | MMXU4.MX.PPV.phsCA.cVal.mag.f |
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| 657 | MMXU4.MX.PhV.phsA.cVal.mag.f |
| 658 | MMXU4.MX.PhV.phsA.cVal.ang.f |

| Enumeration | IEC 61850 report dataset items |
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| 660 | MMXU4.MX.PhV.phsB.cVal.ang.f |
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| 662 | MMXU4.MX.PhV.phsC.cVal.ang.f |
| 663 | MMXU4.MX.A.phsA.cVal.mag.f |
| 664 | MMXU4.MX.A.phsA.cVal.ang.f |
| 665 | MMXU4.MX.A.phsB.cVal.mag.f |
| 666 | MMXU4.MX.A.phsB.cVal.ang.f |
| 667 | MMXU4.MX.A.phsC.cVal.mag.f |
| 668 | MMXU4.MX.A.phsC.cVal.ang.f |
| 669 | MMXU4.MX.A.neut.cVal.mag.f |
| 670 | MMXU4.MX.A.neut.cVal.ang.f |
| 671 | MMXU4.MX.W.phsA.cVal.mag.f |
| 672 | MMXU4.MX.W.phsB.cVal.mag.f |
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| 676 | MMXU4.MX.VAr.phsC.cVal.mag.f |
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| 678 | MMXU4.MX.VA.phsB.cVal.mag.f |
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| 680 | MMXU4.MX.PF.phsA.cVal.mag.f |
| 681 | MMXU4.MX.PF.phsB.cVal.mag.f |
| 682 | MMXU4.MX.PF.phsC.cVal.mag.f |
| 683 | MMXU5.MX.TotW.mag.f |
| 684 | MMXU5.MX.TotVAr.mag.f |
| 685 | MMXU5.MX.TotVA.mag.f |
| 686 | MMXU5.MX.TotPF.mag.f |
| 687 | MMXU5.MX.Hz.mag.f |
| 688 | MMXU5.MX.PPV.phsAB.cVal.mag.f |
| 689 | MMXU5.MX.PPV.phsAB.cVal.ang.f |
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| 704 | MMXU5.MX.A.phsC.cVal.mag.f |
| 705 | MMXU5.MX.A.phsC.cVal.ang.f |
| 706 | MMXU5.MX.A.neut.cVal.mag.f |
| 707 | MMXU5.MX.A.neut.cVal.ang.f |
| 708 | MMXU5.MX.W.phsA.cVal.mag.f |
| 709 | MMXU5.MX.W.phsB.cVal.mag.f |
| 710 | MMXU5.MX.W.phsC.cVal.mag.f |
| 711 | MMXU5.MX.VAr.phsA.cVal.mag.f |

| Enumeration | IEC 61850 report dataset items |
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| 715 | MMXU5.MX.VA.phsB.cVal.mag.f |
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| 717 | MMXU5.MX.PF.phsA.cVal.mag.f |
| 718 | MMXU5.MX.PF.phsB.cVal.mag.f |
| 719 | MMXU5.MX.PF.phsC.cVal.mag.f |
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| 721 | MMXU6.MX.TotVAr.mag.f |
| 722 | MMXU6.MX.TotVA.mag.f |
| 723 | MMXU6.MX.TotPF.mag.f |
| 724 | MMXU6.MX.Hz.mag.f |
| 725 | MMXU6.MX.PPV.phsAB.cVal.mag.f |
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| 732 | MMXU6.MX.PhV.phsA.cVal.ang.f |
| 733 | MMXU6.MX.PhV.phsB.cVal.mag.f |
| 734 | MMXU6.MX.PhV.phsB.cVal.ang.f |
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| 736 | MMXU6.MX.PhV.phsC.cVal.ang.f |
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| 738 | MMXU6.MX.A.phsA.cVal.ang.f |
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| 741 | MMXU6.MX.A.phsC.cVal.mag.f |
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| 743 | MMXU6.MX.A.neut.cVal.mag.f |
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| 748 | MMXU6.MX.VAr.phsA.cVal.mag.f |
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| 752 | MMXU6.MX.VA.phsB.cVal.mag.f |
| 753 | MMXU6.MX.VA.phsC.cVal.mag.f |
| 754 | MMXU6.MX.PF.phsA.cVal.mag.f |
| 755 | MMXU6.MX.PF.phsB.cVal.mag.f |
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| 757 | GGIO4.MX.AnIn1.mag.f |
| 758 | GGIO4.MX.AnIn2.mag.f |
| 759 | GGIO4.MX.AnIn3.mag.f |
| 760 | GGIO4.MX.AnIn4.mag.f |
| 761 | GGIO4.MX.AnIn5.mag.f |
| 762 | GGIO4.MX.AnIn6.mag.f |
| 763 | GGIO4.MX.AnIn7.mag.f |
| 764 | GGIO4.MX.AnIn8.mag.f |

| Enumeration | IEC 61850 report dataset items |
|---|---|
| 765 | GGIO4.MX.AnIn9.mag.f |
| 766 | GGIO4.MX.AnIn10.mag.f |
| 767 | GGIO4.MX.AnIn11.mag.f |
| 768 | GGIO4.MX.AnIn12.mag.f |
| 769 | GGIO4.MX.AnIn13.mag.f |
| 770 | GGIO4.MX.AnIn14.mag.f |
| 771 | GGIO4.MX.AnIn15.mag.f |
| 772 | GGIO4.MX.AnIn16.mag.f |
| 773 | GGIO4.MX.AnIn17.mag.f |
| 774 | GGIO4.MX.AnIn18.mag.f |
| 775 | GGIO4.MX.AnIn19.mag.f |
| 776 | GGIO4.MX.AnIn20.mag.f |
| 777 | GGIO4.MX.AnIn21.mag.f |
| 778 | GGIO4.MX.AnIn22.mag.f |
| 779 | GGIO4.MX.AnIn23.mag.f |
| 780 | GGIO4.MX.AnIn24.mag.f |
| 781 | GGIO4.MX.AnIn25.mag.f |
| 782 | GGIO4.MX.AnIn26.mag.f |
| 783 | GGIO4.MX.AnIn27.mag.f |
| 784 | GGIO4.MX.AnIn28.mag.f |
| 785 | GGIO4.MX.AnIn29.mag.f |
| 786 | GGIO4.MX.AnIn30.mag.f |
| 787 | GGIO4.MX.AnIn31.mag.f |
| 788 | GGIO4.MX.AnIn32.mag.f |
| 789 | XSWI1.ST.Loc.stVal |
| 790 | XSWI1.ST.Pos.stVal |
| 791 | XSWI2.ST.Loc.stVal |
| 792 | XSWI2.ST.Pos.stVal |
| 793 | XSWI3.ST.Loc.stVal |
| 794 | XSWI3.ST.Pos.stVal |
| 795 | XSWI4.ST.Loc.stVal |
| 796 | XSWI4.ST.Pos.stVal |
| 797 | XSWI5.ST.Loc.stVal |
| 798 | XSWI5.ST.Pos.stVal |
| 799 | XSWI6.ST.Loc.stVal |
| 800 | XSWI6.ST.Pos.stVal |
| 801 | XSWI7.ST.Loc.stVal |
| 802 | XSWI7.ST.Pos.stVal |
| 803 | XSWI8.ST.Loc.stVal |
| 804 | XSWI8.ST.Pos.stVal |
| 805 | XSWI9.ST.Loc.stVal |
| 806 | XSWI9.ST.Pos.stVal |
| 807 | XSWI10.ST.Loc.stVal |
| 808 | XSWI10.ST.Pos.stVal |
| 809 | XSWI11.ST.Loc.stVal |
| 810 | XSWI11.ST.Pos.stVal |
| 811 | XSWI12.ST.Loc.stVal |
| 812 | XSWI12.ST.Pos.stVal |
| 813 | XSWI13.ST.Loc.stVal |
| 814 | XSWI13.ST.Pos.stVal |
| 815 | XSWI14.ST.Loc.stVal |
| 816 | XSWI14.ST.Pos.stVal |
| 817 | XSWI15.ST.Loc.stVal |
| 818 | XSWI15.ST.Pos.stVal |
| 819 | XSWI16.ST.Loc.stVal |
| 820 | XSWI16.ST.Pos.stVal |
| 821 | XSWI17.ST.Loc.stVal |
| 822 | XSWI17.ST.Pos.stVal |
| 823 | XSWI18.ST.Loc.stVal |
| 824 | XSWI18.ST.Pos.stVal |
| 825 | XSWI19.ST.Loc.stVal |
| 826 | XSWI19.ST.Pos.stVal |
| 827 | XSWI20.ST.Loc.stVal |
| 828 | XSWI20.ST.Pos.stVal |
| 829 | XSWI21.ST.Loc.stVal |
| 830 | XSWI21.ST.Pos.stVal |
| 831 | XSWI22.ST.Loc.stVal |
| 832 | XSWI22.ST.Pos.stVal |
| 833 | XSWI23.ST.Loc.stVal |
| 834 | XSWI23.ST.Pos.stVal |
| 835 | XSWI24.ST.Loc.stVal |
| 836 | XSWI24.ST.Pos.stVal |
| 837 | XCBR1.ST.Loc.stVal |
| 838 | XCBR1.ST.Pos.stVal |
| 839 | XCBR2.ST.Loc.stVal |
| 840 | XCBR2.ST.Pos.stVal |
| 841 | XCBR3.ST.Loc.stVal |
| 842 | XCBR3.ST.Pos.stVal |
| 843 | XCBR4.ST.Loc.stVal |
| 844 | XCBR4.ST.Pos.stVal |
| 845 | XCBR5.ST.Loc.stVal |
| 846 | XCBR5.ST.Pos.stVal |
| 847 | XCBR6.ST.Loc.stVal |
| 848 | XCBR6.ST.Pos.stVal |

**F616**
**ENUMERATION: IEC 61850 GOOSE DATASET ITEMS**

| Enumeration | GOOSE dataset items |
|---|---|
| 0 | None |
| 1 | GGIO1.ST.Ind1.q |
| 2 | GGIO1.ST.Ind1.stVal |
| 3 | GGIO1.ST.Ind2.q |
| 4 | GGIO1.ST.Ind2.stVal |
| 5 | GGIO1.ST.Ind3.q |
| 6 | GGIO1.ST.Ind3.stVal |
| 7 | GGIO1.ST.Ind4.q |
| 8 | GGIO1.ST.Ind4.stVal |
| 9 | GGIO1.ST.Ind5.q |
| 10 | GGIO1.ST.Ind5.stVal |
| 11 | GGIO1.ST.Ind6.q |
| 12 | GGIO1.ST.Ind6.stVal |
| 13 | GGIO1.ST.Ind7.q |
| 14 | GGIO1.ST.Ind7.stVal |
| 15 | GGIO1.ST.Ind8.q |
| 16 | GGIO1.ST.Ind8.stVal |

| Enumeration | GOOSE dataset items |
|---|---|
| 17 | GGIO1.ST.Ind9.q |
| 18 | GGIO1.ST.Ind9.stVal |
| 19 | GGIO1.ST.Ind10.q |
| 20 | GGIO1.ST.Ind10.stVal |
| 21 | GGIO1.ST.Ind11.q |
| 22 | GGIO1.ST.Ind11.stVal |
| 23 | GGIO1.ST.Ind12.q |
| 24 | GGIO1.ST.Ind12.stVal |
| 25 | GGIO1.ST.Ind13.q |
| 26 | GGIO1.ST.Ind13.stVal |
| 27 | GGIO1.ST.Ind14.q |
| 28 | GGIO1.ST.Ind14.stVal |
| 29 | GGIO1.ST.Ind15.q |
| 30 | GGIO1.ST.Ind15.stVal |
| 31 | GGIO1.ST.Ind16.q |
| 32 | GGIO1.ST.Ind16.stVal |
| 33 | GGIO1.ST.Ind17.q |
| 34 | GGIO1.ST.Ind17.stVal |
| 35 | GGIO1.ST.Ind18.q |
| 36 | GGIO1.ST.Ind18.stVal |
| 37 | GGIO1.ST.Ind19.q |
| 38 | GGIO1.ST.Ind19.stVal |
| 39 | GGIO1.ST.Ind20.q |
| 40 | GGIO1.ST.Ind20.stVal |
| 41 | GGIO1.ST.Ind21.q |
| 42 | GGIO1.ST.Ind21.stVal |
| 43 | GGIO1.ST.Ind22.q |
| 44 | GGIO1.ST.Ind22.stVal |
| 45 | GGIO1.ST.Ind23.q |
| 46 | GGIO1.ST.Ind23.stVal |
| 47 | GGIO1.ST.Ind24.q |
| 48 | GGIO1.ST.Ind24.stVal |
| 49 | GGIO1.ST.Ind25.q |
| 50 | GGIO1.ST.Ind25.stVal |
| 51 | GGIO1.ST.Ind26.q |
| 52 | GGIO1.ST.Ind26.stVal |
| 53 | GGIO1.ST.Ind27.q |
| 54 | GGIO1.ST.Ind27.stVal |
| 55 | GGIO1.ST.Ind28.q |
| 56 | GGIO1.ST.Ind28.stVal |
| 57 | GGIO1.ST.Ind29.q |
| 58 | GGIO1.ST.Ind29.stVal |
| 59 | GGIO1.ST.Ind30.q |
| 60 | GGIO1.ST.Ind30.stVal |
| 61 | GGIO1.ST.Ind31.q |
| 62 | GGIO1.ST.Ind31.stVal |
| 63 | GGIO1.ST.Ind32.q |
| 64 | GGIO1.ST.Ind32.stVal |
| 65 | GGIO1.ST.Ind33.q |
| 66 | GGIO1.ST.Ind33.stVal |
| 67 | GGIO1.ST.Ind34.q |
| 68 | GGIO1.ST.Ind34.stVal |
| 69 | GGIO1.ST.Ind35.q |

| Enumeration | GOOSE dataset items |
|---|---|
| 70 | GGIO1.ST.Ind35.stVal |
| 71 | GGIO1.ST.Ind36.q |
| 72 | GGIO1.ST.Ind36.stVal |
| 73 | GGIO1.ST.Ind37.q |
| 74 | GGIO1.ST.Ind37.stVal |
| 75 | GGIO1.ST.Ind38.q |
| 76 | GGIO1.ST.Ind38.stVal |
| 77 | GGIO1.ST.Ind39.q |
| 78 | GGIO1.ST.Ind39.stVal |
| 79 | GGIO1.ST.Ind40.q |
| 80 | GGIO1.ST.Ind40.stVal |
| 81 | GGIO1.ST.Ind41.q |
| 82 | GGIO1.ST.Ind41.stVal |
| 83 | GGIO1.ST.Ind42.q |
| 84 | GGIO1.ST.Ind42.stVal |
| 85 | GGIO1.ST.Ind43.q |
| 86 | GGIO1.ST.Ind43.stVal |
| 87 | GGIO1.ST.Ind44.q |
| 88 | GGIO1.ST.Ind44.stVal |
| 89 | GGIO1.ST.Ind45.q |
| 90 | GGIO1.ST.Ind45.stVal |
| 91 | GGIO1.ST.Ind46.q |
| 92 | GGIO1.ST.Ind46.stVal |
| 93 | GGIO1.ST.Ind47.q |
| 94 | GGIO1.ST.Ind47.stVal |
| 95 | GGIO1.ST.Ind48.q |
| 96 | GGIO1.ST.Ind48.stVal |
| 97 | GGIO1.ST.Ind49.q |
| 98 | GGIO1.ST.Ind49.stVal |
| 99 | GGIO1.ST.Ind50.q |
| 100 | GGIO1.ST.Ind50.stVal |
| 101 | GGIO1.ST.Ind51.q |
| 102 | GGIO1.ST.Ind51.stVal |
| 103 | GGIO1.ST.Ind52.q |
| 104 | GGIO1.ST.Ind52.stVal |
| 105 | GGIO1.ST.Ind53.q |
| 106 | GGIO1.ST.Ind53.stVal |
| 107 | GGIO1.ST.Ind54.q |
| 108 | GGIO1.ST.Ind54.stVal |
| 109 | GGIO1.ST.Ind55.q |
| 110 | GGIO1.ST.Ind55.stVal |
| 111 | GGIO1.ST.Ind56.q |
| 112 | GGIO1.ST.Ind56.stVal |
| 113 | GGIO1.ST.Ind57.q |
| 114 | GGIO1.ST.Ind57.stVal |
| 115 | GGIO1.ST.Ind58.q |
| 116 | GGIO1.ST.Ind58.stVal |
| 117 | GGIO1.ST.Ind59.q |
| 118 | GGIO1.ST.Ind59.stVal |
| 119 | GGIO1.ST.Ind60.q |
| 120 | GGIO1.ST.Ind60.stVal |
| 121 | GGIO1.ST.Ind61.q |
| 122 | GGIO1.ST.Ind61.stVal |

| Enumeration | GOOSE dataset items |
|---|---|
| 123 | GGIO1.ST.Ind62.q |
| 124 | GGIO1.ST.Ind62.stVal |
| 125 | GGIO1.ST.Ind63.q |
| 126 | GGIO1.ST.Ind63.stVal |
| 127 | GGIO1.ST.Ind64.q |
| 128 | GGIO1.ST.Ind64.stVal |
| 129 | GGIO1.ST.Ind65.q |
| 130 | GGIO1.ST.Ind65.stVal |
| 131 | GGIO1.ST.Ind66.q |
| 132 | GGIO1.ST.Ind66.stVal |
| 133 | GGIO1.ST.Ind67.q |
| 134 | GGIO1.ST.Ind67.stVal |
| 135 | GGIO1.ST.Ind68.q |
| 136 | GGIO1.ST.Ind68.stVal |
| 137 | GGIO1.ST.Ind69.q |
| 138 | GGIO1.ST.Ind69.stVal |
| 139 | GGIO1.ST.Ind70.q |
| 140 | GGIO1.ST.Ind70.stVal |
| 141 | GGIO1.ST.Ind71.q |
| 142 | GGIO1.ST.Ind71.stVal |
| 143 | GGIO1.ST.Ind72.q |
| 144 | GGIO1.ST.Ind72.stVal |
| 145 | GGIO1.ST.Ind73.q |
| 146 | GGIO1.ST.Ind73.stVal |
| 147 | GGIO1.ST.Ind74.q |
| 148 | GGIO1.ST.Ind74.stVal |
| 149 | GGIO1.ST.Ind75.q |
| 150 | GGIO1.ST.Ind75.stVal |
| 151 | GGIO1.ST.Ind76.q |
| 152 | GGIO1.ST.Ind76.stVal |
| 153 | GGIO1.ST.Ind77.q |
| 154 | GGIO1.ST.Ind77.stVal |
| 155 | GGIO1.ST.Ind78.q |
| 156 | GGIO1.ST.Ind78.stVal |
| 157 | GGIO1.ST.Ind79.q |
| 158 | GGIO1.ST.Ind79.stVal |
| 159 | GGIO1.ST.Ind80.q |
| 160 | GGIO1.ST.Ind80.stVal |
| 161 | GGIO1.ST.Ind81.q |
| 162 | GGIO1.ST.Ind81.stVal |
| 163 | GGIO1.ST.Ind82.q |
| 164 | GGIO1.ST.Ind82.stVal |
| 165 | GGIO1.ST.Ind83.q |
| 166 | GGIO1.ST.Ind83.stVal |
| 167 | GGIO1.ST.Ind84.q |
| 168 | GGIO1.ST.Ind84.stVal |
| 169 | GGIO1.ST.Ind85.q |
| 170 | GGIO1.ST.Ind85.stVal |
| 171 | GGIO1.ST.Ind86.q |
| 172 | GGIO1.ST.Ind86.stVal |
| 173 | GGIO1.ST.Ind87.q |
| 174 | GGIO1.ST.Ind87.stVal |
| 175 | GGIO1.ST.Ind88.q |

| Enumeration | GOOSE dataset items |
|---|---|
| 176 | GGIO1.ST.Ind88.stVal |
| 177 | GGIO1.ST.Ind89.q |
| 178 | GGIO1.ST.Ind89.stVal |
| 179 | GGIO1.ST.Ind90.q |
| 180 | GGIO1.ST.Ind90.stVal |
| 181 | GGIO1.ST.Ind91.q |
| 182 | GGIO1.ST.Ind91.stVal |
| 183 | GGIO1.ST.Ind92.q |
| 184 | GGIO1.ST.Ind92.stVal |
| 185 | GGIO1.ST.Ind93.q |
| 186 | GGIO1.ST.Ind93.stVal |
| 187 | GGIO1.ST.Ind94.q |
| 188 | GGIO1.ST.Ind94.stVal |
| 189 | GGIO1.ST.Ind95.q |
| 190 | GGIO1.ST.Ind95.stVal |
| 191 | GGIO1.ST.Ind96.q |
| 192 | GGIO1.ST.Ind96.stVal |
| 193 | GGIO1.ST.Ind97.q |
| 194 | GGIO1.ST.Ind97.stVal |
| 195 | GGIO1.ST.Ind98.q |
| 196 | GGIO1.ST.Ind98.stVal |
| 197 | GGIO1.ST.Ind99.q |
| 198 | GGIO1.ST.Ind99.stVal |
| 199 | GGIO1.ST.Ind100.q |
| 200 | GGIO1.ST.Ind100.stVal |
| 201 | GGIO1.ST.Ind101.q |
| 202 | GGIO1.ST.Ind101.stVal |
| 203 | GGIO1.ST.Ind102.q |
| 204 | GGIO1.ST.Ind102.stVal |
| 205 | GGIO1.ST.Ind103.q |
| 206 | GGIO1.ST.Ind103.stVal |
| 207 | GGIO1.ST.Ind104.q |
| 208 | GGIO1.ST.Ind104.stVal |
| 209 | GGIO1.ST.Ind105.q |
| 210 | GGIO1.ST.Ind105.stVal |
| 211 | GGIO1.ST.Ind106.q |
| 212 | GGIO1.ST.Ind106.stVal |
| 213 | GGIO1.ST.Ind107.q |
| 214 | GGIO1.ST.Ind107.stVal |
| 215 | GGIO1.ST.Ind108.q |
| 216 | GGIO1.ST.Ind108.stVal |
| 217 | GGIO1.ST.Ind109.q |
| 218 | GGIO1.ST.Ind109.stVal |
| 219 | GGIO1.ST.Ind110.q |
| 220 | GGIO1.ST.Ind110.stVal |
| 221 | GGIO1.ST.Ind111.q |
| 222 | GGIO1.ST.Ind111.stVal |
| 223 | GGIO1.ST.Ind112.q |
| 224 | GGIO1.ST.Ind112.stVal |
| 225 | GGIO1.ST.Ind113.q |
| 226 | GGIO1.ST.Ind113.stVal |
| 227 | GGIO1.ST.Ind114.q |
| 228 | GGIO1.ST.Ind114.stVal |

| Enumeration | GOOSE dataset items |
|---|---|
| 229 | GGIO1.ST.Ind115.q |
| 230 | GGIO1.ST.Ind115.stVal |
| 231 | GGIO1.ST.Ind116.q |
| 232 | GGIO1.ST.Ind116.stVal |
| 233 | GGIO1.ST.Ind117.q |
| 234 | GGIO1.ST.Ind117.stVal |
| 235 | GGIO1.ST.Ind118.q |
| 236 | GGIO1.ST.Ind118.stVal |
| 237 | GGIO1.ST.Ind119.q |
| 238 | GGIO1.ST.Ind119.stVal |
| 239 | GGIO1.ST.Ind120.q |
| 240 | GGIO1.ST.Ind120.stVal |
| 241 | GGIO1.ST.Ind121.q |
| 242 | GGIO1.ST.Ind121.stVal |
| 243 | GGIO1.ST.Ind122.q |
| 244 | GGIO1.ST.Ind122.stVal |
| 245 | GGIO1.ST.Ind123.q |
| 246 | GGIO1.ST.Ind123.stVal |
| 247 | GGIO1.ST.Ind124.q |
| 248 | GGIO1.ST.Ind124.stVal |
| 249 | GGIO1.ST.Ind125.q |
| 250 | GGIO1.ST.Ind125.stVal |
| 251 | GGIO1.ST.Ind126.q |
| 252 | GGIO1.ST.Ind126.stVal |
| 253 | GGIO1.ST.Ind127.q |
| 254 | GGIO1.ST.Ind127.stVal |
| 255 | GGIO1.ST.Ind128.q |
| 256 | GGIO1.ST.Ind128.stVal |
| 257 | MMXU1.MX.TotW.mag.f |
| 258 | MMXU1.MX.TotVAr.mag.f |
| 259 | MMXU1.MX.TotVA.mag.f |
| 260 | MMXU1.MX.TotPF.mag.f |
| 261 | MMXU1.MX.Hz.mag.f |
| 262 | MMXU1.MX.PPV.phsAB.cVal.mag.f |
| 263 | MMXU1.MX.PPV.phsAB.cVal.ang.f |
| 264 | MMXU1.MX.PPV.phsBC.cVal.mag.f |
| 265 | MMXU1.MX.PPV.phsBC.cVal.ang.f |
| 266 | MMXU1.MX.PPV.phsCA.cVal.mag.f |
| 267 | MMXU1.MX.PPV.phsCA.cVal.ang.f |
| 268 | MMXU1.MX.PhV.phsA.cVal.mag.f |
| 269 | MMXU1.MX.PhV.phsA.cVal.ang.f |
| 270 | MMXU1.MX.PhV.phsB.cVal.mag.f |
| 271 | MMXU1.MX.PhV.phsB.cVal.ang.f |
| 272 | MMXU1.MX.PhV.phsC.cVal.mag.f |
| 273 | MMXU1.MX.PhV.phsC.cVal.ang.f |
| 274 | MMXU1.MX.A.phsA.cVal.mag.f |
| 275 | MMXU1.MX.A.phsA.cVal.ang.f |
| 276 | MMXU1.MX.A.phsB.cVal.mag.f |
| 277 | MMXU1.MX.A.phsB.cVal.ang.f |
| 278 | MMXU1.MX.A.phsC.cVal.mag.f |
| 279 | MMXU1.MX.A.phsC.cVal.ang.f |
| 280 | MMXU1.MX.A.neut.cVal.mag.f |
| 281 | MMXU1.MX.A.neut.cVal.ang.f |

| Enumeration | GOOSE dataset items |
|---|---|
| 282 | MMXU1.MX.W.phsA.cVal.mag.f |
| 283 | MMXU1.MX.W.phsB.cVal.mag.f |
| 284 | MMXU1.MX.W.phsC.cVal.mag.f |
| 285 | MMXU1.MX.VAr.phsA.cVal.mag.f |
| 286 | MMXU1.MX.VAr.phsB.cVal.mag.f |
| 287 | MMXU1.MX.VAr.phsC.cVal.mag.f |
| 288 | MMXU1.MX.VA.phsA.cVal.mag.f |
| 289 | MMXU1.MX.VA.phsB.cVal.mag.f |
| 290 | MMXU1.MX.VA.phsC.cVal.mag.f |
| 291 | MMXU1.MX.PF.phsA.cVal.mag.f |
| 292 | MMXU1.MX.PF.phsB.cVal.mag.f |
| 293 | MMXU1.MX.PF.phsC.cVal.mag.f |
| 294 | MMXU2.MX.TotW.mag.f |
| 295 | MMXU2.MX.TotVAr.mag.f |
| 296 | MMXU2.MX.TotVA.mag.f |
| 297 | MMXU2.MX.TotPF.mag.f |
| 298 | MMXU2.MX.Hz.mag.f |
| 299 | MMXU2.MX.PPV.phsAB.cVal.mag.f |
| 300 | MMXU2.MX.PPV.phsAB.cVal.ang.f |
| 301 | MMXU2.MX.PPV.phsBC.cVal.mag.f |
| 302 | MMXU2.MX.PPV.phsBC.cVal.ang.f |
| 303 | MMXU2.MX.PPV.phsCA.cVal.mag.f |
| 304 | MMXU2.MX.PPV.phsCA.cVal.ang.f |
| 305 | MMXU2.MX.PhV.phsA.cVal.mag.f |
| 306 | MMXU2.MX.PhV.phsA.cVal.ang.f |
| 307 | MMXU2.MX.PhV.phsB.cVal.mag.f |
| 308 | MMXU2.MX.PhV.phsB.cVal.ang.f |
| 309 | MMXU2.MX.PhV.phsC.cVal.mag.f |
| 310 | MMXU2.MX.PhV.phsC.cVal.ang.f |
| 311 | MMXU2.MX.A.phsA.cVal.mag.f |
| 312 | MMXU2.MX.A.phsA.cVal.ang.f |
| 313 | MMXU2.MX.A.phsB.cVal.mag.f |
| 314 | MMXU2.MX.A.phsB.cVal.ang.f |
| 315 | MMXU2.MX.A.phsC.cVal.mag.f |
| 316 | MMXU2.MX.A.phsC.cVal.ang.f |
| 317 | MMXU2.MX.A.neut.cVal.mag.f |
| 318 | MMXU2.MX.A.neut.cVal.ang.f |
| 319 | MMXU2.MX.W.phsA.cVal.mag.f |
| 320 | MMXU2.MX.W.phsB.cVal.mag.f |
| 321 | MMXU2.MX.W.phsC.cVal.mag.f |
| 322 | MMXU2.MX.VAr.phsA.cVal.mag.f |
| 323 | MMXU2.MX.VAr.phsB.cVal.mag.f |
| 324 | MMXU2.MX.VAr.phsC.cVal.mag.f |
| 325 | MMXU2.MX.VA.phsA.cVal.mag.f |
| 326 | MMXU2.MX.VA.phsB.cVal.mag.f |
| 327 | MMXU2.MX.VA.phsC.cVal.mag.f |
| 328 | MMXU2.MX.PF.phsA.cVal.mag.f |
| 329 | MMXU2.MX.PF.phsB.cVal.mag.f |
| 330 | MMXU2.MX.PF.phsC.cVal.mag.f |
| 331 | MMXU3.MX.TotW.mag.f |
| 332 | MMXU3.MX.TotVAr.mag.f |
| 333 | MMXU3.MX.TotVA.mag.f |
| 334 | MMXU3.MX.TotPF.mag.f |

| Enumeration | GOOSE dataset items |
|---|---|
| 335 | MMXU3.MX.Hz.mag.f |
| 336 | MMXU3.MX.PPV.phsAB.cVal.mag.f |
| 337 | MMXU3.MX.PPV.phsAB.cVal.ang.f |
| 338 | MMXU3.MX.PPV.phsBC.cVal.mag.f |
| 339 | MMXU3.MX.PPV.phsBC.cVal.ang.f |
| 340 | MMXU3.MX.PPV.phsCA.cVal.mag.f |
| 341 | MMXU3.MX.PPV.phsCA.cVal.ang.f |
| 342 | MMXU3.MX.PhV.phsA.cVal.mag.f |
| 343 | MMXU3.MX.PhV.phsA.cVal.ang.f |
| 344 | MMXU3.MX.PhV.phsB.cVal.mag.f |
| 345 | MMXU3.MX.PhV.phsB.cVal.ang.f |
| 346 | MMXU3.MX.PhV.phsC.cVal.mag.f |
| 347 | MMXU3.MX.PhV.phsC.cVal.ang.f |
| 348 | MMXU3.MX.A.phsA.cVal.mag.f |
| 349 | MMXU3.MX.A.phsA.cVal.ang.f |
| 350 | MMXU3.MX.A.phsB.cVal.mag.f |
| 351 | MMXU3.MX.A.phsB.cVal.ang.f |
| 352 | MMXU3.MX.A.phsC.cVal.mag.f |
| 353 | MMXU3.MX.A.phsC.cVal.ang.f |
| 354 | MMXU3.MX.A.neut.cVal.mag.f |
| 355 | MMXU3.MX.A.neut.cVal.ang.f |
| 356 | MMXU3.MX.W.phsA.cVal.mag.f |
| 357 | MMXU3.MX.W.phsB.cVal.mag.f |
| 358 | MMXU3.MX.W.phsC.cVal.mag.f |
| 359 | MMXU3.MX.VAr.phsA.cVal.mag.f |
| 360 | MMXU3.MX.VAr.phsB.cVal.mag.f |
| 361 | MMXU3.MX.VAr.phsC.cVal.mag.f |
| 362 | MMXU3.MX.VA.phsA.cVal.mag.f |
| 363 | MMXU3.MX.VA.phsB.cVal.mag.f |
| 364 | MMXU3.MX.VA.phsC.cVal.mag.f |
| 365 | MMXU3.MX.PF.phsA.cVal.mag.f |
| 366 | MMXU3.MX.PF.phsB.cVal.mag.f |
| 367 | MMXU3.MX.PF.phsC.cVal.mag.f |
| 368 | MMXU4.MX.TotW.mag.f |
| 369 | MMXU4.MX.TotVAr.mag.f |
| 370 | MMXU4.MX.TotVA.mag.f |
| 371 | MMXU4.MX.TotPF.mag.f |
| 372 | MMXU4.MX.Hz.mag.f |
| 373 | MMXU4.MX.PPV.phsAB.cVal.mag.f |
| 374 | MMXU4.MX.PPV.phsAB.cVal.ang.f |
| 375 | MMXU4.MX.PPV.phsBC.cVal.mag.f |
| 376 | MMXU4.MX.PPV.phsBC.cVal.ang.f |
| 377 | MMXU4.MX.PPV.phsCA.cVal.mag.f |
| 378 | MMXU4.MX.PPV.phsCA.cVal.ang.f |
| 379 | MMXU4.MX.PhV.phsA.cVal.mag.f |
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| 383 | MMXU4.MX.PhV.phsC.cVal.mag.f |
| 384 | MMXU4.MX.PhV.phsC.cVal.ang.f |
| 385 | MMXU4.MX.A.phsA.cVal.mag.f |
| 386 | MMXU4.MX.A.phsA.cVal.ang.f |
| 387 | MMXU4.MX.A.phsB.cVal.mag.f |

| Enumeration | GOOSE dataset items |
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| 388 | MMXU4.MX.A.phsB.cVal.ang.f |
| 389 | MMXU4.MX.A.phsC.cVal.mag.f |
| 390 | MMXU4.MX.A.phsC.cVal.ang.f |
| 391 | MMXU4.MX.A.neut.cVal.mag.f |
| 392 | MMXU4.MX.A.neut.cVal.ang.f |
| 393 | MMXU4.MX.W.phsA.cVal.mag.f |
| 394 | MMXU4.MX.W.phsB.cVal.mag.f |
| 395 | MMXU4.MX.W.phsC.cVal.mag.f |
| 396 | MMXU4.MX.VAr.phsA.cVal.mag.f |
| 397 | MMXU4.MX.VAr.phsB.cVal.mag.f |
| 398 | MMXU4.MX.VAr.phsC.cVal.mag.f |
| 399 | MMXU4.MX.VA.phsA.cVal.mag.f |
| 400 | MMXU4.MX.VA.phsB.cVal.mag.f |
| 401 | MMXU4.MX.VA.phsC.cVal.mag.f |
| 402 | MMXU4.MX.PF.phsA.cVal.mag.f |
| 403 | MMXU4.MX.PF.phsB.cVal.mag.f |
| 404 | MMXU4.MX.PF.phsC.cVal.mag.f |
| 405 | MMXU5.MX.TotW.mag.f |
| 406 | MMXU5.MX.TotVAr.mag.f |
| 407 | MMXU5.MX.TotVA.mag.f |
| 408 | MMXU5.MX.TotPF.mag.f |
| 409 | MMXU5.MX.Hz.mag.f |
| 410 | MMXU5.MX.PPV.phsAB.cVal.mag.f |
| 411 | MMXU5.MX.PPV.phsAB.cVal.ang.f |
| 412 | MMXU5.MX.PPV.phsBC.cVal.mag.f |
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| 414 | MMXU5.MX.PPV.phsCA.cVal.mag.f |
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| 416 | MMXU5.MX.PhV.phsA.cVal.mag.f |
| 417 | MMXU5.MX.PhV.phsA.cVal.ang.f |
| 418 | MMXU5.MX.PhV.phsB.cVal.mag.f |
| 419 | MMXU5.MX.PhV.phsB.cVal.ang.f |
| 420 | MMXU5.MX.PhV.phsC.cVal.mag.f |
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| 423 | MMXU5.MX.A.phsA.cVal.ang.f |
| 424 | MMXU5.MX.A.phsB.cVal.mag.f |
| 425 | MMXU5.MX.A.phsB.cVal.ang.f |
| 426 | MMXU5.MX.A.phsC.cVal.mag.f |
| 427 | MMXU5.MX.A.phsC.cVal.ang.f |
| 428 | MMXU5.MX.A.neut.cVal.mag.f |
| 429 | MMXU5.MX.A.neut.cVal.ang.f |
| 430 | MMXU5.MX.W.phsA.cVal.mag.f |
| 431 | MMXU5.MX.W.phsB.cVal.mag.f |
| 432 | MMXU5.MX.W.phsC.cVal.mag.f |
| 433 | MMXU5.MX.VAr.phsA.cVal.mag.f |
| 434 | MMXU5.MX.VAr.phsB.cVal.mag.f |
| 435 | MMXU5.MX.VAr.phsC.cVal.mag.f |
| 436 | MMXU5.MX.VA.phsA.cVal.mag.f |
| 437 | MMXU5.MX.VA.phsB.cVal.mag.f |
| 438 | MMXU5.MX.VA.phsC.cVal.mag.f |
| 439 | MMXU5.MX.PF.phsA.cVal.mag.f |
| 440 | MMXU5.MX.PF.phsB.cVal.mag.f |

| Enumeration | GOOSE dataset items |
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| 441 | MMXU5.MX.PF.phsC.cVal.mag.f |
| 442 | MMXU6.MX.TotW.mag.f |
| 443 | MMXU6.MX.TotVAr.mag.f |
| 444 | MMXU6.MX.TotVA.mag.f |
| 445 | MMXU6.MX.TotPF.mag.f |
| 446 | MMXU6.MX.Hz.mag.f |
| 447 | MMXU6.MX.PPV.phsAB.cVal.mag.f |
| 448 | MMXU6.MX.PPV.phsAB.cVal.ang.f |
| 449 | MMXU6.MX.PPV.phsBC.cVal.mag.f |
| 450 | MMXU6.MX.PPV.phsBC.cVal.ang.f |
| 451 | MMXU6.MX.PPV.phsCA.cVal.mag.f |
| 452 | MMXU6.MX.PPV.phsCA.cVal.ang.f |
| 453 | MMXU6.MX.PhV.phsA.cVal.mag.f |
| 454 | MMXU6.MX.PhV.phsA.cVal.ang.f |
| 455 | MMXU6.MX.PhV.phsB.cVal.mag.f |
| 456 | MMXU6.MX.PhV.phsB.cVal.ang.f |
| 457 | MMXU6.MX.PhV.phsC.cVal.mag.f |
| 458 | MMXU6.MX.PhV.phsC.cVal.ang.f |
| 459 | MMXU6.MX.A.phsA.cVal.mag.f |
| 460 | MMXU6.MX.A.phsA.cVal.ang.f |
| 461 | MMXU6.MX.A.phsB.cVal.mag.f |
| 462 | MMXU6.MX.A.phsB.cVal.ang.f |
| 463 | MMXU6.MX.A.phsC.cVal.mag.f |
| 464 | MMXU6.MX.A.phsC.cVal.ang.f |
| 465 | MMXU6.MX.A.neut.cVal.mag.f |
| 466 | MMXU6.MX.A.neut.cVal.ang.f |
| 467 | MMXU6.MX.W.phsA.cVal.mag.f |
| 468 | MMXU6.MX.W.phsB.cVal.mag.f |
| 469 | MMXU6.MX.W.phsC.cVal.mag.f |
| 470 | MMXU6.MX.VAr.phsA.cVal.mag.f |
| 471 | MMXU6.MX.VAr.phsB.cVal.mag.f |
| 472 | MMXU6.MX.VAr.phsC.cVal.mag.f |
| 473 | MMXU6.MX.VA.phsA.cVal.mag.f |
| 474 | MMXU6.MX.VA.phsB.cVal.mag.f |
| 475 | MMXU6.MX.VA.phsC.cVal.mag.f |
| 476 | MMXU6.MX.PF.phsA.cVal.mag.f |
| 477 | MMXU6.MX.PF.phsB.cVal.mag.f |
| 478 | MMXU6.MX.PF.phsC.cVal.mag.f |
| 479 | GGIO4.MX.AnIn1.mag.f |
| 480 | GGIO4.MX.AnIn2.mag.f |
| 481 | GGIO4.MX.AnIn3.mag.f |
| 482 | GGIO4.MX.AnIn4.mag.f |
| 483 | GGIO4.MX.AnIn5.mag.f |
| 484 | GGIO4.MX.AnIn6.mag.f |
| 485 | GGIO4.MX.AnIn7.mag.f |
| 486 | GGIO4.MX.AnIn8.mag.f |
| 487 | GGIO4.MX.AnIn9.mag.f |
| 488 | GGIO4.MX.AnIn10.mag.f |
| 489 | GGIO4.MX.AnIn11.mag.f |
| 490 | GGIO4.MX.AnIn12.mag.f |
| 491 | GGIO4.MX.AnIn13.mag.f |
| 492 | GGIO4.MX.AnIn14.mag.f |
| 493 | GGIO4.MX.AnIn15.mag.f |

| Enumeration | GOOSE dataset items |
|---|---|
| 494 | GGIO4.MX.AnIn16.mag.f |
| 495 | GGIO4.MX.AnIn17.mag.f |
| 496 | GGIO4.MX.AnIn18.mag.f |
| 497 | GGIO4.MX.AnIn19.mag.f |
| 498 | GGIO4.MX.AnIn20.mag.f |
| 499 | GGIO4.MX.AnIn21.mag.f |
| 500 | GGIO4.MX.AnIn22.mag.f |
| 501 | GGIO4.MX.AnIn23.mag.f |
| 502 | GGIO4.MX.AnIn24.mag.f |
| 503 | GGIO4.MX.AnIn25.mag.f |
| 504 | GGIO4.MX.AnIn26.mag.f |
| 505 | GGIO4.MX.AnIn27.mag.f |
| 506 | GGIO4.MX.AnIn28.mag.f |
| 507 | GGIO4.MX.AnIn29.mag.f |
| 508 | GGIO4.MX.AnIn30.mag.f |
| 509 | GGIO4.MX.AnIn31.mag.f |
| 510 | GGIO4.MX.AnIn32.mag.f |
| 511 | GGIO5.ST.UIntIn1.q |
| 512 | GGIO5.ST.UIntIn1.stVal |
| 513 | GGIO5.ST.UIntIn2.q |
| 514 | GGIO5.ST.UIntIn2.stVal |
| 515 | GGIO5.ST.UIntIn3.q |
| 516 | GGIO5.ST.UIntIn3.stVal |
| 517 | GGIO5.ST.UIntIn4.q |
| 518 | GGIO5.ST.UIntIn4.stVal |
| 519 | GGIO5.ST.UIntIn5.q |
| 520 | GGIO5.ST.UIntIn5.stVal |
| 521 | GGIO5.ST.UIntIn6.q |
| 522 | GGIO5.ST.UIntIn6.stVal |
| 523 | GGIO5.ST.UIntIn7.q |
| 524 | GGIO5.ST.UIntIn7.stVal |
| 525 | GGIO5.ST.UIntIn8.q |
| 526 | GGIO5.ST.UIntIn8.stVal |
| 527 | GGIO5.ST.UIntIn9.q |
| 528 | GGIO5.ST.UIntIn9.stVal |
| 529 | GGIO5.ST.UIntIn10.q |
| 530 | GGIO5.ST.UIntIn10.stVal |
| 531 | GGIO5.ST.UIntIn11.q |
| 532 | GGIO5.ST.UIntIn11.stVal |
| 533 | GGIO5.ST.UIntIn12.q |
| 534 | GGIO5.ST.UIntIn12.stVal |
| 535 | GGIO5.ST.UIntIn13.q |
| 536 | GGIO5.ST.UIntIn13.stVal |
| 537 | GGIO5.ST.UIntIn14.q |
| 538 | GGIO5.ST.UIntIn14.stVal |
| 539 | GGIO5.ST.UIntIn15.q |
| 540 | GGIO5.ST.UIntIn15.stVal |
| 541 | GGIO5.ST.UIntIn16.q |
| 542 | GGIO5.ST.UIntIn16.stVal |
| 543 | PDIF1.ST.Str.general |
| 544 | PDIF1.ST.Op.general |
| 545 | PDIF2.ST.Str.general |
| 546 | PDIF2.ST.Op.general |

| Enumeration | GOOSE dataset items |
|---|---|
| 547 | PDIF3.ST.Str.general |
| 548 | PDIF3.ST.Op.general |
| 549 | PDIF4.ST.Str.general |
| 550 | PDIF4.ST.Op.general |
| 551 | PDIS1.ST.Str.general |
| 552 | PDIS1.ST.Op.general |
| 553 | PDIS2.ST.Str.general |
| 554 | PDIS2.ST.Op.general |
| 555 | PDIS3.ST.Str.general |
| 556 | PDIS3.ST.Op.general |
| 557 | PDIS4.ST.Str.general |
| 558 | PDIS4.ST.Op.general |
| 559 | PDIS5.ST.Str.general |
| 560 | PDIS5.ST.Op.general |
| 561 | PDIS6.ST.Str.general |
| 562 | PDIS6.ST.Op.general |
| 563 | PDIS7.ST.Str.general |
| 564 | PDIS7.ST.Op.general |
| 565 | PDIS8.ST.Str.general |
| 566 | PDIS8.ST.Op.general |
| 567 | PDIS9.ST.Str.general |
| 568 | PDIS9.ST.Op.general |
| 569 | PDIS10.ST.Str.general |
| 570 | PDIS10.ST.Op.general |
| 571 | PIOC1.ST.Str.general |
| 572 | PIOC1.ST.Op.general |
| 573 | PIOC2.ST.Str.general |
| 574 | PIOC2.ST.Op.general |
| 575 | PIOC3.ST.Str.general |
| 576 | PIOC3.ST.Op.general |
| 577 | PIOC4.ST.Str.general |
| 578 | PIOC4.ST.Op.general |
| 579 | PIOC5.ST.Str.general |
| 580 | PIOC5.ST.Op.general |
| 581 | PIOC6.ST.Str.general |
| 582 | PIOC6.ST.Op.general |
| 583 | PIOC7.ST.Str.general |
| 584 | PIOC7.ST.Op.general |
| 585 | PIOC8.ST.Str.general |
| 586 | PIOC8.ST.Op.general |
| 587 | PIOC9.ST.Str.general |
| 588 | PIOC9.ST.Op.general |
| 589 | PIOC10.ST.Str.general |
| 590 | PIOC10.ST.Op.general |
| 591 | PIOC11.ST.Str.general |
| 592 | PIOC11.ST.Op.general |
| 593 | PIOC12.ST.Str.general |
| 594 | PIOC12.ST.Op.general |
| 595 | PIOC13.ST.Str.general |
| 596 | PIOC13.ST.Op.general |
| 597 | PIOC14.ST.Str.general |
| 598 | PIOC14.ST.Op.general |
| 599 | PIOC15.ST.Str.general |

| Enumeration | GOOSE dataset items |
|---|---|
| 600 | PIOC15.ST.Op.general |
| 601 | PIOC16.ST.Str.general |
| 602 | PIOC16.ST.Op.general |
| 603 | PIOC17.ST.Str.general |
| 604 | PIOC17.ST.Op.general |
| 605 | PIOC18.ST.Str.general |
| 606 | PIOC18.ST.Op.general |
| 607 | PIOC19.ST.Str.general |
| 608 | PIOC19.ST.Op.general |
| 609 | PIOC20.ST.Str.general |
| 610 | PIOC20.ST.Op.general |
| 611 | PIOC21.ST.Str.general |
| 612 | PIOC21.ST.Op.general |
| 613 | PIOC22.ST.Str.general |
| 614 | PIOC22.ST.Op.general |
| 615 | PIOC23.ST.Str.general |
| 616 | PIOC23.ST.Op.general |
| 617 | PIOC24.ST.Str.general |
| 618 | PIOC24.ST.Op.general |
| 619 | PIOC25.ST.Str.general |
| 620 | PIOC25.ST.Op.general |
| 621 | PIOC26.ST.Str.general |
| 622 | PIOC26.ST.Op.general |
| 623 | PIOC27.ST.Str.general |
| 624 | PIOC27.ST.Op.general |
| 625 | PIOC28.ST.Str.general |
| 626 | PIOC28.ST.Op.general |
| 627 | PIOC29.ST.Str.general |
| 628 | PIOC29.ST.Op.general |
| 629 | PIOC30.ST.Str.general |
| 630 | PIOC30.ST.Op.general |
| 631 | PIOC31.ST.Str.general |
| 632 | PIOC31.ST.Op.general |
| 633 | PIOC32.ST.Str.general |
| 634 | PIOC32.ST.Op.general |
| 635 | PIOC33.ST.Str.general |
| 636 | PIOC33.ST.Op.general |
| 637 | PIOC34.ST.Str.general |
| 638 | PIOC34.ST.Op.general |
| 639 | PIOC35.ST.Str.general |
| 640 | PIOC35.ST.Op.general |
| 641 | PIOC36.ST.Str.general |
| 642 | PIOC36.ST.Op.general |
| 643 | PIOC37.ST.Str.general |
| 644 | PIOC37.ST.Op.general |
| 645 | PIOC38.ST.Str.general |
| 646 | PIOC38.ST.Op.general |
| 647 | PIOC39.ST.Str.general |
| 648 | PIOC39.ST.Op.general |
| 649 | PIOC40.ST.Str.general |
| 650 | PIOC40.ST.Op.general |
| 651 | PIOC41.ST.Str.general |
| 652 | PIOC41.ST.Op.general |

| Enumeration | GOOSE dataset items |
|---|---|
| 653 | PIOC42.ST.Str.general |
| 654 | PIOC42.ST.Op.general |
| 655 | PIOC43.ST.Str.general |
| 656 | PIOC43.ST.Op.general |
| 657 | PIOC44.ST.Str.general |
| 658 | PIOC44.ST.Op.general |
| 659 | PIOC45.ST.Str.general |
| 660 | PIOC45.ST.Op.general |
| 661 | PIOC46.ST.Str.general |
| 662 | PIOC46.ST.Op.general |
| 663 | PIOC47.ST.Str.general |
| 664 | PIOC47.ST.Op.general |
| 665 | PIOC48.ST.Str.general |
| 666 | PIOC48.ST.Op.general |
| 667 | PIOC49.ST.Str.general |
| 668 | PIOC49.ST.Op.general |
| 669 | PIOC50.ST.Str.general |
| 670 | PIOC50.ST.Op.general |
| 671 | PIOC51.ST.Str.general |
| 672 | PIOC51.ST.Op.general |
| 673 | PIOC52.ST.Str.general |
| 674 | PIOC52.ST.Op.general |
| 675 | PIOC53.ST.Str.general |
| 676 | PIOC53.ST.Op.general |
| 677 | PIOC54.ST.Str.general |
| 678 | PIOC54.ST.Op.general |
| 679 | PIOC55.ST.Str.general |
| 680 | PIOC55.ST.Op.general |
| 681 | PIOC56.ST.Str.general |
| 682 | PIOC56.ST.Op.general |
| 683 | PIOC57.ST.Str.general |
| 684 | PIOC57.ST.Op.general |
| 685 | PIOC58.ST.Str.general |
| 686 | PIOC58.ST.Op.general |
| 687 | PIOC59.ST.Str.general |
| 688 | PIOC59.ST.Op.general |
| 689 | PIOC60.ST.Str.general |
| 690 | PIOC60.ST.Op.general |
| 691 | PIOC61.ST.Str.general |
| 692 | PIOC61.ST.Op.general |
| 693 | PIOC62.ST.Str.general |
| 694 | PIOC62.ST.Op.general |
| 695 | PIOC63.ST.Str.general |
| 696 | PIOC63.ST.Op.general |
| 697 | PIOC64.ST.Str.general |
| 698 | PIOC64.ST.Op.general |
| 699 | PIOC65.ST.Str.general |
| 700 | PIOC65.ST.Op.general |
| 701 | PIOC66.ST.Str.general |
| 702 | PIOC66.ST.Op.general |
| 703 | PIOC67.ST.Str.general |
| 704 | PIOC67.ST.Op.general |
| 705 | PIOC68.ST.Str.general |

| Enumeration | GOOSE dataset items |
|---|---|
| 706 | PIOC68.ST.Op.general |
| 707 | PIOC69.ST.Str.general |
| 708 | PIOC69.ST.Op.general |
| 709 | PIOC70.ST.Str.general |
| 710 | PIOC70.ST.Op.general |
| 711 | PIOC71.ST.Str.general |
| 712 | PIOC71.ST.Op.general |
| 713 | PIOC72.ST.Str.general |
| 714 | PIOC72.ST.Op.general |
| 715 | PTOC1.ST.Str.general |
| 716 | PTOC1.ST.Op.general |
| 717 | PTOC2.ST.Str.general |
| 718 | PTOC2.ST.Op.general |
| 719 | PTOC3.ST.Str.general |
| 720 | PTOC3.ST.Op.general |
| 721 | PTOC4.ST.Str.general |
| 722 | PTOC4.ST.Op.general |
| 723 | PTOC5.ST.Str.general |
| 724 | PTOC5.ST.Op.general |
| 725 | PTOC6.ST.Str.general |
| 726 | PTOC6.ST.Op.general |
| 727 | PTOC7.ST.Str.general |
| 728 | PTOC7.ST.Op.general |
| 729 | PTOC8.ST.Str.general |
| 730 | PTOC8.ST.Op.general |
| 731 | PTOC9.ST.Str.general |
| 732 | PTOC9.ST.Op.general |
| 733 | PTOC10.ST.Str.general |
| 734 | PTOC10.ST.Op.general |
| 735 | PTOC11.ST.Str.general |
| 736 | PTOC11.ST.Op.general |
| 737 | PTOC12.ST.Str.general |
| 738 | PTOC12.ST.Op.general |
| 739 | PTOC13.ST.Str.general |
| 740 | PTOC13.ST.Op.general |
| 741 | PTOC14.ST.Str.general |
| 742 | PTOC14.ST.Op.general |
| 743 | PTOC15.ST.Str.general |
| 744 | PTOC15.ST.Op.general |
| 745 | PTOC16.ST.Str.general |
| 746 | PTOC16.ST.Op.general |
| 747 | PTOC17.ST.Str.general |
| 748 | PTOC17.ST.Op.general |
| 749 | PTOC18.ST.Str.general |
| 750 | PTOC18.ST.Op.general |
| 751 | PTOC19.ST.Str.general |
| 752 | PTOC19.ST.Op.general |
| 753 | PTOC20.ST.Str.general |
| 754 | PTOC20.ST.Op.general |
| 755 | PTOC21.ST.Str.general |
| 756 | PTOC21.ST.Op.general |
| 757 | PTOC22.ST.Str.general |
| 758 | PTOC22.ST.Op.general |

| Enumeration | GOOSE dataset items |
|---|---|
| 759 | PTOC23.ST.Str.general |
| 760 | PTOC23.ST.Op.general |
| 761 | PTOC24.ST.Str.general |
| 762 | PTOC24.ST.Op.general |
| 763 | PTOV1.ST.Str.general |
| 764 | PTOV1.ST.Op.general |
| 765 | PTOV2.ST.Str.general |
| 766 | PTOV2.ST.Op.general |
| 767 | PTOV3.ST.Str.general |
| 768 | PTOV3.ST.Op.general |
| 769 | PTOV4.ST.Str.general |
| 770 | PTOV4.ST.Op.general |
| 771 | PTOV5.ST.Str.general |
| 772 | PTOV5.ST.Op.general |
| 773 | PTOV6.ST.Str.general |
| 774 | PTOV6.ST.Op.general |
| 775 | PTOV7.ST.Str.general |
| 776 | PTOV7.ST.Op.general |
| 777 | PTOV8.ST.Str.general |
| 778 | PTOV8.ST.Op.general |
| 779 | PTOV9.ST.Str.general |
| 780 | PTOV9.ST.Op.general |
| 781 | PTOV10.ST.Str.general |
| 782 | PTOV10.ST.Op.general |
| 783 | PTRC1.ST.Tr.general |
| 784 | PTRC1.ST.Op.general |
| 785 | PTRC2.ST.Tr.general |
| 786 | PTRC2.ST.Op.general |
| 787 | PTRC3.ST.Tr.general |
| 788 | PTRC3.ST.Op.general |
| 789 | PTRC4.ST.Tr.general |
| 790 | PTRC4.ST.Op.general |
| 791 | PTRC5.ST.Tr.general |
| 792 | PTRC5.ST.Op.general |
| 793 | PTRC6.ST.Tr.general |
| 794 | PTRC6.ST.Op.general |
| 795 | PTUV1.ST.Str.general |
| 796 | PTUV1.ST.Op.general |
| 797 | PTUV2.ST.Str.general |
| 798 | PTUV2.ST.Op.general |
| 799 | PTUV3.ST.Str.general |
| 800 | PTUV3.ST.Op.general |
| 801 | PTUV4.ST.Str.general |
| 802 | PTUV4.ST.Op.general |
| 803 | PTUV5.ST.Str.general |
| 804 | PTUV5.ST.Op.general |
| 805 | PTUV6.ST.Str.general |
| 806 | PTUV6.ST.Op.general |
| 807 | PTUV7.ST.Str.general |
| 808 | PTUV7.ST.Op.general |
| 809 | PTUV8.ST.Str.general |
| 810 | PTUV8.ST.Op.general |
| 811 | PTUV9.ST.Str.general |

| Enumeration | GOOSE dataset items |
|---|---|
| 812 | PTUV9.ST.Op.general |
| 813 | PTUV10.ST.Str.general |
| 814 | PTUV10.ST.Op.general |
| 815 | PTUV11.ST.Str.general |
| 816 | PTUV11.ST.Op.general |
| 817 | PTUV12.ST.Str.general |
| 818 | PTUV12.ST.Op.general |
| 819 | PTUV13.ST.Str.general |
| 820 | PTUV13.ST.Op.general |
| 821 | RBRF1.ST.OpEx.general |
| 822 | RBRF1.ST.OpIn.general |
| 823 | RBRF2.ST.OpEx.general |
| 824 | RBRF2.ST.OpIn.general |
| 825 | RBRF3.ST.OpEx.general |
| 826 | RBRF3.ST.OpIn.general |
| 827 | RBRF4.ST.OpEx.general |
| 828 | RBRF4.ST.OpIn.general |
| 829 | RBRF5.ST.OpEx.general |
| 830 | RBRF5.ST.OpIn.general |
| 831 | RBRF6.ST.OpEx.general |
| 832 | RBRF6.ST.OpIn.general |
| 833 | RBRF7.ST.OpEx.general |
| 834 | RBRF7.ST.OpIn.general |
| 835 | RBRF8.ST.OpEx.general |
| 836 | RBRF8.ST.OpIn.general |
| 837 | RBRF9.ST.OpEx.general |
| 838 | RBRF9.ST.OpIn.general |
| 839 | RBRF10.ST.OpEx.general |
| 840 | RBRF10.ST.OpIn.general |
| 841 | RBRF11.ST.OpEx.general |
| 842 | RBRF11.ST.OpIn.general |
| 843 | RBRF12.ST.OpEx.general |
| 844 | RBRF12.ST.OpIn.general |
| 845 | RBRF13.ST.OpEx.general |
| 846 | RBRF13.ST.OpIn.general |
| 847 | RBRF14.ST.OpEx.general |
| 848 | RBRF14.ST.OpIn.general |
| 849 | RBRF15.ST.OpEx.general |
| 850 | RBRF15.ST.OpIn.general |
| 851 | RBRF16.ST.OpEx.general |
| 852 | RBRF16.ST.OpIn.general |
| 853 | RBRF17.ST.OpEx.general |
| 854 | RBRF17.ST.OpIn.general |
| 855 | RBRF18.ST.OpEx.general |
| 856 | RBRF18.ST.OpIn.general |
| 857 | RBRF19.ST.OpEx.general |
| 858 | RBRF19.ST.OpIn.general |
| 859 | RBRF20.ST.OpEx.general |
| 860 | RBRF20.ST.OpIn.general |
| 861 | RBRF21.ST.OpEx.general |
| 862 | RBRF21.ST.OpIn.general |
| 863 | RBRF22.ST.OpEx.general |
| 864 | RBRF22.ST.OpIn.general |

| Enumeration | GOOSE dataset items |
|---|---|
| 865 | RBRF23.ST.OpEx.general |
| 866 | RBRF23.ST.OpIn.general |
| 867 | RBRF24.ST.OpEx.general |
| 868 | RBRF24.ST.OpIn.general |
| 869 | RFLO1.MX.FltDiskm.mag.f |
| 870 | RFLO2.MX.FltDiskm.mag.f |
| 871 | RFLO3.MX.FltDiskm.mag.f |
| 872 | RFLO4.MX.FltDiskm.mag.f |
| 873 | RFLO5.MX.FltDiskm.mag.f |
| 874 | RPSB1.ST.Str.general |
| 875 | RPSB1.ST.Op.general |
| 876 | RPSB1.ST.BlkZn.stVal |
| 877 | RREC1.ST.Op.general |
| 878 | RREC1.ST.AutoRecSt.stVal |
| 879 | RREC2.ST.Op.general |
| 880 | RREC2.ST.AutoRecSt.stVal |
| 881 | RREC3.ST.Op.general |
| 882 | RREC3.ST.AutoRecSt.stVal |
| 883 | RREC4.ST.Op.general |
| 884 | RREC4.ST.AutoRecSt.stVal |
| 885 | RREC5.ST.Op.general |
| 886 | RREC5.ST.AutoRecSt.stVal |
| 887 | RREC6.ST.Op.general |
| 888 | RREC6.ST.AutoRecSt.stVal |
| 889 | CSWI1.ST.Loc.stVal |
| 890 | CSWI1.ST.Pos.stVal |
| 891 | CSWI2.ST.Loc.stVal |
| 892 | CSWI2.ST.Pos.stVal |
| 893 | CSWI3.ST.Loc.stVal |
| 894 | CSWI3.ST.Pos.stVal |
| 895 | CSWI4.ST.Loc.stVal |
| 896 | CSWI4.ST.Pos.stVal |
| 897 | CSWI5.ST.Loc.stVal |
| 898 | CSWI5.ST.Pos.stVal |
| 899 | CSWI6.ST.Loc.stVal |
| 900 | CSWI6.ST.Pos.stVal |
| 901 | CSWI7.ST.Loc.stVal |
| 902 | CSWI7.ST.Pos.stVal |
| 903 | CSWI8.ST.Loc.stVal |
| 904 | CSWI8.ST.Pos.stVal |
| 905 | CSWI9.ST.Loc.stVal |
| 906 | CSWI9.ST.Pos.stVal |
| 907 | CSWI10.ST.Loc.stVal |
| 908 | CSWI10.ST.Pos.stVal |
| 909 | CSWI11.ST.Loc.stVal |
| 910 | CSWI11.ST.Pos.stVal |
| 911 | CSWI12.ST.Loc.stVal |
| 912 | CSWI12.ST.Pos.stVal |
| 913 | CSWI13.ST.Loc.stVal |
| 914 | CSWI13.ST.Pos.stVal |
| 915 | CSWI14.ST.Loc.stVal |
| 916 | CSWI14.ST.Pos.stVal |
| 917 | CSWI15.ST.Loc.stVal |

| Enumeration | GOOSE dataset items |
|---|---|
| 918 | CSWI15.ST.Pos.stVal |
| 919 | CSWI16.ST.Loc.stVal |
| 920 | CSWI16.ST.Pos.stVal |
| 921 | CSWI17.ST.Loc.stVal |
| 922 | CSWI17.ST.Pos.stVal |
| 923 | CSWI18.ST.Loc.stVal |
| 924 | CSWI18.ST.Pos.stVal |
| 925 | CSWI19.ST.Loc.stVal |
| 926 | CSWI19.ST.Pos.stVal |
| 927 | CSWI20.ST.Loc.stVal |
| 928 | CSWI20.ST.Pos.stVal |
| 929 | CSWI21.ST.Loc.stVal |
| 930 | CSWI21.ST.Pos.stVal |
| 931 | CSWI22.ST.Loc.stVal |
| 932 | CSWI22.ST.Pos.stVal |
| 933 | CSWI23.ST.Loc.stVal |
| 934 | CSWI23.ST.Pos.stVal |
| 935 | CSWI24.ST.Loc.stVal |
| 936 | CSWI24.ST.Pos.stVal |
| 937 | CSWI25.ST.Loc.stVal |
| 938 | CSWI25.ST.Pos.stVal |
| 939 | CSWI26.ST.Loc.stVal |
| 940 | CSWI26.ST.Pos.stVal |
| 941 | CSWI27.ST.Loc.stVal |
| 942 | CSWI27.ST.Pos.stVal |
| 943 | CSWI28.ST.Loc.stVal |
| 944 | CSWI28.ST.Pos.stVal |
| 945 | CSWI29.ST.Loc.stVal |
| 946 | CSWI29.ST.Pos.stVal |
| 947 | CSWI30.ST.Loc.stVal |
| 948 | CSWI30.ST.Pos.stVal |
| 949 | XSWI1.ST.Loc.stVal |
| 950 | XSWI1.ST.Pos.stVal |
| 951 | XSWI2.ST.Loc.stVal |
| 952 | XSWI2.ST.Pos.stVal |
| 953 | XSWI3.ST.Loc.stVal |
| 954 | XSWI3.ST.Pos.stVal |
| 955 | XSWI4.ST.Loc.stVal |
| 956 | XSWI4.ST.Pos.stVal |
| 957 | XSWI5.ST.Loc.stVal |
| 958 | XSWI5.ST.Pos.stVal |
| 959 | XSWI6.ST.Loc.stVal |
| 960 | XSWI6.ST.Pos.stVal |
| 961 | XSWI7.ST.Loc.stVal |
| 962 | XSWI7.ST.Pos.stVal |
| 963 | XSWI8.ST.Loc.stVal |
| 964 | XSWI8.ST.Pos.stVal |
| 965 | XSWI9.ST.Loc.stVal |
| 966 | XSWI9.ST.Pos.stVal |
| 967 | XSWI10.ST.Loc.stVal |
| 968 | XSWI10.ST.Pos.stVal |
| 969 | XSWI11.ST.Loc.stVal |
| 970 | XSWI11.ST.Pos.stVal |

| Enumeration | GOOSE dataset items |
|---|---|
| 971 | XSWI12.ST.Loc.stVal |
| 972 | XSWI12.ST.Pos.stVal |
| 973 | XSWI13.ST.Loc.stVal |
| 974 | XSWI13.ST.Pos.stVal |
| 975 | XSWI14.ST.Loc.stVal |
| 976 | XSWI14.ST.Pos.stVal |
| 977 | XSWI15.ST.Loc.stVal |
| 978 | XSWI15.ST.Pos.stVal |
| 979 | XSWI16.ST.Loc.stVal |
| 980 | XSWI16.ST.Pos.stVal |
| 981 | XSWI17.ST.Loc.stVal |
| 982 | XSWI17.ST.Pos.stVal |
| 983 | XSWI18.ST.Loc.stVal |
| 984 | XSWI18.ST.Pos.stVal |
| 985 | XSWI19.ST.Loc.stVal |
| 986 | XSWI19.ST.Pos.stVal |
| 987 | XSWI20.ST.Loc.stVal |
| 988 | XSWI20.ST.Pos.stVal |
| 989 | XSWI21.ST.Loc.stVal |
| 990 | XSWI21.ST.Pos.stVal |
| 991 | XSWI22.ST.Loc.stVal |
| 992 | XSWI22.ST.Pos.stVal |
| 993 | XSWI23.ST.Loc.stVal |
| 994 | XSWI23.ST.Pos.stVal |
| 995 | XSWI24.ST.Loc.stVal |
| 996 | XSWI24.ST.Pos.stVal |
| 997 | XCBR1.ST.Loc.stVal |
| 998 | XCBR1.ST.Pos.stVal |
| 999 | XCBR2.ST.Loc.stVal |
| 1000 | XCBR2.ST.Pos.stVal |
| 1001 | XCBR3.ST.Loc.stVal |
| 1002 | XCBR3.ST.Pos.stVal |
| 1003 | XCBR4.ST.Loc.stVal |
| 1004 | XCBR4.ST.Pos.stVal |
| 1005 | XCBR5.ST.Loc.stVal |
| 1006 | XCBR5.ST.Pos.stVal |
| 1007 | XCBR6.ST.Loc.stVal |
| 1008 | XCBR6.ST.Pos.stVal |

**F617**
**ENUMERATION: LOGIN ROLES**

| Enumeration | Role |
|---|---|
| 0 | None |
| 1 | Administrator |
| 2 | Supervisor |
| 3 | Engineer |
| 4 | Operator |
| 5 | Factory |

**F618**
**BITFIED: SECURITY STATUS INDICATOR**

Has been activated, whether the password has been set.

1 = Bit#0, Administrator password was set. The list is continued for all other roles (Engineer = bit#2, Operator = bit#3, Observer = bit#3).

**F619**
**ENUMERATION: RADIUS AUTHENTICATION METHOD**

0 = EAP-TTLS

**F621**
**ENUMERATION: MODBUS LOGIN ROLES**

| Enumeration | Role |
|---|---|
| 0 | None |
| 1 | Administrator |
| 2 | Supervisor |
| 3 | Engineer |
| 4 | Operator |
| 5 | Observer |

**F623**
**ENUMERATION: REAL-TIME CLOCK SYNCHRONIZING SOURCE CONFIGURATION**

| Enumeration | Item |
|---|---|
| 0 | None |
| 1 | PP/IRIG-B/PTP/SNTP |
| 2 | IRIG-B/PP/PTP/SNTP |
| 3 | PP/PTP/IRIG-B/SNTP |

**F624**
**ENUMERATION: REAL-TIME CLOCK SYNCHRONZING SOURCE ACTUALS**

| Enumeration | Item |
|---|---|
| 0 | None |
| 1 | Port 1 PTP Clock |
| 2 | Port 2 PTP Clock |
| 3 | Port 3 PTP Clock |
| 4 | IRIG-B |
| 5 | SNTP |

**F625**
**ENUMERATION: PTP STATE**

| Enumeration | Item |
|---|---|
| 0 | Disabled |
| 1 | No Signal |
| 2 | Calibrating |
| 3 | Synchronized |
| 4 | Synchronized (No PDelay) |

**F626**
**ENUMERATION: NETWORK PORT FOR REMOTE DEVICE**

| Enumeration | Item |
|---|---|
| 0 | None |
| 1 | Network Port 1 |
| 2 | Network Port 2 |
| 3 | Network Port 3 |

**F627**
**ENUMERATION: REDUNDANCY MODE**

| Enumeration | Item |
|---|---|
| 0 | None |
| 1 | Failover |
| 2 | PRP |

**F628**
**ENUMERATION: SECURITY BYPASS ACCESS**

Disables security on local access, remote access, or both.

| Enumeration | Item |
|---|---|
| 0 | Disabled |
| 1 | Local and Remote |
| 2 | Local |
| 3 | Remote |

**F629**
**ENUMERATION: SCADA PROTOCOL**

0 = DNP 3.0, 1 = IEC 60870-5-104, 2 = IEC 60870-5-103

**F630**
**ENUMERATION: IEC 103 ASDU TYPE**

0 = 3, 1 = 9

**F631**
**ENUMERATION: VIRTUAL INPUTS FOR IEC 103**

| Enumeration | Item |
|---|---|
| 0 | OFF |
| 1 | Virtual Input 1 |
| 2 | Virtual Input 2 |
| 3 | Virtual Input 3 |
| ↓ | ↓ |
| 64 | Virtual Input 64 |

### C.1.1 INTRODUCTION

The IEC 61850 standard is the result of electric utilities and vendors of electronic equipment to produce standardized communications systems. IEC 61850 is a series of standards describing client/server and peer-to-peer communications, substation design and configuration, testing, environmental and project standards. The complete set includes:

- IEC 61850-1: Introduction and overview
- IEC 61850-2: Glossary
- IEC 61850-3: General requirements
- IEC 61850-4: System and project management
- IEC 61850-5: Communications and requirements for functions and device models
- IEC 61850-6: Configuration description language for communication in electrical substations related to IEDs
- IEC 61850-7-1: Basic communication structure for substation and feeder equipment - Principles and models
- IEC 61850-7-2: Basic communication structure for substation and feeder equipment - Abstract communication service interface (ACSI)
- IEC 61850-7-3: Basic communication structure for substation and feeder equipment – Common data classes
- IEC 61850-7-4: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes
- IEC 61850-8-1: Specific Communication Service Mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3
- IEC 61850-9-1: Specific Communication Service Mapping (SCSM) – Sampled values over serial unidirectional multidrop point to point link
- IEC 61850-9-2: Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3
- IEC 61850-10: Conformance testing

These documents can be obtained from the IEC (http://www.iec.ch). It is strongly recommended that all those involved with any IEC 61850 implementation obtain this document set.

### C.1.2 COMMUNICATION PROFILES

IEC 61850 specifies the use of the Manufacturing Message Specification (MMS) at the upper (application) layer for transfer of real-time data. This protocol has been in existence for several of years and provides a set of services suitable for the transfer of data within a substation LAN environment. Actual MMS protocol services are mapped to IEC 61850 abstract services in IEC 61850-8-1.

The L30 relay supports IEC 61850 server services over TCP/IP. The TCP/IP profile requires the L30 to have an IP address to establish communications. These addresses are located in the **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **COMMUNICATIONS** ⇨⇩ **NETWORK** menu. It is possible to have up to five simultaneous connections (in addition to DNP and Modbus/TCP (non-IEC 61850) connections).

- **Client/server**: This is a connection-oriented type of communication. The connection is initiated by the client, and communication activity is controlled by the client. IEC 61850 clients are often substation computers running HMI programs or SOE logging software. Servers are usually substation equipment such as protection relays, meters, RTUs, transformer tap changers, or bay controllers.
- **Peer-to-peer**: This is a non-connection-oriented, high speed type of communication usually between substation equipment such as protection relays. GSSE and GOOSE are methods of peer-to-peer communication.
- **Substation configuration language (SCL)**: A substation configuration language is a number of files used to describe the configuration of substation equipment. Each configured device has an IEC Capability Description (ICD) file. The substation single line information is stored in a System Specification Description (SSD) file. The entire substation configuration is stored in a Substation Configuration Description (SCD) file. The SCD file is the combination of the individual ICD files and the SSD file.

### C.1.3 FILE TRANSFER BY IEC 61850

The L30 supports file transfer by IEC 61850. The approach is as follows, using the SISCO AX-S4 61850 client software as an example.

1. In the AX-S4 61850 Explorer window, click the **Tools** menu and access the SISCO File Transfer Utility.
2. Select the **Remote AR Name** from the drop-down list. Available files appear in the **File Specification** area on the right side of the window.
3. With the **Copy** option active, select a file to transfer and click the **Go** button. The file is copied and displays in the **Local** list on the left side of the window.
4. Repeat the process to transfer any other files.



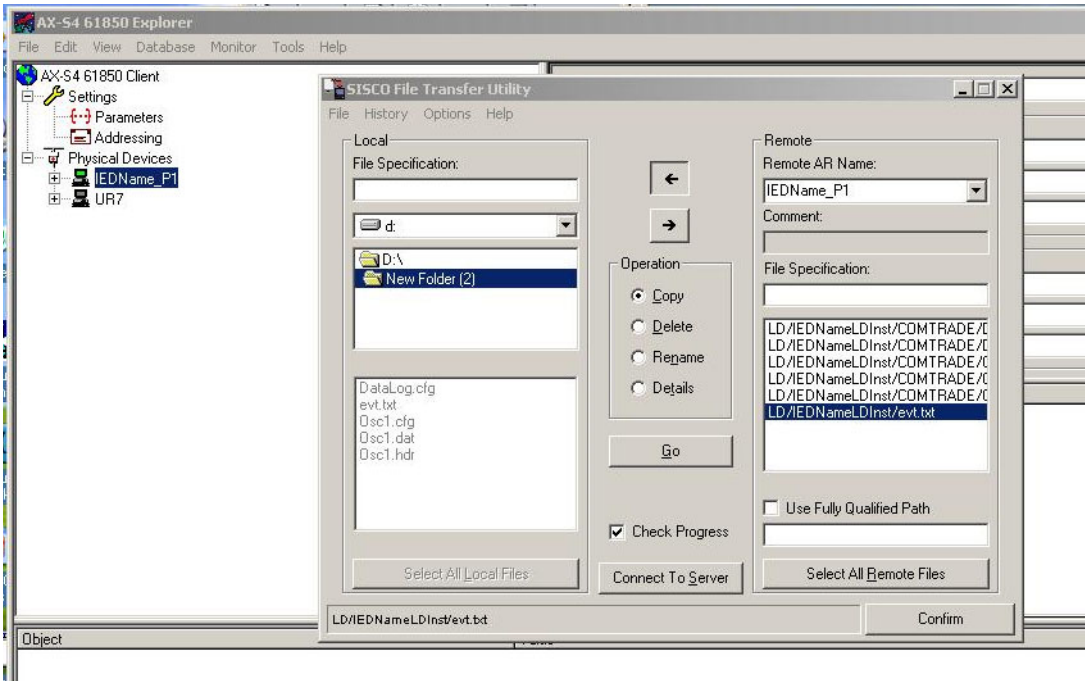



**Figure C–1: FILE TRANSFER BY IEC 61850**

### C.2.1 OVERVIEW

IEC 61850 defines an object-oriented approach to data and services. An IEC 61850 *physical device* can contain one or more *logical device(s)*. Each logical device can contain many *logical nodes*. Each logical node can contain many *data objects*. Each data object is composed of *data attributes* and *data attribute components*. Services are available at each level for performing various functions, such as reading, writing, control commands, and reporting.

Each L30 IED represents one IEC 61850 physical device. The physical device contains one logical device, and the logical device contains many logical nodes. The logical node LPHD1 contains information about the L30 IED physical device. The logical node LLN0 contains information about the L30 IED logical device.

### C.2.2 GGIO1: DIGITAL STATUS VALUES

The GGIO1 logical node is available in the L30 to provide access to as many 128 digital status points and associated timestamps and quality flags. The data content must be configured before the data can be used. GGIO1 provides digital status points for access by clients.

It is intended that clients use GGIO1 in order to access digital status values from the L30. Configuration settings are provided to allow the selection of the number of digital status indications available in GGIO1 (8 to 128), and to allow the choice of the L30 FlexLogic operands that drive the status of the GGIO1 status indications. Clients can utilize the IEC 61850 buffered and unbuffered reporting features available from GGIO1 in order to build sequence of events (SOE) logs and HMI display screens. Buffered reporting should generally be used for SOE logs since the buffering capability reduces the chances of missing data state changes. Unbuffered reporting should generally be used for local status display.

### C.2.3 GGIO2: DIGITAL CONTROL VALUES

The GGIO2 logical node is available to provide access to the L30 virtual inputs. Virtual inputs are single-point control (binary) values that can be written by clients. They are generally used as control inputs. GGIO2 provides access to the virtual inputs through the IEC 61850 standard control model (ctlModel) services:

- Status only.
- Direct control with normal security.
- SBO control with normal security.

Configuration settings are available to select the control model for each point. Each virtual input used through GGIO2 should have its **VIRTUAL INPUT 1(64) FUNCTION** setting programmed as “Enabled” and its corresponding **GGIO2 CF SPSCO1(64) CTLMODEL** setting programmed to the appropriate control configuration.

### C.2.4 GGIO3: DIGITAL STATUS AND ANALOG VALUES FROM GOOSE DATA

The GGIO3 logical node is available to provide access for clients to values received via configurable GOOSE messages. The values of the digital status indications and analog values in GGIO3 originate in GOOSE messages sent from other devices.

### C.2.5 GGIO4: GENERIC ANALOG MEASURED VALUES

The GGIO4 logical node provides access to as many as 32 analog value points, as well as associated timestamps and quality flags. The data content must be configured before the data can be used. GGIO4 provides analog values for access by clients.

It is intended that clients use GGIO4 to access generic analog values from the L30. Configuration settings allow the selection of the number of analog values available in GGIO4 (4 to 32) and the choice of the FlexAnalog values that determine the value of the GGIO4 analog inputs. Clients can utilize polling or the IEC 61850 unbuffered reporting feature available from GGIO4 in order to obtain the analog values provided by GGIO4.

### C.2.6 MMXU: ANALOG MEASURED VALUES

A limited number of measured analog values are available through the MMXU logical nodes.

Each MMXU logical node provides data from a L30 current and voltage source. There is one MMXU available for each configurable source (programmed in the **SETTINGS** ⇨⇩ **SYSTEM SETUP** ⇨⇩ **SIGNAL SOURCES** menu). MMXU1 provides data from L30 source 1, and MMXU2 provides data from L30 source 2.

MMXU data is provided in two forms: instantaneous and deadband. The instantaneous values are updated every time a read operation is performed by a client. The deadband values are calculated as described in IEC 61850 parts 7-1 and 7-3. The selection of appropriate deadband settings for the L30 is described in chapter 5 of this manual.

IEC 61850 buffered and unbuffered reporting capability is available in all MMXU logical nodes. MMXUx logical nodes provide the following data for each source:

- MMXU1.MX.TotW: three-phase real power
- MMXU1.MX.TotVAr: three-phase reactive power
- MMXU1.MX.TotVA: three-phase apparent power
- MMXU1.MX.TotPF: three-phase power factor
- MMXU1.MX.Hz: frequency
- MMXU1.MX.PPV.phsAB: phase AB voltage magnitude and angle
- MMXU1.MX.PPV.phsBC: phase BC voltage magnitude and angle
- MMXU1.MX.PPV.phsCA: Phase CA voltage magnitude and angle
- MMXU1.MX.PhV.phsA: phase AG voltage magnitude and angle
- MMXU1.MX.PhV.phsB: phase BG voltage magnitude and angle
- MMXU1.MX.PhV.phsC: phase CG voltage magnitude and angle
- MMXU1.MX.A.phsA: phase A current magnitude and angle
- MMXU1.MX.A.phsB: phase B current magnitude and angle
- MMXU1.MX.A.phsC: phase C current magnitude and angle
- MMXU1.MX.A.neut: ground current magnitude and angle
- MMXU1.MX.W.phsA: phase A real power
- MMXU1.MX.W.phsB: phase B real power
- MMXU1.MX.W.phsC: phase C real power
- MMXU1.MX.VAr.phsA: phase A reactive power
- MMXU1.MX.VAr.phsB: phase B reactive power
- MMXU1.MX.VAr.phsC: phase C reactive power
- MMXU1.MX.VA.phsA: phase A apparent power
- MMXU1.MX.VA.phsB: phase B apparent power
- MMXU1.MX.VA.phsC: phase C apparent power
- MMXU1.MX.PF.phsA: phase A power factor
- MMXU1.MX.PF.phsB: phase B power factor
- MMXU1.MX.PF.phsC: phase C power factor

### C.2.7 PROTECTION AND OTHER LOGICAL NODES

The following list describes the protection elements for all UR-series relays. The L30 relay will contain a subset of protection elements from this list.

- PDIF: bus differential, transformer instantaneous differential, transformer percent differential, current differential

- PDIS: phase distance, ground distance
- PIOC: phase instantaneous overcurrent, neutral instantaneous overcurrent, ground instantaneous overcurrent, negative-sequence instantaneous overcurrent.
- PTOC: phase time overcurrent, neutral time overcurrent, ground time overcurrent, negative-sequence time overcurrent, neutral directional overcurrent, negative-sequence directional overcurrent
- PTUV: phase undervoltage, auxiliary undervoltage, third harmonic neutral undervoltage
- PTOV: phase overvoltage, neutral overvoltage, auxiliary overvoltage, negative sequence overvoltage
- RBRF: breaker failure
- RREC: autoreclosure
- RPSB: power swing detection
- RFLO: fault locator
- XCBR: breaker control
- XSWI: circuit switch
- CSWI: switch controller



The protection elements listed above contain *start* (pickup) and *operate* flags. For example, the start flag for PIOC1 is PIOC1.ST.Str.general. The operate flag for PIOC1 is PIOC1.ST.Op.general. For the L30 protection elements, these flags take their values from the pickup and operate FlexLogic operands for the corresponding element.

Some protection elements listed above contain directional start values. For example, the directional start value for PDIS1 is PDIS1.ST.Str.dirGeneral. This value is built from the directional FlexLogic operands for the element.

The RFLO logical node contains the measurement of the distance to fault calculation in kilometers. This value originates in the fault locator function.

The XCBR logical node is directly associated with the breaker control feature.

- XCBR1.ST.Loc: This is the state of the XCBR1 local/remote switch. A setting is provided to assign a FlexLogic operand to determine the state. When local mode is true, IEC 61850 client commands will be rejected.
- XCBR1.ST.Opcnt: This is an operation counter as defined in IEC 61850. Command settings are provided to allow the counter to be cleared.
- XCBR1.ST.Pos: This is the position of the breaker. The breaker control FlexLogic operands are used to determine this state.
  - Intermediate state (00) is indicated when the BREAKER 1 OPEN and BREAKER 1 CLOSED operands are both On.
  - Off state (01) is indicated when the BREAKER 1 OPEN operand is On.
  - On state (10) is indicated when the BREAKER 1 CLOSED operand is On.
  - Bad state (11) is indicated when the BREAKER 1 OPEN and BREAKER 1 CLOSED operands are Off.
- XCBR1.ST.BlkOpn: This is the state of the block open command logic. When true, breaker open commands from IEC 61850 clients will be rejected.
- XCBR1.ST.BlkCls: This is the state of the block close command logic. When true, breaker close commands from IEC 61850 clients will be rejected.
- XCBR1.CO.Pos: This is where IEC 61850 clients can issue open or close commands to the breaker. SBO control with normal security is the only supported IEC 61850 control model.
- XCBR1.CO.BlkOpn: This is where IEC 61850 clients can issue block open commands to the breaker. Direct control with normal security is the only supported IEC 61850 control model.
- XCBR1.CO.BlkCls: This is where IEC 61850 clients can issue block close commands to the breaker. Direct control with normal security is the only supported IEC 61850 control model.

### C.3.1 BUFFERED/UNBUFFERED REPORTING

IEC 61850 buffered and unbuffered reporting is provided in the GGIO1 logical nodes (for binary status values) and MMXU1 to MMXU6 (for analog measured values). Report settings can be configured using an IEC 61850 client, substation configurator software, or via an IEC 61850 client. The following items can be configured:

- **TrgOps**: Trigger options. The following bits are supported by the L30:
  - Bit 1: data-change
  - Bit 4: integrity
  - Bit 5: general interrogation
- **OptFlds**: Option Fields. The following bits are supported by the L30:
  - Bit 1: sequence-number
  - Bit 2: report-time-stamp
  - Bit 3: reason-for-inclusion
  - Bit 4: data-set-name
  - Bit 5: data-reference
  - Bit 6: buffer-overflow (for buffered reports only)
  - Bit 7: entryID (for buffered reports only)
  - Bit 8: conf-revision
  - Bit 9: segmentation
- **IntgPd**: Integrity period.
- **BufTm**: Buffer time.

### C.3.2 FILE TRANSFER

MMS file services are supported to allow transfer of oscillography, event record, or other files from a L30 relay.

### C.3.3 TIMESTAMPS AND SCANNING

The timestamp values associated with all IEC 61850 data items represent the *time of the last change* of either the value or quality flags of the data item. To accomplish this functionality, all IEC 61850 data items must be regularly scanned for data changes, and the timestamp updated when a change is detected, regardless of the connection status of any IEC 61850 clients. For applications where there is no IEC 61850 client in use, the IEC 61850 **SERVER SCANNING** setting can be programmed as "Disabled". If a client is in use, this setting should be programmed as "Enabled" to ensure the proper generation of IEC 61850 timestamps.

### C.3.4 LOGICAL DEVICE NAME

The logical device name is used to identify the IEC 61850 logical device that exists within the L30. This name is composed of two parts: the IED name setting and the logical device instance. The complete logical device name is the combination of the two character strings programmed in the **IEDNAME** and **LD INST** settings. The default values for these strings are "IEDName" and "LDInst". These values should be changed to reflect a logical naming convention for all IEC 61850 logical devices in the system.

### C.3.5 LOCATION

The LPHD1 logical node contains a data attribute called *location* (LPHD1.DC.PhyNam.location). This is a character string meant to describe the physical location of the L30. This attribute is programmed through the **LOCATION** setting and its default value is "Location". This value should be changed to describe the actual physical location of the L30.

### C.3.6 LOGICAL NODE NAME PREFIXES

IEC 61850 specifies that each logical node can have a name with a total length of 11 characters. The name is composed of:

- A five or six-character name prefix.
- A four-character standard name (for example, MMXU, GGIO, PIOC, etc.).
- A one or two-character instantiation index.

Complete names are of the form `xxxxxxPIOC1`, where the `xxxxxx` character string is configurable. Details regarding the logical node naming rules are given in IEC 61850 parts 6 and 7-2. It is recommended that a consistent naming convention be used for an entire substation project.

### C.3.7 CONNECTION TIMING



A built-in TCP/IP connection timeout of two minutes is employed by the L30 to detect 'dead' connections. If there is no data traffic on a TCP connection for greater than two minutes, the connection will be aborted by the L30. This frees up the connection to be used by other clients. Therefore, when using IEC 61850 reporting, clients should configure report control block items such that an integrity report will be issued at least every two minutes (120000 ms). This ensures that the L30 will not abort the connection. If other MMS data is being polled on the same connection at least once every two minutes, this timeout will not apply.

### C.3.8 NON-IEC 61850 DATA

The L30 relay makes available a number of non-IEC 61850 data items. These data items can be accessed through the "UR" MMS domain. IEC 61850 data can be accessed through the standard IEC 61850 logical device. To access the non-IEC data items, the **INCLUDE NON-IEC DATA** setting must be "Enabled".

### C.3.9 COMMUNICATION SOFTWARE UTILITIES

The exact structure and values of the supported IEC 61850 logical nodes can be seen by connecting to a L30 relay with an MMS browser, such as the "MMS Object Explorer and AXS4-MMS" DDE/OPC server from Sisco Inc.

### C.4.1 OVERVIEW

IEC 61850 specifies two types of peer-to-peer data transfer services: Generic Substation State Events (GSSE) and Generic Object Oriented Substation Events (GOOSE). GSSE services are compatible with UCA 2.0 GOOSE. IEC 61850 GOOSE services provide virtual LAN (VLAN) support, Ethernet priority tagging, and Ethertype Application ID configuration. The support for VLANs and priority tagging allows for the optimization of Ethernet network traffic. GOOSE messages can be given a higher priority than standard Ethernet traffic, and they can be separated onto specific VLANs. Because of the additional features of GOOSE services versus GSSE services, it is recommended that GOOSE be used wherever backwards compatibility with GSSE (or UCA 2.0 GOOSE) is not required.

Devices that transmit GSSE and/or GOOSE messages also function as servers. Each GSSE publisher contains a "GSSE control block" to configure and control the transmission. Each GOOSE publisher contains a "GOOSE control block" to configure and control the transmission. The transmission is also controlled via device settings. These settings can be seen in the ICD and/or SCD files, or in the device configuration software or files.



IEC 61850 recommends a default priority value of 4 for GOOSE. Ethernet traffic that does not contain a priority tag has a default priority of 1. More details are specified in IEC 61850 part 8-1.

IEC 61850 recommends that the Ethertype Application ID number be configured according to the GOOSE source. In the L30, the transmitted GOOSE Application ID number must match the configured receive Application ID number in the receiver. A common number may be used for all GOOSE transmitters in a system. More details are specified in IEC 61850 part 8-1.

### C.4.2 GSSE CONFIGURATION

IEC 61850 Generic Substation Status Event (GSSE) communication is compatible with UCA GOOSE communication. GSSE messages contain a number of double point status data items. These items are transmitted in two pre-defined data structures named DNA and UserSt. Each DNA and UserSt item is referred to as a 'bit pair'. GSSE messages are transmitted in response to state changes in any of the data points contained in the message. GSSE messages always contain the same number of DNA and UserSt bit pairs. Depending the on the configuration, only some of these bit pairs may have values that are of interest to receiving devices.

The **GSSE FUNCTION**, **GSSE ID**, and **GSSE DESTINATION MAC ADDRESS** settings are used to configure GSSE transmission. **GSSE FUNCTION** is set to "Enabled" to enable the transmission. If a valid multicast Ethernet MAC address is entered for the **GSSE DESTINATION MAC ADDRESS** setting, this address will be used as the destination MAC address for GSSE messages. If a valid multicast Ethernet MAC address is not entered (for example, 00 00 00 00 00 00), the L30 will use the source Ethernet MAC address as the destination, with the multicast bit set.

### C.4.3 FIXED GOOSE

The L30 supports two types of IEC 61850 Generic Object Oriented Substation Event (GOOSE) communication: fixed GOOSE and configurable GOOSE. All GOOSE messages contain IEC 61850 data collected into a *dataset*. It is this dataset that is transferred using GOOSE message services. The dataset transferred using the L30 fixed GOOSE is the same data that is transferred using the GSSE feature; that is, the DNA and UserSt bit pairs. The FlexLogic operands that determine the state of the DNA and UserSt bit pairs are configurable via settings, but the fixed GOOSE dataset always contains the same DNA/UserSt data structure. Upgrading from GSSE to GOOSE services is simply a matter of enabling fixed GOOSE and disabling GSSE. The remote inputs and outputs are configured in the same manner for both GSSE and fixed GOOSE.

It is recommended that the fixed GOOSE be used for implementations that require GOOSE data transfer between UR-series IEDs. Configurable GOOSE may be used for implementations that require GOOSE data transfer between UR-series IEDs and devices from other manufacturers.

### C.4.4 CONFIGURABLE GOOSE

The configurable GOOSE feature allows for the configuration of the datasets to be transmitted or received from the L30. The L30 supports the configuration of eight transmission and reception datasets, allowing for the optimization of data transfer between devices.

Items programmed for dataset 1 and 2 will have changes in their status transmitted as soon as the change is detected. Dataset 1 should be used for high-speed transmission of data that is required for applications such as transfer tripping, blocking, and breaker fail initiate. At least one digital status value needs to be configured in dataset 1 to enable transmission of all data configured for dataset 1. Configuring analog data only to dataset 1 will not activate transmission.

Items programmed for datasets 3 through 8 will have changes in their status transmitted at a maximum rate of every 100 ms. Datasets 3 through 8 will regularly analyze each data item configured within them every 100 ms to identify if any changes have been made. If any changes in the data items are detected, these changes will be transmitted through a GOOSE message. If there are no changes detected during this 100 ms period, no GOOSE message will be sent.

For all datasets 1 through 8, the integrity GOOSE message will still continue to be sent at the pre-configured rate even if no changes in the data items are detected.

The GOOSE functionality was enhanced to prevent the relay from flooding a communications network with GOOSE messages due to an oscillation being created that is triggering a message.



The L30 has the ability of detecting if a data item in one of the GOOSE datasets is erroneously oscillating. This can be caused by events such as errors in logic programming, inputs improperly being asserted and de-asserted, or failed station components. If erroneously oscillation is detected, the L30 will stop sending GOOSE messages from the dataset for a minimum period of one second. Should the oscillation persist after the one second time-out period, the L30 will continue to block transmission of the dataset. The L30 will assert the **MAINTENANCE ALERT: GGIO Ind XXX oscill** self-test error message on the front panel display, where **XXX** denotes the data item detected as oscillating.

The configurable GOOSE feature is recommended for applications that require GOOSE data transfer between UR-series IEDs and devices from other manufacturers. Fixed GOOSE is recommended for applications that require GOOSE data transfer between UR-series IEDs.

IEC 61850 GOOSE messaging contains a number of configurable parameters, all of which must be correct to achieve the successful transfer of data. It is critical that the configured datasets at the transmission and reception devices are an exact match in terms of data structure, and that the GOOSE addresses and name strings match exactly. Manual configuration is possible, but third-party substation configuration software may be used to automate the process. The EnerVista UR Setup software can produce IEC 61850 ICD files and import IEC 61850 SCD files produced by a substation configurator (see the IEC 61850 IED configuration information later in this appendix).

**NOTICE** Use independent ports for IEC 61850 communication and take care when configuring the settings, else loss of protection or misoperation of the relay can result.

The following example illustrates the configuration required to transfer IEC 61850 data items between two devices. The general steps required for transmission configuration are:

1. Configure the transmission dataset.
2. Configure the GOOSE service settings.
3. Configure the data.

The general steps required for reception configuration are:

1. Configure the reception dataset.
2. Configure the GOOSE service settings.
3. Configure the data.

This example shows how to configure the transmission and reception of three IEC 61850 data items: a single point status value, its associated quality flags, and a floating point analog value.

The following procedure illustrates the transmission configuration.

1. Configure the transmission dataset by making the following changes in the **PRODUCT SETUP** ⇨⇩ **COMMUNICATION** ⇨⇩ **IEC 61850 PROTOCOL** ⇨ **GSSE/GOOSE CONFIGURATION** ⇨ **TRANSMISSION** ⇨⇩ **CONFIGURABLE GOOSE** ⇨ **CONFIGURABLE GOOSE 1** ⇨⇩ **CONFIG GSE 1 DATASET ITEMS** settings menu:
   - Set **ITEM 1** to “GGIO1.ST.Ind1.q” to indicate quality flags for GGIO1 status indication 1.
   - Set **ITEM 2** to “GGIO1.ST.Ind1.stVal” to indicate the status value for GGIO1 status indication 1.

   The transmission dataset now contains a set of quality flags and a single point status Boolean value. The reception dataset on the receiving device must exactly match this structure.

2. Configure the GOOSE service settings by making the following changes in the **PRODUCT SETUP ⇨⇩ COMMUNICATION ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨ TRANSMISSION ⇨⇩ CONFIGURABLE GOOSE ⇨ CONFIGURABLE GOOSE 1** settings menu:
   – Set **CONFIG GSE 1 FUNCTION** to "Enabled".
   – Set **CONFIG GSE 1 ID** to an appropriate descriptive string (the default value is "GOOSEOut_1").
   – Set **CONFIG GSE 1 DST MAC** to a multicast address (for example, 01 00 00 12 34 56).
   – Set the **CONFIG GSE 1 VLAN PRIORITY**; the default value of "4" is OK for this example.
   – Set the **CONFIG GSE 1 VLAN ID** value; the default value is "0", but some switches may require this value to be "1".
   – Set the **CONFIG GSE 1 ETYPE APPID** value. This setting represents the Ethertype application ID and must match the configuration on the receiver (the default value is "0").
   – Set the **CONFIG GSE 1 CONFREV** value. This value changes automatically as described in IEC 61850 part 7-2. For this example it can be left at its default value.
3. Configure the data by making the following changes in the **PRODUCT SETUP ⇨⇩ COMMUNICATION ⇨⇩ IEC 61850 PROTOCOL ⇨ GGIO1 STATUS CONFIGURATION** settings menu:
   – Set **GGIO1 INDICATION 1** to a FlexLogic operand used to provide the status of GGIO1.ST.Ind1.stVal (for example, a contact input, virtual input, a protection element status, etc.).

The L30 must be rebooted (control power removed and re-applied) before these settings take effect.

The following procedure illustrates the reception configuration.

1. Configure the reception dataset by making the following changes in the **PRODUCT SETUP ⇨⇩ COMMUNICATION ⇨⇩ IEC 61850 PROTOCOL ⇨ GSSE/GOOSE CONFIGURATION ⇨⇩ RECEPTION ⇨⇩ CONFIGURABLE GOOSE ⇨ CONFIGURABLE GOOSE 1 ⇨⇩ CONFIG GSE 1 DATASET ITEMS** settings menu:
   – Set **ITEM 1** to "GGIO3.ST.Ind1.q" to indicate quality flags for GGIO3 status indication 1.
   – Set **ITEM 2** to "GGIO3.ST.Ind1.stVal" to indicate the status value for GGIO3 status indication 1.

   The reception dataset now contains a set of quality flags, a single point status Boolean value, and a floating point analog value. This matches the transmission dataset configuration above.
2. Configure the GOOSE service settings by making the following changes in the **INPUTS/OUTPUTS ⇨⇩ REMOTE DEVICES ⇨⇩ REMOTE DEVICE 1** settings menu:
   – Set **REMOTE DEVICE 1 ID** to match the GOOSE ID string for the transmitting device. Enter "GOOSEOut_1".
   – Set **REMOTE DEVICE 1 ETYPE APPID** to match the Ethertype application ID from the transmitting device. This is "0" in the example above.
   – Set the **REMOTE DEVICE 1 DATASET** value. This value represents the dataset number in use. Since we are using configurable GOOSE 1 in this example, program this value as "GOOSEIn 1".
3. Configure the data by making the following changes in the **INPUTS/OUTPUTS ⇨⇩ REMOTE INPUTS ⇨⇩ REMOTE INPUT 1** settings menu:
   – Set **REMOTE IN 1 DEVICE** to "GOOSEOut_1".
   – Set **REMOTE IN 1 ITEM** to "Dataset Item 2". This assigns the value of the GGIO3.ST.Ind1.stVal single point status item to remote input 1.

Remote input 1 can now be used in FlexLogic equations or other settings. The L30 must be rebooted (control power removed and re-applied) before these settings take effect.

The value of remote input 1 (Boolean on or off) in the receiving device will be determined by the GGIO1.ST.Ind1.stVal value in the sending device. The above settings will be automatically populated by the EnerVista UR Setup software when a complete SCD file is created by third party substation configurator software.

### C.4.5 ETHERNET MAC ADDRESS FOR GSSE/GOOSE

Ethernet capable devices each contain a unique identifying address called a Media Access Control (MAC) address. This address cannot be changed and is unique for each Ethernet device produced worldwide. The address is six bytes in length and is usually represented as six hexadecimal values (for example, 00 A0 F4 01 02 03). It is used in all Ethernet frames as the 'source' address of the frame. Each Ethernet frame also contains a *destination* address. The destination address can be different for each Ethernet frame depending on the intended destination of the frame.

A special type of destination address called a *multicast* address is used when the Ethernet frame can be received by more than one device. An Ethernet MAC address is multicast when the least significant bit of the first byte is set (for example, 01 00 00 00 00 00 is a multicast address).

GSSE and GOOSE messages must have multicast destination MAC addresses.

By default, the L30 is configured to use an automated multicast MAC scheme. If the L30 destination MAC address setting is not a valid multicast address (that is, the least significant bit of the first byte is not set), the address used as the destination MAC will be the same as the local MAC address, but with the multicast bit set. Thus, if the local MAC address is 00 A0 F4 01 02 03, then the destination MAC address will be 01 A0 F4 01 02 03.



### C.4.6 GSSE ID AND GOOSE ID SETTINGS

GSSE messages contain an identifier string used by receiving devices to identify the sender of the message, defined in IEC 61850 part 8-1 as GsID. This is a programmable 65-character string. This string should be chosen to provide a descriptive name of the originator of the GSSE message.

GOOSE messages contain an identifier string used by receiving devices to identify the sender of the message, defined in IEC 61850 part 8-1 as GoID. This programmable 65-character string should be a descriptive name of the originator of the GOOSE message. GOOSE messages also contain two additional character strings used for identification of the message: DatSet - the name of the associated dataset, and GoCBRef - the reference (name) of the associated GOOSE control block. These strings are automatically populated and interpreted by the L30; no settings are required.

## C.5.1 OVERVIEW

The L30 can be configured for IEC 61850 via the EnerVista UR Setup software as follows.

1. An ICD file is generated for the L30 by the EnerVista UR Setup software that describe the capabilities of the IED.
2. The ICD file is then imported into a system configurator along with other ICD files for other IEDs (from GE or other vendors) for system configuration.
3. The result is saved to a SCD file, which is then imported back to EnerVista UR Setup to create one or more settings file(s). The settings file(s) can then be used to update the relay(s) with the new configuration information.

The configuration process is illustrated below.



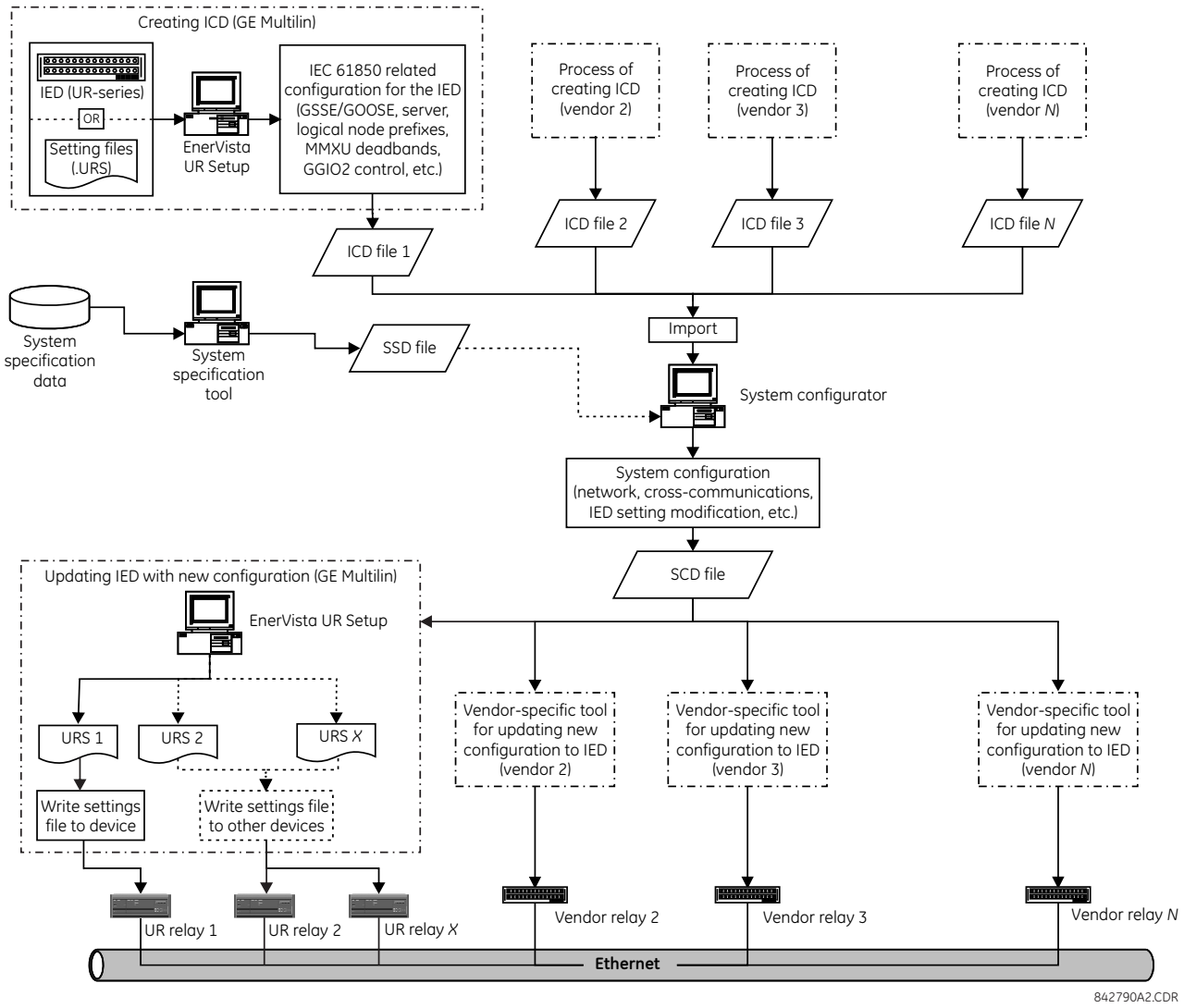



**Figure C–2: IED CONFIGURATION PROCESS**

The following acronyms and abbreviations are used in the procedures describing the IED configuration process for IEC 61850:

- BDA: Basic Data Attribute, that is not structured
- DAI: Instantiated Data Attribute
- DO: Data Object type or instance, depending on the context

- DOI: Instantiated Data Object
- IED: Intelligent Electronic Device
- LDInst: Instantiated Logical Device
- LNInst: Instantiated Logical Node
- SCL: Substation Configuration Description Language. The configuration language is an application of the Extensible Markup Language (XML) version 1.0.
- SDI: Instantiated Sub DATA; middle name part of a structured DATA name
- UR: GE Multilin Universal Relay series
- URI: Universal Resource Identifier
- URS: UR-series relay setting file
- XML: Extensible Markup Language

The following SCL variants are also used:

- ICD: IED Capability Description
- CID: Configured IED Description
- SSD: System Specification Description
- SCD: Substation Configuration Description

The following IEC related tools are referenced in the procedures that describe the IED configuration process for IEC 61850:

- **System configurator** or **Substation configurator**: This is an IED independent system level tool that can import or export configuration files defined by IEC 61850-6. It can import configuration files (ICD) from several IEDs for system level engineering and is used to add system information shared by different IEDs. The system configuration generates a substation related configuration file (SCD) which is fed back to the IED configurator (for example, EnerVista UR Setup) for system related IED configuration. The system configurator should also be able to read a system specification file (SSD) to use as base for starting system engineering, or to compare it with an engineered system for the same substation.
- **IED configurator**: This is a vendor specific tool that can directly or indirectly generate an ICD file from the IED (for example, from a settings file). It can also import a system SCL file (SCD) to set communication configuration parameters (that is, required addresses, reception GOOSE datasets, IDs of incoming GOOSE datasets, etc.) for the IED. The IED configurator functionality is implemented in the EnerVista UR Setup software.

### C.5.2 CONFIGURING IEC 61850 SETTINGS

Before creating an ICD file, the user can customize the IEC 61850 related settings for the IED. For example, the IED name and logical device instance can be specified to uniquely identify the IED within the substation, or transmission GOOSE datasets created so that the system configurator can configure the cross-communication links to send GOOSE messages from the IED. Once the IEC 61850 settings are configured, the ICD creation process will recognize the changes and generate an ICD file that contains the updated settings.

Some of the IED settings will be modified during they system configuration process. For example, a new IP address may be assigned, line items in a Transmission GOOSE dataset may be added or deleted, or prefixes of some logical nodes may be changed. While all new configurations will be mapped to the L30 settings file when importing an SCD file, all unchanged settings will preserve the same values in the new settings file.

These settings can be configured either directly through the relay panel or through the EnerVista UR Setup software (preferred method). The full list of IEC 61850 related settings for are as follows:

- Network configuration: IP address, IP subnet mask, and default gateway IP address (access through the **Settings > Product Setup > Communications > Network** menu tree in EnerVista UR Setup).
- Server configuration: IED name and logical device instance (access through the **Settings > Product Setup > Communications > IEC 61850 > Server Configuration** menu tree in EnerVista UR Setup).
- Logical node prefixes, which includes prefixes for all logical nodes except LLN0 (access through the **Settings > Product Setup > Communications > IEC 61850 > Logical Node Prefixes** menu tree in EnerVista UR Setup).

- MMXU deadbands, which includes deadbands for all available MMXUs. The number of MMXUs is related to the number of CT/VT modules in the relay. There are two MMXUs for each CT/VT module. For example, if a relay contains two CT/VT modules, there will be four MMXUs available (access through the **Settings > Product Setup > Communications > IEC 61850 > MMXU Deadbands** menu tree in EnerVista UR Setup).
- GGIO1 status configuration, which includes the number of status points in GGIO1 as well as the potential internal mappings for each GGIO1 indication. However only the number of status points will be used in the ICD creation process (access through the **Settings > Product Setup > Communications > IEC 61850 > GGIO1 Status Configuration** menu tree in EnerVista UR Setup).
- GGIO2 control configuration, which includes ctlModels for all SPCSOs within GGIO2 (access through the **Settings > Product Setup > Communications > IEC 61850 > GGIO2 Control Configuration** menu tree in EnerVista UR Setup).
- Configurable transmission GOOSE, which includes eight configurable datasets that can be used for GOOSE transmission. The GOOSE ID can be specified for each dataset (it must be unique within the IED as well as across the whole substation), as well as the destination MAC address, VLAN priority, VLAN ID, ETYPE APPID, and the dataset items. The selection of the dataset item is restricted by firmware version; for version 7.2x, only GGIO1.ST.Indx.stVal and GGIO1.ST.Indx.q are valid selection (where *x* is between 1 to *N*, and *N* is determined by number of GGIO1 status points). Although configurable transmission GOOSE can also be created and altered by some third-party system configurators, we recommend configuring transmission GOOSE for GE Multilin IEDs before creating the ICD, and strictly within EnerVista UR Setup software or the front panel display (access through the **Settings > Product Setup > Communications > IEC 61850 > GSSE/GOOSE Configuration > Transmission > Tx Configurable GOOSE** menu tree in EnerVista UR Setup).
- Configurable reception GOOSE, which includes eight configurable datasets that can be used for GOOSE reception. However, unlike datasets for transmission, datasets for reception only contains dataset items, and they are usually created automatically by process of importing the SCD file (access through the **Settings > Product Setup > Communications > IEC 61850 > GSSE/GOOSE Configuration > Reception > Rx Configurable GOOSE** menu tree in EnerVista UR Setup).
- Remote devices configuration, which includes remote device ID (GOOSE ID or GoID of the incoming transmission GOOSE dataset), ETYPE APPID (of the GSE communication block for the incoming transmission GOOSE), and DATASET (which is the name of the associated reception GOOSE dataset). These settings are usually done automatically by process of importing SCD file (access through the **Settings > Inputs/Outputs > Remote Devices** menu tree in EnerVista UR Setup).
- Remote inputs configuration, which includes device (remote device ID) and item (which dataset item in the associated reception GOOSE dataset to map) values. Only the items with cross-communication link created in SCD file should be mapped. These configurations are usually done automatically by process of importing SCD file (access through the **Settings > Inputs/Outputs > Remote Inputs** menu tree in EnerVista UR Setup).

### C.5.3 ABOUT ICD FILES

The SCL language is based on XML, and its syntax definition is described as a W3C XML Schema. ICD is one type of SCL file (which also includes SSD, CID and SCD files). The ICD file describes the capabilities of an IED and consists of four major sections:

- Header
- Communication
- IEDs
- DataTypeTemplates

The root file structure of an ICD file is illustrated below.

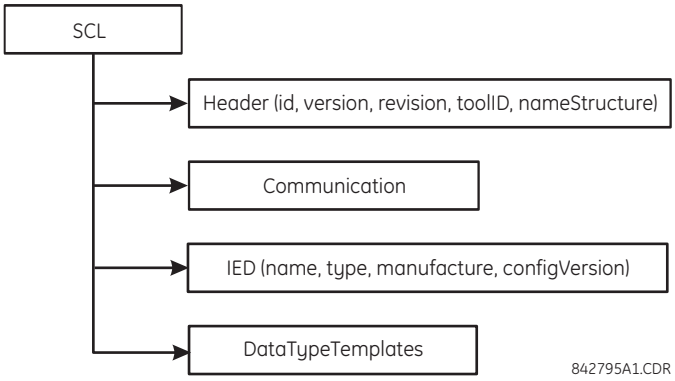



**Figure C–3: ICD FILE STRUCTURE, SCL (ROOT) NODE**

The **Header** node identifies the ICD file and its version, and specifies options for the mapping of names to signals

The **Communication** node describes the direct communication connection possibilities between logical nodes by means of logical buses (sub-networks) and IED access ports. The communication section is structured as follows.

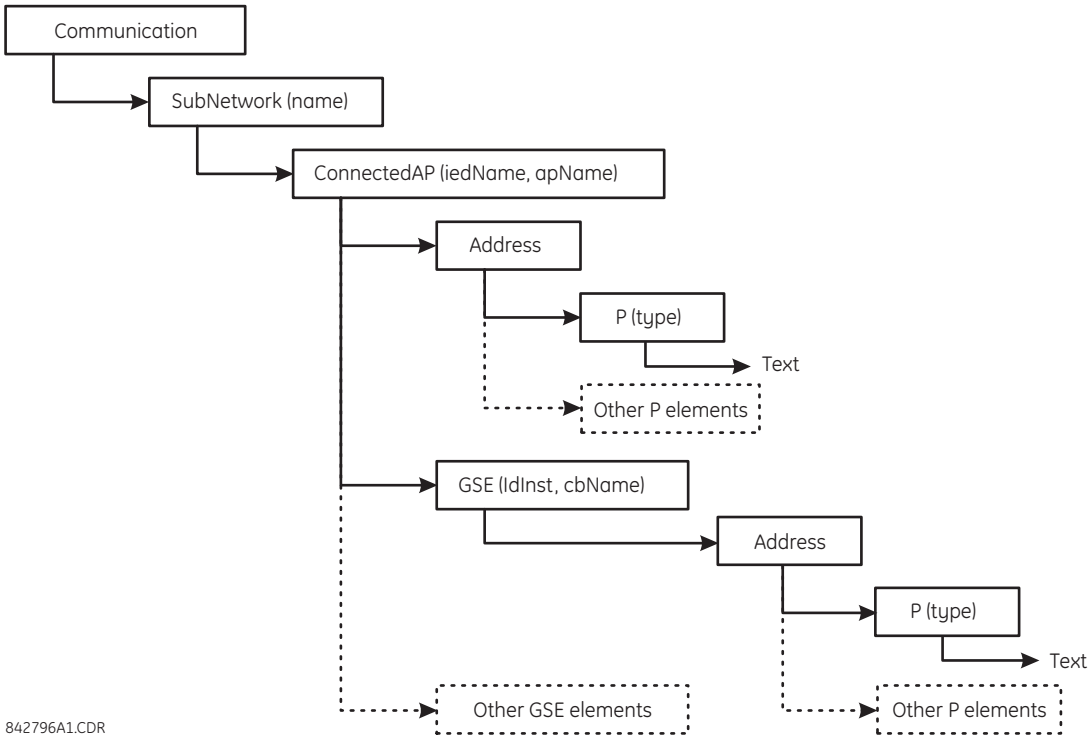



**Figure C–4: ICD FILE STRUCTURE, COMMUNICATIONS NODE**

The **SubNetwork** node contains all access points which can (logically) communicate with the sub-network protocol and without the intervening router. The **ConnectedAP** node describes the IED access point connected to this sub-network. The **Address** node contains the address parameters of the access point. The **GSE** node provides the address element for stating the control block related address parameters, where **IdInst** is the instance identification of the logical device within the IED on which the control block is located, and **cbName** is the name of the control block.

The **IED** node describes the (pre-)configuration of an IED: its access points, the logical devices, and logical nodes instantiated on it. Furthermore, it defines the capabilities of an IED in terms of communication services offered and, together with its **LNType**, instantiated data (DO) and its default or configuration values. There should be only one IED section in an ICD since it only describes one IED.

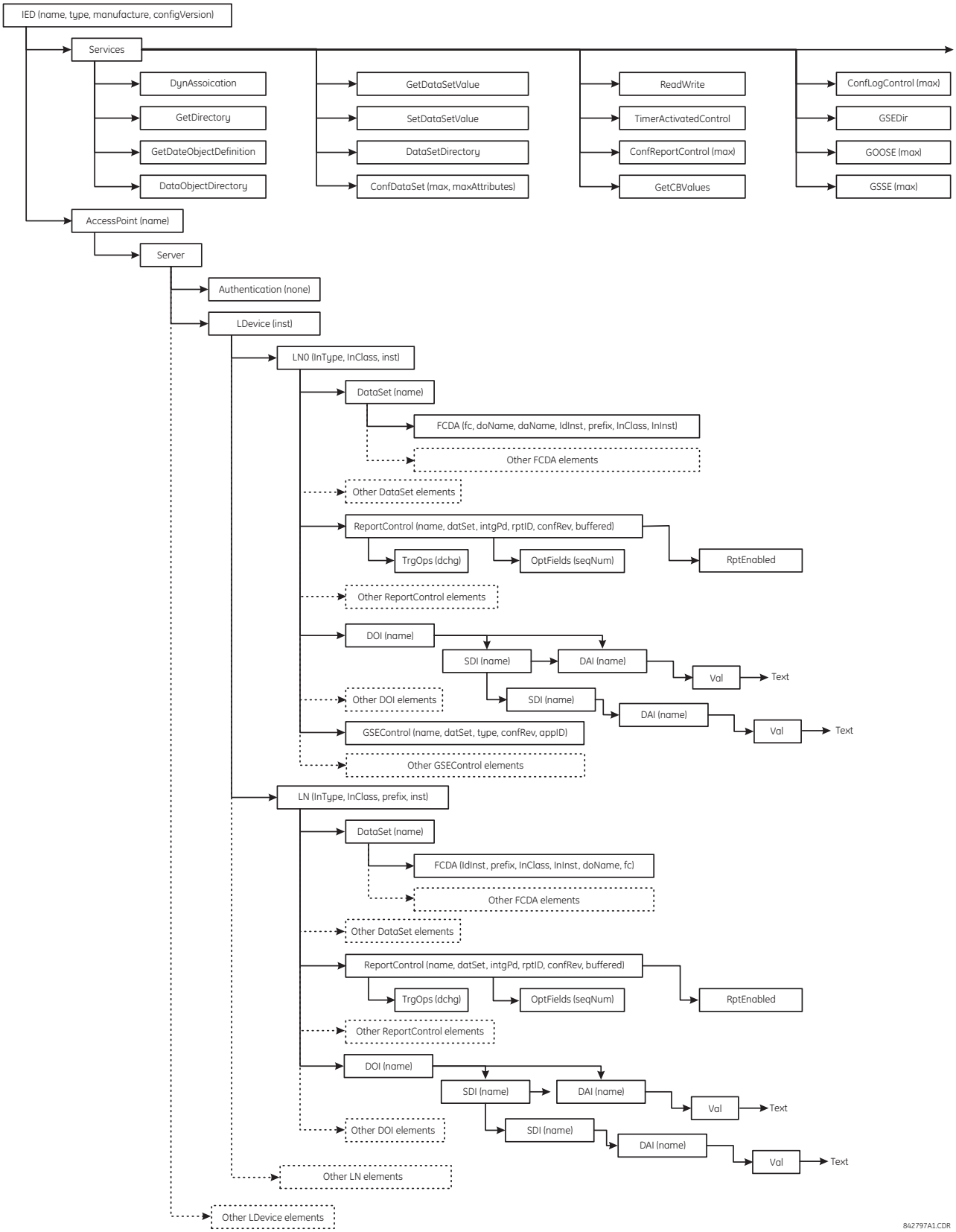



**Figure C–5: ICD FILE STRUCTURE, IED NODE**

The **DataTypeTemplates** node defines instantiable logical node types. A logical node type is an instantiable template of the data of a logical node. A **LnodeType** is referenced each time that this instantiable type is needed with an IED. A logical node type template is built from DATA (DO) elements, which again have a DO type, which is derived from the DATA classes (CDC). DOs consist of attributes (DA) or of elements of already defined DO types (SDO). The attribute (DA) has a functional constraint, and can either have a basic type, be an enumeration, or a structure of a **DAType**. The DAType is built from BDA elements, defining the structure elements, which again can be **BDA** elements of have a base type such as DA.

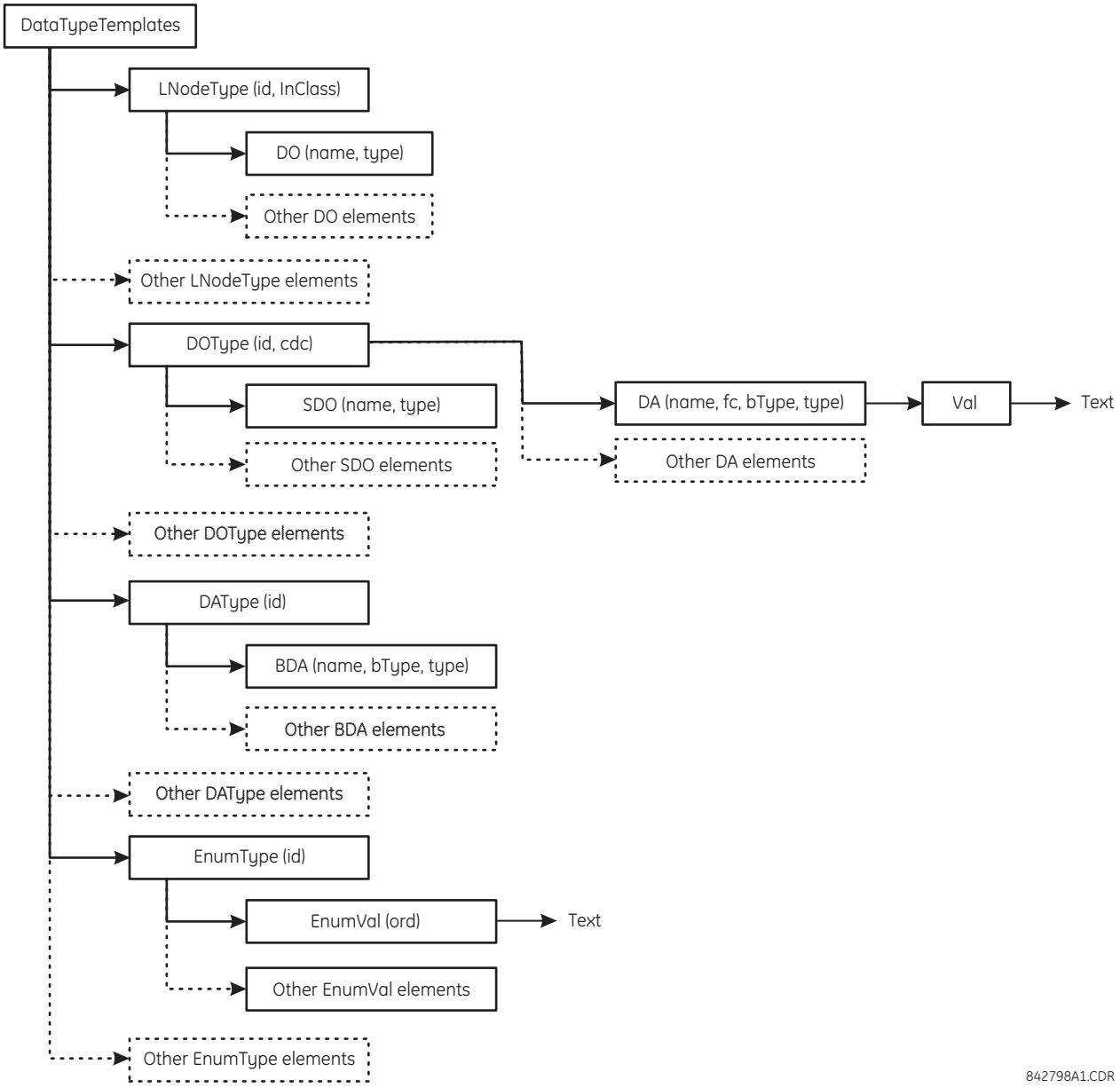
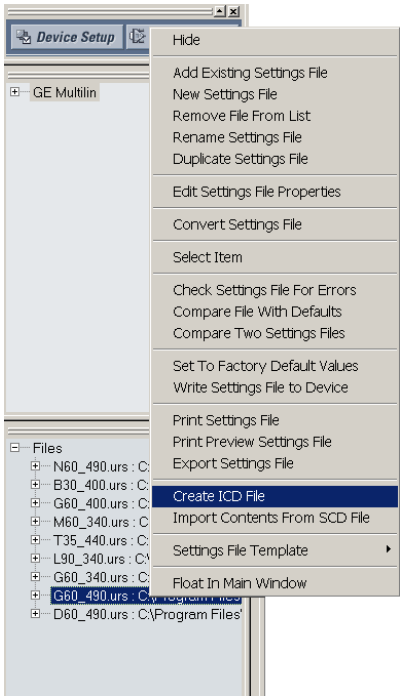



**Figure C–6: ICD FILE STRUCTURE, DATATYPETEMPLATES NODE**

### C.5.4 CREATING AN ICD FILE WITH ENERVISTA UR SETUP

An ICD file can be created directly from a connected L30 IED or from an offline L30 settings file with the EnerVista UR Setup software using the following procedure:

1. Right-click the connected UR-series relay or settings file and select **Create ICD File**.




2. The EnerVista UR Setup will prompt to save the file. Select the file path and enter the name for the ICD file, then click **OK** to generate the file.

The time to create an ICD file from the offline L30 settings file is typically much quicker than create an ICD file directly from the relay.

### C.5.5 ABOUT SCD FILES

System configuration is performed in the system configurator. While many vendors (including GE Multilin) are working their own system configuration tools, there are some system configurators available in the market (for example, Siemens DIGSI version 4.6 or above and ASE Visual SCL Beta 0.12).

Although the configuration tools vary from one vendor to another, the procedure is pretty much the same. First, a substation project must be created, either as an empty template or with some system information by importing a system specification file (SSD). Then, IEDs are added to the substation. Since each IED is represented by its associated ICD, the ICD files are imported into the substation project, and the system configurator validates the ICD files during the importing process. If the ICD files are successfully imported into the substation project, it may be necessary to perform some additional minor steps to attach the IEDs to the substation (see the system configurator manual for details).

Once all IEDs are inserted into the substation, further configuration is possible, such as:

- Assigning network addresses to individual IEDs.
- Customizing the prefixes of logical nodes.
- Creating cross-communication links (configuring GOOSE messages to send from one IED to others).

When system configurations are complete, the results are saved to an SCD file, which contains not only the configuration for each IED in the substation, but also the system configuration for the entire substation. Finally, the SCD file is passed back to the IED configurator (vendor specific tool) to update the new configuration into the IED.

The SCD file consists of at least five major sections:

- Header.
- Substation.
- Communication.
- IED section (one or more).
- DataTypeTemplates.

The root file structure of an SCD file is illustrated below.

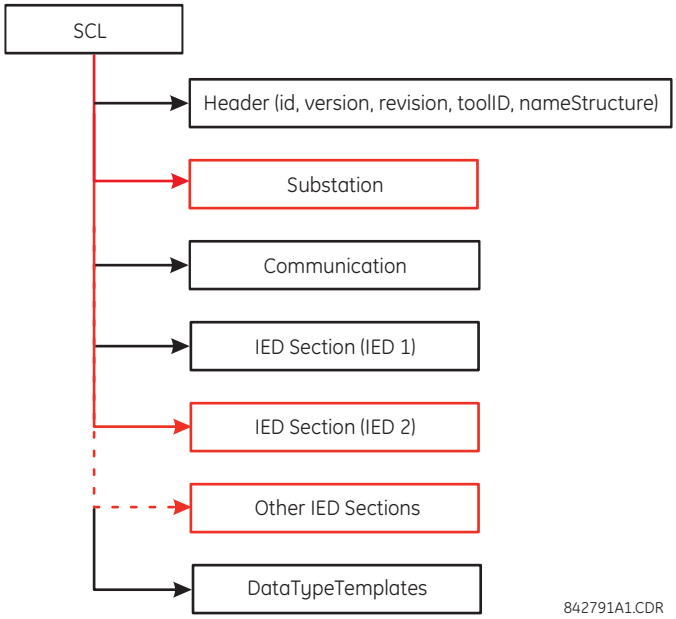



**Figure C–7: SCD FILE STRUCTURE, SCL (ROOT) NODE**

Like ICD files, the **Header** node identifies the SCD file and its version, and specifies options for the mapping of names to signals.

The **Substation** node describes the substation parameters:

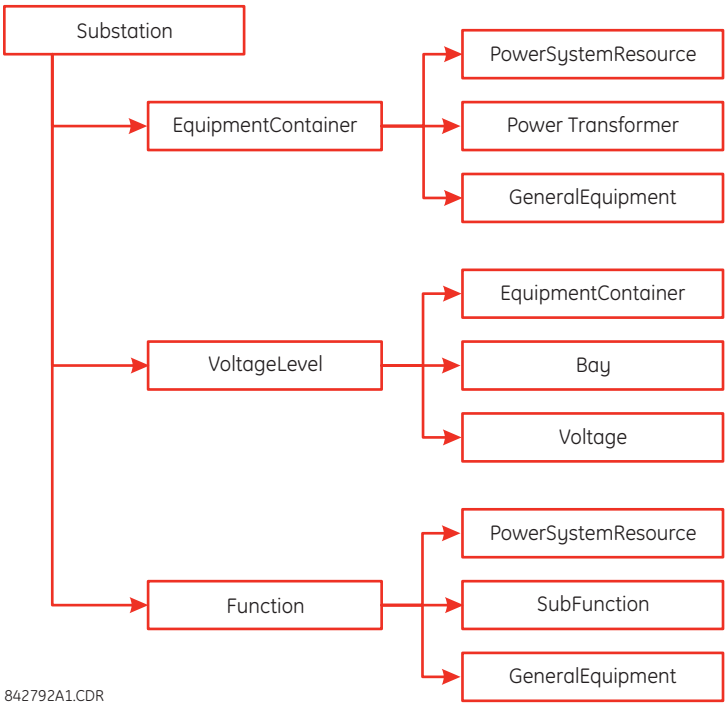



**Figure C–8: SCD FILE STRUCTURE, SUBSTATION NODE**

The **Communication** node describes the direct communication connection possibilities between logical nodes by means of logical buses (sub-networks) and IED access ports. The communication section is structured as follows.

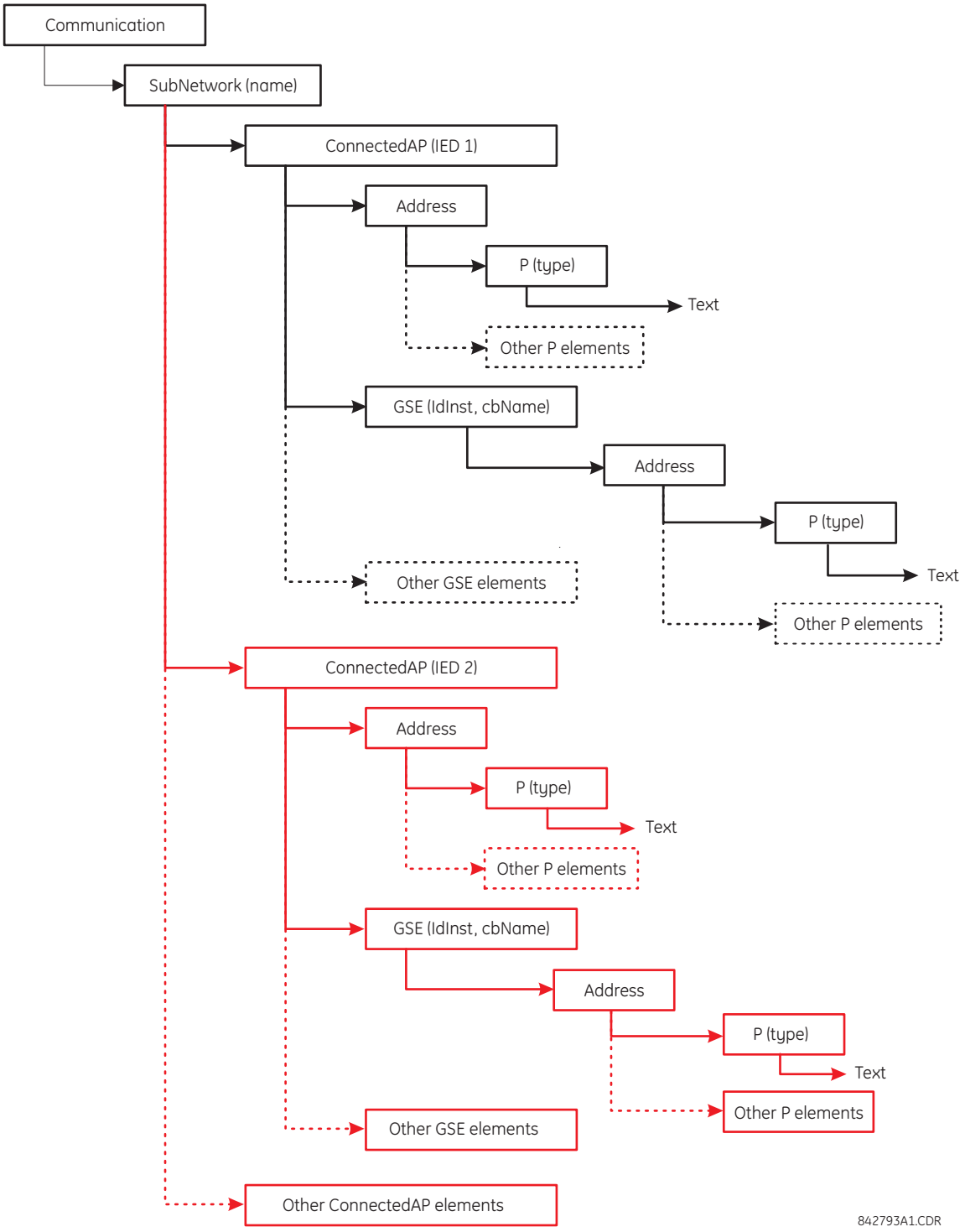



**Figure C–9: SCD FILE STRUCTURE, COMMUNICATIONS NODE**

The **SubNetwork** node contains all access points which can (logically) communicate with the sub-network protocol and without the intervening router. The **ConnectedAP** node describes the IED access point connected to this sub-network. The **Address** node contains the address parameters of the access point. The **GSE** node provides the address element for stating the control block related address parameters, where **ldInst** is the instance identification of the logical device within the IED on which the control block is located, and **cbName** is the name of the control block.

The **IED Section** node describes the configuration of an IED.

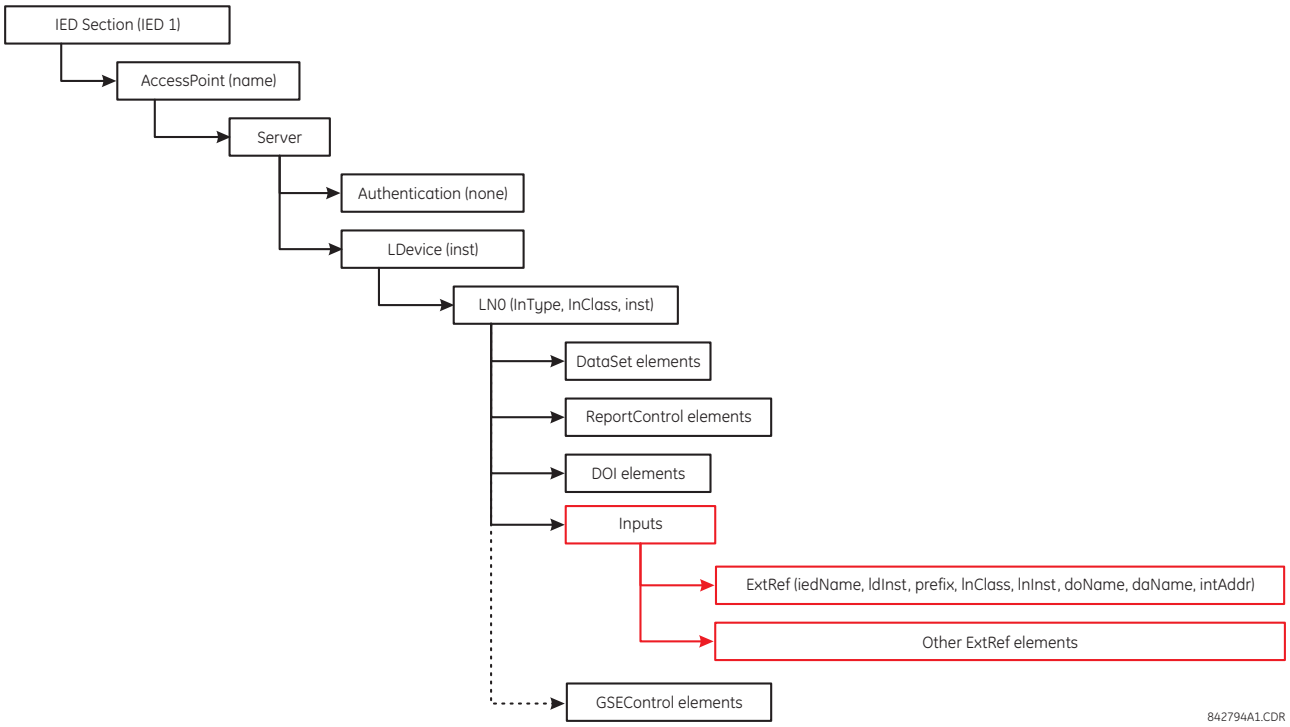
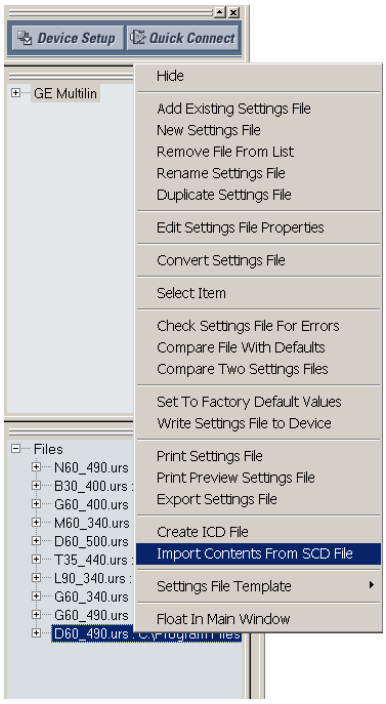



**Figure C–10: SCD FILE STRUCTURE, IED NODE**

## C.5.6 IMPORTING AN SCD FILE WITH ENERVISTA UR SETUP

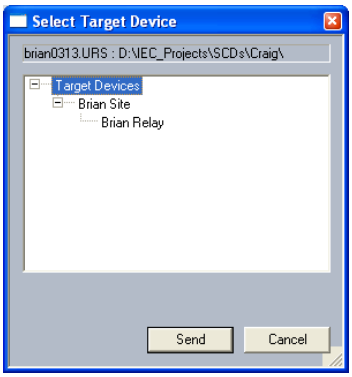
The following procedure describes how to update the L30 with the new configuration from an SCD file with the EnerVista UR Setup software.

1. Right-click anywhere in the files panel and select the **Import Contents From SCD File** item.




2. Select the saved SCD file and click **Open**.
3. The software will open the SCD file and then prompt the user to save a UR-series settings file. Select a location and name for the URS (UR-series relay settings) file.

   If there is more than one GE Multilin IED defined in the SCD file, the software prompt the user to save a UR-series settings file for each IED.
4. After the URS file is created, modify any settings (if required).
5. To update the relay with the new settings, right-click on the settings file in the settings tree and select the **Write Settings File to Device** item.
6. The software will prompt for the target device. Select the target device from the list provided and click **Send**. The new settings will be updated to the selected device.



### C.6.1 ACSI BASIC CONFORMANCE STATEMENT

| SERVICES | | SERVER/ PUBLISHER | UR-FAMILY |
|---|---|---|---|
| **CLIENT-SERVER ROLES** | | | |
| B11 | **Server** side (of Two-party Application-Association) | **c1** | **Yes** |
| B12 | **Client** side (of Two-party Application-Association) | **---** | |
| **SCSMS SUPPORTED** | | | |
| B21 | **SCSM**: IEC 61850-8-1 used | | **Yes** |
| B22 | **SCSM**: IEC 61850-9-1 used | | |
| B23 | **SCSM**: IEC 61850-9-2 used | | |
| B24 | **SCSM**: other | | |
| **GENERIC SUBSTATION EVENT MODEL (GSE)** | | | |
| B31 | **Publisher** side | **O** | **Yes** |
| B32 | **Subscriber** side | **---** | **Yes** |
| **TRANSMISSION OF SAMPLED VALUE MODEL (SVC)** | | | |
| B41 | **Publisher** side | **O** | |
| B42 | **Subscriber** side | **---** | |

NOTE

**c1**: shall be "M" if support for LOGICAL-DEVICE model has been declared
**O**: Optional
**M**: Mandatory

### C.6.2 ACSI MODELS CONFORMANCE STATEMENT

| SERVICES | | SERVER/ PUBLISHER | UR-FAMILY |
|---|---|---|---|
| **IF SERVER SIDE (B11) SUPPORTED** | | | |
| M1 | **Logical device** | **c2** | **Yes** |
| M2 | **Logical node** | **c3** | **Yes** |
| M3 | **Data** | **c4** | **Yes** |
| M4 | **Data set** | **c5** | **Yes** |
| M5 | **Substitution** | **O** | |
| M6 | **Setting group control** | **O** | |
| | **REPORTING** | | |
| M7 | **Buffered report control** | **O** | **Yes** |
| M7-1 | sequence-number | | |
| M7-2 | report-time-stamp | | |
| M7-3 | reason-for-inclusion | | |
| M7-4 | data-set-name | | |
| M7-5 | data-reference | | |
| M7-6 | buffer-overflow | | |
| M7-7 | entryID | | |
| M7-8 | BufTm | | |
| M7-9 | IntgPd | | |
| M7-10 | GI | | |
| M8 | **Unbuffered report control** | **O** | **Yes** |
| M8-1 | sequence-number | | |
| M8-2 | report-time-stamp | | |
| M8-3 | reason-for-inclusion | | |

| SERVICES | | SERVER/ PUBLISHER | UR-FAMILY |
|---|---|---|---|
| M8-4 | data-set-name | | |
| M8-5 | data-reference | | |
| M8-6 | BufTm | | |
| M8-7 | IntgPd | | |
| M8-8 | GI | | |
| | **Logging** | **O** | |
| M9 | **Log control** | **O** | |
| M9-1 | IntgPd | | |
| M10 | **Log** | **O** | |
| M11 | **Control** | **M** | **Yes** |
| **IF GSE (B31/32) IS SUPPORTED** | | | |
| | **GOOSE** | **O** | **Yes** |
| M12-1 | entryID | | |
| M12-2 | DataRefInc | | |
| M13 | **GSSE** | **O** | **Yes** |
| **IF SVC (B41/B42) IS SUPPORTED** | | | |
| M14 | Multicast SVC | **O** | |
| M15 | Unicast SVC | **O** | |
| M16 | **Time** | **M** | **Yes** |
| M17 | **File transfer** | **O** | **Yes** |

NOTE

**c2**: shall be "M" if support for LOGICAL-NODE model has been declared
**c3**: shall be "M" if support for DATA model has been declared
**c4**: shall be "M" if support for DATA-SET, Substitution, Report, Log Control, or Time models has been declared
**c5**: shall be "M" if support for Report, GSE, or SMV models has been declared
**M**: Mandatory

### C.6.3 ACSI SERVICES CONFORMANCE STATEMENT

In the table below, the acronym AA refers to Application Associations (TP: Two Party / MC: Multicast). The c6 to c10 entries are defined in the notes following the table.

| SERVICES | | AA: TP/MC | SERVER/ PUBLISHER | UR FAMILY |
|---|---|---|---|---|
| **SERVER (CLAUSE 7)** | | | | |
| S1 | ServerDirectory | TP | M | Yes |
| **APPLICATION ASSOCIATION (CLAUSE 8)** | | | | |
| S2 | Associate | TP | M | Yes |
| S3 | Abort | TP | M | Yes |
| S4 | Release | TP | M | Yes |
| **LOGICAL DEVICE (CLAUSE 9)** | | | | |
| S5 | LogicalDeviceDirectory | TP | M | Yes |
| **LOGICAL NODE (CLAUSE 10)** | | | | |
| S6 | LogicalNodeDirectory | TP | M | Yes |
| S7 | GetAllDataValues | TP | M | Yes |
| **DATA (CLAUSE 11)** | | | | |
| S8 | GetDataValues | TP | M | Yes |
| S9 | SetDataValues | TP | O | Yes |
| S10 | GetDataDirectory | TP | M | Yes |
| S11 | GetDataDefinition | TP | M | Yes |

| SERVICES | | AA: TP/MC | SERVER/ PUBLISHER | UR FAMILY |
|---|---|---|---|---|
| **DATA SET (CLAUSE 12)** | | | | |
| S12 | GetDataSetValues | TP | M | Yes |
| S13 | SetDataSetValues | TP | O | |
| S14 | CreateDataSet | TP | O | |
| S15 | DeleteDataSet | TP | O | |
| S16 | GetDataSetDirectory | TP | O | Yes |
| **SETTING GROUP CONTROL (CLAUSE 16)** | | | | |
| S18 | SelectActiveSG | TP | O | |
| S19 | SelectEditSG | TP | O | |
| S20 | SetSGValues | TP | O | |
| S21 | ConfirmEditSGValues | TP | O | |
| S22 | GetSGValues | TP | O | |
| S23 | GetSGCBValues | TP | O | |
| **REPORTING (CLAUSE 17)** | | | | |
| | **BUFFERED REPORT CONTROL BLOCK (BRCB)** | | | |
| S24 | Report | TP | c6 | Yes |
| S24-1 | data-change (dchg) | | | Yes |
| S24-2 | qchg-change (qchg) | | | |
| S24-3 | data-update (dupd) | | | |
| S25 | GetBRCBValues | TP | c6 | Yes |
| S26 | SetBRCBValues | TP | c6 | Yes |
| | **UNBUFFERED REPORT CONTROL BLOCK (URCB)** | | | |
| S27 | Report | TP | c6 | Yes |
| S27-1 | data-change (dchg) | | | Yes |
| S27-2 | qchg-change (qchg) | | | |
| S27-3 | data-update (dupd) | | | |
| S28 | GetURCBValues | TP | c6 | Yes |
| S29 | SetURCBValues | TP | c6 | Yes |
| **LOGGING (CLAUSE 17)** | | | | |
| | **LOG CONTROL BLOCK** | | | |
| S30 | GetLCBValues | TP | M | |
| S31 | SetLCBValues | TP | M | |
| | **LOG** | | | |
| S32 | QueryLogByTime | TP | M | |
| S33 | QueryLogByEntry | TP | M | |
| S34 | GetLogStatusValues | TP | M | |
| **GENERIC SUBSTATION EVENT MODEL (GSE) (CLAUSE 18, ANNEX C)** | | | | |
| | **GOOSE-CONTROL-BLOCK (CLAUSE 18)** | | | |
| S35 | SendGOOSEMessage | MC | c8 | Yes |
| S36 | GetReference | TP | c9 | |
| S37 | GetGOOSEElementNumber | TP | c9 | |
| S38 | GetGoCBValues | TP | O | Yes |
| S39 | SetGoCBValues | TP | O | Yes |
| | **GSSE-CONTROL-BLOCK (ANNEX C)** | | | |
| S40 | SendGSSEMessage | MC | c8 | Yes |
| S41 | GetReference | TP | c9 | |
| S42 | GetGSSEElementNumber | TP | c9 | |
| S43 | GetGsCBValues | TP | O | Yes |

| SERVICES | | AA: TP/MC | SERVER/ PUBLISHER | UR FAMILY |
|---|---|---|---|---|
| S44 | SetGsCBValues | TP | O | Yes |
| **TRANSMISSION OF SAMPLED VALUE MODEL (SVC) (CLAUSE 19)** | | | | |
| | **MULTICAST SVC** | | | |
| S45 | SendMSVMessage | MC | c10 | |
| S46 | GetMSVCBValues | TP | O | |
| S47 | SetMSVCBValues | TP | O | |
| | **UNICAST SVC** | | | |
| S48 | SendUSVMessage | MC | c10 | |
| S49 | GetUSVCBValues | TP | O | |
| S50 | SetUSVCBValues | TP | O | |
| **CONTROL (CLAUSE 20)** | | | | |
| S51 | Select | | O | Yes |
| S52 | SelectWithValue | TP | O | |
| S53 | Cancel | TP | O | Yes |
| S54 | Operate | TP | M | Yes |
| S55 | Command-Termination | TP | O | |
| S56 | TimeActivated-Operate | TP | O | |
| **FILE TRANSFER (CLAUSE 23)** | | | | |
| S57 | GetFile | TP | M | Yes |
| S58 | SetFile | TP | O | |
| S59 | DeleteFile | TP | O | |
| S60 | GetFileAttributeValues | TP | M | Yes |
| **TIME (CLAUSE 5.5)** | | | | |
| T1 | Time resolution of internal clock (nearest negative power of 2 in seconds) | | | 20 |
| T2 | Time accuracy of internal clock | | | SNTP, IRIG-B |
| T3 | Supported TimeStamp resolution (nearest value of $2^{-n}$ in seconds, according to 6.1.2.9.3.2) | | | 20 |

NOTE

**c6**: shall declare support for at least one (BRCB or URCB)
**c7**: shall declare support for at least one (QueryLogByTime or QueryLogAfter)
**c8**: shall declare support for at least one (SendGOOSEMessage or SendGSSEMessage)
**c9**: shall declare support if TP association is available
**c10**: shall declare support for at least one (SendMSVMessage or SendUSVMessage)

## C.7.1 LOGICAL NODES TABLE

The UR-series of relays supports IEC 61850 logical nodes as indicated in the following table. Note that the actual instantiation of each logical node is determined by the product order code. For example. the logical node “PDIS” (distance protection) is available only in the D60 Line Distance Relay.

**Table C–1: IEC 61850 LOGICAL NODES (Sheet 1 of 4)**

| NODES | UR-FAMILY |
|---|---|
| **L: SYSTEM LOGICAL NODES** | |
| LPHD: Physical device information | Yes |
| LLN0: Logical node zero | Yes |
| LCCH: Physical communication channel supervision | --- |
| LGOS: GOOSE subscription | --- |
| LSVS: Sampled value subscription | --- |
| LTIM: Time management | --- |
| LTMS: Time master supervision | --- |
| LTRK: Service tracking | --- |
| **A: LOGICAL NODES FOR AUTOMATIC CONTROL** | |
| ANCR: Neutral current regulator | --- |
| ARCO: Reactive power control | --- |
| ATCC: Automatic tap changer controller | --- |
| AVCO: Voltage control | --- |
| **C: LOGICAL NODES FOR CONTROL** | |
| CALH: Alarm handling | --- |
| CCGR: Cooling group control | --- |
| CILO: Interlocking | --- |
| CPOW: Point-on-wave switching | --- |
| CSWI: Switch controller | Yes |
| CSYN: Synchronizer controller | --- |
| **F: LOGICAL NODES FOR FUNCTIONAL BLOCKS** | |
| FCNT: Counter | --- |
| FCSD: Curve shape description | --- |
| FFIL: Generic filler | --- |
| FLIM: Control function output limitation | --- |
| FPID: PID regulator | --- |
| FRMP: Ramp function | --- |
| FSPT: Set-point control function | --- |
| FXOT: Action at over threshold | --- |
| FXUT: Action at under threshold | --- |
| **G: LOGICAL NODES FOR GENERIC REFERENCES** | |
| GAPC: Generic automatic process control | --- |
| GGIO: Generic process I/O | Yes |
| GLOG: Generic log | --- |
| GSAL: Generic security application | --- |
| **I: LOGICAL NODES FOR INTERFACING AND ARCHIVING** | |
| IARC: Archiving | --- |
| IHMI: Human machine interface | --- |
| ISAF: Safety alarm function | --- |
| ITCI: Telecontrol interface | --- |
| ITMI: Telemonitoring interface | --- |

**Table C–1: IEC 61850 LOGICAL NODES (Sheet 2 of 4)**

| NODES | UR-FAMILY |
|---|---|
| ITPC: Teleprotection communication interfaces | --- |
| **K: LOGICAL NODES FOR MECHANICAL AND NON-ELECTRIC PRIMARY EQUIPMENT** | |
| KFAN: Fan | --- |
| KFIL: Filter | --- |
| KPMP: Pump | --- |
| KTNK: Tank | --- |
| KVLV: Valve control | --- |
| **M: LOGICAL NODES FOR METERING AND MEASUREMENT** | |
| MENV: Environmental information | --- |
| MFLK: Flicker measurement name | --- |
| MHAI: Harmonics or interharmonics | --- |
| MHAN: Non phase related harmonics or interharmonics | --- |
| MHYD: Hydrological information | --- |
| MMDC: DC measurement | --- |
| MMET: Meteorological information | --- |
| MMTN: Metering | --- |
| MMTR: Metering | --- |
| MMXN: Non-phase-related measurement | Yes |
| MMXU: Measurement | Yes |
| MSQI: Sequence and imbalance | Yes |
| MSTA: Metering statistics | --- |
| **P: LOGICAL NODES FOR PROTECTION FUNCTIONS** | |
| PDIF: Differential | Yes |
| PDIR: Direction comparison | --- |
| PDIS: Distance | Yes |
| PDOP: Directional overpower | --- |
| PDUP: Directional underpower | --- |
| PFRC: Rate of change of frequency | --- |
| PHAR: Harmonic restraint | --- |
| PHIZ: Ground detector | --- |
| PIOC: Instantaneous overcurrent | Yes |
| PMRI Motor restart inhibition | --- |
| PMSS: Motor starting time supervision | --- |
| POPF: Over power factor | --- |
| PPAM: Phase angle measuring | --- |
| PRTR: Rotor protection | --- |
| PSCH: Protection scheme | --- |
| PSDE: Sensitive directional earth fault | --- |
| PTEF: Transient earth fault | --- |
| PTOC: Time overcurrent | Yes |
| PTOF: Overfrequency | --- |
| PTOV: Overvoltage | Yes |
| PTRC: Protection trip conditioning | Yes |
| PTTR: Thermal overload | --- |
| PTUC: Undercurrent | --- |
| PTUF: Underfrequency | --- |
| PTUV: Undervoltage | Yes |

**Table C–1: IEC 61850 LOGICAL NODES (Sheet 3 of 4)**

| NODES | UR-FAMILY |
|---|---|
| PUPF: Underpower factor | --- |
| PVOC: Voltage controlled time overcurrent | --- |
| PVPH: Volts per Hz | --- |
| PZSU: Zero speed or underspeed | --- |
| **Q: LOGICAL NODES FOR POWER QUALITY EVENTS** | |
| QFVR: Frequency variation | --- |
| QITR: Current transient | --- |
| QIUB: Current unbalance variation | --- |
| QVTR: Voltage transient | --- |
| QVUB: Voltage unbalance variation | --- |
| QVVR: Voltage variation | --- |
| **R: LOGICAL NODES FOR PROTECTION-RELATED FUNCTIONS** | |
| RADR: Disturbance recorder channel analogue | --- |
| RBDR: Disturbance recorder channel binary | --- |
| RBRF: Breaker failure | --- |
| RDIR: Directional element | --- |
| RDRE: Disturbance recorder function | --- |
| RDRS: Disturbance record handling | --- |
| RFLO: Fault locator | Yes |
| RMXU: Differential measurements | --- |
| RPSB: Power swing detection/blocking | Yes |
| RREC: Autoreclosing | Yes |
| RSYN: Synchronism-check or synchronizing | --- |
| **S: LOGICAL NODES FOR SENSORS AND MONITORING** | |
| SARC: Monitoring and diagnostics for arcs | --- |
| SCBR: Circuit breaker supervision | --- |
| SIMG: Insulation medium supervision (gas) | --- |
| SIML: Insulation medium supervision (liquid) | --- |
| SLTC: Tap changer supervision | --- |
| SOPM: Supervision of operating mechanism | --- |
| SPDC: Monitoring and diagnostics for partial discharges | --- |
| SPTR: Power transformer supervision | --- |
| SSWI: Circuit switch supervision | --- |
| STMP: Temperature supervision | --- |
| SVBR: Vibration supervision | --- |
| **T: LOGICAL NODES FOR INSTRUMENT TRANSFORMERS** | |
| TANG: Angle | --- |
| TAXD: Axial displacement | --- |
| TCTR: Current transformer | --- |
| TDST: Distance | --- |
| TFLW: Liquid flow | --- |
| TFRQ: Frequency | --- |
| TGSN: Generic sensor | --- |
| THUM: Humidity | --- |
| TLVL: Media level | --- |
| TMGF: Magnetic field | --- |
| TMVM: Movement sensor | --- |

**Table C–1: IEC 61850 LOGICAL NODES (Sheet 4 of 4)**

| NODES | UR-FAMILY |
|---|---|
| TPOS: Position indicator | --- |
| TPRS: Pressure sensor | --- |
| TRTN: Rotation transmitter | --- |
| TSND: Sound pressure sensor | --- |
| TTMP: Temperature sensor | --- |
| TTNS: Mechanical tension | --- |
| TVBR: Vibration sensor | --- |
| TVTR: Voltage transformer | --- |
| TWPH: Water acidity | --- |
| **X: LOGICAL NODES FOR SWITCHGEAR** | |
| XCBR: Circuit breaker | Yes |
| XSWI: Circuit switch | Yes |
| **Y: LOGICAL NODES FOR POWER TRANSFORMERS** | |
| YEFN: Earth fault neutralizer (Petersen coil) | --- |
| YLTC: Tap changer | --- |
| YPSH: Power shunt | --- |
| YPTR: Power transformer | --- |
| **Z: LOGICAL NODES FOR FURTHER POWER SYSTEM EQUIPMENT** | |
| ZAXN: Auxiliary network | --- |
| ZBAT: Battery | --- |
| ZBSH: Bushing | --- |
| ZCAB: Power cable | --- |
| ZCAP: Capacitor bank | --- |
| ZCON: Converter | --- |
| ZGEN: Generator | --- |
| ZGIL: Gas insulated line | --- |
| ZLIN: Power overhead line | --- |
| ZMOT: Motor | --- |
| ZREA: Reactor | --- |
| ZRES: Resistor | --- |
| ZRRC: Rotating reactive component | --- |
| ZSAR: Surge arrestor | --- |
| ZSCR: Semi-conductor controlled rectifier | --- |
| ZSMC: Synchronous machine | --- |
| ZTCF: Thyristor controlled frequency converter | --- |
| ZTRC: Thyristor controlled reactive component | --- |

C

### D.1.1 OVERVIEW

IEC 60870-5-103 is defined as a companion standard for the informative element of the protection equipment. IEC 60870-5-103 defines communication for a serial, unbalanced link only. Communication speeds are defined as either 9600 or 19200 baud.

This manual assumes basic knowledge of the IEC 60870-5-103 protocol and the standard IEC 60870 documents relating to the protocol.

Standard IEC 60870 documents relating to IEC 60870-5-103:

- IEC 60870-5-1 Transmission frame formats
- IEC 60870-5-2 Link transmission procedures
- IEC 60870-5-3 General structure of application data
- IEC 60870-5-4 Definition and coding of application information elements
- IEC 60870-5-5 Basic application functions
- IEC 60870-5-6 Conformance testing guidelines

An IEC 60870-5-103 device is required to provide an interoperability table. Interoperability means that any required application data in the device, which can be coded into an IEC 60870-5-103 data type, can be mapped into the IEC 60870-5-103 address space. This data is recognized by any IEC 60870-5-103 master.



### D.1.2 FACTOR AND OFFSET CALCULATION TO TRANSMIT MEASURAND

The general formula for the transmitted value is Xt = a * X + b

where X is the measurand, a is the multiplication factor, b is the offset and Xt is the value transmitted.

The conditions for determining a and b, when the values exceed the range are:

4096 = a*Xmax + b (Xmax is the maximum value for the measurand)

-4095 =a*Xmin + b (Xmin is the minimum value for the measurand)

By solving the above system of equations for a and b, we find that:

a = 8191 / (Xmax - Xmin)

b = -4096 * (Xmax + Xmin) / (Xmax - Xmin)

So

Xt = 8191/(Xmax - Xmin)) * X - 4096 * (Xmax + Xmin) / (Xmax - Xmin)

We may further simplify the above formula for situations where:

1)

Xmin = -Xmax (positive and negative values) :

Xt = (8191/2*Xmax) * X

**a = 4096/Xmax**

**b = 0**

2)

If Xmin = 0 (only positive values)

Xt = (8191/Xmax) * X - 4096

**a = 2 * 4096/Xmax**

**b = -4096**

To calculate Xmax, one needs to know the rated value for the specific type of measurand.

Xmax = 2.4 * Xrated

The boxes indicate the following: ☒ – used in standard direction; ☐ – not used.

**1. PHYSICAL LAYER**

**Electrical interface**

☒ EIA RS-485

32 Number of loads for one protection equipment

**Optical interface**

☐ Glass fibre

☐ Plastic fibre

☐ F-SMA type connector

☐ BFOC/2.5 type connector

**Transmission speed**

☒ 9600 bits/s

☒ 19200 bits/s

**2. LINK LAYER**

There are no choices for the link layer.

**3. APPLICATION LAYER**

**Transmission mode for application data**

Mode 1 (least significant octet first), as defined in 4.10 of IEC 60870-5-4, is used exclusively in this companion standard.

**Common address of ASDU**

☒ One COMMON ADDRESS OF ASDU (identical with station address)

☐ More than one COMMON ADDRESS OF ASDU

**Selection of standard information numbers in monitor direction**

**System functions in monitor direction**

| | INF | Semantics |
|---|---|---|
| ☒ | <0> | End of general interrogation |
| ☒ | <0> | Time synchronization |
| ☒ | <2> | Reset FCB |
| ☒ | <3> | Reset CU |
| ☒ | <4> | Start/restart |
| ☒ | <5> | Power on |

**Status indications in monitor direction**

| | INF | Semantics |
|---|---|---|
| ☐ | <16> | Auto-recloser active |
| ☐ | <17> | Teleprotection active |
| ☐ | <18> | Protection active |
| ☐ | <19> | LED reset |
| ☐ | <20> | Monitor direction blocked |
| ☐ | <21> | Test mode |

- ☐ <22> Local parameter setting
- ☐ <23> Characteristic 1
- ☐ <24> Characteristic 2
- ☐ <25> Characteristic 3
- ☐ <26> Characteristic 4
- ☐ <27> Auxiliary input 1
- ☐ <28> Auxiliary input 2
- ☐ <29> Auxiliary input 3
- ☐ <30> Auxiliary input 4

**Supervision indications in monitor direction**

**INF Semantics**

- ☐ <32> Measurand supervision I
- ☐ <33> Measurand supervision V
- ☐ <35> Phase sequence supervision
- ☐ <36> Trip circuit supervision
- ☐ <37> I>> back-up operation
- ☐ <38> VT fuse failure
- ☐ <39> Teleprotection disturbed
- ☐ <46> Group warning
- ☐ <47> Group alarm

**Earth fault indications in monitor direction**

**INF Semantics**

- ☐ <48> Earth fault $L_1$
- ☐ <49> Earth fault $L_2$
- ☐ <50> Earth fault $L_3$
- ☐ <51> Earth fault forward, meaning line
- ☐ <52> Earth fault reverse, meaning busbar

**Fault indications in monitor direction**

**INF Semantics**

- ☐ <64> Start/pick-up $L_1$
- ☐ <65> Start/pick-up $L_2$
- ☐ <66> Start/pick-up $L_3$
- ☐ <67> Start/pick-up N
- ☐ <68> General trip
- ☐ <69> Trip $L_1$
- ☐ <70> Trip $L_2$
- ☐ <71> Trip $L_3$
- ☐ <72> Trip I>> (back-up operation)
- ☐ <73> Fault location X in ohms
- ☐ <74> Fault forward/line

- ☐ <75> Fault reverse/busbar
- ☐ <76> Teleprotection signal transmitted
- ☐ <77> Teleprotection signal received
- ☐ <78> Zone 1
- ☐ <79> Zone 2
- ☐ <80> Zone 3
- ☐ <81> Zone 4
- ☐ <82> Zone 5
- ☐ <83> Zone 6
- ☐ <84> General start / pick-up
- ☐ <85> Breaker failure
- ☐ <86> Trip measuring system $L_1$
- ☐ <87> Trip measuring system $L_2$
- ☐ <88> Trip measuring system $L_3$
- ☐ <89> Trip measuring system E
- ☐ <90> Trip I>
- ☐ <91> Trip I>>
- ☐ <92> Trip IN>
- ☐ <93> Trip IN>>

**Auto-reclosure indications in monitor direction**

**INF Semantics**

- ☐ <128> CB 'on' by AR
- ☐ <129> CB 'on' by long-time AR
- ☐ <130> AR blocked

**Measurands in monitor direction**

**INF Semantics**

- ☐ <144> Measurand I
- ☐ <145> Measurands I, V
- ☐ <146> Measurands I, V, P, Q
- ☐ <147> Measurands $I_N$, $V_{EN}$
- ☐ <148> Measurands $I_{L123}$, $V_{L123}$, P, Q, f

**Generic functions in monitor direction**

**INF Semantics**

- ☐ <240> Read headings of all defined groups
- ☐ <241> Read values or attributes of all entries of one group
- ☐ <243> Read directory of a single entry
- ☐ <244> Read value or attribute of a single entry
- ☐ <245> End of general interrogation of generic data
- ☐ <249> Write entry with confirmation
- ☐ <250> Write entry with execution

☐ <251> Write entry aborted

**Selection of standard information numbers in control direction**

**System functions in control direction**

| | INF | Semantics |
|---|---|---|
| ☒ | <0> | Initiation of general interrogation |
| ☒ | <0> | Time synchronization |

**General commands in control direction**

| | INF | Semantics |
|---|---|---|
| ☐ | <16> | Auto-recloser on/off |
| ☐ | <17> | Teleprotection on/off |
| ☐ | <18> | Protection on/off |
| ☐ | <19> | LED reset |
| ☐ | <23> | Activate characteristic 1 |
| ☐ | <24> | Activate characteristic 2 |
| ☐ | <25> | Activate characteristic 3 |
| ☐ | <26> | Activate characteristic 4 |

**Generic functions in control direction**

| | INF | Semantics |
|---|---|---|
| ☐ | <240> | Read headings of all defined groups |
| ☐ | <241> | Read values or attributes of all entries of one group |
| ☐ | <243> | Read directory of a single entry |
| ☐ | <244> | Read value or attribute of a single entry |
| ☐ | <245> | General interrogation of generic data |
| ☐ | <248> | Write entry |
| ☐ | <249> | Write entry with confirmation |
| ☐ | <250> | Write entry with execution |
| ☐ | <251> | Write entry abort |

**Basic application functions**

- ☐ Test mode
- ☐ Blocking of monitor direction
- ☐ Disturbance data
- ☐ Generic services
- ☐ Private data

**Miscellaneous**

| MEASURAND | MAX MVAL = TIMES RATED VALUE | | |
|---|---|---|---|
| | 1,2 | OR | 2,4 |
| Current $L_1$ | ☐ | | ☒ |
| Current $L_2$ | ☐ | | ☒ |
| Current $L_3$ | ☐ | | ☒ |
| Voltage $L_{1-E}$ | ☐ | | ☒ |
| Voltage $L_{2-E}$ | ☐ | | ☒ |

| MEASURAND | MAX MVAL = TIMES RATED VALUE | | |
|---|---|---|---|
| | 1,2 | OR | 2,4 |
| Voltage $L_{3-E}$ | ☐ | | ☒ |
| Active power P | ☐ | | ☒ |
| Reactive power Q | ☐ | | ☒ |
| Frequency f | ☐ | | ☒ |
| Voltage $L_1$-$L_2$ | ☐ | | ☒ |

D

## E.1.1 INTEROPERABILITY DOCUMENT

This document is adapted from the IEC 60870-5-104 standard. For this section the boxes indicate the following: ☒ – used in standard direction; ☐ – not used; ■ – cannot be selected in IEC 60870-5-104 standard.

**1. SYSTEM OR DEVICE:**

☐ System Definition

☐ Controlling Station Definition (Master)

☒ **Controlled Station Definition (Slave)**

**2. NETWORK CONFIGURATION:**

■ ~~Point-to-Point~~ ■ ~~Multipoint~~

■ ~~Multiple Point-to-Point~~ ■ ~~Multipoint Star~~

**3. PHYSICAL LAYER**

**Transmission Speed (control direction):**

| Unbalanced Interchange Circuit V.24/V.28 Standard: | Unbalanced Interchange Circuit V.24/V.28 Recommended if >1200 bits/s: | Balanced Interchange Circuit X.24/X.27: |
|---|---|---|
| ■ ~~100 bits/sec.~~ | ■ ~~2400 bits/sec.~~ | ■ ~~2400 bits/sec.~~ |
| ■ ~~200 bits/sec.~~ | ■ ~~4800 bits/sec.~~ | ■ ~~4800 bits/sec.~~ |
| ■ ~~300 bits/sec.~~ | ■ ~~9600 bits/sec.~~ | ■ ~~9600 bits/sec.~~ |
| ■ ~~600 bits/sec.~~ | | ■ ~~19200 bits/sec.~~ |
| ■ ~~1200 bits/sec.~~ | | ■ ~~38400 bits/sec.~~ |
| | | ■ ~~56000 bits/sec.~~ |
| | | ■ ~~64000 bits/sec.~~ |

**Transmission Speed (monitor direction):**

| Unbalanced Interchange Circuit V.24/V.28 Standard: | Unbalanced Interchange Circuit V.24/V.28 Recommended if >1200 bits/s: | Balanced Interchange Circuit X.24/X.27: |
|---|---|---|
| ■ ~~100 bits/sec.~~ | ■ ~~2400 bits/sec.~~ | ■ ~~2400 bits/sec.~~ |
| ■ ~~200 bits/sec.~~ | ■ ~~4800 bits/sec.~~ | ■ ~~4800 bits/sec.~~ |
| ■ ~~300 bits/sec.~~ | ■ ~~9600 bits/sec.~~ | ■ ~~9600 bits/sec.~~ |
| ■ ~~600 bits/sec.~~ | | ■ ~~19200 bits/sec.~~ |
| ■ ~~1200 bits/sec.~~ | | ■ ~~38400 bits/sec.~~ |
| | | ■ ~~56000 bits/sec.~~ |
| | | ■ ~~64000 bits/sec.~~ |

**4. LINK LAYER**

| Link Transmission Procedure: | Address Field of the Link: |
|---|---|
| ■ ~~Balanced Transmission~~ | ■ ~~Not Present (Balanced Transmission Only)~~ |
| ■ ~~Unbalanced Transmission~~ | ■ ~~One Octet~~ |
| | ■ ~~Two Octets~~ |
| | ■ ~~Structured~~ |
| | ■ ~~Unstructured~~ |
| **Frame Length (maximum length, number of octets): Not selectable in companion IEC 60870-5-104 standard** | |

When using an unbalanced link layer, the following Application Service Data Unit (ASDU) types are returned in class 2 messages (low priority) with the indicated causes of transmission:

■ ~~The standard assignment of ASDUs to class 2 messages is used as follows~~:

■ ~~A special assignment of ASDUs to class 2 messages is used as follows~~:

## 5. APPLICATION LAYER

**Transmission Mode for Application Data:**
Mode 1 (least significant octet first), as defined in Clause 4.10 of IEC 60870-5-4, is used exclusively in this companion standard.

**Common Address of ASDU:**

■ ~~One Octet~~

☒ Two Octets

**Information Object Address:**

■ ~~One Octet~~ ☒ Structured

■ ~~Two Octets~~ ☒ Unstructured

☒ Three Octets

**Cause of Transmission:**

■ ~~One Octet~~

☒ Two Octets (with originator address). Originator address is set to zero if not used.

**Maximum Length of APDU:** 253 (the maximum length may be reduced by the system.

**Selection of standard ASDUs:**

For the following lists, the boxes indicate the following: ☒ – used in standard direction; ☐ – not used; ■ – cannot be selected in IEC 60870-5-104 standard.

**Process information in monitor direction**

| | |
|---|---|
| ☒ <1> := Single-point information | M_SP_NA_1 |
| ■ ~~<2> := Single-point information with time tag~~ | ~~M_SP_TA_1~~ |
| ☐ <3> := Double-point information | M_DP_NA_1 |
| ■ ~~<4> := Double-point information with time tag~~ | ~~M_DP_TA_1~~ |
| ☐ <5> := Step position information | M_ST_NA_1 |
| ■ ~~<6> := Step position information with time tag~~ | ~~M_ST_TA_1~~ |
| ☐ <7> := Bitstring of 32 bits | M_BO_NA_1 |
| ■ ~~<8> := Bitstring of 32 bits with time tag~~ | ~~M_BO_TA_1~~ |
| ☐ <9> := Measured value, normalized value | M_ME_NA_1 |
| ■ ~~<10> := Measured value, normalized value with time tag~~ | ~~M_NE_TA_1~~ |
| ☐ <11> := Measured value, scaled value | M_ME_NB_1 |
| ■ ~~<12> := Measured value, scaled value with time tag~~ | ~~M_NE_TB_1~~ |
| ☒ <13> := Measured value, short floating point value | M_ME_NC_1 |
| ■ ~~<14> := Measured value, short floating point value with time tag~~ | ~~M_NE_TC_1~~ |
| ☒ <15> := Integrated totals | M_IT_NA_1 |
| ■ ~~<16> := Integrated totals with time tag~~ | ~~M_IT_TA_1~~ |
| ■ ~~<17> := Event of protection equipment with time tag~~ | ~~M_EP_TA_1~~ |
| ■ ~~<18> := Packed start events of protection equipment with time tag~~ | ~~M_EP_TB_1~~ |
| ■ ~~<19> := Packed output circuit information of protection equipment with time tag~~ | ~~M_EP_TC_1~~ |
| ☐ <20> := Packed single-point information with status change detection | M_SP_NA_1 |

| | |
|---|---|
| ☐ <21> := Measured value, normalized value without quantity descriptor | M_ME_ND_1 |
| ☒ <30> := Single-point information with time tag CP56Time2a | M_SP_TB_1 |
| ☐ <31> := Double-point information with time tag CP56Time2a | M_DP_TB_1 |
| ☐ <32> := Step position information with time tag CP56Time2a | M_ST_TB_1 |
| ☐ <33> := Bitstring of 32 bits with time tag CP56Time2a | M_BO_TB_1 |
| ☐ <34> := Measured value, normalized value with time tag CP56Time2a | M_ME_TD_1 |
| ☐ <35> := Measured value, scaled value with time tag CP56Time2a | M_ME_TE_1 |
| ☐ <36> := Measured value, short floating point value with time tag CP56Time2a | M_ME_TF_1 |
| ☒ <37> := Integrated totals with time tag CP56Time2a | M_IT_TB_1 |
| ☐ <38> := Event of protection equipment with time tag CP56Time2a | M_EP_TD_1 |
| ☐ <39> := Packed start events of protection equipment with time tag CP56Time2a | M_EP_TE_1 |
| ☐ <40> := Packed output circuit information of protection equipment with time tag CP56Time2a | M_EP_TF_1 |

Either the ASDUs of the set <2>, <4>, <6>, <8>, <10>, <12>, <14>, <16>, <17>, <18>, and <19> or of the set <30> to <40> are used.

**Process information in control direction**

| | |
|---|---|
| ☒ <45> := Single command | C_SC_NA_1 |
| ☐ <46> := Double command | C_DC_NA_1 |
| ☐ <47> := Regulating step command | C_RC_NA_1 |
| ☐ <48> := Set point command, normalized value | C_SE_NA_1 |
| ☐ <49> := Set point command, scaled value | C_SE_NB_1 |
| ☐ <50> := Set point command, short floating point value | C_SE_NC_1 |
| ☐ <51> := Bitstring of 32 bits | C_BO_NA_1 |
| ☒ <58> := Single command with time tag CP56Time2a | C_SC_TA_1 |
| ☐ <59> := Double command with time tag CP56Time2a | C_DC_TA_1 |
| ☐ <60> := Regulating step command with time tag CP56Time2a | C_RC_TA_1 |
| ☐ <61> := Set point command, normalized value with time tag CP56Time2a | C_SE_TA_1 |
| ☐ <62> := Set point command, scaled value with time tag CP56Time2a | C_SE_TB_1 |
| ☐ <63> := Set point command, short floating point value with time tag CP56Time2a | C_SE_TC_1 |
| ☐ <64> := Bitstring of 32 bits with time tag CP56Time2a | C_BO_TA_1 |

Either the ASDUs of the set <45> to <51> or of the set <58> to <64> are used.

**System information in monitor direction**

| | |
|---|---|
| ☒ <70> := End of initialization | M_EI_NA_1 |

**System information in control direction**

| | |
|---|---|
| ☒ <100> := Interrogation command | C_IC_NA_1 |
| ☒ <101> := Counter interrogation command | C_CI_NA_1 |
| ☒ <102> := Read command | C_RD_NA_1 |
| ☒ <103> := Clock synchronization command (see Clause 7.6 in standard) | C_CS_NA_1 |
| ■ ~~<104> := Test command~~ | ~~C_TS_NA_1~~ |
| ☒ <105> := Reset process command | C_RP_NA_1 |
| ■ <106> := Delay acquisition command | C_CD_NA_1 |
| ☒ <107> := Test command with time tag CP56Time2a | C_TS_TA_1 |

**Parameter in control direction**

| | |
|---|---|
| ☐ <110> := Parameter of measured value, normalized value | PE_ME_NA_1 |
| ☐ <111> := Parameter of measured value, scaled value | PE_ME_NB_1 |
| ☒ <112> := Parameter of measured value, short floating point value | PE_ME_NC_1 |
| ☐ <113> := Parameter activation | PE_AC_NA_1 |

**File transfer**

| | |
|---|---|
| ☐ <120> := File Ready | F_FR_NA_1 |
| ☐ <121> := Section Ready | F_SR_NA_1 |
| ☐ <122> := Call directory, select file, call file, call section | F_SC_NA_1 |
| ☐ <123> := Last section, last segment | F_LS_NA_1 |
| ☐ <124> := Ack file, ack section | F_AF_NA_1 |
| ☐ <125> := Segment | F_SG_NA_1 |
| ☐ <126> := Directory (blank or X, available only in monitor [standard] direction) | C_CD_NA_1 |

**Type identifier and cause of transmission assignments**
(station-specific parameters)

In the following table:

•Shaded boxes are not required.

•Black boxes are not permitted in this companion standard.

•Blank boxes indicate functions or ASDU not used.

•'**X**' if only used in the standard direction

| TYPE IDENTIFICATION | | CAUSE OF TRANSMISSION | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PERIODIC, CYCLIC | BACKGROUND SCAN | SPONTANEOUS | INITIALIZED | REQUEST OR REQUESTED | ACTIVATION | ACTIVATION CONFIRMATION | DEACTIVATION | DEACTIVATION CONFIRMATION | ACTIVATION TERMINATION | RETURN INFO CAUSED BY LOCAL CMD | FILE TRANSFER | INTERROGATED BY GROUP <NUMBER> | REQUEST BY GROUP <N> COUNTER REQ | UNKNOWN TYPE IDENTIFICATION | UNKNOWN CAUSE OF TRANSMISSION | UNKNOWN COMMON ADDRESS OF ASDU | UNKNOWN INFORMATION OBJECT ADDR | UNKNOWN INFORMATION OBJECT ADDR |
| NO. | MNEMONIC | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 20 to 36 | 37 to 41 | 44 | 45 | 46 | 47 |
| <1> | M_SP_NA_1 | | | X | | X | | | | | | X | X | | X | | | | | |
| <2> | M_SP_TA_1 | | | | | | | | | | | | | | | | | | | |
| <3> | M_DP_NA_1 | | | | | | | | | | | | | | | | | | | |
| <4> | M_DP_TA_1 | | | | | | | | | | | | | | | | | | | |
| <5> | M_ST_NA_1 | | | | | | | | | | | | | | | | | | | |
| <6> | M_ST_TA_1 | | | | | | | | | | | | | | | | | | | |
| <7> | M_BO_NA_1 | | | | | | | | | | | | | | | | | | | |
| <8> | M_BO_TA_1 | | | | | | | | | | | | | | | | | | | |
| <9> | M_ME_NA_1 | | | | | | | | | | | | | | | | | | | |

| TYPE IDENTIFICATION | | CAUSE OF TRANSMISSION | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PERIODIC, CYCLIC | BACKGROUND SCAN | SPONTANEOUS | INITIALIZED | REQUEST OR REQUESTED | ACTIVATION | ACTIVATION CONFIRMATION | DEACTIVATION | DEACTIVATION CONFIRMATION | ACTIVATION TERMINATION | RETURN INFO CAUSED BY LOCAL CMD | FILE TRANSFER | INTERROGATED BY GROUP <NUMBER> | REQUEST BY GROUP <N> COUNTER REQ | UNKNOWN TYPE IDENTIFICATION | UNKNOWN CAUSE OF TRANSMISSION | UNKNOWN COMMON ADDRESS OF ASDU | UNKNOWN INFORMATION OBJECT ADDR | UNKNOWN INFORMATION OBJECT ADDR |
| NO. | MNEMONIC | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 20 to 36 | 37 to 41 | 44 | 45 | 46 | 47 |
| <10> | M_ME_TA_1 | | | | | | | | | | | | | | | | | | | |
| <11> | M_ME_NB_1 | | | | | | | | | | | | | | | | | | | |
| <12> | M_ME_TB_1 | | | | | | | | | | | | | | | | | | | |
| <13> | M_ME_NC_1 | X | | X | | X | | | | | | | | | X | | | | | |
| <14> | M_ME_TC_1 | | | | | | | | | | | | | | | | | | | |
| <15> | M_IT_NA_1 | | | X | | | | | | | | | | | | X | | | | |
| <16> | M_IT_TA_1 | | | | | | | | | | | | | | | | | | | |
| <17> | M_EP_TA_1 | | | | | | | | | | | | | | | | | | | |
| <18> | M_EP_TB_1 | | | | | | | | | | | | | | | | | | | |
| <19> | M_EP_TC_1 | | | | | | | | | | | | | | | | | | | |
| <20> | M_PS_NA_1 | | | | | | | | | | | | | | | | | | | |
| <21> | M_ME_ND_1 | | | | | | | | | | | | | | | | | | | |
| <30> | M_SP_TB_1 | | | X | | | | | | | | X | X | | | | | | | |
| <31> | M_DP_TB_1 | | | | | | | | | | | | | | | | | | | |
| <32> | M_ST_TB_1 | | | | | | | | | | | | | | | | | | | |
| <33> | M_BO_TB_1 | | | | | | | | | | | | | | | | | | | |
| <34> | M_ME_TD_1 | | | | | | | | | | | | | | | | | | | |
| <35> | M_ME_TE_1 | | | | | | | | | | | | | | | | | | | |
| <36> | M_ME_TF_1 | | | | | | | | | | | | | | | | | | | |
| <37> | M_IT_TB_1 | | | X | | | | | | | | | | | | X | | | | |
| <38> | M_EP_TD_1 | | | | | | | | | | | | | | | | | | | |
| <39> | M_EP_TE_1 | | | | | | | | | | | | | | | | | | | |
| <40> | M_EP_TF_1 | | | | | | | | | | | | | | | | | | | |
| <45> | C_SC_NA_1 | | | | | | X | X | X | X | X | | | | | | | | | |
| <46> | C_DC_NA_1 | | | | | | | | | | | | | | | | | | | |
| <47> | C_RC_NA_1 | | | | | | | | | | | | | | | | | | | |
| <48> | C_SE_NA_1 | | | | | | | | | | | | | | | | | | | |
| <49> | C_SE_NB_1 | | | | | | | | | | | | | | | | | | | |
| <50> | C_SE_NC_1 | | | | | | | | | | | | | | | | | | | |
| <51> | C_BO_NA_1 | | | | | | | | | | | | | | | | | | | |
| <58> | C_SC_TA_1 | | | | | | X | X | X | X | X | | | | | | | | | |
| <59> | C_DC_TA_1 | | | | | | | | | | | | | | | | | | | |
| <60> | C_RC_TA_1 | | | | | | | | | | | | | | | | | | | |

| TYPE IDENTIFICATION | | CAUSE OF TRANSMISSION | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PERIODIC, CYCLIC | BACKGROUND SCAN | SPONTANEOUS | INITIALIZED | REQUEST OR REQUESTED | ACTIVATION | ACTIVATION CONFIRMATION | DEACTIVATION | DEACTIVATION CONFIRMATION | ACTIVATION TERMINATION | RETURN INFO CAUSED BY LOCAL CMD | FILE TRANSFER | INTERROGATED BY GROUP <NUMBER> | REQUEST BY GROUP <N> COUNTER REQ | UNKNOWN TYPE IDENTIFICATION | UNKNOWN CAUSE OF TRANSMISSION | UNKNOWN COMMON ADDRESS OF ASDU | UNKNOWN INFORMATION OBJECT ADDR | UNKNOWN INFORMATION OBJECT ADDR |
| NO. | MNEMONIC | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 20 to 36 | 37 to 41 | 44 | 45 | 46 | 47 |
| <61> | C_SE_TA_1 | | | | | | | | | | | | | | | | | | | |
| <62> | C_SE_TB_1 | | | | | | | | | | | | | | | | | | | |
| <63> | C_SE_TC_1 | | | | | | | | | | | | | | | | | | | |
| <64> | C_BO_TA_1 | | | | | | | | | | | | | | | | | | | |
| <70> | M_EI_NA_1*) | | | | X | | | | | | | | | | | | | | | |
| <100> | C_IC_NA_1 | | | | | | X | X | X | X | X | | | | | | | | | |
| <101> | C_CI_NA_1 | | | | | | X | X | | | X | | | | | | | | | |
| <102> | C_RD_NA_1 | | | | | X | | | | | | | | | | | | | | |
| <103> | C_CS_NA_1 | | | X | | | X | X | | | | | | | | | | | | |
| <104> | C_TS_NA_1 | | | | | | | | | | | | | | | | | | | |
| <105> | C_RP_NA_1 | | | | | | X | X | | | | | | | | | | | | |
| <106> | C_CD_NA_1 | | | | | | | | | | | | | | | | | | | |
| <107> | C_TS_TA_1 | | | | | | | | | | | | | | | | | | | |
| <110> | P_ME_NA_1 | | | | | | | | | | | | | | | | | | | |
| <111> | P_ME_NB_1 | | | | | | | | | | | | | | | | | | | |
| <112> | P_ME_NC_1 | | | | | | X | X | | | | | | | X | | | | | |
| <113> | P_AC_NA_1 | | | | | | | | | | | | | | | | | | | |
| <120> | F_FR_NA_1 | | | | | | | | | | | | | | | | | | | |
| <121> | F_SR_NA_1 | | | | | | | | | | | | | | | | | | | |
| <122> | F_SC_NA_1 | | | | | | | | | | | | | | | | | | | |
| <123> | F_LS_NA_1 | | | | | | | | | | | | | | | | | | | |
| <124> | F_AF_NA_1 | | | | | | | | | | | | | | | | | | | |
| <125> | F_SG_NA_1 | | | | | | | | | | | | | | | | | | | |
| <126> | F_DR_TA_1*) | | | | | | | | | | | | | | | | | | | |

## 6. BASIC APPLICATION FUNCTIONS

**Station Initialization:**

☒ Remote initialization

**Cyclic Data Transmission:**

☒ Cyclic data transmission

**Read Procedure:**

☒ Read procedure

**Spontaneous Transmission:**

☒ Spontaneous transmission

**Double transmission of information objects with cause of transmission spontaneous:**

The following type identifications may be transmitted in succession caused by a single status change of an information object. The particular information object addresses for which double transmission is enabled are defined in a project-specific list.

☐ Single point information: M_SP_NA_1, M_SP_TA_1, M_SP_TB_1, and M_PS_NA_1

☐ Double point information: M_DP_NA_1, M_DP_TA_1, and M_DP_TB_1

☐ Step position information: M_ST_NA_1, M_ST_TA_1, and M_ST_TB_1

☐ Bitstring of 32 bits: M_BO_NA_1, M_BO_TA_1, and M_BO_TB_1 (if defined for a specific project)

☐ Measured value, normalized value: M_ME_NA_1, M_ME_TA_1, M_ME_ND_1, and M_ME_TD_1

☐ Measured value, scaled value: M_ME_NB_1, M_ME_TB_1, and M_ME_TE_1

☐ Measured value, short floating point number: M_ME_NC_1, M_ME_TC_1, and M_ME_TF_1

**Station interrogation:**

☒ Global

| | | | |
|---|---|---|---|
| ☒ Group 1 | ☒ Group 5 | ☒ Group 9 | ☒ Group 13 |
| ☒ Group 2 | ☒ Group 6 | ☒ Group 10 | ☒ Group 14 |
| ☒ Group 3 | ☒ Group 7 | ☒ Group 11 | ☒ Group 15 |
| ☒ Group 4 | ☒ Group 8 | ☒ Group 12 | ☒ Group 16 |

**Clock synchronization:**

☒ Clock synchronization (optional, see Clause 7.6)

**Command transmission:**

☒ Direct command transmission

☐ Direct setpoint command transmission

☒ Select and execute command

☐ Select and execute setpoint command

☒ C_SE ACTTERM used

☒ No additional definition

☒ Short pulse duration (duration determined by a system parameter in the outstation)

☒ Long pulse duration (duration determined by a system parameter in the outstation)

☒ Persistent output

☒ Supervision of maximum delay in command direction of commands and setpoint commands

Maximum allowable delay of commands and setpoint commands: **10 s**

**Transmission of integrated totals:**

☒ Mode A: Local freeze with spontaneous transmission

☒ Mode B: Local freeze with counter interrogation

☒ Mode C: Freeze and transmit by counter-interrogation commands

☒ Mode D: Freeze by counter-interrogation command, frozen values reported simultaneously

☒ Counter read

☒ Counter freeze without reset

☒ Counter freeze with reset

☒ Counter reset

☒ General request counter

☒ Request counter group 1

☒ Request counter group 2

☒ Request counter group 3

☒ Request counter group 4

**Parameter loading:**

☒ Threshold value

☐ Smoothing factor

☐ Low limit for transmission of measured values

☐ High limit for transmission of measured values

**Parameter activation:**

☐ Activation/deactivation of persistent cyclic or periodic transmission of the addressed object

**Test procedure:**

☐ Test procedure



**File transfer:**

File transfer in monitor direction:

☐ Transparent file

☐ Transmission of disturbance data of protection equipment

☐ Transmission of sequences of events

☐ Transmission of sequences of recorded analog values

File transfer in control direction:

☐ Transparent file

**Background scan:**

☐ Background scan

**Acquisition of transmission delay:**

■ ~~Acquisition of transmission delay~~

**Definition of time outs:**

| PARAMETER | DEFAULT VALUE | REMARKS | SELECTED VALUE |
|---|---|---|---|
| $t_0$ | 30 s | Timeout of connection establishment | 120 s |
| $t_1$ | 15 s | Timeout of send or test APDUs | 15 s |
| $t_2$ | 10 s | Timeout for acknowledgements in case of no data messages $t_2 < t_1$ | 10 s |
| $t_3$ | 20 s | Timeout for sending test frames in case of a long idle state | 20 s |

Maximum range of values for all time outs: 1 to 255 s, accuracy 1 s

**Maximum number of outstanding I-format APDUs *k* and latest acknowledge APDUs (*w*):**

| PARAMETER | DEFAULT VALUE | REMARKS | SELECTED VALUE |
|---|---|---|---|
| *k* | 12 APDUs | Maximum difference receive sequence number to send state variable | 12 APDUs |
| *w* | 8 APDUs | Latest acknowledge after receiving *w* I-format APDUs | 8 APDUs |

Maximum range of values *k*: 1 to 32767 ($2^{15}$ – 1) APDUs, accuracy 1 APDU

Maximum range of values *w*: 1 to 32767 APDUs, accuracy 1 APDU
Recommendation: *w* should not exceed two-thirds of *k*.

**Portnumber:**

| PARAMETER | VALUE | REMARKS |
|---|---|---|
| Portnumber | 2404 | In all cases |

**RFC 2200 suite:**

RFC 2200 is an official Internet Standard which describes the state of standardization of protocols used in the Internet as determined by the Internet Architecture Board (IAB). It offers a broad spectrum of actual standards used in the Internet. The suitable selection of documents from RFC 2200 defined in this standard for given projects has to be chosen by the user of this standard.

☒ Ethernet 802.3

☐ Serial X.21 interface

☐ Other selection(s) from RFC 2200 (list below if selected)

## E.1.2 POINT LIST

The IEC 60870-5-104 data points are configured through the **SETTINGS** ⇨ **PRODUCT SETUP** ⇨⇩ **COMMUNICATIONS** ⇨⇩ **DNP / IEC104 POINT LISTS** menu. See the Communications section of chapter 5 for details.

The following table provides a 'Device Profile Document' in the standard format defined in the DNP 3.0 Subset Definitions Document.

**Table F–1: DNP V3.00 DEVICE PROFILE (Sheet 1 of 3)**

| | |
|---|---|
| (Also see the IMPLEMENTATION TABLE in the following section) | |
| Vendor Name: **General Electric Multilin** | |
| Device Name: **UR Series Relay** | |
| **Highest DNP Level Supported:**<br>For Requests: **Level 2**<br>For Responses: **Level 2** | **Device Function:**<br>☐ Master<br>☒ **Slave** |
| Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):<br>**Binary Inputs (Object 1)**<br>**Binary Input Changes (Object 2)**<br>**Binary Outputs (Object 10)**<br>**Control Relay Output Block (Object 12)**<br>**Binary Counters (Object 20)**<br>**Frozen Counters (Object 21)**<br>**Counter Change Event (Object 22)**<br>**Frozen Counter Event (Object 23)**<br>**Analog Inputs (Object 30)**<br>**Analog Input Changes (Object 32)**<br>**Analog Deadbands (Object 34)**<br>**Time and Date (Object 50)**<br>**File Transfer (Object 70)**<br>**Internal Indications (Object 80)** | |
| **Maximum Data Link Frame Size (octets):**<br>Transmitted: **292**<br>Received: **292** | **Maximum Application Fragment Size (octets):**<br>Transmitted: **configurable up to 2048**<br>Received: **2048** |
| **Maximum Data Link Re-tries:**<br>☒ **None**<br>☐ Fixed at 3<br>☐ Configurable | **Maximum Application Layer Re-tries:**<br>☒ **None**<br>☐ Configurable |
| **Requires Data Link Layer Confirmation:**<br>☒ Never<br>☐ Always<br>☐ Sometimes<br>☐ Configurable | |

**Table F–1: DNP V3.00 DEVICE PROFILE (Sheet 2 of 3)**

**Requires Application Layer Confirmation:**

- ☐ Never
- ☐ Always
- ☒ When reporting Event Data
- ☒ When sending multi-fragment responses
- ☐ Sometimes
- ☐ Configurable

**Timeouts while waiting for:**

| | | | | |
|---|---|---|---|---|
| Data Link Confirm: | ☒ None | ☐ Fixed at ____ | ☐ Variable | ☐ Configurable |
| Complete Appl. Fragment: | ☒ **None** | ☐ Fixed at ____ | ☐ Variable | ☐ Configurable |
| Application Confirm: | ☐ None | ☒ **Fixed at 10 s** | ☐ Variable | ☐ Configurable |
| Complete Appl. Response: | ☒ **None** | ☐ Fixed at ____ | ☐ Variable | ☐ Configurable |

**Others:**

| | |
|---|---|
| Transmission Delay: | **No intentional delay** |
| Need Time Interval: | **Configurable (default = 24 hrs.)** |
| Select/Operate Arm Timeout: | **10 s** |
| Binary input change scanning period: | **8 times per power system cycle** |
| Analog input change scanning period: | **500 ms** |
| Counter change scanning period: | **500 ms** |
| Frozen counter event scanning period: | **500 ms** |
| Unsolicited response notification delay: | **100 ms** |
| Unsolicited response retry delay | **configurable 0 to 60 sec.** |

**Sends/Executes Control Operations:**

| | | | | |
|---|---|---|---|---|
| WRITE Binary Outputs | ☒ **Never** | ☐ Always | ☐ Sometimes | ☐ Configurable |
| SELECT/OPERATE | ☐ Never | ☒ **Always** | ☐ Sometimes | ☐ Configurable |
| DIRECT OPERATE | ☐ Never | ☒ **Always** | ☐ Sometimes | ☐ Configurable |
| DIRECT OPERATE – NO ACK | ☐ Never | ☒ **Always** | ☐ Sometimes | ☐ Configurable |

| | | | | |
|---|---|---|---|---|
| Count > 1 | ☒ **Never** | ☐ Always | ☐ Sometimes | ☐ Configurable |
| Pulse On | ☐ Never | ☐ Always | ☒ **Sometimes** | ☐ Configurable |
| Pulse Off | ☐ Never | ☐ Always | ☒ **Sometimes** | ☐ Configurable |
| Latch On | ☐ Never | ☐ Always | ☒ **Sometimes** | ☐ Configurable |
| Latch Off | ☐ Never | ☐ Always | ☒ **Sometimes** | ☐ Configurable |
| Queue | ☒ **Never** | ☐ Always | ☐ Sometimes | ☐ Configurable |
| Clear Queue | ☒ **Never** | ☐ Always | ☐ Sometimes | ☐ Configurable |

**Explanation of 'Sometimes':** Object 12 points are mapped to UR Virtual Inputs. The persistence of Virtual Inputs is determined by the **VIRTUAL INPUT X TYPE** settings. Both "Pulse On" and "Latch On" operations perform the same function in the UR; that is, the appropriate Virtual Input is put into the "On" state. If the Virtual Input is set to "Self-Reset", it will reset after one pass of FlexLogic. The On/Off times and Count value are ignored. "Pulse Off" and "Latch Off" operations put the appropriate Virtual Input into the "Off" state. "Trip" and "Close" operations both put the appropriate Virtual Input into the "On" state.

**Table F–1: DNP V3.00 DEVICE PROFILE (Sheet 3 of 3)**

| | |
|---|---|
| **Reports Binary Input Change Events when no specific variation requested:**<br>☐ Never<br>☒ **Only time-tagged**<br>☐ Only non-time-tagged<br>☐ Configurable | **Reports time-tagged Binary Input Change Events when no specific variation requested:**<br>☐ Never<br>☒ Binary Input Change With Time<br>☐ Binary Input Change With Relative Time<br>☐ Configurable (attach explanation) |
| **Sends Unsolicited Responses:**<br>☐ **Never**<br>☒ Configurable<br>☐ Only certain objects<br>☐ Sometimes (attach explanation)<br>☒ ENABLE/DISABLE unsolicited Function codes supported | **Sends Static Data in Unsolicited Responses:**<br>☒ Never<br>☐ When Device Restarts<br>☐ When Status Flags Change<br><br>No other options are permitted. |
| **Default Counter Object/Variation:**<br>☐ No Counters Reported<br>☐ Configurable (attach explanation)<br>☒ **Default Object: 20**<br>**Default Variation: 1**<br>☒ **Point-by-point list attached** | **Counters Roll Over at:**<br>☐ No Counters Reported<br>☐ Configurable (attach explanation)<br>☒ **16 Bits (Counter 8)**<br>☒ **32 Bits (Counters 0 to 7, 9)**<br>☐ Other Value: _____<br>☒ **Point-by-point list attached** |
| **Sends Multi-Fragment Responses:**<br>☒ **Yes**<br>☐ No | |

F

The following table identifies the variations, function codes, and qualifiers supported by the L30 in both request messages and in response messages. For static (non-change-event) objects, requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01. Static object requests sent with qualifiers 17 or 28 will be responded with qualifiers 17 or 28. For change-event objects, qualifiers 17 or 28 are always responded.

**Table F–2: IMPLEMENTATION TABLE (Sheet 1 of 4)**

| OBJECT | | | REQUEST | | RESPONSE | |
|---|---|---|---|---|---|---|
| OBJECT NO. | VARIATION NO. | DESCRIPTION | FUNCTION CODES (DEC) | QUALIFIER CODES (HEX) | FUNCTION CODES (DEC) | QUALIFIER CODES (HEX) |
| 1 | 0 | Binary Input (Variation 0 is used to request default variation) | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | | |
| | 1 | Binary Input | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | 2 | Binary Input with Status | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| 2 | 0 | Binary Input Change (Variation 0 is used to request default variation) | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | | |
| | 1 | Binary Input Change without Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 2 | Binary Input Change with Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response<br>130 (unsol. resp.) | 17, 28 (index) |
| | 3 | Binary Input Change with Relative Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | | |
| 10 | 0 | Binary Output Status (Variation 0 is used to request default variation) | 1 (read) | 00, 01(start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | | |
| | 2 | Binary Output Status | 1 (read) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| 12 | 1 | Control Relay Output Block | 3 (select)<br>4 (operate)<br>5 (direct op)<br>6 (dir. op, noack) | 00, 01 (start-stop)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | echo of request |
| 20 | 0 | Binary Counter<br>(Variation 0 is used to request default variation) | 1 (read)<br>7 (freeze)<br>8 (freeze noack)<br>9 (freeze clear)<br>10 (frz. cl. noack)<br>22 (assign class) | 00, 01(start-stop)<br>06(no range, or all)<br>07, 08(limited quantity)<br>17, 28(index) | | |
| | 1 | 32-Bit Binary Counter | 1 (read)<br>7 (freeze)<br>8 (freeze noack)<br>9 (freeze clear)<br>10 (frz. cl. noack)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. See the Communications section in Chapter 5 for details. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the L30 is not restarted, but the DNP process is restarted.

**Table F–2: IMPLEMENTATION TABLE (Sheet 2 of 4)**

| OBJECT | | | REQUEST | | RESPONSE | |
|---|---|---|---|---|---|---|
| OBJECT NO. | VARIATION NO. | DESCRIPTION | FUNCTION CODES (DEC) | QUALIFIER CODES (HEX) | FUNCTION CODES (DEC) | QUALIFIER CODES (HEX) |
| 20 cont'd | 2 | 16-Bit Binary Counter | 1 (read)<br>7 (freeze)<br>8 (freeze noack)<br>9 (freeze clear)<br>10 (frz. cl. noack)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | 5 | 32-Bit Binary Counter without Flag | 1 (read)<br>7 (freeze)<br>8 (freeze noack)<br>9 (freeze clear)<br>10 (frz. cl. noack)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | 6 | 16-Bit Binary Counter without Flag | 1 (read)<br>7 (freeze)<br>8 (freeze noack)<br>9 (freeze clear)<br>10 (frz. cl. noack)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| 21 | 0 | Frozen Counter<br>(Variation 0 is used to request default variation) | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | | |
| | 1 | 32-Bit Frozen Counter | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | 2 | 16-Bit Frozen Counter | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | 9 | 32-Bit Frozen Counter without Flag | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | 10 | 16-Bit Frozen Counter without Flag | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| 22 | 0 | Counter Change Event (Variation 0 is used to request default variation) | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | | |
| | 1 | 32-Bit Counter Change Event | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 2 | 16-Bit Counter Change Event | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 5 | 32-Bit Counter Change Event with Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 6 | 16-Bit Counter Change Event with Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| 23 | 0 | Frozen Counter Event (Variation 0 is used to request default variation) | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | | |
| | 1 | 32-Bit Frozen Counter Event | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 2 | 16-Bit Frozen Counter Event | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. See the Communications section in Chapter 5 for details. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the L30 is not restarted, but the DNP process is restarted.

**Table F–2: IMPLEMENTATION TABLE (Sheet 3 of 4)**

| OBJECT | | | REQUEST | | RESPONSE | |
|---|---|---|---|---|---|---|
| OBJECT NO. | VARIATION NO. | DESCRIPTION | FUNCTION CODES (DEC) | QUALIFIER CODES (HEX) | FUNCTION CODES (DEC) | QUALIFIER CODES (HEX) |
| 23 cont'd | 5 | 32-Bit Frozen Counter Event with Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 6 | 16-Bit Frozen Counter Event with Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| 30 | 0 | Analog Input (Variation 0 is used to request default variation) | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | | |
| | 1 | 32-Bit Analog Input | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | 2 | 16-Bit Analog Input | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | 3 | 32-Bit Analog Input without Flag | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | 4 | 16-Bit Analog Input without Flag | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | 5 | short floating point | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06(no range, or all)<br>07, 08(limited quantity)<br>17, 28(index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| 32 | 0 | Analog Change Event (Variation 0 is used to request default variation) | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | | |
| | 1 | 32-Bit Analog Change Event without Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 2 | 16-Bit Analog Change Event without Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 3 | 32-Bit Analog Change Event with Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 4 | 16-Bit Analog Change Event with Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 5 | short floating point Analog Change Event without Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| | 7 | short floating point Analog Change Event with Time | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index) |
| 34 | 0 | Analog Input Reporting Deadband (Variation 0 is used to request default variation) | 1 (read) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | | |
| | 1 | 16-bit Analog Input Reporting Deadband (default – see Note 1) | 1 (read) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | | | 2 (write) | 00, 01 (start-stop)<br>07, 08 (limited quantity)<br>17, 28 (index) | | |

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. See the Communications section in Chapter 5 for details. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the L30 is not restarted, but the DNP process is restarted.

**Table F–2: IMPLEMENTATION TABLE (Sheet 4 of 4)**

| OBJECT | | | REQUEST | | RESPONSE | |
|---|---|---|---|---|---|---|
| OBJECT NO. | VARIATION NO. | DESCRIPTION | FUNCTION CODES (DEC) | QUALIFIER CODES (HEX) | FUNCTION CODES (DEC) | QUALIFIER CODES (HEX) |
| 34 cont'd | 2 | 32-bit Analog Input Reporting Deadband | 1 (read) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| | | | 2 (write) | 00, 01 (start-stop)<br>07, 08 (limited quantity)<br>17, 28 (index) | | |
| | 3 | Short floating point Analog Input Reporting Deadband | 1 (read) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| 50 | 1 | Time and Date<br>(default – see Note 1) | 1 (read)<br>2 (write) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07 (limited qty=1)<br>08 (limited quantity)<br>17, 28 (index) | 129 (response) | 00, 01 (start-stop)<br>17, 28 (index)<br>*(see Note 2)* |
| 52 | 2 | Time Delay Fine | | | 129 (response) | 07 (limited quantity)<br>(quantity = 1) |
| 60 | 0 | Class 0, 1, 2, and 3 Data | 1 (read)<br>20 (enable unsol)<br>21 (disable unsol)<br>22 (assign class) | 06 (no range, or all) | | |
| | 1 | Class 0 Data | 1 (read)<br>22 (assign class) | 06 (no range, or all) | | |
| | 2 | Class 1 Data | 1 (read)<br>20 (enable unsol)<br>21 (disable unsol)<br>22 (assign class) | 06 (no range, or all)<br>07, 08 (limited quantity) | | |
| | 3 | Class 2 Data | | | | |
| | 4 | Class 3 Data | | | | |
| 70 | 0 | File event - any variation | 1 (read) | 06 (no range, or all)<br>07, 08 (limited quantity) | | |
| | | | 22 (assign class) | 06 (no range, or all) | | |
| | 2 | File authentication | 29 (authenticate) | 5b (free format) | 129 (response) | 5b (free format) |
| | 3 | File command | 25 (open)<br>27 (delete) | 5b (free format) | | |
| | 4 | File command status | 26 (close)<br>30 (abort) | 5b (free format) | 129 (response)<br>130 (unsol. resp.) | 5b (free format) |
| | 5 | File transfer | 1 (read)<br>2 (write) | 5b (free format) | 129 (response)<br>130 (unsol. resp.) | 5b (free format) |
| | 6 | File transfer status | | | 129 (response)<br>130 (unsol. resp.) | 5b (free format) |
| | 7 | File descriptor | 28 (get file info.) | 5b (free format) | 129 (response)<br>130 (unsol. resp.) | 5b (free format) |
| 80 | 1 | Internal Indications | 1 (read) | 00, 01 (start-stop)<br>(index =7) | 129 (response) | 00, 01 (start-stop) |
| | | | 2 (write)<br>*(see Note 3)* | 00 (start-stop)<br>(index =7) | | |
| --- | | No Object (function code only)<br>*see Note 3* | 13 (cold restart) | | | |
| --- | | No Object (function code only) | 14 (warm restart) | | | |
| --- | | No Object (function code only) | 23 (delay meas.) | | | |

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. See the Communications section in Chapter 5 for details. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the L30 is not restarted, but the DNP process is restarted.

### F.2.1 BINARY INPUT POINTS

The DNP binary input data points are configured through the **PRODUCT SETUP** ⇨⇩ **COMMUNICATIONS** ⇨⇩ **DNP / IEC104 POINT LISTS** ⇨ **BINARY INPUT / MSP POINTS** menu. See the Communications section of Chapter 5 for details. When a freeze function is performed on a binary counter point, the frozen value is available in the corresponding frozen counter point.

**BINARY INPUT POINTS**

Static (Steady-State) Object Number: **1**

Change Event Object Number: **2**

Request Function Codes supported: **1 (read), 22 (assign class)**

Static Variation reported when variation 0 requested: **2 (Binary Input with status), Configurable**

Change Event Variation reported when variation 0 requested: **2 (Binary Input Change with Time), Configurable**

Change Event Scan Rate: **8 times per power system cycle**

Change Event Buffer Size: **500**

Default Class for All Points: **1**

Supported Control Relay Output Block fields: Pulse On, Pulse Off, Latch On, Latch Off, Paired Trip, Paired Close.

**BINARY OUTPUT STATUS POINTS**

Object Number: **10**

Request Function Codes supported: **1 (read)**

Default Variation reported when Variation 0 requested: **2 (Binary Output Status)**

**CONTROL RELAY OUTPUT BLOCKS**

Object Number: **12**

Request Function Codes supported: **3 (select), 4 (operate), 5 (direct operate), 6 (direct operate, noack)**

**Table F–3: BINARY/CONTROL OUTPUTS**

| POINT | NAME/DESCRIPTION |
|---|---|
| 0 | Virtual Input 1 |
| 1 | Virtual Input 2 |
| 2 | Virtual Input 3 |
| 3 | Virtual Input 4 |
| 4 | Virtual Input 5 |
| 5 | Virtual Input 6 |
| 6 | Virtual Input 7 |
| 7 | Virtual Input 8 |
| 8 | Virtual Input 9 |
| 9 | Virtual Input 10 |
| 10 | Virtual Input 11 |
| 11 | Virtual Input 12 |
| 12 | Virtual Input 13 |
| 13 | Virtual Input 14 |
| 14 | Virtual Input 15 |
| 15 | Virtual Input 16 |
| 16 | Virtual Input 17 |
| 17 | Virtual Input 18 |
| 18 | Virtual Input 19 |
| 19 | Virtual Input 20 |
| 20 | Virtual Input 21 |
| 21 | Virtual Input 22 |
| 22 | Virtual Input 23 |
| 23 | Virtual Input 24 |
| 24 | Virtual Input 25 |
| 25 | Virtual Input 26 |
| 26 | Virtual Input 27 |
| 27 | Virtual Input 28 |
| 28 | Virtual Input 29 |
| 29 | Virtual Input 30 |
| 30 | Virtual Input 31 |
| 31 | Virtual Input 32 |

**Table F–3: BINARY/CONTROL OUTPUTS**

| POINT | NAME/DESCRIPTION |
|---|---|
| 32 | Virtual Input 33 |
| 33 | Virtual Input 34 |
| 34 | Virtual Input 35 |
| 35 | Virtual Input 36 |
| 36 | Virtual Input 37 |
| 37 | Virtual Input 38 |
| 38 | Virtual Input 39 |
| 39 | Virtual Input 40 |
| 40 | Virtual Input 41 |
| 41 | Virtual Input 42 |
| 42 | Virtual Input 43 |
| 43 | Virtual Input 44 |
| 44 | Virtual Input 45 |
| 45 | Virtual Input 46 |
| 46 | Virtual Input 47 |
| 47 | Virtual Input 48 |
| 48 | Virtual Input 49 |
| 49 | Virtual Input 50 |
| 50 | Virtual Input 51 |
| 51 | Virtual Input 52 |
| 52 | Virtual Input 53 |
| 53 | Virtual Input 54 |
| 54 | Virtual Input 55 |
| 55 | Virtual Input 56 |
| 56 | Virtual Input 57 |
| 57 | Virtual Input 58 |
| 58 | Virtual Input 59 |
| 59 | Virtual Input 60 |
| 60 | Virtual Input 61 |
| 61 | Virtual Input 62 |
| 62 | Virtual Input 63 |
| 63 | Virtual Input 64 |

## F.2.3 COUNTERS

The following table lists both Binary Counters (Object 20) and Frozen Counters (Object 21). When a freeze function is performed on a Binary Counter point, the frozen value is available in the corresponding Frozen Counter point.

**BINARY COUNTERS**

Static (Steady-State) Object Number: **20**

Change Event Object Number: **22**

Request Function Codes supported: **1 (read), 7 (freeze), 8 (freeze noack), 9 (freeze and clear), 10 (freeze and clear, noack), 22 (assign class)**

Static Variation reported when variation 0 requested: **1 (32-Bit Binary Counter with Flag)**

Change Event Variation reported when variation 0 requested: **1 (32-Bit Counter Change Event without time)**

Change Event Buffer Size: **10**

Default Class for all points: **3**

**FROZEN COUNTERS**

Static (Steady-State) Object Number: **21**

Change Event Object Number: **23**

Request Function Codes supported: **1 (read)**

Static Variation reported when variation 0 requested: **1 (32-Bit Frozen Counter with Flag)**

Change Event Variation reported when variation 0 requested: **1 (32-Bit Frozen Counter Event without time)**

Change Event Buffer Size: **10**

Default Class for all points: **3**

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### Table F–4: BINARY AND FROZEN COUNTERS

| POINT INDEX | NAME/DESCRIPTION |
|---|---|
| 0 | Digital Counter 1 |
| 1 | Digital Counter 2 |
| 2 | Digital Counter 3 |
| 3 | Digital Counter 4 |
| 4 | Digital Counter 5 |
| 5 | Digital Counter 6 |
| 6 | Digital Counter 7 |
| 7 | Digital Counter 8 |
| 8 | Oscillography Trigger Count |
| 9 | Events Since Last Clear |

A counter freeze command has no meaning for counters 8 and 9. L30 Digital Counter values are represented as 32-bit integers. The DNP 3.0 protocol defines counters to be unsigned integers. Care should be taken when interpreting negative counter values.

### F.2.4 ANALOG INPUTS

The DNP analog input data points are configured through the **PRODUCT SETUP** ⇨⇩ **COMMUNICATIONS** ⇨⇩ **DNP / IEC104 POINT LISTS** ⇨ **ANALOG INPUT / MME POINTS** menu. See the Communications section of Chapter 5 for details.

It is important to note that 16-bit and 32-bit variations of analog inputs are transmitted through DNP as signed numbers. Even for analog input points that are not valid as negative values, the maximum positive representation is 32767 for 16-bit values and 2147483647 for 32-bit values. This is a DNP requirement.

The deadbands for all Analog Input points are in the same units as the Analog Input quantity. For example, an Analog Input quantity measured in volts has a corresponding deadband in units of volts. This is in conformance with DNP Technical Bulletin 9809-001: Analog Input Reporting Deadband. Relay settings are available to set default deadband values according to data type. Deadbands for individual Analog Input Points can be set using DNP Object 34.

Static (Steady-State) Object Number: **30**

Change Event Object Number: **32**

Request Function Codes supported: **1 (read), 2 (write, deadbands only), 22 (assign class)**

Static Variation reported when variation 0 requested: **1 (32-Bit Analog Input)**

Change Event Variation reported when variation 0 requested: **1 (Analog Change Event without Time)**

Change Event Scan Rate: defaults to **500 ms**

Change Event Buffer Size: **256**

Default Class for all Points: **2**

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### G.1.1 RADIUS SERVER CONFIGURATION

The following procedure is an example of how to set up a simple RADIUS server. You install the RADIUS server software on a separate computer. In this example, we use FreeRADIUS third-party software.

1. Download and install FreeRADIUS from www.freeradius.org as the RADIUS server. This is a Windows 32-bit installation that is known to work. If you try another third-party tool and it does not work, use the FreeRADIUS software.
2. Open the radiusd.conf file in the <Path_to_Radius>\etc\raddb folder, locate the "bind_address" field, and enter your RADIUS server IP address. An example is

   ```
   bind_address = 10.14.61.122
   ```

   Text editor software that supports direct editing and saving of UNIX text encodings and line breaks, such as EditPad Lite, is needed for this editing.
3. In the users.conf file in the <Path_to_Radius>\etc\raddb folder, add the following text to configure a user "Tester" with an Administrator role.

   ```
   Tester               User-Password == "TesterPw1#"
                       GE-UR-Role = Administrator
   ```
4. In the clients.conf file in the <Path_to_Radius>\etc\raddb folder, add the following text to define the UR as a RADIUS client, where the client IP address is 10.14.61.132, the shared secret specified here is also configured on the UR device for successful authentication, and the shortname is a short, optional alias that can be used in place of the IP address.

   ```
   client 10.14.61.132 {
   secret = Testing!123
   shortname = ur1-test
   }
   ```

   Alternatively, you can specify one secret for a network of clients, where in the following example the clients are all within the 10.14.61.0/24 subnet and the shared secret specified here is also configured on all the UR devices in the subnet for successful authentication.

   ```
   client 10.14.61.0/24 {
   secret = Testing!123
   shortname = net1-test
   }
   ```
5. In the <Path_to_Radius>\etc\raddb folder, create a file called dictionary.ge and add the following content.

   ```
   # ############################################################
   #  GE VSAs
   ############################################################

   VENDOR                          GE              2910

   # Management authorization
   BEGIN-VENDOR                    GE

   # Role ID
   ATTRIBUTE                       GE-UR-Role      1           integer

   # GE-UR-ROLE values
   VALUE GE-UR-Role                Administrator   1
   VALUE GE-UR-Role                Supervisor      2
   VALUE GE-UR-Role                Engineer        3
   VALUE GE-UR-Role                Operator        4
   VALUE GE-UR-Role                Observer        5

   END-VENDOR                      GE
   ############################################################
   ```
6. In the dictionary file in the <Path_to_Radius>\etc\raddb folder, add the following line.

```
$INCLUDE dictionary.ge
```

For example, the file can look like the following:

```
$INCLUDE ../share/freeradius/dictionary
$INCLUDE dictionary.ge
```

7. For the first start, run the RADIUS server in debug mode to ensure that there are no compiling errors.

   ```
   <Path_to_Radius>/start_radiusd_debug.bat
   ```

8. Set up the RADIUS parameters on the UR as follows.

   If logging in, select **Device** for the **Authentication Type**, and use Administrator for the **User Name**. The default password is "ChangeMe1#".

   Access **Settings > Product Setup > Security**. Configure the IP address (10.14.61.122 in this example) and ports (default values in this example) for the RADIUS server. Leave the GE vendor ID field at the default of 2910. Update the RADIUS shared secret (Testing!123 in this example) as specified in the clients.conf file. Restart the relay for the IP address and port changes to take effect.

9. Verify operation. Log in to the UR software as follows. In the login window, select **Server** as the **Authentication Type**, enter the user name entered (for example user name Tester and password "TesterPw1#"). Check that the RADIUS server log file shows the access with an "Access-Accept" entry.

### H.1.1 REVISION HISTORY

**Table H–1: REVISION HISTORY**

| MANUAL P/N | L30 REVISION | RELEASE DATE | ECO |
|---|---|---|---|
| 1601-9050-T1 | 5.6x | 27 June 2008 | 08-0390 |
| 1601-9050-U1 | 5.7x | 29 May 2009 | 09-0938 |
| 1601-9050-U2 | 5.7x | 30 September 2009 | 09-1165 |
| 1601-9050-V1 | 5.8x | 29 May 2010 | 09-1457 |
| 1601-9050-V2 | 5.8x | 04 January 2011 | 11-2237 |
| 1601-9050-W1 | 5.9x | 12 January 2011 | 11-2227 |
| 1601-9050-X1 | 6.0x | 21 December 2011 | 11-2840 |
| 1601-9050-X2 | 6.0x | 5 April 2012 | 12-3254 |
| 1601-9050-Y1 | 7.0x | 30 September 2012 | 12-3529 |
| 1601-9050-Y2 | 7.0x | 11 November 2012 | 12-3601 |
| 1601-9050-Z1 | 7.1x | 30 March 2013 | 13-0126 |
| 1601-9050-AA1 | 7.2x | 1 August 2013 | 13-0401 |
| 1601-9050-AA2 | 7.2x | 31 December 2014 | 14-1732 |
| 1601-9050-AA3 | 7.2x | 1 September 2015 | 15-2215 |
| 1601-9050-AA4 | 7.2x | 15 April 2016 | 16-2786 |
| 1601-9050-AA5 | 7.2x | 15 August 2017 | 17-3978 |
| 1601-9050-AA6 | 7.2x | 24 May 2021 | 21-6381 |
| 1601-9050-AA7 | 7.2x | 11 August 2021 | 21-6542 |

### H.1.2 CHANGES TO THE L30 MANUAL

**Table H–2: MAJOR UPDATES FOR L30 MANUAL REVISION AA7**

| PAGE (AA6) | PAGE (AA7) | CHANGE | DESCRIPTION |
|---|---|---|---|
| --- | --- | Update | General revision |
| | | | |
| 7-14 | 7-14 | Add | Added Instantaneous Protection Elements Trip Security section to self-tests |

**Table H–3: MAJOR UPDATES FOR L30 MANUAL REVISION AA6**

| PAGE (AA5) | PAGE (AA6) | CHANGE | DESCRIPTION |
|---|---|---|---|
| --- | --- | Update | General revision |
| | | | |
| 2- | 2- | Update | Updated Dropout Level specification for several elements, changing percent range to a number |
| 2- | 2- | Delete | Deleted end-of-manufacturing modules 2G, 74, 75, 7E, 7L from order code tables |
| 2-9 | 2-9 | Update | Updated order codes from SH / SL to RH / RL for the redundant power supply for horizontal units. The power supply modules were upgraded in 2014 to SH and SL, but the order codes when purchasing a UR remain as RH and RL so that customers do not need to change order codes. The order codes for the power supply replacement modules are correct as SH and SL. |
| 2-9 | 2-9 | Add | Added order codes for Inter-relay communication modules in U column for horizontal unit |
| | | | |
| 3- | 3- | Update | Updated Typical Wiring Diagram at CPU module, CPU Module Communications Wiring figure, and Options for IRIG-B Connection figure |
| | | | |
| 6- | 6- | Add | Added Remote Resources to Actual Values menu and added its Field Unit section |
| | | | |
| B- | B- | Update | Updated Modbus memory map and F codes |
| G- | G- | Update | Updated RADIUS appendix |

### Table H–4: MAJOR UPDATES FOR L30 MANUAL REVISION AA5

| PAGE (AA4) | PAGE (AA5) | CHANGE | DESCRIPTION |
|---|---|---|---|
| --- | --- | Update | General revision |
| --- | --- | Update | Updated CT Failure Detector by adding number of elements in FlexLogic operands table, settings, and Modbus memory map |
| | | | |
| 3-36 | 3-36 | Update | Updated RS422 and Fiber Interface Connection figure for the clock channels (from 7a and 7b to 1a and 1b) |

### Table H–5: MAJOR UPDATES FOR L30 MANUAL REVISION AA4

| PAGE (AA3) | PAGE (AA4) | CHANGE | DESCRIPTION |
|---|---|---|---|
| --- | --- | Update | General revision, including updated branding from GE Digital Energy to GE Grid Solutions |
| --- | --- | Delete | Deleted EAC logo from title page and deleted EAC certification from Approvals specifications because document not translated into Russian |
| 2-14 | 2-14 | Delete | Deleted software options A4, B4, D4 from order code tables |

### Table H–6: MAJOR UPDATES FOR L30 MANUAL REVISION AA3

| PAGE (AA2) | PAGE (AA3) | CHANGE | DESCRIPTION |
|---|---|---|---|
| --- | --- | Update | General revision throughout document |
| --- | --- | Update | Updated numbers of elements throughout document |
| --- | --- | Add | Added EAC compliance information throughout, including logo on title page, rear panel, added specifications, added life expectancy and decommissioning, added sections on Uninstall and Clear Files and Data, Repairs, Storage, and Disposal |
| | | | |
| 2-19 | 2-19 | Add | Added UR Signal Processing section |
| 2-22 | 2-22 | Delete | Deleted the Functionality section |
| | | | |
| 4-22 | 4-22 | Delete | Deleted Standard Faceplate section on how to customize LED and blank panels. Clear Lexan front cover (part number 1501-0014) no longer being sold. Units with blank LED panels no longer being sold. |
| | | | |
| 5-140 | 5-140 | Update | Updated FlexLogic operands table |
| | | | |
| A- | A- | Update | Updated FlexAnalog and FlexInteger tables |
| B- | B- | Update | Updated Modbus memory map and F codes |

### Table H–7: MAJOR UPDATES FOR L30 MANUAL REVISION AA2

| PAGE (AA1) | PAGE (AA2) | CHANGE | DESCRIPTION |
|---|---|---|---|
| --- | --- | Update | General revision throughout document |
| --- | --- | Update | Updated references to digital inputs/outputs to contact inputs/outputs for consistency |
| | | | |
| 3-8 | 3-8 | Update | Updated Figure 3-10 Typical Wiring Diagram to include delta voltage input options |
| | | | |
| 5-23 | 5-23 | Add | Added Syslog Format section |
| 5-31 | 5-31 | Add | Added Far-End Fault Indication (FEFI) section |
| | | | |
| B- | B- | Update | Updated Modbus memory map and F codes |
| H-7 | H-7 | Update | Updated product warranty from 24 months to 10 years |

### Table H–8: MAJOR UPDATES FOR L30 MANUAL REVISION AA1

| PAGE (Z1) | PAGE (AA1) | CHANGE | DESCRIPTION |
|---|---|---|---|
| --- | --- | Add | Added content for IEC 60870-5-103 throughout document |
| | | | |
| 2- | 2- | Update | Updated order codes |
| 2- | 2- | Update | Updated specifications |
| | | | |
| 5-109 | 5-109 | Update | Updated hysteresis numbers and logic diagrams in section 5.4.8 Phasor Measurement Unit |
| | | | |
| 8- | --- | Delete | Deleted chapter 8 on security, moving content to other chapters |
| | | | |
| --- | 11- | Add | Added Maintenance chapter, moving content from other chapters and adding new instructions to replace the battery |
| | | | |
| --- | D- | Add | Added new appendix on IEC 60870-5-103 interoperability |

## H.2.1 STANDARD ABBREVIATIONS

A ..... Ampere
AC ..... Alternating Current
A/D ..... Analog to Digital
AE ..... Accidental Energization, Application Entity
AMP ..... Ampere
ANG ..... Angle
ANSI ..... American National Standards Institute
AR ..... Automatic Reclosure
ASDU ..... Application-layer Service Data Unit
ASYM ..... Asymmetry
AUTO ..... Automatic
AUX ..... Auxiliary
AVG ..... Average

BCS ..... Best Clock Selector
BER ..... Bit Error Rate
BF ..... Breaker Fail
BFI ..... Breaker Failure Initiate
BKR ..... Breaker
BLK ..... Block
BLKG ..... Blocking
BNC ..... Bayonet Neill-Concelman
BPNT ..... Breakpoint of a characteristic
BRKR ..... Breaker

CAP ..... Capacitor
CC ..... Coupling Capacitor
CCVT ..... Coupling Capacitor Voltage Transformer
CFG ..... Configure / Configurable
.CFG ..... Filename extension for oscillography files
CHK ..... Check
CHNL ..... Channel
CLS ..... Close
CLSD ..... Closed
CMND ..... Command
CMPRSN ..... Comparison
CO ..... Contact Output
COM ..... Communication
COMM ..... Communications
COMP ..... Compensated, Comparison
CONN ..... Connection
CONT ..... Continuous, Contact
CO-ORD ..... Coordination
CPU ..... Central Processing Unit
CRC ..... Cyclic Redundancy Code
CRT, CRNT .... Current
CSA ..... Canadian Standards Association
CT ..... Current Transformer
CVT ..... Capacitive Voltage Transformer

D/A ..... Digital to Analog
DC (dc) ..... Direct Current
DD ..... Disturbance Detector
DFLT ..... Default
DGNST ..... Diagnostics
DI ..... Digital Input
DIFF ..... Differential
DIR ..... Directional
DISCREP ..... Discrepancy
DIST ..... Distance
DMD ..... Demand
DNP ..... Distributed Network Protocol
DPO ..... Dropout
DSP ..... Digital Signal Processor
dt ..... Rate of Change
DTT ..... Direct Transfer Trip
DUTT ..... Direct Under-reaching Transfer Trip

EAD ..... Expert Arc Detector
ENCRMNT ..... Encroachment
EPRI ..... Electric Power Research Institute
.EVT ..... Filename extension for event recorder files
EXT ..... Extension, External

F ..... Field
FAIL ..... Failure
FD ..... Fault Detector
FDH ..... Fault Detector high-set
FDL ..... Fault Detector low-set
FLA ..... Full Load Current
FO ..... Fiber Optic
FREQ ..... Frequency
FSK ..... Frequency-Shift Keying
FTP ..... File Transfer Protocol
FxE ..... FlexElement™
FWD ..... Forward

G ..... Generator
GE ..... General Electric
GND ..... Ground
GNTR ..... Generator
GOOSE ..... General Object Oriented Substation Event
GPS ..... Global Positioning System

HARM ..... Harmonic / Harmonics
HCT ..... High Current Time
HGF ..... High-Impedance Ground Fault (CT)
HIZ ..... High-Impedance and Arcing Ground
HMI ..... Human-Machine Interface
HTTP ..... Hyper Text Transfer Protocol
HYB ..... Hybrid

I ..... Instantaneous
I_0 ..... Zero Sequence current
I_1 ..... Positive Sequence current
I_2 ..... Negative Sequence current
IA ..... Phase A current
IAB ..... Phase A minus B current
IB ..... Phase B current
IBC ..... Phase B minus C current
IC ..... Phase C current
ICA ..... Phase C minus A current
ID ..... Identification
IED ..... Intelligent Electronic Device
IEC ..... International Electrotechnical Commission
IEEE ..... Institute of Electrical and Electronic Engineers
IG ..... Ground (not residual) current
Igd ..... Differential Ground current
IN ..... CT Residual Current (3I0) or Input
INC SEQ ..... Incomplete Sequence
INIT ..... Initiate
INST ..... Instantaneous
INV ..... Inverse
I/O ..... Input/Output
IOC ..... Instantaneous Overcurrent
IOV ..... Instantaneous Overvoltage
IRIG ..... Inter-Range Instrumentation Group
ISO ..... International Standards Organization
IUV ..... Instantaneous Undervoltage

K0 ..... Zero Sequence Current Compensation
kA ..... kiloAmpere
kV ..... kiloVolt

LED ..... Light Emitting Diode
LEO ..... Line End Open
LFT BLD ..... Left Blinder
LOOP ..... Loopback
LPU ..... Line Pickup
LRA ..... Locked-Rotor Current
LTC ..... Load Tap-Changer

M ..... Machine
mA ..... MilliAmpere
MAG ..... Magnitude
MAN ..... Manual / Manually
MAX ..... Maximum
MIC ..... Model Implementation Conformance
MIN ..... Minimum, Minutes
MMI ..... Man Machine Interface
MMS ..... Manufacturing Message Specification
MRT ..... Minimum Response Time
MSG ..... Message
MTA ..... Maximum Torque Angle
MTR ..... Motor
MVA ..... MegaVolt-Ampere (total 3-phase)

MVA_A ..... MegaVolt-Ampere (phase A)
MVA_B ..... MegaVolt-Ampere (phase B)
MVA_C ..... MegaVolt-Ampere (phase C)
MVAR ..... MegaVar (total 3-phase)
MVAR_A..... MegaVar (phase A)
MVAR_B..... MegaVar (phase B)
MVAR_C ..... MegaVar (phase C)
MVARH ..... MegaVar-Hour
MW..... MegaWatt (total 3-phase)
MW_A..... MegaWatt (phase A)
MW_B ..... MegaWatt (phase B)
MW_C ..... MegaWatt (phase C)
MWH ..... MegaWatt-Hour

N..... Neutral
N/A, n/a ..... Not Applicable
NEG ..... Negative
NMPLT ..... Nameplate
NOM..... Nominal
NTR..... Neutral

O ..... Over
OC, O/C ..... Overcurrent
O/P, Op..... Output
OP ..... Operate
OPER ..... Operate
OPERATG..... Operating
O/S ..... Operating System
OSI ..... Open Systems Interconnect
OSB..... Out-of-Step Blocking
OUT..... Output
OV ..... Overvoltage
OVERFREQ ... Overfrequency
OVLD ..... Overload

P..... Phase
PC ..... Phase Comparison, Personal Computer
PCNT ..... Percent
PF..... Power Factor (total 3-phase)
PF_A ..... Power Factor (phase A)
PF_B ..... Power Factor (phase B)
PF_C ..... Power Factor (phase C)
PFLL..... Phase and Frequency Lock Loop
PHS..... Phase
PICS..... Protocol Implementation & Conformance Statement
PKP ..... Pickup
PLC ..... Power Line Carrier
POS..... Positive
POTT..... Permissive Over-reaching Transfer Trip
PRESS ..... Pressure
PP ..... Power Profile
PRI ..... Primary
PROT ..... Protection
PSEL ..... Presentation Selector
pu ..... Per Unit
PUIB..... Pickup Current Block
PUIT ..... Pickup Current Trip
PUSHBTN ..... Pushbutton
PUTT..... Permissive Under-reaching Transfer Trip
PWM ..... Pulse Width Modulated
PWR..... Power

QUAD..... Quadrilateral

R..... Rate, Reverse
RCA..... Reach Characteristic Angle
REF ..... Reference
REM ..... Remote
REV..... Reverse
RI..... Reclose Initiate
RIP ..... Reclose In Progress
RGT BLD..... Right Blinder
RMA ..... Return Materials Authorization
RMS ..... Root Mean Square
ROCOF ..... Rate of Change of Frequency
ROD ..... Remote Open Detector
RST ..... Reset
RSTR ..... Restrained
RTD..... Resistance Temperature Detector
RTU..... Remote Terminal Unit

RX (Rx)..... Receive, Receiver

s..... second
S ..... Sensitive
SAT ..... CT Saturation
SBO ..... Select Before Operate
SCADA..... Supervisory Control and Data Acquisition
SEC ..... Secondary
SEL ..... Select / Selector / Selection
SENS ..... Sensitive
SEQ ..... Sequence
SFTP..... Secure Shell (SSH) File Transfer Protocol, Secure File Transfer Protocol
SIR..... Source Impedance Ratio
SNTP ..... Simple Network Time Protocol
SRC ..... Source
SSB..... Single Side Band
SSEL..... Session Selector
STATS..... Statistics
SUPN..... Supervision
SUPV ..... Supervise / Supervision
SV ..... Supervision, Service
SYNC..... Synchrocheck
SYNCHCHK.... Synchrocheck

T..... Time, transformer
TC ..... Thermal Capacity
TCP..... Transmission Control Protocol
TCU ..... Thermal Capacity Used
TD MULT ..... Time Dial Multiplier
TEMP..... Temperature
TFTP..... Trivial File Transfer Protocol
THD ..... Total Harmonic Distortion
TMR..... Timer
TOC ..... Time Overcurrent
TOV ..... Time Overvoltage
TRANS..... Transient
TRANSF ..... Transfer
TSEL..... Transport Selector
TUC ..... Time Undercurrent
TUV..... Time Undervoltage
TX (Tx)..... Transmit, Transmitter

U ..... Under
UC..... Undercurrent
UCA ..... Utility Communications Architecture
UDP ..... User Datagram Protocol
UL ..... Underwriters Laboratories
UNBAL..... Unbalance
UR..... Universal Relay
URC..... Universal Recloser Control
.URS ..... Filename extension for settings files
UV..... Undervoltage

V/Hz..... Volts per Hertz
V_0 ..... Zero Sequence voltage
V_1 ..... Positive Sequence voltage
V_2 ..... Negative Sequence voltage
VA ..... Phase A voltage
VAB..... Phase A to B voltage
VAG ..... Phase A to Ground voltage
VARH ..... Var-hour voltage
VB ..... Phase B voltage
VBA..... Phase B to A voltage
VBG ..... Phase B to Ground voltage
VC ..... Phase C voltage
VCA..... Phase C to A voltage
VCG ..... Phase C to Ground voltage
VF ..... Variable Frequency
VIBR ..... Vibration
VT ..... Voltage Transformer
VTFF ..... Voltage Transformer Fuse Failure
VTLOS ..... Voltage Transformer Loss Of Signal

WDG ..... Winding
WH..... Watt-hour
w/ opt ..... With Option
WRT..... With Respect To

X ..... Reactance
XDUCER..... Transducer

H

XFMR ..... Transformer

Z..... Impedance, Zone

### H.3.1 GE MULTILIN WARRANTY

For products shipped as of 1 October 2013, GE Grid Solutions warrants most of its GE manufactured products for 10 years. For warranty details including any limitations and disclaimers, see the GE Grid Solutions Terms and Conditions at https://www.gegridsolutions.com/multilin/warranty.htm

For products shipped before 1 October 2013, the standard 24-month warranty applies.

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