GE VERNOVA

C70

Capacitor Bank Protection and Control System



Instruction Manual

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ABBREVIATIONS

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C70 Capacitor Bank Protection and Control System

Chapter 1: Introduction

This chapter outlines safety and technical support information.

1.1 Safety symbols and definitions

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.

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

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

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

NOTICE Indicates practices not related to personal injury.

1.1.1 General cautions and warnings

The following general safety precautions and warnings apply.

DANGER **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.

⚠CAUTION **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.**

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.

1.2 For further assistance

For product support, contact the information and call center as follows:

GE Grid Solutions
650 Markland Street
Markham, Ontario
Canada L6C 0M1
Worldwide telephone: +1 905 927 7070
Europe/Middle East/Africa telephone: +34 94 485 88 54
North America toll-free: 1 800 547 8629
Fax: +1 905 927 5098
Worldwide e-mail: multilin.tech@ge.com
Europe e-mail: multilin.tech.euro@ge.com
Website: http://www.gegridsolutions.com/multilin

C70 Capacitor Bank Protection and Control System

Chapter 2: Product description

This chapter outlines the product, order codes, and specifications.

2.1 Product description

The C70 Capacitor Bank Protection and Control System is part of the Universal Relay (UR) series of products. It is a microprocessor-based relay for protection and control of small, medium, and large three-phase capacitor banks. The relay can be ordered with up to three current transformer/voltage transformer (CT/VT) modules, allowing for flexible application in variety of bank configurations.

The key protection functions cover grounded and ungrounded, single and parallel banks. Sensitive protection functions support compensation for both external (system) unbalance and inherent unbalance of the capacitor bank itself. Both voltage and current-based balance protection functions are available. Algorithms are developed to automatically select compensation settings after repairs or other alternations of the bank.

The relay supports a variety of bank configurations through flexible configurations of its AC inputs, installed voltage and current transformers, and resulting protection techniques.

The relay incorporates an automatic voltage regulator (AVR) responding to voltage, reactive power, or power factor. A separate timer function initiates controls on a pre-defined time/date basis. These on-off type controls are meant to automatically close or open the associated breaker. A supervisory function is provided to program the local/remote, auto/manual functionality, temporary inhibit closing after tripping, and other auxiliary functions, such as operation counters.

A capacitor control element provides remote/local and auto/manual control regulation, trip/close interlocking, and seal-in. A user-programmable time delay inhibits closing until after the bank discharges itself to a safe level.

The relay can also equipped with a serial 64/128 kbps direct input/output module for fast and reliable peer-to-peer communication with other UR-series devices.

The C70 metering functions include true root mean square (RMS) and phasors for currents and voltages, current and voltage harmonics and total harmonic distortion (THD), symmetrical components, frequency, power, power factor.

Diagnostic features include an event recorder capable of storing 1024 time-tagged events, oscillography capable of storing up to 64 records with programmable trigger, content and sampling rate, and data logger acquisition of up to 16 channels, with programmable content and sampling rate. The internal clock used for time-tagging can be synchronized with an IRIG-B signal, using the Simple Network Time Protocol (SNTP) over the Ethernet port, or using the Precision Time Protocol (PTP). This precise time stamping allows the sequence of events to be determined throughout the system. Events can also be programmed (via FlexLogic™ equations) to trigger oscillography data capture that can be set to record the measured parameters before and after the event for viewing on a computer. These tools significantly reduce troubleshooting time and simplify report generation in the event of a system fault.

Several options are available for communication. A faceplate RS232 port can be used to connect to a computer to program settings and monitor actual values. 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. 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-TX Ethernet interface provides fast, reliable communications in noisy environments. The Ethernet port supports IEC 61850, Modbus/TCP, TFTP, and PTP (according to IEEE Std. 1588-2008 or IEC 61588), and it allows access to the relay via any standard web browser (C70 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.

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

The C70 uses flash memory technology that allows field upgrading as new features are added. Firmware and software are upgradable.

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 supported

Device number	Function
27P	Phase undervoltage
50BF	Breaker failure
50DD	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
51P	Phase time overcurrent
51_2	Negative-sequence time overcurrent
59B	Bank phase overvoltage

Device number	Function
59N	Neutral overvoltage
59NU	Neutral voltage unbalance
59P	Phase overvoltage
59X	Auxiliary overvoltage
59_2	Negative-sequence overvoltage
60N	Bank neutral current unbalance
60P	Bank phase current unbalance
67N	Neutral directional overcurrent
67P	Phase directional overcurrent
67_2	Negative-sequence directional overcurrent
87V	Bank voltage differential

Figure 2-1: Single-line diagram

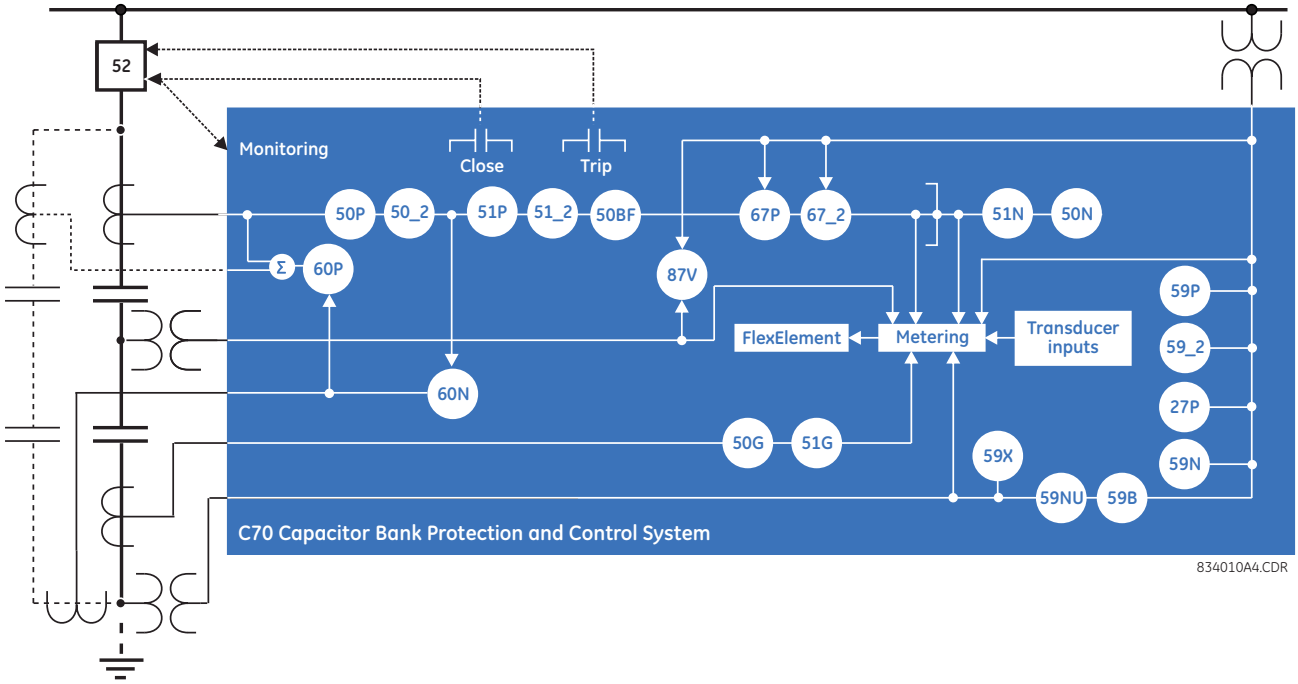


Table 2-2: Other device functions

Function	Function	Function
Breaker control	Direct inputs and outputs (32)	Time and date
Breaker flashover	Event recorder	Time synchronization over IRIG-B or IEEE 1588
Breaker restrike	FlexElements™ (16)	Time synchronization over SNTP
Capacitor control supervision	FlexLogic equations	Transducer inputs and outputs
Contact inputs (up to 96)	Frequency metering	User-definable displays
Contact outputs (up to 64)	IEC 60870-5-103 communications	User-programmable fault reports
Control pushbuttons	IEC 61850 communications	User-programmable LEDs
CyberSentry™ security	Modbus communications	User-programmable pushbuttons
Current metering: true RMS, phasors, symmetrical	Modbus user map	User-programmable self-tests
	Non-volatile latches	Virtual inputs (64)
Data logger	Non-volatile selector switch	Virtual outputs (96)
Digital counters (8)	Oscillography	Voltage metering: true RMS, phasors, symmetrical
Digital elements (48)	Power metering	
Disconnect switches	Power factor metering	Voltage regulator
DNP 3.0 or IEC 60870-5-104 protocol	Setting groups (6)	VT fuse failure

2.2 Security

The following security features are available:

- Password security — Basic security present by default
- EnerVista security — Role-based access to various EnerVista software screens and configuration elements. The feature is present by default in the EnerVista software.

- CyberSentry security — Advanced security available as a software option. When purchased, the options are automatically enabled, and the default Password security and EnerVista security are disabled.

2.2.0.1 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.

2.2.0.2 Password security

Password security is a basic security feature present by default.

Two levels of password security are provided: command and setting. Use of a password for each level controls whether users can enter commands and/or change settings.

The C70 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 C70, 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.

2.2.0.3 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:

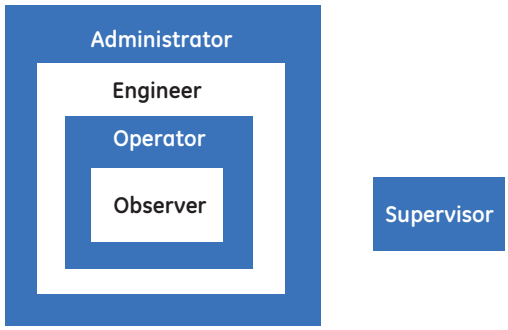
- An Authentication, Authorization, Accounting (AAA) Remote Authentication Dial-In User Service (RADIUS) client that is centrally managed, enables user attribution, provides accounting of all user activities, and uses secure standards-based strong cryptography for authentication and credential protection
- 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 roles)
- 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 (see figure) so that access of UR devices by multiple personnel within a substation is allowed.

Figure 2-2: CyberSentry user roles



The table lists user roles 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 Tests	RW	RW	R	R	R
|---------- Control Pushbuttons	RW	RW	R	R	R
|---------- User-Programmable Pushbuttons	RW	RW	R	R	R
|---------- Flex state Parameters	RW	RW	R	R	R
|---------- User-Definable Displays	RW	RW	R	R	R
|---------- Direct I/O	RW	RW	R	R	R
|---------- Teleprotection	RW	RW	R	R	R
|---------- Installation	RW	RW	R	R	R
|---------- System Setup	RW	RW	R	R	R

Roles	Administrator	Engineer	Operator	Supervisor	Observer
|---------- 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 Inputs	RW	RW	R	R	R
|---------- Contact Input threshold	RW	RW	R	R	R
|---------- Virtual Inputs	RW	RW	R	R	R
|---------- Contact Outputs	RW	RW	R	R	R
|---------- Virtual Outputs	RW	RW	R	R	R
|---------- Resetting	RW	RW	R	R	R
|---------- 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
|---------- 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
|---------- Metering	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:

RW = read and write access

R = read access

Supervisor = RW (default), Administrator = R (default), Administrator = RW (only if Supervisor role is disabled)

NA = the permission is not enforced by CyberSentry security

CyberSentry user authentication

The following types of authentication are supported by CyberSentry 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 the 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 is displayed in plain text by the EnerVista software or UR device, nor is such information ever transmitted without cryptographic protection.

CyberSentry server authentication

The UR has been designed to direct automatically the 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 detects automatically whether an authentication request is to be handled remotely or locally. As there are five local accounts possible on the UR, if the user ID credential does not match one of the five local accounts, the UR forwards automatically 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.

2.3 Order codes

The order code is on the product label and indicates the product options applicable.

The C70 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. Module options are specified at the time of ordering.

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 depends 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 HardFiber process bus module provides an interface to HardFiber Bricks.

2.3.1 Order codes with enhanced CT/VT modules

Table 2-4: C70 order codes for horizontal units

	C70 - * ** - * * * - F ** - H ** - M ** - P ** - U ** - W/X **		Full Size Horizontal Mount
BASE UNIT	C70		Base Unit
CPU	T		RS485 with 3 100Base-FX Ethernet, multimode, SFP with LC
	U		RS485 with 1 100Base-TX Ethernet, SFP RJ-45 + 2 100Base-FX Ethernet, multimode, SFP with LC
	V		RS485 with 3 100Base-TX Ethernet, SFP with RJ-45
SOFTWARE		00	No software options
		03	IEC 61850
		12	Enhanced capacitor bank control (time and date, capacitor control supervision, automatic voltage regulator)
		13	Enhanced capacitor bank control and IEC 61850
		A0	CyberSentry Lvl 1
		A3	CyberSentry Lvl 1 and IEC 61850
		AC	CyberSentry Lvl 1 and enhanced capacitor bank control
		AD	CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
		B0	IEEE 1588
		B3	IEEE 1588 and IEC 61850

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C70	- *	**	- *	*	*	- F **	- H **	- M **	- P **	- U **	- W/X **	Full Size Horizontal Mount
		BC										IEEE 1588 and enhanced capacitor bank control
		BD										IEEE 1588, IEC 61850, and enhanced capacitor bank control
		C0										Parallel Redundancy Protocol (PRP)
		C3										PRP and IEC 61850
		CC										PRP and Enhanced Capacitor Bank Control
		CD										PRP, IEC 61850, and Enhanced Capacitor Bank Control
		D0										IEEE 1588 and CyberSentry Lvl 1
		D3										IEEE 1588, CyberSentry Lvl 1, and IEC 61850
		DC										IEEE 1588, CyberSentry Lvl 1, and enhanced capacitor bank control
		DD										IEEE 1588, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
		E0										IEEE 1588 and PRP
		E3										IEEE 1588, PRP, and IEC 61850
		EC										IEEE 1588, PRP, enhanced capacitor bank control
		ED										IEEE 1588, PRP, IEC 61850, and enhanced capacitor bank control
		F0										PRP and CyberSentry Lvl 1
		F3										PRP, CyberSentry Lvl 1, and IEC 61850
		FC										PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
		FD										PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
		G0										IEEE 1588, PRP, and CyberSentry Lvl 1
		G3										IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850
		GC										IEEE 1588, PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
		GD										IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
		J0										IEC 60870-5-103
		J3										IEC 60870-5-103 and IEC 61850
		JC										IEC 60870-5-103 and enhanced capacitor bank control
		JD										IEC 60870-5-103, IEC 61850, and enhanced capacitor bank control
		K0										IEEE 1588, PRP, and IEC 60870-5-103
		K3										IEEE 1588, PRP, IEC 60870-5-103, and IEC 61850
		KC										IEEE 1588, PRP, IEC 60870-5-103, and enhanced capacitor bank control
		KD										IEEE 1588, PRP, IEC 60870-5-103, IEC 61850, and enhanced capacitor bank control
		L0										IEC 60870-5-103, IEEE 1588, PRP, and CyberSentry Lvl 1
		L3										IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850
		LC										IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
		LD										IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
MOUNT/ COATING			H									Horizontal (19" rack)
			A									Horizontal (19" rack) with harsh-environment coating
FACEPLATE/ DISPLAY				C								English display
				P								English display with 4 small and 12 large programmable pushbuttons
				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 (redundant supply must be same type as main supply)				H								125 / 250 V AC/DC power supply
				H							RH	125 / 250 V AC/DC with redundant 125 / 250 V AC/DC power supply
				L								24 to 48 V (DC only) power supply
				L							RL	24 to 48 V (DC only) with redundant 24 to 48 V DC power supply
CT/VT DSP								XX		XX		None
					8L			8L		8L		Standard 4CT/4VT with enhanced diagnostics
					8N			8N		8N		Standard 8CT with enhanced diagnostics
					8V			8V		8V		Standard 8VT with enhanced diagnostics
CONTACT INPUTS/ OUTPUTS						XX	XX	XX	XX	XX	XX	None
						4C	4C	4C	4C	4C	4C	4 Solid-state (current with optional voltage) MOSFET outputs
						6A	6A	6A	6A	6A	6A	2 Form-A (voltage with optional current) and 2 Form-C outputs, 8 contact inputs
						6B	6B	6B	6B	6B	6B	2 Form-A (voltage with optional current) and 4 Form-C outputs, 4 contact inputs
						6C	6C	6C	6C	6C	6C	8 Form-C outputs
						6D	6D	6D	6D	6D	6D	16 Contact inputs
						6E	6E	6E	6E	6E	6E	4 Form-C outputs, 8 contact inputs
						6F	6F	6F	6F	6F	6F	8 Fast Form-C outputs
						6G	6G	6G	6G	6G	6G	4 Form-A (voltage with optional current) outputs, 8 contact inputs
						6H	6H	6H	6H	6H	6H	6 Form-A (voltage with optional current) outputs, 4 contact inputs
						6K	6K	6K	6K	6K	6K	4 Form-C and 4 Fast Form-C outputs
						6L	6L	6L	6L	6L	6L	2 Form-A (current with optional voltage) and 2 Form-C outputs, 8 contact inputs
						6M	6M	6M	6M	6M	6M	2 Form-A (current with optional voltage) and 4 Form-C outputs, 4 contact inputs
						6N	6N	6N	6N	6N	6N	4 Form-A (current with optional voltage) outputs, 8 contact inputs
						6P	6P	6P	6P	6P	6P	6 Form-A (current with optional voltage) outputs, 4 contact inputs
						6R	6R	6R	6R	6R	6R	2 Form-A (no monitoring) and 2 Form-C outputs, 8 contact inputs
						6S	6S	6S	6S	6S	6S	2 Form-A (no monitoring) and 4 Form-C outputs, 4 contact inputs
						6T	6T	6T	6T	6T	6T	4 Form-A (no monitoring) outputs, 8 contact inputs
						6U	6U	6U	6U	6U	6U	6 Form-A (no monitoring) outputs, 4 contact inputs
						6V	6V	6V	6V	6V	6V	2 Form-A outputs, 1 Form-C output, 2 Form-A (no monitoring) latching outputs, 8 contact inputs
TRANSDUCER INPUTS/OUTPUTS							5A	5A	5A	5A	5A	4 DCmA inputs, 4 DCmA outputs (only one 5A module is allowed)
INTER-RELAY COMMUNICATIONS (select a maximum of 1 per unit)										2H	2H	IEEE C37.94, 820 nm, 128 kbps, multimode, LED, 2 Channels
										2I	2I	Channel 1 - IEEE C37.94, MM, 64/128 kbps; Channel 2 - 1300 nm, single-mode, Laser
										2J	2J	Channel 1 - IEEE C37.94, MM, 64/128 kbps; Channel 2 - 1550 nm, single-mode, Laser
										77	77	IEEE C37.94, 820 nm, multimode, LED, 2 Channels
										7H	7H	820 nm, multi-mode, LED, 2 Channels
										7I	7I	1300 nm, multi-mode, LED, 2 Channels
										7S	7S	G.703, 2 Channels
										7W	7W	RS422, 2 Channels

Table 2-5: C70 order codes for reduced-size vertical units

	C70	- *	**	- *	*	*	- F	**	- H	**	- M	**	- P/R	**	Reduced Size Vertical Mount (see note regarding P/R slot below)
BASE UNIT	C70	|	|	|	|	|	|	|	|	|	|	|	|	|	Base Unit
CPU		T	|	|	|	|	|	|	|	|	|	|	|	|	RS485 with 3 100Base-FX Ethernet, multimode, SFP with LC
		U	|	|	|	|	|	|	|	|	|	|	|	|	RS485 with 1 100Base-TX Ethernet, SFP RJ-45 + 2 100Base-FX Ethernet, multimode, SFP with LC
		V	|	|	|	|	|	|	|	|	|	|	|	|	RS485 with 3 100Base-TX Ethernet, SFP with RJ-45
SOFTWARE			00	|	|	|	|	|	|	|	|	|	|	|	No software options
			03	|	|	|	|	|	|	|	|	|	|	|	IEC 61850
			12	|	|	|	|	|	|	|	|	|	|	|	Enhanced capacitor bank control (time and date, capacitor control supervision, automatic voltage regulator)
			13	|	|	|	|	|	|	|	|	|	|	|	Enhanced capacitor bank control and IEC 61850
			A0	|	|	|	|	|	|	|	|	|	|	|	CyberSentry Lvl 1
			A3	|	|	|	|	|	|	|	|	|	|	|	CyberSentry Lvl 1 and IEC 61850
			AC	|	|	|	|	|	|	|	|	|	|	|	CyberSentry Lvl 1 and enhanced capacitor bank control
			AD	|	|	|	|	|	|	|	|	|	|	|	CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
			B0	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588
			B3	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588 and IEC 61850
			BC	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588 and enhanced capacitor bank control
			BD	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, IEC 61850, and enhanced capacitor bank control
			C0	|	|	|	|	|	|	|	|	|	|	|	Parallel Redundancy Protocol (PRP)
			C3	|	|	|	|	|	|	|	|	|	|	|	PRP and IEC 61850
			CC	|	|	|	|	|	|	|	|	|	|	|	PRP and enhanced capacitor bank control
			CD	|	|	|	|	|	|	|	|	|	|	|	PRP, IEC 61850, and enhanced capacitor bank control
			D0	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588 and CyberSentry Lvl 1
			D3	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, CyberSentry Lvl 1, and IEC 61850
			DC	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, CyberSentry Lvl 1, and enhanced capacitor bank control
			DD	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
			E0	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588 and PRP
			E3	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, and IEC 61850
			EC	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, enhanced capacitor bank control
			ED	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, IEC 61850, and enhanced capacitor bank control
			F0	|	|	|	|	|	|	|	|	|	|	|	PRP and CyberSentry Lvl 1
			F3	|	|	|	|	|	|	|	|	|	|	|	PRP, CyberSentry Lvl 1, and IEC 61850
			FC	|	|	|	|	|	|	|	|	|	|	|	PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
			FD	|	|	|	|	|	|	|	|	|	|	|	PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
			G0	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, and CyberSentry Lvl 1
			G3	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850
			GC	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
			GD	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
			J0	|	|	|	|	|	|	|	|	|	|	|	IEC 60870-5-103
			J3	|	|	|	|	|	|	|	|	|	|	|	IEC 60870-5-103 and IEC 61850
			JC	|	|	|	|	|	|	|	|	|	|	|	IEC 60870-5-103 and enhanced capacitor bank control
			JD	|	|	|	|	|	|	|	|	|	|	|	IEC 60870-5-103, IEC 61850, and enhanced capacitor bank control
			K0	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, and IEC 60870-5-103
			K3	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, IEC 60870-5-103, and IEC 61850
			KC	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, IEC 60870-5-103, and enhanced capacitor bank control
			KD	|	|	|	|	|	|	|	|	|	|	|	IEEE 1588, PRP, IEC 60870-5-103, IEC 61850, and enhanced capacitor bank control
			L0	|	|	|	|	|	|	|	|	|	|	|	IEC 60870-5-103, IEEE 1588, PRP, and CyberSentry Lvl 1
			L3	|	|	|	|	|	|	|	|	|	|	|	IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850
			LC	|	|	|	|	|	|	|	|	|	|	|	IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
			LD	|	|	|	|	|	|	|	|	|	|	|	IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
MOUNT/ COATING				V	|	|	|	|	|	|	|	|	|	|	Vertical (3/4 rack)
				B	|	|	|	|	|	|	|	|	|	|	Vertical (3/4 rack) with harsh-environment 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
CT/VT DSP							XX	|	XX	|	XX	|	|	None
							8L	|	8L	|	|	|	|	Standard 4CT/4VT with enhanced diagnostics
							8N	|	8N	|	|	|	|	Standard 8CT with enhanced diagnostics
							8V	|	8V	|	|	|	|	Standard 8VT with enhanced diagnostics
CONTACT INPUTS/OUTPUTS								XX	XX	|	XX	|	|	|	None
								4C	4C	|	4C	|	|	|	4 Solid-state (current with optional voltage) MOSFET outputs
								6A	6A	|	6A	|	|	|	2 Form-A (voltage with optional current) and 2 Form-C outputs, 8 contact inputs
								6B	6B	|	6B	|	|	|	2 Form-A (voltage with optional current) and 4 Form-C outputs, 4 contact inputs
								6C	6C	|	6C	|	|	|	8 Form-C outputs
								6D	6D	|	6D	|	|	|	16 Contact inputs
								6E	6E	|	6E	|	|	|	4 Form-C outputs, 8 contact inputs
								6F	6F	|	6F	|	|	|	8 Fast Form-C outputs
								6G	6G	|	6G	|	|	|	4 Form-A (voltage with optional current) outputs, 8 contact inputs
								6H	6H	|	6H	|	|	|	6 Form-A (voltage with optional current) outputs, 4 contact 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 contact inputs
								6M	6M	|	6M	|	|	|	2 Form-A (current with optional voltage) and 4 Form-C outputs, 4 contact inputs
								6N	6N	|	6N	|	|	|	4 Form-A (current with optional voltage) outputs, 8 contact inputs
								6P	6P	|	6P	|	|	|	6 Form-A (current with optional voltage) outputs, 4 contact inputs
								6R	6R	|	6R	|	|	|	2 Form-A (no monitoring) and 2 Form-C outputs, 8 contact inputs
								6S	6S	|	6S	|	|	|	2 Form-A (no monitoring) and 4 Form-C outputs, 4 contact inputs
								6T	6T	|	6T	|	|	|	4 Form-A (no monitoring) outputs, 8 contact inputs
								6U	6U	|	6U	|	|	|	6 Form-A (no monitoring) outputs, 4 contact inputs
								6V	6V	|	6V	|	|	|	2 Form-A outputs, 1 Form-C output, 2 Form-A (no monitoring) latching outputs, 8 contact inputs
TRANSDUCER INPUTS/OUTPUTS									5A	|	5A	|	|	|	4 DCmA inputs, 4 DCmA outputs (only one 5A module is allowed)

	C70	-	*	**	-	*	*	*	- F	**	- H	**	- M	**	- P/R	**		Reduced Size Vertical Mount (see note regarding P/R slot below)
INTER-RELAY COMMUNICATIONS (select a maximum of 1 per unit) For the last module, slot P is used for digital input/output modules; slot R is used for inter-relay communications modules.																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 - 1300 nm, single-mode, Laser
																77		IEEE C37.94, 820 nm, multimode, LED, 2 Channels
																7H		820 nm, multimode, LED, 2 Channels
																7I		1300 nm, multimode, LED, 2 Channels
																7S		G.703, 2 Channels
																7W		RS422, 2 Channels

2.3.2 Order codes with process bus modules

Table 2-6: C70 order codes for horizontal units with process bus

	C70	-	*	**	-	*	*	*	- F	**	- H	**	- M	**	- P	**	- U	**	- W/X	**	Full Size Horizontal Mount
BASE UNIT	C70																				Base Unit
CPU			T																		RS485 with 3 100Base-FX Ethernet, multimode, SFP with LC
			U																		RS485 with 1 100Base-TX Ethernet, SFP RJ-45 + 2 100Base-FX Ethernet, multimode, SFP with LC
			V																		RS485 with 3 100Base-TX Ethernet, SFP with RJ-45
SOFTWARE				00																	No software options
				03																	IEC 61850
				12																	Enhanced capacitor bank control (time and date, capacitor control supervision, automatic voltage regulator)
				13																	Enhanced capacitor bank control and IEC 61850
				A0																	CyberSentry Lvl 1
				A3																	CyberSentry Lvl 1 and IEC 61850
				AC																	CyberSentry Lvl 1 and enhanced capacitor bank control
				AD																	CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
				B0																	IEEE 1588
				B3																	IEEE 1588 and IEC 61850
				BC																	IEEE 1588 and enhanced capacitor bank control
				BD																	IEEE 1588, IEC 61850, and enhanced capacitor bank control
				C0																	Parallel Redundancy Protocol (PRP)
				C3																	PRP and IEC 61850
				CC																	PRP and enhanced capacitor bank control
				CD																	PRP, IEC 61850, and enhanced capacitor bank control
				D0																	IEEE 1588 and CyberSentry Lvl 1
				D3																	IEEE 1588, CyberSentry Lvl 1, and IEC 61850
				DC																	IEEE 1588, CyberSentry Lvl 1, and enhanced capacitor bank control
				DD																	IEEE 1588, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
				E0																	IEEE 1588 and PRP
				E3																	IEEE 1588, PRP, and IEC 61850
				EC																	IEEE 1588, PRP, enhanced capacitor bank control
				ED																	IEEE 1588, PRP, IEC 61850, and enhanced capacitor bank control
				F0																	PRP and CyberSentry Lvl 1
				F3																	PRP, CyberSentry Lvl 1, and IEC 61850
				FC																	PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
				FD																	PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
				G0																	IEEE 1588, PRP, and CyberSentry Lvl 1
				G3																	IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850
				GC																	IEEE 1588, PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
				GD																	IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
				J0																	IEC 60870-5-103
				J3																	IEC 60870-5-103 and IEC 61850
				JC																	IEC 60870-5-103 and enhanced capacitor bank control
				JD																	IEC 60870-5-103, IEC 61850, and enhanced capacitor bank control
				K0																	IEEE 1588, PRP, and IEC 60870-5-103
				K3																	IEEE 1588, PRP, IEC 60870-5-103, and IEC 61850
				KC																	IEEE 1588, PRP, IEC 60870-5-103, and enhanced capacitor bank control
				KD																	IEEE 1588, PRP, IEC 60870-5-103, IEC 61850, and enhanced capacitor bank control
				L0																	IEC 60870-5-103, IEEE 1588, PRP, and CyberSentry Lvl 1
				L3																	IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850
				LC																	IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
				LD																	IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
MOUNT/ COATING					H																Horizontal (19" rack)
					A																Horizontal (19" rack) with harsh environmental coating
FACEPLATE/ DISPLAY						C															English display
						P															English display with 4 small and 12 large programmable pushbuttons
						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 (redundant supply must be same type as main supply)							H														125 / 250 V AC/DC power supply
							H													RH	125 / 250 V AC/DC with redundant 125 / 250 V AC/DC power supply
							L														24 to 48 V (DC only) power supply
							L													RL	24 to 48 V (DC only) with redundant 24 to 48 V DC power supply

	C70	- *	**	- *	*	*	- F **	- H **	- M **	- P **	- U **	- W/X **	Full Size Horizontal Mount
PROCESS BUS MODULE							XX		XX				None
								81					Eight-port digital process bus module
CONTACT INPUTS/OUTPUTS										XX	XX	XX	None
										4C	4C		4 Solid-state (current with optional voltage) MOSFET outputs
										6A	6A		2 Form-A (voltage with optional current) and 2 Form-C outputs, 8 contact inputs
										6B	6B		2 Form-A (voltage with optional current) and 4 Form-C outputs, 4 contact inputs
										6C	6C		8 Form-C outputs
										6D	6D		16 Contact inputs
										6E	6E		4 Form-C outputs, 8 contact inputs
										6F	6F		8 Fast Form-C outputs
										6G	6G		4 Form-A (voltage with optional current) outputs, 8 contact inputs
										6H	6H		6 Form-A (voltage with optional current) outputs, 4 contact inputs
										6K	6K		4 Form-C and 4 Fast Form-C outputs
										6L	6L		2 Form-A (current with optional voltage) and 2 Form-C outputs, 8 contact inputs
										6M	6M		2 Form-A (current with optional voltage) and 4 Form-C outputs, 4 contact inputs
										6N	6N		4 Form-A (current with optional voltage) outputs, 8 contact inputs
										6P	6P		6 Form-A (current with optional voltage) outputs, 4 contact inputs
										6R	6R		2 Form-A (no monitoring) and 2 Form-C outputs, 8 contact inputs
										6S	6S		2 Form-A (no monitoring) and 4 Form-C outputs, 4 contact inputs
										6T	6T		4 Form-A (no monitoring) outputs, 8 contact inputs
										6U	6U		6 Form-A (no monitoring) outputs, 4 contact inputs
										6V	6V		2 Form-A outputs, 1 Form-C output, 2 Form-A (no monitoring) latching outputs, 8 contact inputs
INTER-RELAY COMMUNICATIONS (select a maximum of 1 per unit)												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
												77	IEEE C37.94, 820 nm, multimode, LED, 2 Channels
												7H	820 nm, multimode, LED, 2 Channels
												7I	1300 nm, multimode, LED, 2 Channels
												7S	G.703, 2 Channels
												7W	RS422, 2 Channels

Table 2-7: C70 order codes for reduced-size vertical units with process bus

	C70	- *	**	- *	*	*	- F **	- H **	- M **	- P/R **	Reduced Size Vertical Mount (see note regarding P/R slot below)
BASE UNIT	C70										Base Unit
CPU		T									RS485 with 3 100Base-FX Ethernet, multimode, SFP with LC
		U									RS485 with 1 100Base-TX Ethernet, SFP RJ-45 + 2 100Base-FX Ethernet, multimode, SFP with LC
		V									RS485 with 3 100Base-TX Ethernet, SFP with RJ-45
SOFTWARE			00								No software options
			03								IEC 61850
			12								Enhanced capacitor bank control (time and date, capacitor control supervision, automatic voltage regulator)
			13								Enhanced capacitor bank control and IEC 61850
			A0								CyberSentry Lvl 1
			A3								CyberSentry Lvl 1 and IEC 61850
			AC								CyberSentry Lvl 1 and enhanced capacitor bank control
			AD								CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
			B0								IEEE 1588
			B3								IEEE 1588 and IEC 61850
			BC								IEEE 1588 and enhanced capacitor bank control
			BD								IEEE 1588, IEC 61850, and enhanced capacitor bank control
			C0								Parallel Redundancy Protocol (PRP)
			C3								PRP and IEC 61850
			CC								PRP and enhanced capacitor bank control
			CD								PRP, IEC 61850, and enhanced capacitor bank control
			D0								IEEE 1588 and CyberSentry Lvl 1
			D3								IEEE 1588, CyberSentry Lvl 1, and IEC 61850
			DC								IEEE 1588, CyberSentry Lvl 1, and enhanced capacitor bank control
			DD								IEEE 1588, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
			E0								IEEE 1588 and PRP
			E3								IEEE 1588, PRP, and IEC 61850
			EC								IEEE 1588, PRP, enhanced capacitor bank control
			ED								IEEE 1588, PRP, IEC 61850, and enhanced capacitor bank control
			F0								PRP and CyberSentry Lvl 1
			F3								PRP, CyberSentry Lvl 1, and IEC 61850
			FC								PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
			FD								PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
			G0								IEEE 1588, PRP, and CyberSentry Lvl 1
			G3								IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850
			GC								IEEE 1588, PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
			GD								IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
			J0								IEC 60870-5-103
			J3								IEC 60870-5-103 and IEC 61850
			JC								IEC 60870-5-103 and enhanced capacitor bank control
			JD								IEC 60870-5-103, IEC 61850, and enhanced capacitor bank control
			K0								IEEE 1588, PRP, and IEC 60870-5-103
			K3								IEEE 1588, PRP, IEC 60870-5-103, and IEC 61850
			KC								IEEE 1588, PRP, IEC 60870-5-103, and enhanced capacitor bank control
			KD								IEEE 1588, PRP, IEC 60870-5-103, IEC 61850, and enhanced capacitor bank control
			L0								IEC 60870-5-103, IEEE 1588, PRP, and CyberSentry Lvl 1
			L3								IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, and IEC 61850
			LC								IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, and enhanced capacitor bank control
			LD								IEC 60870-5-103, IEEE 1588, PRP, CyberSentry Lvl 1, IEC 61850, and enhanced capacitor bank control
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

C70 - * ** - * * * - F ** - H ** - M ** - P/R **						Reduced Size Vertical Mount (see note regarding P/R slot below)
POWER SUPPLY	H					125 / 250 V AC/DC power supply
	L					24 to 48 V (DC only) power supply
PROCESS BUS MODULE		XX		XX		None
			81			Eight-port digital process bus module
CONTACT INPUTS/OUTPUTS					XX	None
					4A	4 Solid-state (current with optional voltage) MOSFET outputs
					4B	2 Form-A (voltage with optional current) and 2 Form-C outputs, 8 contact inputs
					4C	2 Form-A (voltage with optional current) and 4 Form-C outputs, 4 contact inputs
					4D	8 Form-C outputs
					4L	16 Contact inputs
					6A	4 Form-C outputs, 8 contact inputs
					6B	8 Fast Form-C outputs
					6C	4 Form-A (voltage with optional current) outputs, 8 contact inputs
					6D	6 Form-A (voltage with optional current) outputs, 4 contact inputs
					6F	4 Form-C and 4 Fast Form-C outputs
					6G	2 Form-A (current with optional voltage) and 2 Form-C outputs, 8 contact inputs
					6H	2 Form-A (current with optional voltage) and 4 Form-C outputs, 4 contact inputs
					6K	4 Form-A (current with optional voltage) outputs, 8 contact inputs
					6L	6 Form-A (current with optional voltage) outputs, 4 contact inputs
					6M	2 Form-A (no monitoring) and 2 Form-C outputs, 8 contact inputs
					6N	2 Form-A (no monitoring) and 4 Form-C outputs, 4 contact inputs
					6P	4 Form-A (no monitoring) outputs, 8 contact inputs
					6R	6 Form-A (no monitoring) outputs, 4 contact inputs
					6T	2 Form-A outputs, 1 Form-C output, 2 Form-A (no monitoring) latching outputs, 8 contact inputs
INTER-RELAY COMMUNICATIONS (select a maximum of 1 per unit) For the last module, slot P is used for digital and transducer input/output modules; slot R is used for inter-relay communications modules.					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
					77	IEEE C37.94, 820 nm, multimode, LED, 2 Channels
					7H	820 nm, multimode, LED, 2 Channels
					7I	1300 nm, multimode, LED, 2 Channels
					7S	G.703, 2 Channels
					7W	RS422, 2 Channels

2.3.3 Replacement modules

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

Not all replacement modules apply to the C70 relay. The modules specified in the order codes for the C70 are available as replacement modules for the C70.

The order codes shown here are subject to change without notice. See the web page for the product for the latest options.

Table 2-8: UR order codes for replacement modules, horizontal units

UR - ** - *				
POWER SUPPLY 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		SH	A	125 / 300 V AC/DC
		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-TX Ethernet, SFP RJ-45 + 2 100Base-FX Ethernet, multimode, SFP with LC
		V		RS485 with 3 100Base-TX 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

	UR - **	- *	
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
	8V		Standard 8VT with enhanced diagnostics (only one module supported)
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
TRANSDUCER INPUTS/OUTPUTS	5A		4 DCmA inputs, 4 DCmA outputs (only one 5A or 5D module is allowed)
	5C		8 RTD inputs
	5D		4 RTD inputs, 4 DCmA outputs (only one 5A or 5D module is allowed)
	5E		4 DCmA inputs, 4 RTD inputs
	5F		8 DCmA inputs

Table 2-9: UR 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-TX Ethernet, SFP RJ-45 + 2 100Base-FX Ethernet, multimode, SFP with LC
	V		RS485 with 3 100Base-TX 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

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	UR - ** - *	
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
	8V	Standard 8VT 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

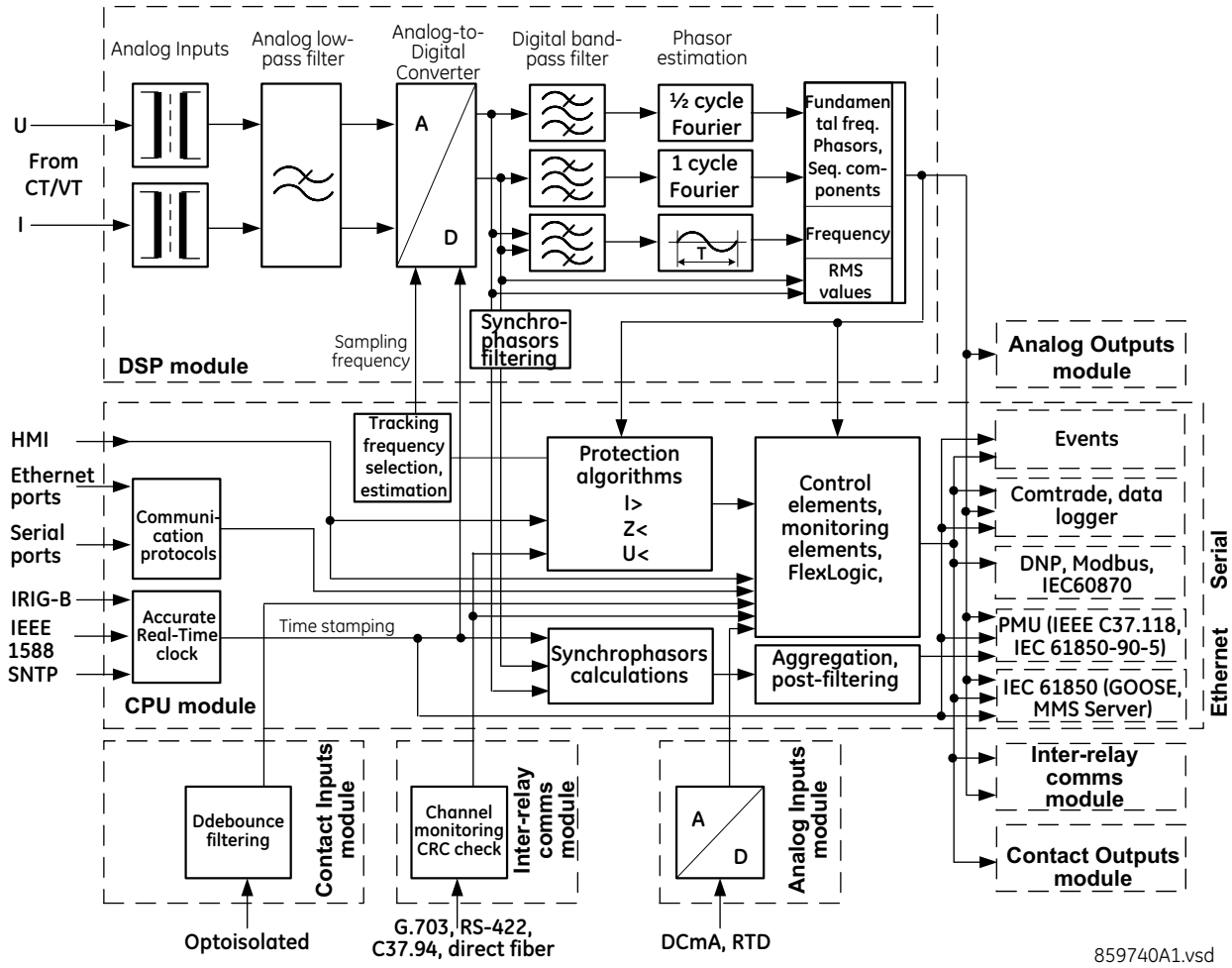
2.4 Signal processing

2.4.1 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:

$$\pm\sqrt{2}\cdot 260(\mathrm{V}) \qquad \textbf{Eq. 2-1}$$

Currents:

$$\pm\sqrt{2}\cdot 46\mathrm{rated}(\mathrm{A}) \qquad \textbf{Eq. 2-2}$$

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:

$$I_{RMS(t)} = \sqrt{\frac{1}{T}\int_{(t-T)}^{t} i^2(t)dt} \qquad \textbf{Eq. 2-3}$$

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.

2.5 Specifications

Specifications are subject to change without notice.

2.5.1 Protection elements

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 intelligent electronic devices (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.

VOLTAGE DIFFERENTIAL

Operation:	per phase
Auto-setting:	on demand from keypad, per phase
Number of elements:	1 per VT bank, maximum of 3
Matching factor:	0.5000 to 2000.0000 in steps of 0.0001, per phase
Number of trip/alarm stages:	4 per phase with individual timers per stage
Pickup threshold:	0.001 to 1.000 pu of bus voltage in steps of 0.001
Pickup level accuracy:	0.003 pu
Hysteresis:	3% or 0.0005 pu, whichever is greater
Pickup delay:	0 to 600.00 s in steps of 0.01
Timer accuracy:	±3% of operate time or ±35 ms, whichever is greater
Operate time:	<35 ms at 60 Hz

CAPACITOR CONTROL

Functionality:	contains remote/local and auto/manual non-volatile latches, collects trip, open and close input requests and issues outputs to control tripping and closing
Closing inhibit delay:	0 to 60 minutes in steps of 1 second
Trip and close seal-in timers:	0 to 60.000 s in steps of 0.001

AUTOMATIC VOLTAGE REGULATOR

Number of elements:	1 per CT/VT module, maximum of 3
Modes:	voltage with load drop compensation or reactive power with power factor limit
Minimum voltage supervision:	0.500 to 1.500 pu in steps of 0.001
Close voltage level:	0.750 to 1.500 pu in steps of 0.001
Open voltage level:	0.750 to 1.500 pu in steps of 0.001
Voltage pickup accuracy:	±0.5% of setting from 10 to 208 V
Close reactive power level:	–1.50 to 1.50 pu in steps of 0.01
Open reactive power level:	–1.50 to 1.50 pu in steps of 0.01
Power pickup accuracy:	±0.05 pu
Power factor limit	0.50 to 1.00 in steps of 0.01
Power factor accuracy:	±0.05
Hysteresis:	0.02 pu (voltage); 0.05 pu (vars)
Close delay:	0 to 65.353 s in steps of 0.001
Open delay:	0 to 65.353 s in steps of 0.001
Timer accuracy:	±3% of operate time or ±20 ms, whichever is greater
Operate time:	<80 ms at 60 Hz

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 × 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/Ground IOC) <20 ms at 3 × pickup at 60 Hz (Neutral IOC)
Timer accuracy:	±3.5% of operate time or ±1/4 cycle (whichever is greater)

NEGATIVE SEQUENCE TOC

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

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

NEGATIVE SEQUENCE DIRECTIONAL OC

Directionality:	Co-existing forward and reverse
Polarizing:	Voltage
Polarizing voltage:	V_2
Operating current:	I_2
Level sensing:	
Zero-sequence:	$\|I\_0\| - K \times \|I\_1\|$
Negative-sequence:	$\|I\_2\| - K \times \|I\_1\|$
Restraint, K:	0.000 to 0.500 in steps of 0.001
Characteristic angle:	0 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:	0.015 to 30.000 pu in steps of 0.01
Dropout level:	97%
Operation time:	<16 ms at 3 × pickup at 60 Hz

PHASE CURRENT UNBALANCE

Operation:	per phase
Auto-setting:	on demand from keypad, per phase
Number of elements:	1 per CT bank, maximum of 3
Inherent unbalance factor:	–0.1000 to 0.1000 in steps of 0.0001, per phase
Number of trip/alarm stages:	4 per phase with individual timers per stage
Pickup threshold:	0.001 to 5.000 pu of split-phase CT nominal in steps of 0.001
Pickup level accuracy:	0.002 pu for <1 pu current and <20 CT mismatch between phase and differential CT
Hysteresis:	3% or 0.001 pu, whichever is greater
Pickup delay:	0 to 600.00 s in steps of 0.01
Timer accuracy:	±3% of operate time or ±35 ms, whichever is greater
Operate time:	<35 ms at 60 Hz

NEUTRAL CURRENT UNBALANCE

Auto-setting:	on demand from keypad
Number of elements:	1 per CT bank, to a maximum of 3
Inherent unbalance factor:	magnitude of 0 to 0.1500 in steps of 0.0001, angle of 0 to 359° in steps of 1
Number of trip/alarm stages:	4, with individual timers per stage
Pickup threshold:	0.001 to 5.000 pu of ground input CT in steps of 0.001
Pickup level accuracy:	0.002 pu for <1 pu current and < 20 CT mismatch between phase and neutral CT
Hysteresis:	3% or 0.001 pu, whichever is greater
Slope:	0.0 to 10.0% in steps of 0.1
Pickup delay:	0 to 600.00 s in steps of 0.01
Timer accuracy:	±3% of operate time or ±35 ms, whichever is greater
Operate time:	<35 ms at 60 Hz

NEUTRAL VOLTAGE UNBALANCE

Operation:	compensated for inherent bank and system unbalance
Auto-setting:	on demand from keypad
Number of elements:	1 per VT bank, maximum of 3
Compensating factor:	0.7500 to 1.2500 in steps of 0.0001

Number of trip/alarm stages: 4 with individual timers
Pickup threshold: 0.001 to 1.000 pu of nominal of the bank neutral point VT in steps of 0.001
Slope: 0 to 10% in steps of 0.1
Pickup level accuracy: 0.003 pu for <10 VT mismatch between phase and neutral VT
Hysteresis: 3% or 0.001 pu whichever is greater
Pickup delay: 0 to 600.00 s in steps of 0.01
Timer accuracy: ±3% of operate time or ±35 ms, whichever is greater
Operate time: <35 ms at 60 Hz

PHASE UNDERVOLTAGE

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

BANK OVERVOLTAGE

Operation: per phase, 3 stages of definite-time, 1 stage of inverse-time
Application: grounded and ungrounded banks
Number of elements: 1 per VT bank, maximum of 3
Pickup threshold: 0.800 to 2.000 pu of bus voltage in steps of 0.001, per phase
Pickup level accuracy: 0.002 pu for operating voltage <70 V
Hysteresis: 0.02 pu
Timing characteristics: Stage 1 to Stage 3: Definite time (Time delay = 0.00 to 600.00 in steps of 0.01 s)
Stage 4: any user-programmable FlexCurve (Stage 4)
Timer accuracy: ±3% of operate time or ±35 ms, whichever is greater
Operate time: <35 ms at 60 Hz

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)

NEUTRAL 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: 0.00 to 600.00 s in steps of 0.01 (definite time) or user-defined curve
Reset delay: 0.00 to 600.00 s in steps of 0.01
Curve timing accuracy at >1.1 pickup: ±3.5% of operate time or ±1 cycle (whichever is greater) from pickup to operate
Operate time: <30 ms at 1.10 pickup at 60 Hz

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

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 FLASHOVER

Operating quantity:	phase current, voltage, and voltage difference
Pickup level voltage:	0 to 1.500 pu in steps of 0.001
Dropout level voltage:	97% of pickup
Pickup level current:	0 to 1.500 pu in steps of 0.001
Dropout level current:	97% of pickup
Level accuracy:	±0.5% or ±0.1% of rated, whichever is greater
Pickup delay:	0 to 65.535 s in steps of 0.001
Timer accuracy:	±3% of operate time or ±42 ms, whichever is greater
Operate time:	<42 ms at 1.10 × pickup at 60 Hz

BREAKER RESTRIKE

Principle:	detection of high-frequency overcurrent condition ¼ cycle after breaker opens
Availability:	one per CT/VT module (not including 8Z modules)
Pickup level:	0.1 to 2.00 pu in steps of 0.01
Reset delay:	0.000 to 65.535 s in steps of 0.001

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:	16
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 and 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 16 on enhanced horizontal front panel 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

TIME OF DAY TIMERS

Number of timers:	5
Setting resolution:	1 minute

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 up to 64 configured digital channels, representing any FlexLogic operand 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

USER-PROGRAMMABLE FAULT REPORT

Number of elements:	2
Pre-fault trigger:	any FlexLogic operand
Fault trigger:	any FlexLogic operand
Recorder quantities:	32 (any FlexAnalog™ value)

DATA LOGGER

Number of channels:	1 to 16
Parameters:	any available analog actual value

2

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:
01 channel for NN days
16 channels for NN days
↓
60-minute rate:
01 channel for NN days
16 channels for NN days

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

CURRENT HARMONICS
Harmonics: 2nd to 25th harmonic: per phase, displayed as a % of $I(f_1)$ (current fundamental frequency phasor)
THD: per phase, displayed as a % of $I(f_1)$
Accuracy:
HARMONICS: with $I(f_1)$ 0.4 to 2.0 × CT rating: ±2% of reading or ±1% of 100%, whichever is greater
THD: with $I(f_1)$ from 0.4 to 2.0 × CT rating: ±2% of reading or ±1% of 100% per each harmonic, whichever is greater
Accuracy applies to: 2nd to 25th harmonic including THD with a regular CT/VT module
2nd to 15th harmonic including THD with a HardFiber Process Bus Module (order code 81)

VOLTAGE HARMONICS
Harmonics: 2nd to 25th harmonic: per phase, displayed as a % of $V(f_1)$ (voltage fundamental frequency phasor)
THD: per phase, displayed as a % of $V(f_1)$
Accuracy:
HARMONICS: with $V(f_1)$ 25 to 208 V: ±2% of reading or ±1% of 100%, whichever is greater
THD: with $V(f_1)$ 25 to 208 V: ±2% of reading or ±1% of 100% per each harmonic, whichever is greater
Accuracy applies to: 2nd to 25th harmonic including THD with a regular CT/VT module
2nd to 15th harmonic including THD with a HardFiber Process Bus Module (order code 81)

FREQUENCY
Accuracy for 20 to 65 Hz 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
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:	20 to 70 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

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

DIRECT INPUTS

Input points:	32
Remote devices:	16
Default states on loss of comms.:	On, Off, Latest/Off, Latest/On
Ring configuration:	Yes, No
Data rate:	64 or 128 kbps
CRC:	32-bit
CRC alarm:	
Responding to:	Rate of messages failing the CRC
Monitoring message count:	10 to 10000 in steps of 1
Alarm threshold:	1 to 1000 in steps of 1
Unreturned message alarm:	
Responding to:	Rate of unreturned messages in the ring configuration
Monitoring message count:	10 to 10000 in steps of 1
Alarm threshold:	1 to 1000 in steps of 1

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:

	UL 508	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

DIRECT OUTPUTS

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 Communications

IEC 61850

IEC 61850: Supports IEC 61850 Edition 2.0. See the UR Series Communications Guide and its conformance statements.

RS232

Front port: 19.2 or 115.2 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 multimode
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, SFTP, HTTP, IEC 60870-5-104, Ethernet Global Data (EGD), IEEE C37.118

2.5.9 Inter-relay communications

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 manufactured 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		-15 dBm	-32 dBm	17 dBm	-8 dBm
1300 nm Laser, Single mode		0 dBm	-34 dBm	34 dBm	-8 dBm
1550 nm Laser, Single mode		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	Maximum 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

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

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 of 1 dB / 5 °C.

TYPICAL LINK DISTANCE

Emitter, fiber 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
1300 nm LED, multimode	62.5/125 µm	ST	4 km	5 km
	50/125 µm	ST	4 km	5 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 can 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
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

2.5.11 Type tests

C70 TYPE TESTS

Test	Reference standard	Test level
Dielectric voltage withstand	EN 60255-5[1]	2.2 kV
Impulse voltage withstand	EN 60255-5[1]	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[1] / 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[1]	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[1]	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

1 Not tested by third party.

2.5.12 Production tests

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. When dust has accumulated on the faceplate display, wipe with a dry cloth.

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.

C70 Capacitor Bank Protection and Control System

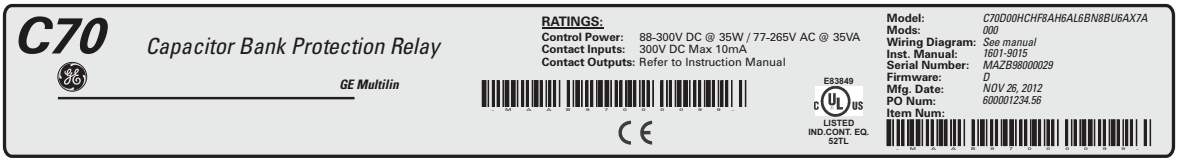
Chapter 3: Installation

This chapter outlines installation of hardware and software. You unpack, check, mount, and wire the unit, then install the software and configure settings.

3.1 Unpack and inspect

Use this procedure to unpack and inspect the unit.

1. Open the relay package and check that the following items have been delivered:
   - C70
   - Mounting screws
   - GE EnerVista™ DVD (software and documentation)
   - C70 Instruction Manual (soft copy on DVD; printed copy if ordered)
   - UR Series Communications Guide (soft copy on DVD; printed copy if Instruction Manual ordered)
   - Certificate of Calibration
   - Test Report
   - EC Declaration of Conformity
   - Front panel label templates and tool
2. Inspect the unit for physical damage.
3. View the rear nameplate and verify that the correct model has been delivered. The model number is at the top right.



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4. For any issues, contact GE Grid Solutions as outlined in the For Further Assistance section in chapter 1.
5. Check that you have the latest copy of the C70 Instruction Manual and the UR Series Communications Guide, for the applicable firmware version, at http://www.gegridsolutions.com/multilin/manuals/index.htm

The Instruction Manual outlines how to install, configure, and use the unit. The Communications Guide is for advanced use with communication protocols. The warranty is included at the end of this instruction manual and on the GE Grid Solutions website.

3.2 Panel cutouts

This section does not apply to the HardFiber Brick; see its instruction manual.

Install the relay in an indoor environment within the environmental specifications. The relay complies with Pollution Category II, which means installation in an office, laboratory, or testing environment.

3.2.1 Horizontal units

The C70 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.

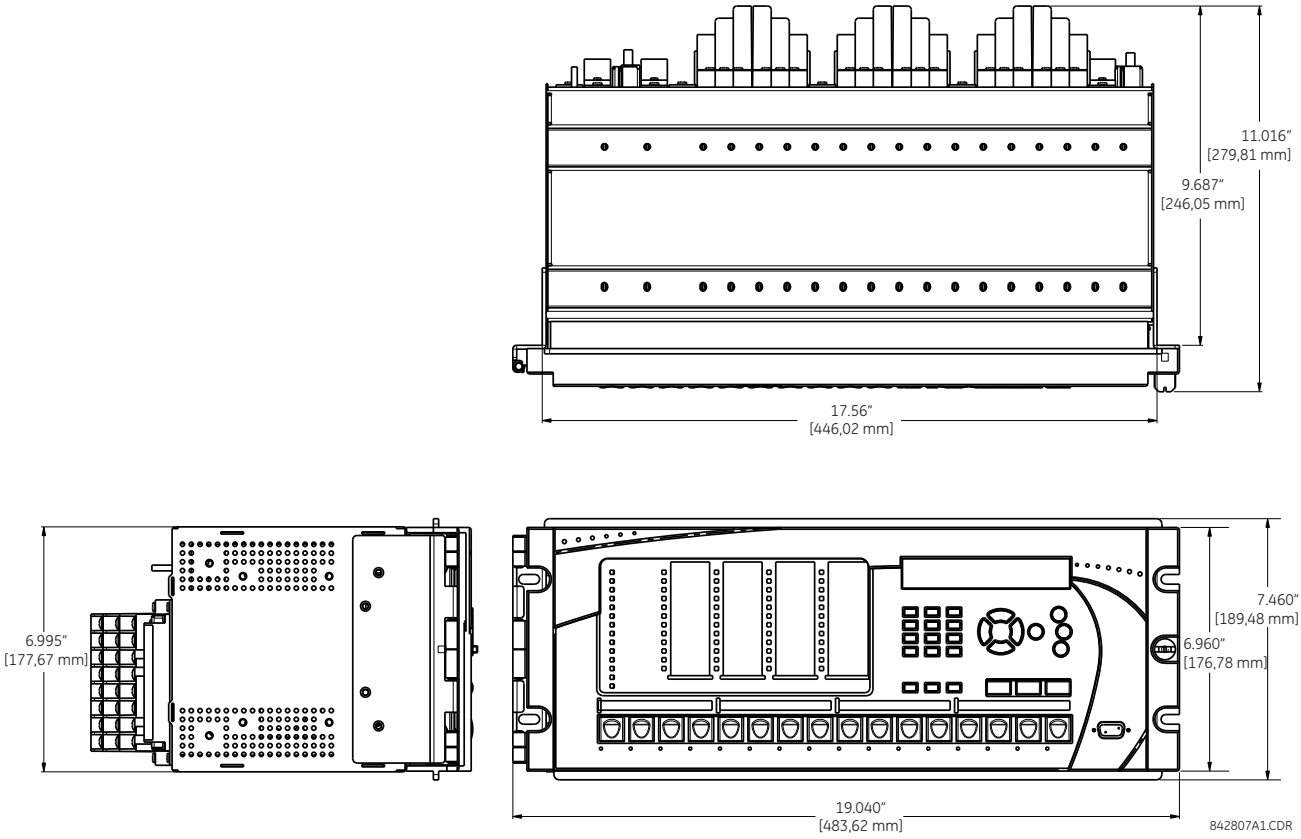
The modular design allows the relay to be upgraded and repaired by qualified service personnel. The faceplate is hinged to allow access to the removable modules, and is itself removable to allow mounting on doors with limited rear depth.

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 in the following figure, 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)



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Figure 3-2: Horizontal dimensions (Rev. 2 enhanced front panel)

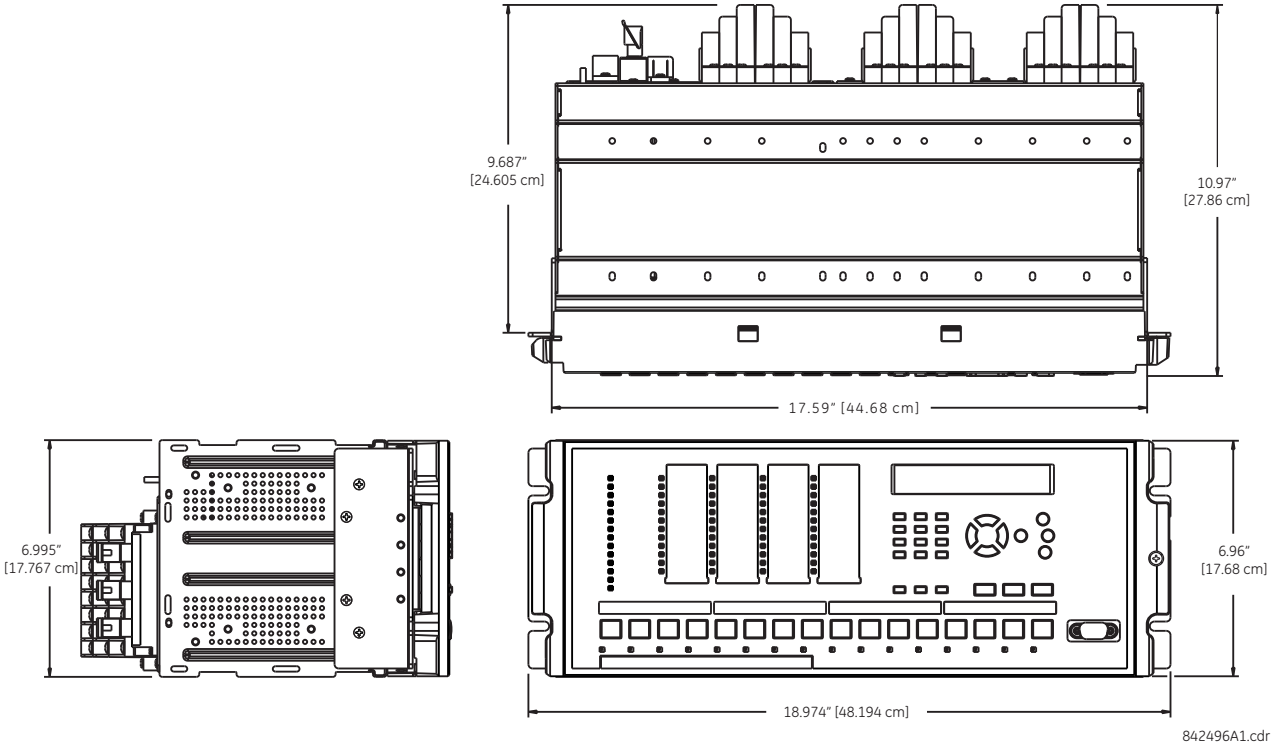


Figure 3-3: Horizontal mounting (enhanced front panel)

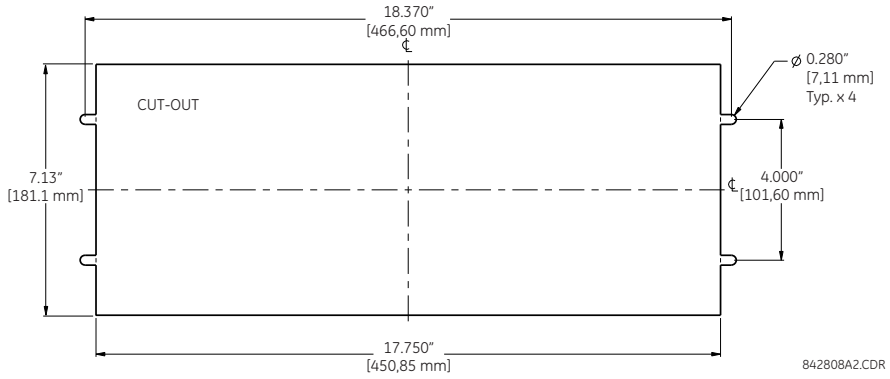
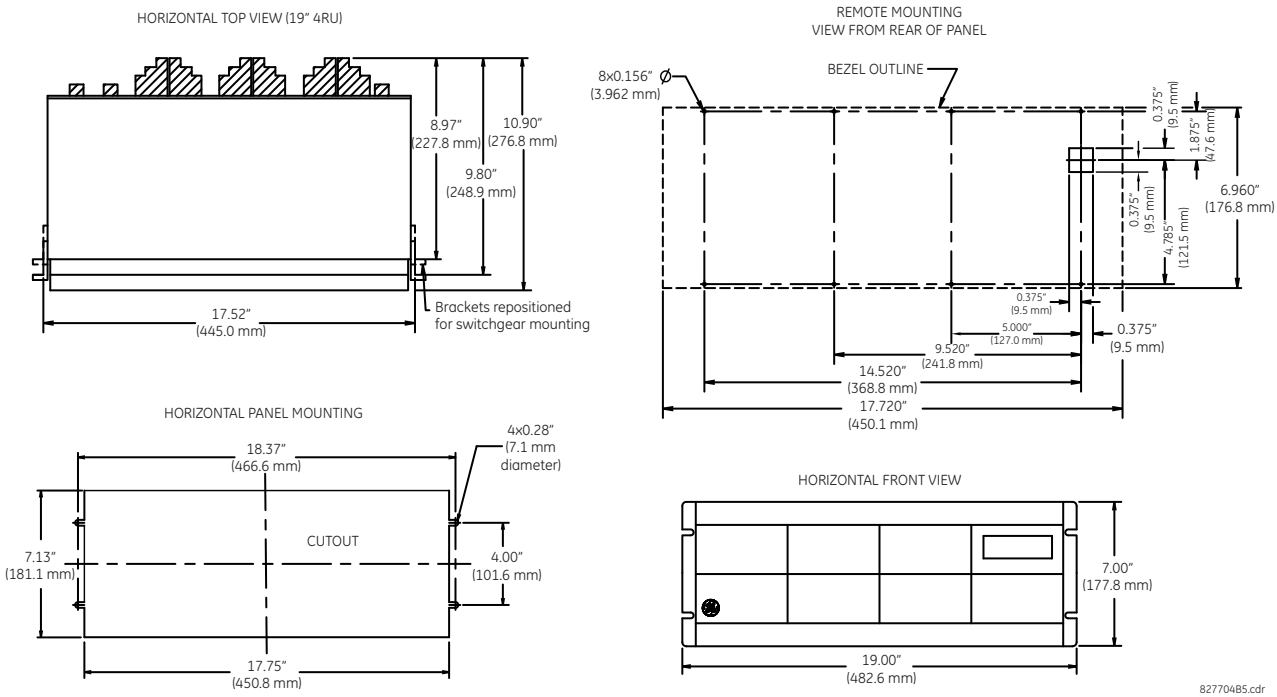
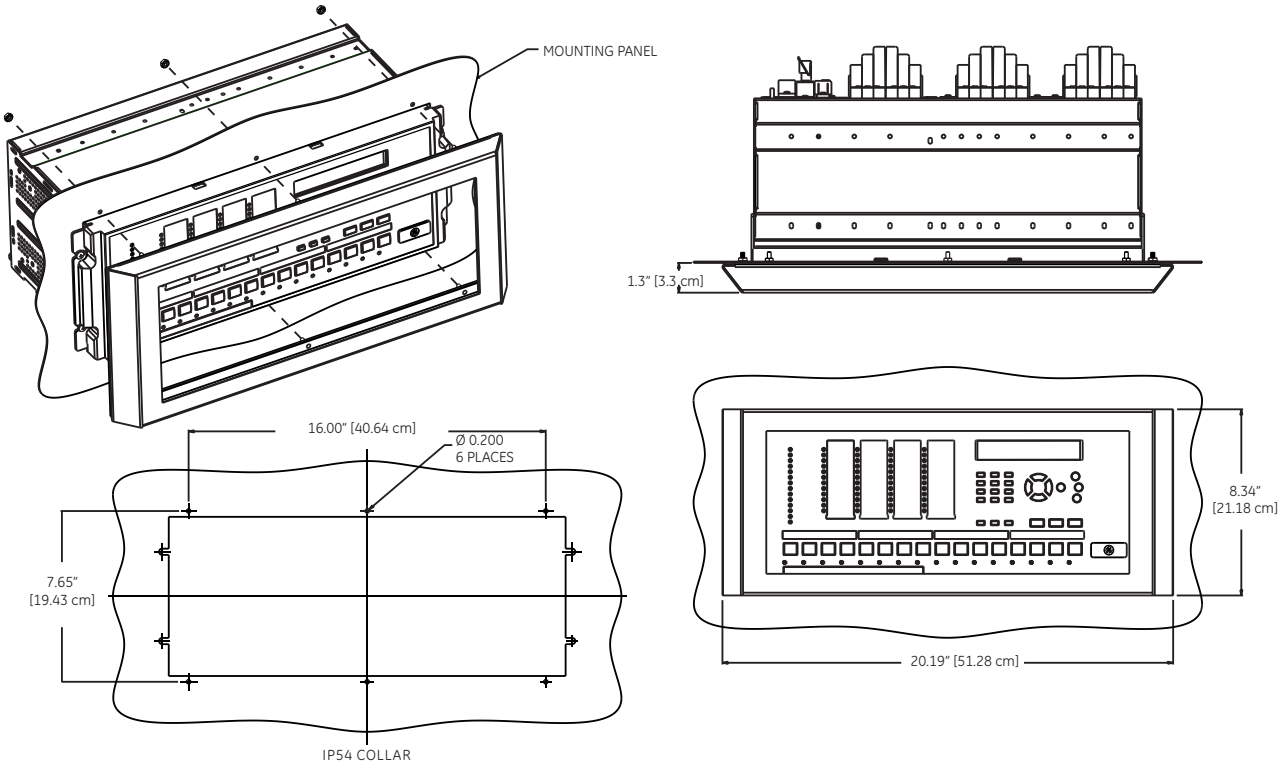


Figure 3-4: Horizontal mounting and dimensions (basic front panel)



3

Figure 3-5: Horizontal dimensions (IP54 mounting collar)



NOTES
1. INSPECT THE COLLAR BEFORE INSTALLATION, VERIFY GASKET IS ADHERED TO THE METAL ON ALL SIDES
2. MAKE SURE THE RELAY IS POSITIONED CENTER TO THE CUT OUT
3. INSTALL IP-54 COLLAR, CONFIRM THE GASKET PROPERLY MATES WITH THE PANEL ON ALL SIDES
SECURE USING #8-32 HEX NUT AT 6 PLACES.

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3.2.2 Vertical units

The C70 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 upgraded and repaired by qualified service personnel. 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 in the following figure, 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 3-6: Vertical dimensions (enhanced panel)

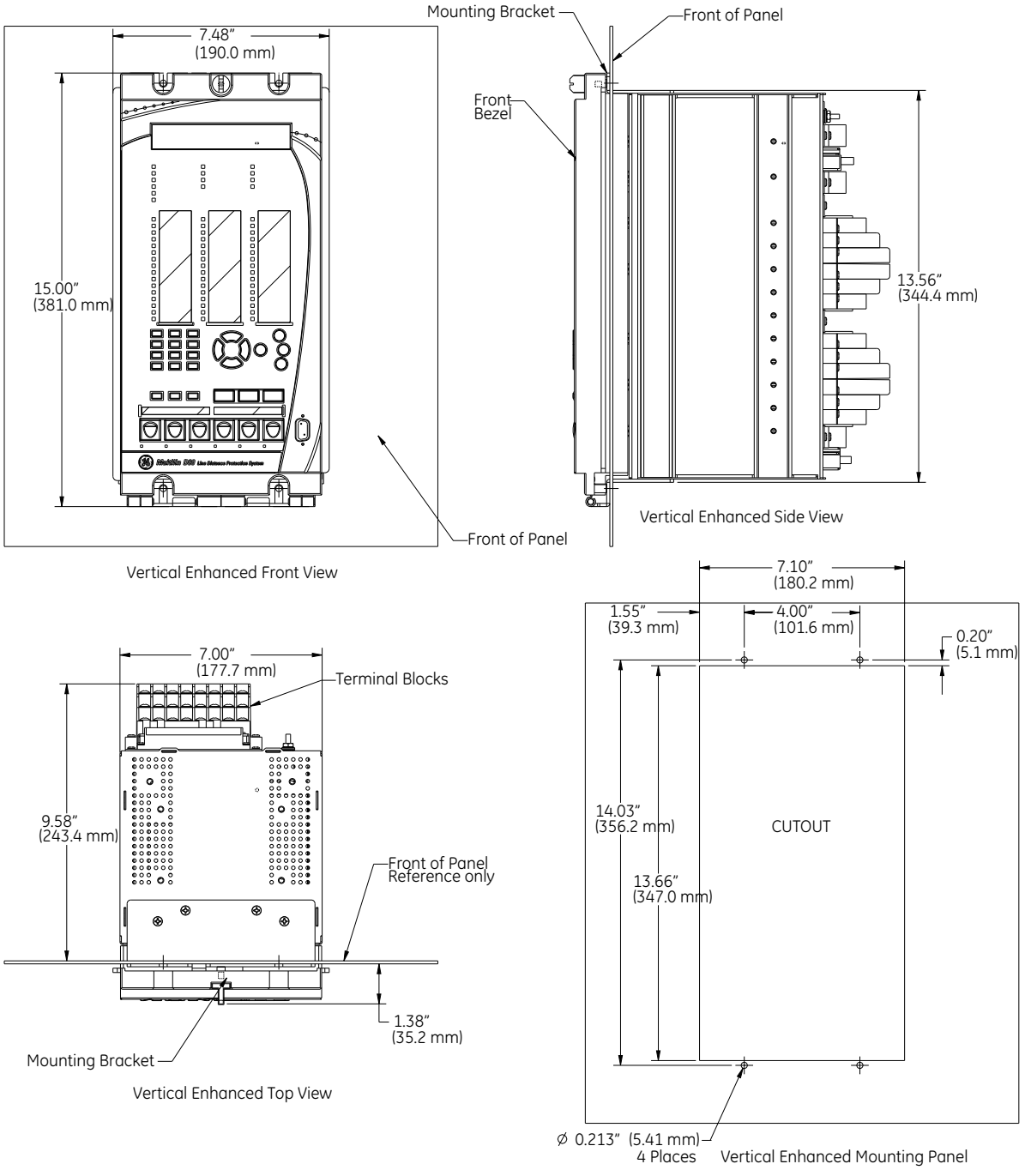
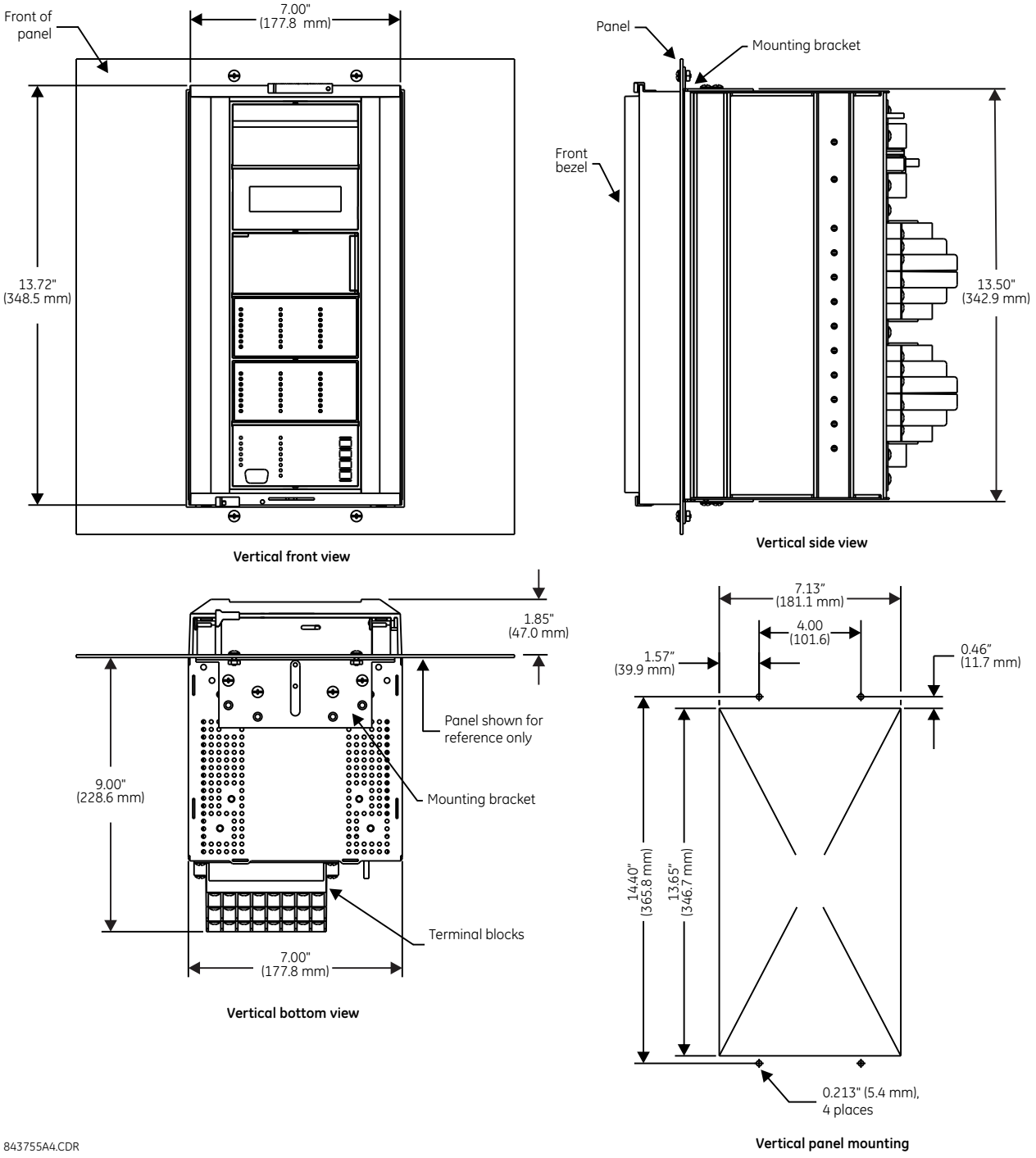


Figure 3-7: Vertical and mounting dimensions (basic panel)



For side-mounting C70 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 C70 devices with the basic front panel, use the following figures.

Figure 3-8: Vertical side-mounting installation (basic panel)

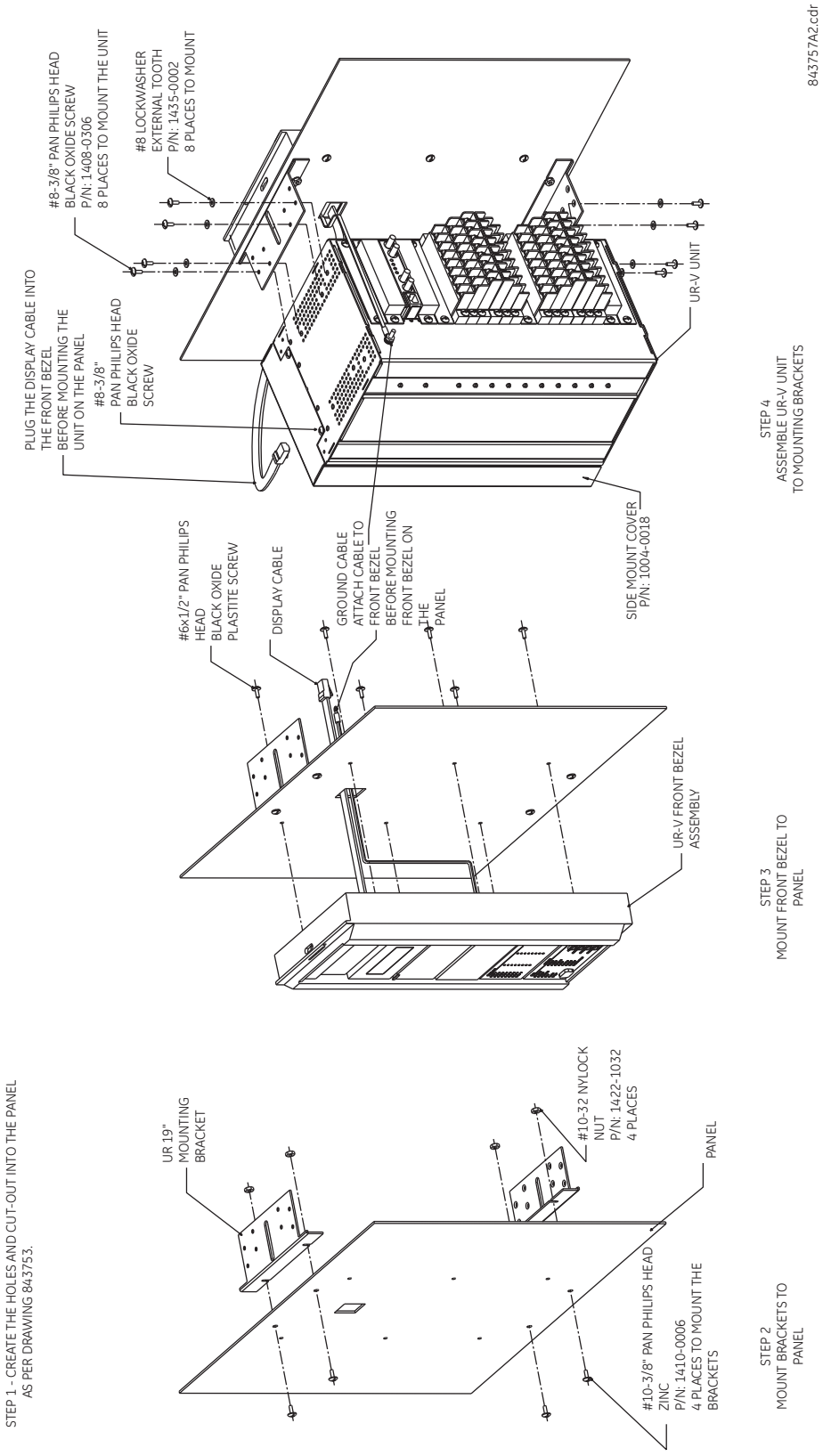
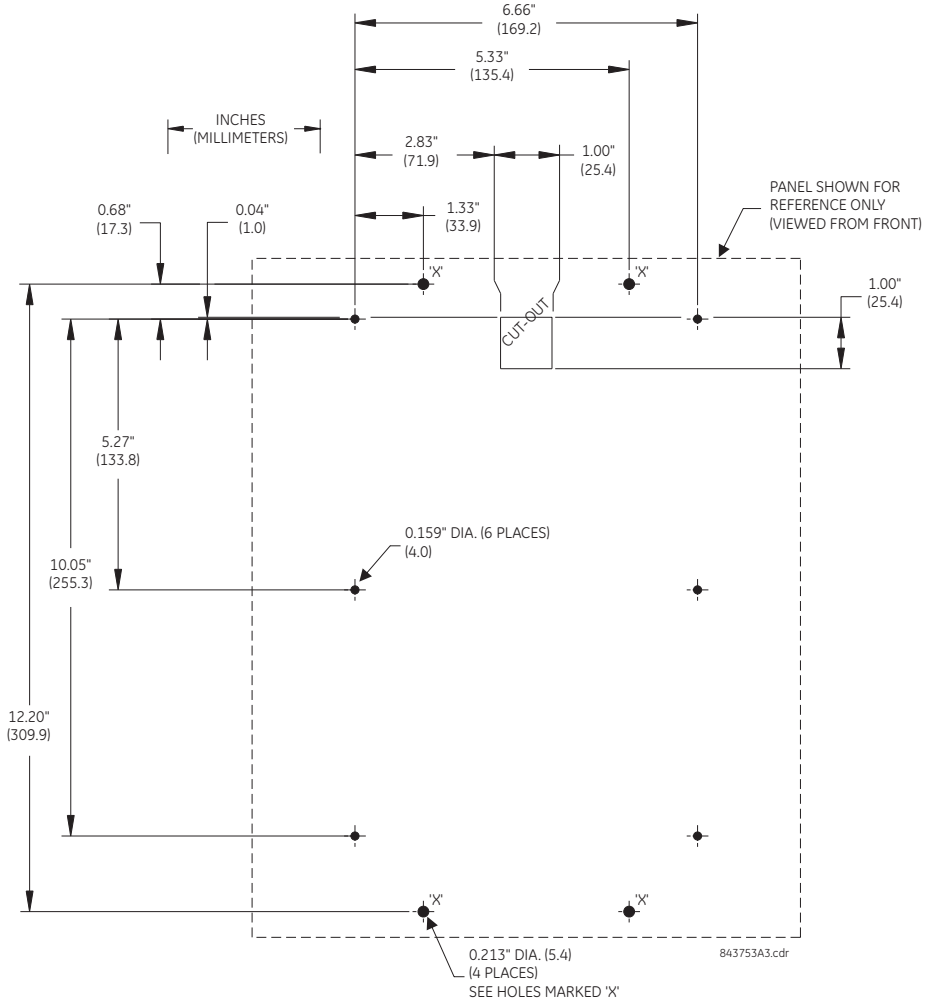
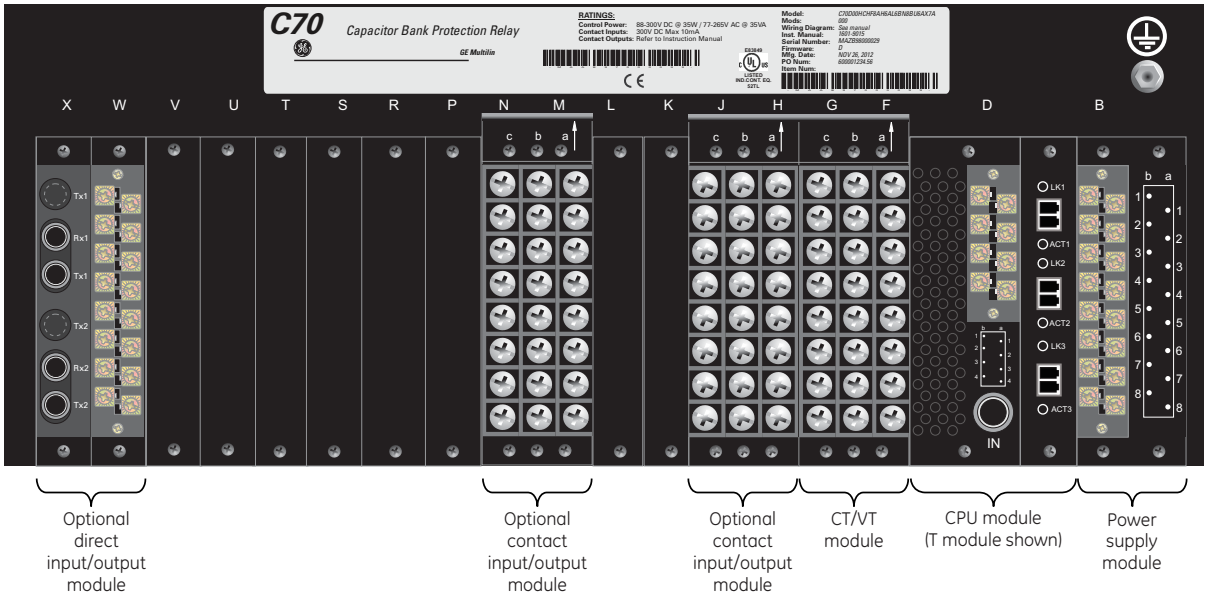


Figure 3-9: Vertical side-mounting rear dimensions (basic panel)



3.2.3 Rear terminal layout

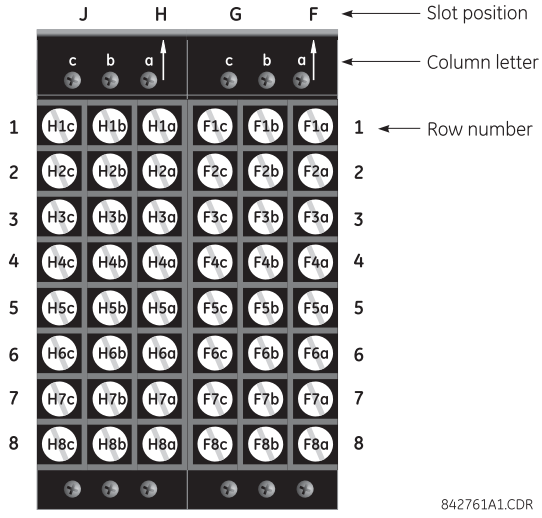


WARNING **Do not touch any rear terminals while the relay is energized, else death or serious injury can result from electrical shock.**

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 and assigned 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), indicated by an arrow marker on the terminal block. The figure shows an example of rear terminal assignments.

Figure 3-10: Example of modules in F and H slots

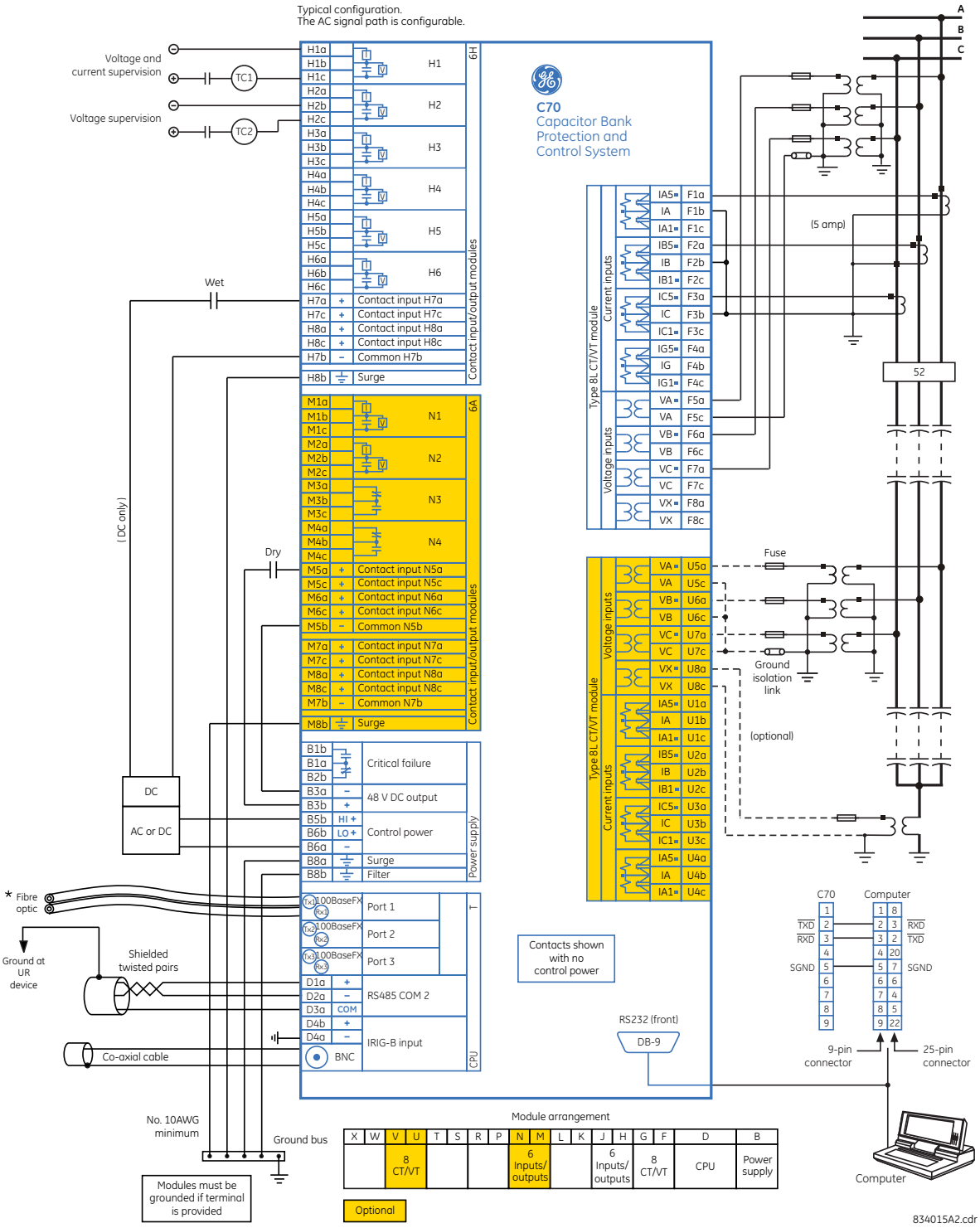


The torque used to connect the terminal blocks to the back of the relay chassis (screws a, b, c shown) is 9 inch-pounds. For the connections to the terminal blocks (rows 1 to 8), use a minimum of 17 inch-pounds. During manufacturing, the power supply and CPU modules are installed in slots B and D of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

3.3 Wiring

3.3.1 Typical wiring

Figure 3-11: Typical wiring diagram (T module shown for CPU)



3.3.2 Dielectric strength

Dielectric strength is the maximum electric strength that can be sustained without breakdown. It is measured in volts.

The table shows the dielectric strength of the UR-series module hardware.

Table 3-1: Dielectric strength of UR series modules

Module type	Module function	Terminals		Dielectric strength
		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 minute.

3.3.3 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 C70, 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 C70 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 follows (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 de-energizes.

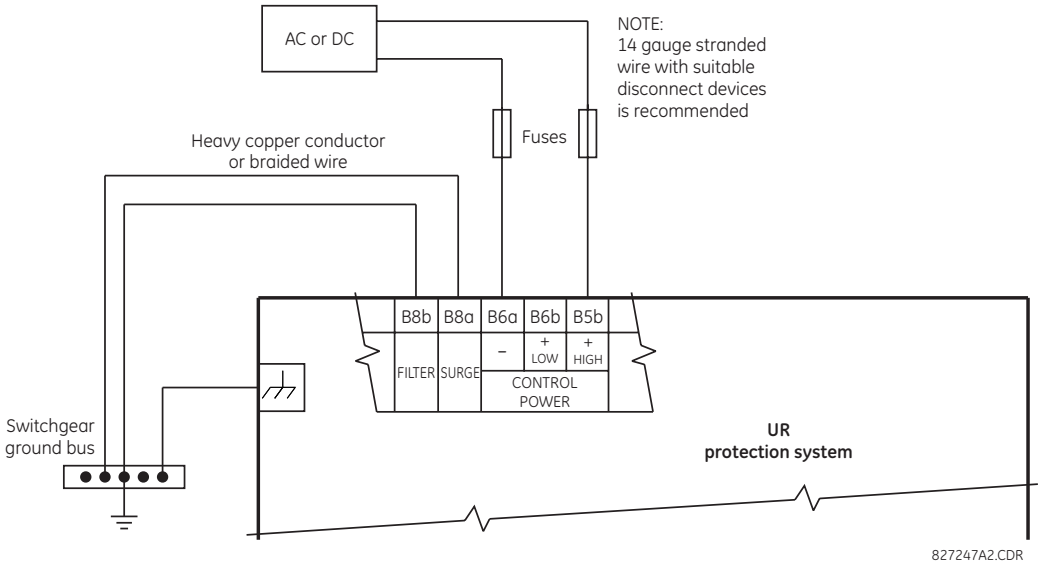
For high-reliability systems, the C70 has a redundant option in which two C70 power supplies are placed in parallel on the bus. If one of the power supplies becomes faulted, the second power supply assumes the full load of the relay without any interruptions. Each power supply has a green LED on the front of the module to indicate that 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, as outlined in the table.

Table 3-2: Power supply LED on front panel

LED indication	Power supply
Continuous on	OK
On/off cycling	Failure
Off	Failure or no power

Figure 3-12: Control power connection



3.3.3.1 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**.

3.3.4 CT/VT modules

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.

A CT/VT module can have current or voltage 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 channels are labeled 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 used commonly; the maximum size is 10 AWG.

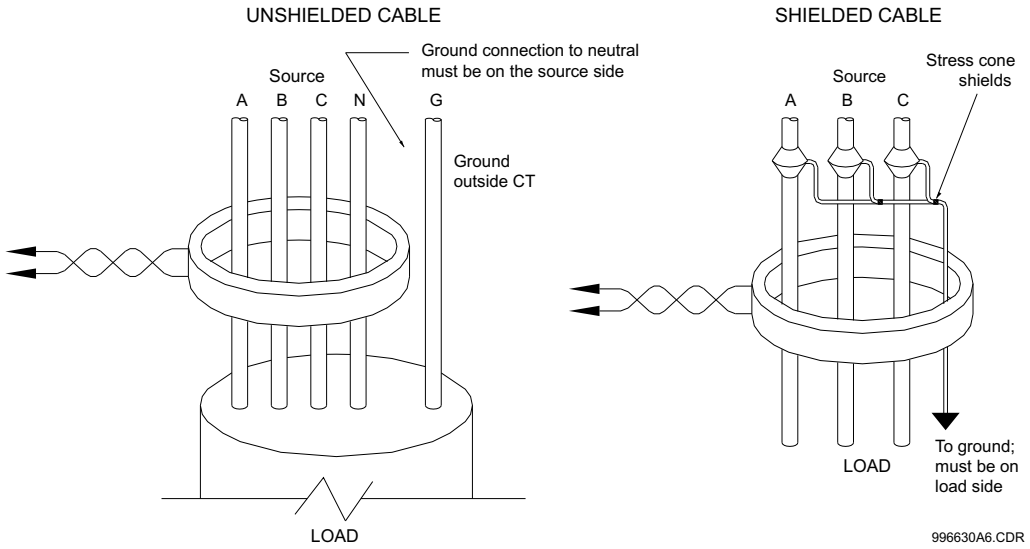
CT/VT modules can be ordered with a standard ground current input that is the same as the phase current input. Each AC current input has an isolating transformer and an automatic shorting mechanism that shorts the input when the module is withdrawn from the chassis. There are no internal ground connections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

These 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

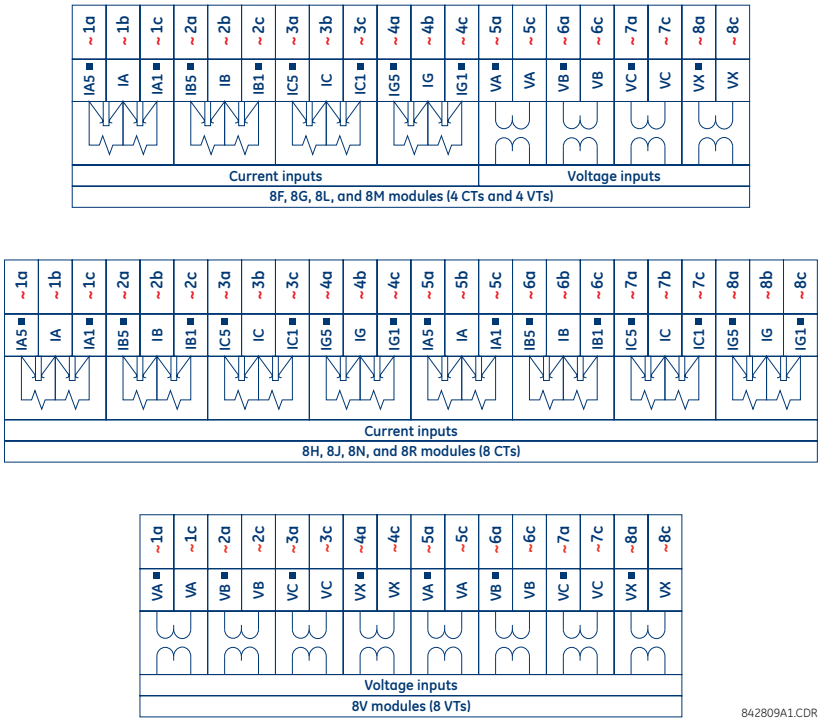


The phase voltage channels are used for most metering and protection purposes. The auxiliary voltage channel is used as input for the synchrocheck and volts-per-hertz features, which are optional features available for some UR models.

NOTE

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

Figure 3-14: CT/VT module wiring



3.3.5 Process bus modules

The C70 can be ordered with a process bus interface module. The module interfaces with the HardFiber Process Bus System, or HardFiber Brick, allowing bidirectional IEC 61850 fiber optic communications with up to eight HardFiber Bricks. The HardFiber system integrates seamlessly with the existing UR-series applications, including protection functions, FlexLogic, metering, and communications.

This process bus system offers the following benefits:

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

For details on the HardFiber system, see its Instruction Manual.

3.3.6 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.

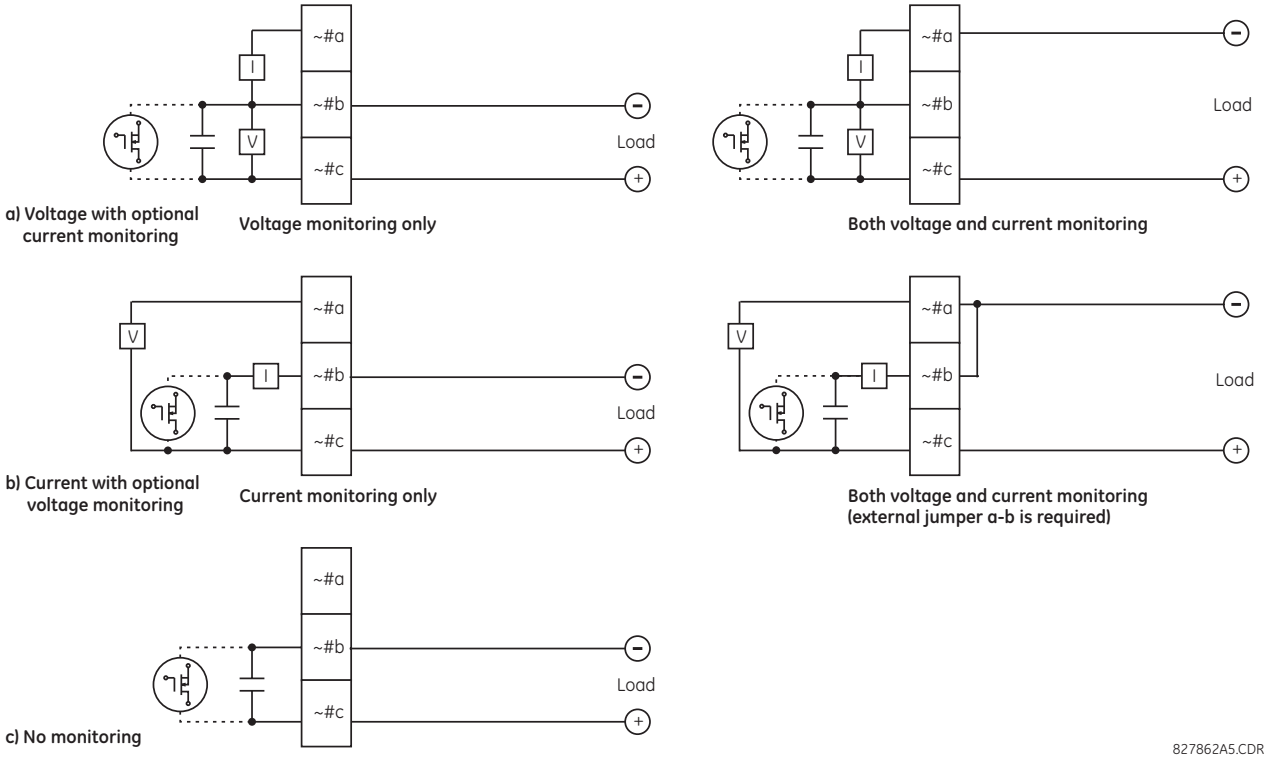
The contact inputs are grouped with a common return. The input/output modules have two versions of grouping: four inputs per common return and two inputs per common return. When a contact input/output module is ordered, four inputs per common is used. If the inputs must be isolated per row, then two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

The tables and diagrams on the following pages illustrate the module types (6A and so on) 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) that 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. Death or serious injury can result from touching live relay contacts.**

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 can 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

Where a tilde "~" symbol appears, substitute the slot position of the module. Where 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, give the FlexLogic operand driving the contact output 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 3-3: 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

3

~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

~4C module	
Terminal assignment	Output
~1	Not Used
~2	Solid-State
~3	Not Used
~4	Solid-State
~5	Not Used
~6	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

~4L module	
Terminal assignment	Output
~1	2 Outputs
~2	2 Outputs
~3	2 Outputs
~4	2 Outputs
~5	2 Outputs
~6	2 Outputs

~4B module	
Terminal assignment	**Output**
~7	Not Used
~8	Solid-State

~4C module	
Terminal assignment	**Output**
~7	Not Used
~8	Solid-State

~4D module	
Terminal assignment	**Output**
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~4L module	
Terminal assignment	**Output**
~7	2 Outputs
~8	Not Used

Figure 3-16: Contact input and output module wiring (Sheet 1 of 2)

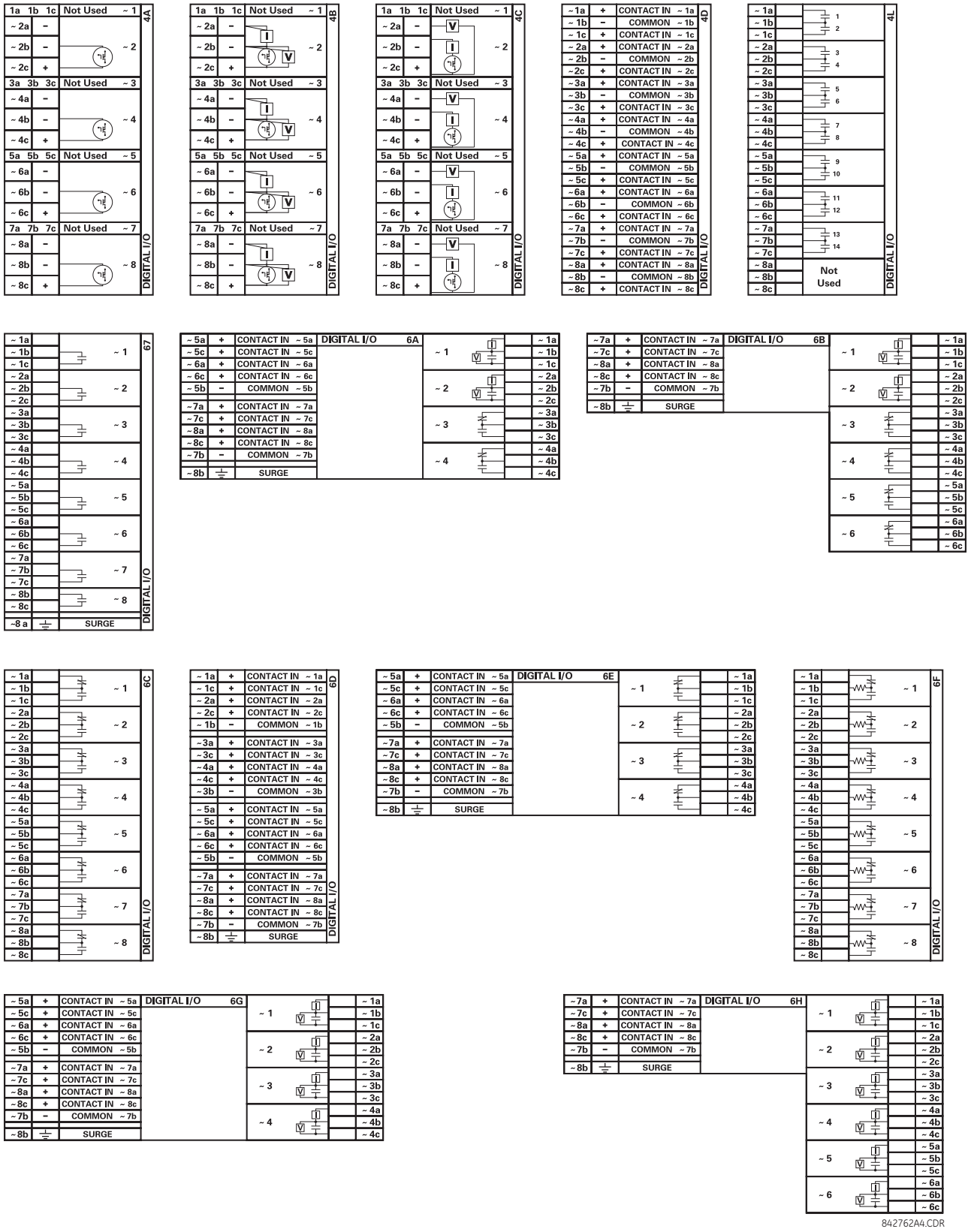
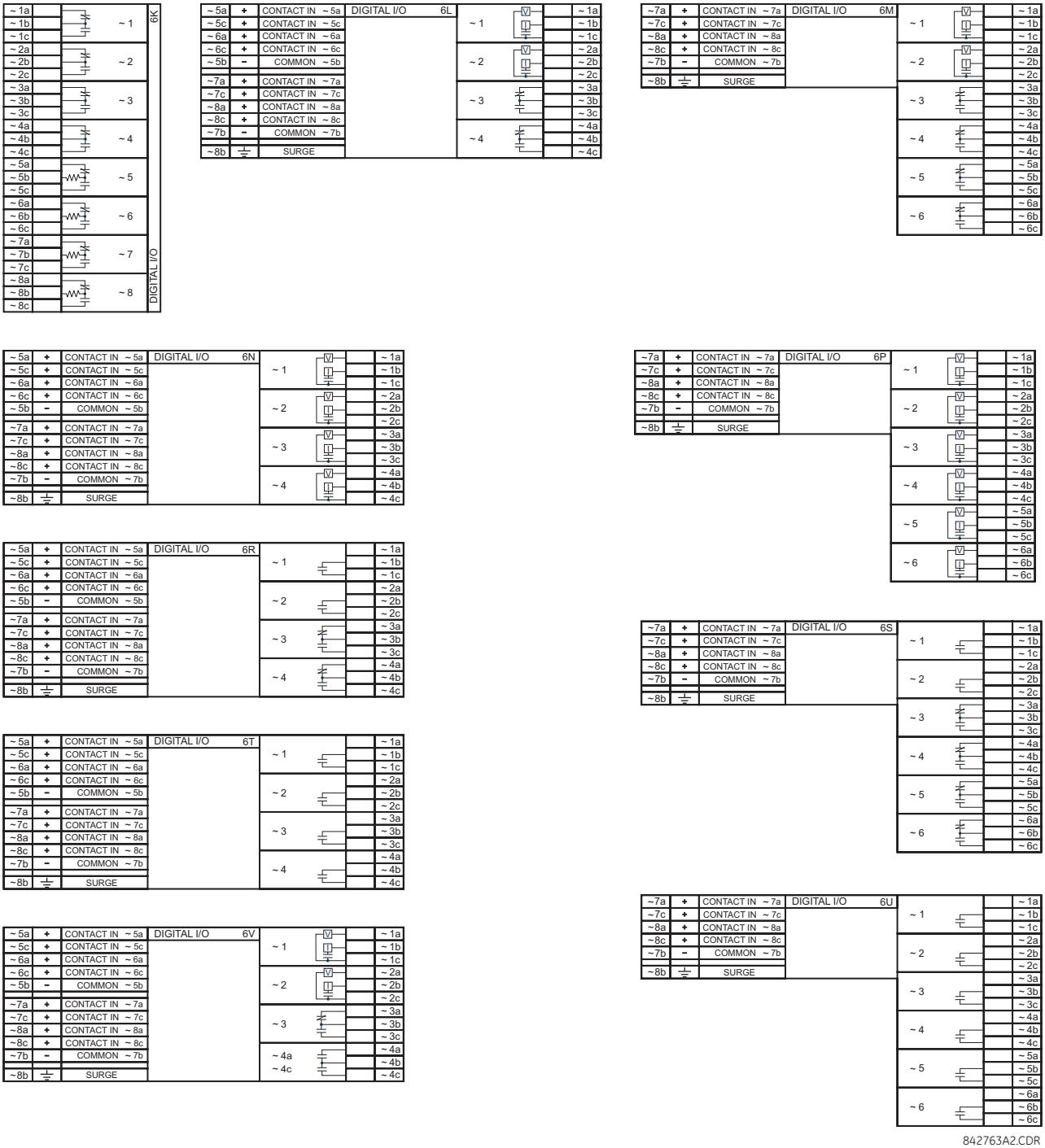


Figure 3-17: Contact input and output module wiring (Sheet 2 of 2)



842763A2.CDR

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

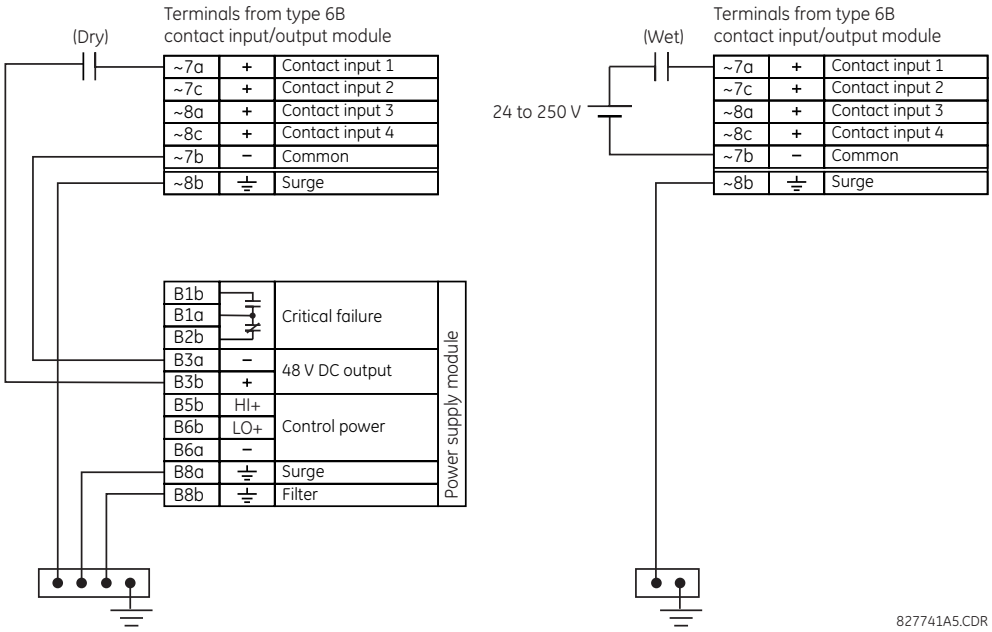
3.3.6.1 Contact inputs

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 that 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

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

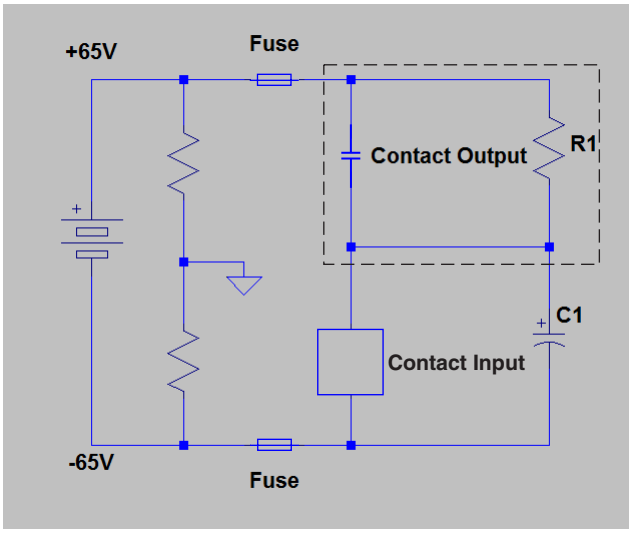
There is no provision in the relay to detect a DC ground fault on 48 V DC control power external output. We recommend using an external DC supply.

3.3.6.2 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 C70 contact input, it can spuriously operate the C70 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 C70 input and the debounce time setting in the C70 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 C70 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

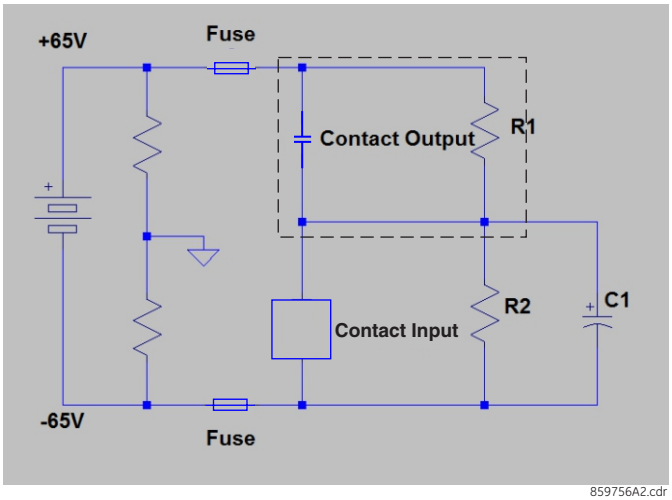


The presence of the impedance path (R1) across the contact output allows the stray (distributed) capacitance C1 to charge as shown, thus developing a voltage across the contact input enough to momentarily operate the input while the capacitance discharges in the presence of DC ground on the positive 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 3-4: 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:

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

$$84 = -149 * e^{(t/0.005)} \quad \textbf{Eq. 3-1}$$

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

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 3-5: 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:

   $$R = (\text{Vthreshold} / 3) / (2 \text{ mA}) \quad \textbf{Eq. 3-2}$$

   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:

   $$PR = 1.3 * (\text{Vbatt})^2 / R \text{ Watts} \quad \textbf{Eq. 3-3}$$
4. Applying the following equation to our example:

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

   $$PR = 1.57 \text{ Watts} \quad \textbf{Eq. 3-4}$$
5. Calculating the voltage across the contact input with the Burden Resistor, Voltage across the contact Input:

   $$\text{Vresistor} = 2 \text{ mA} * 14 \text{ Kohm} = 28 \text{ V}$$

   $$\text{Vresistor} < \text{contact input threshold (84 V)} \quad \textbf{Eq. 3-5}$$

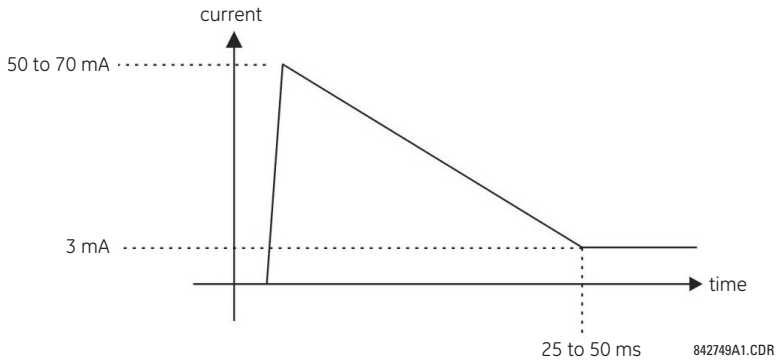
In conclusion, in this example, the contact input does NOT operate falsely with the Burden Resistor across its input AND when a battery ground is present.

3.3.6.3 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 five-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. 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 (see 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.

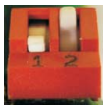
Figure 3-22: Auto-burnish DIP switches



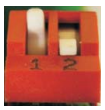
842751A1.CDR



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

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

3.3.6.4 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 contact I/O module with active impedance circuit.

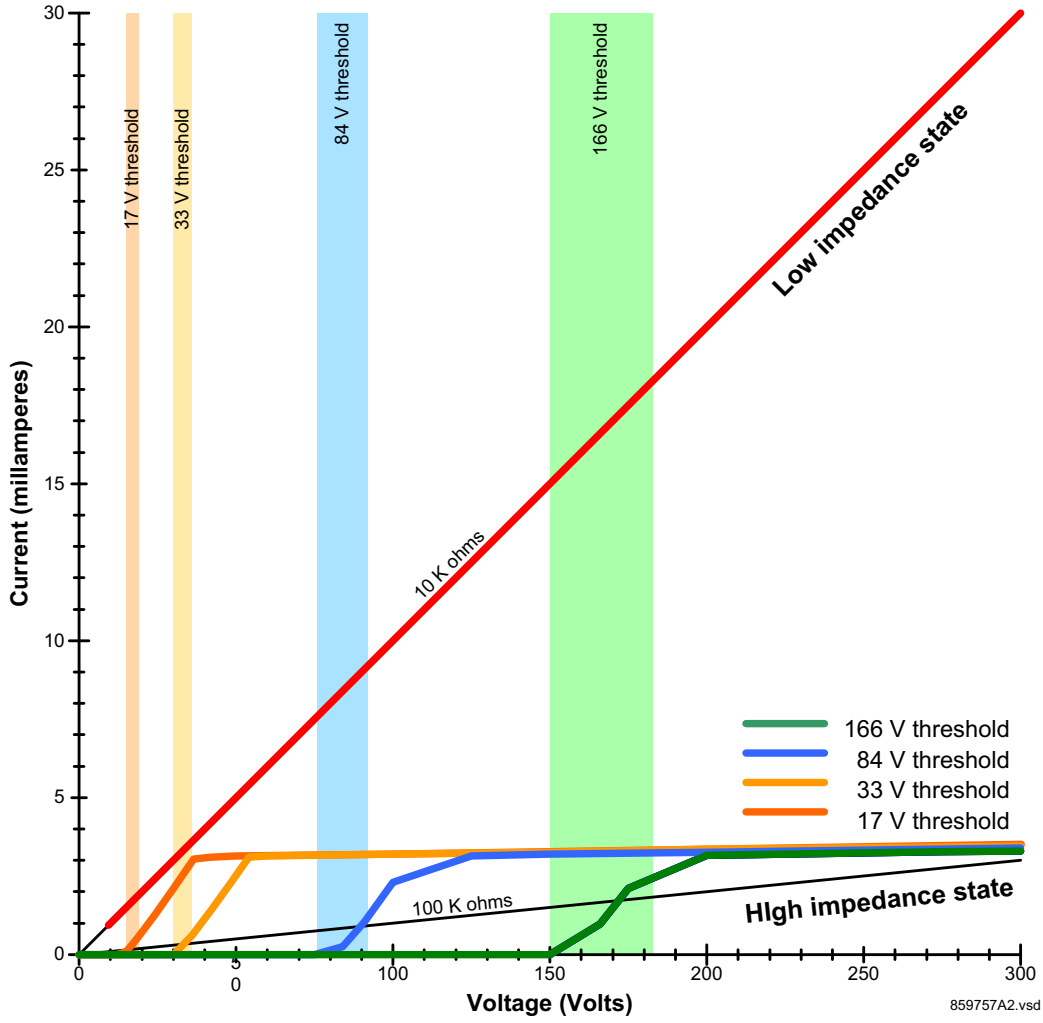
Active impedance contact input can tolerate external cable capacitance of up to 0.2 µF, without entering the ON state for more than 2 ms. The contact input debounce time can still be set above 2 ms for added security to prevent contact input activations cause by external transient ON states.

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



3.3.7 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.

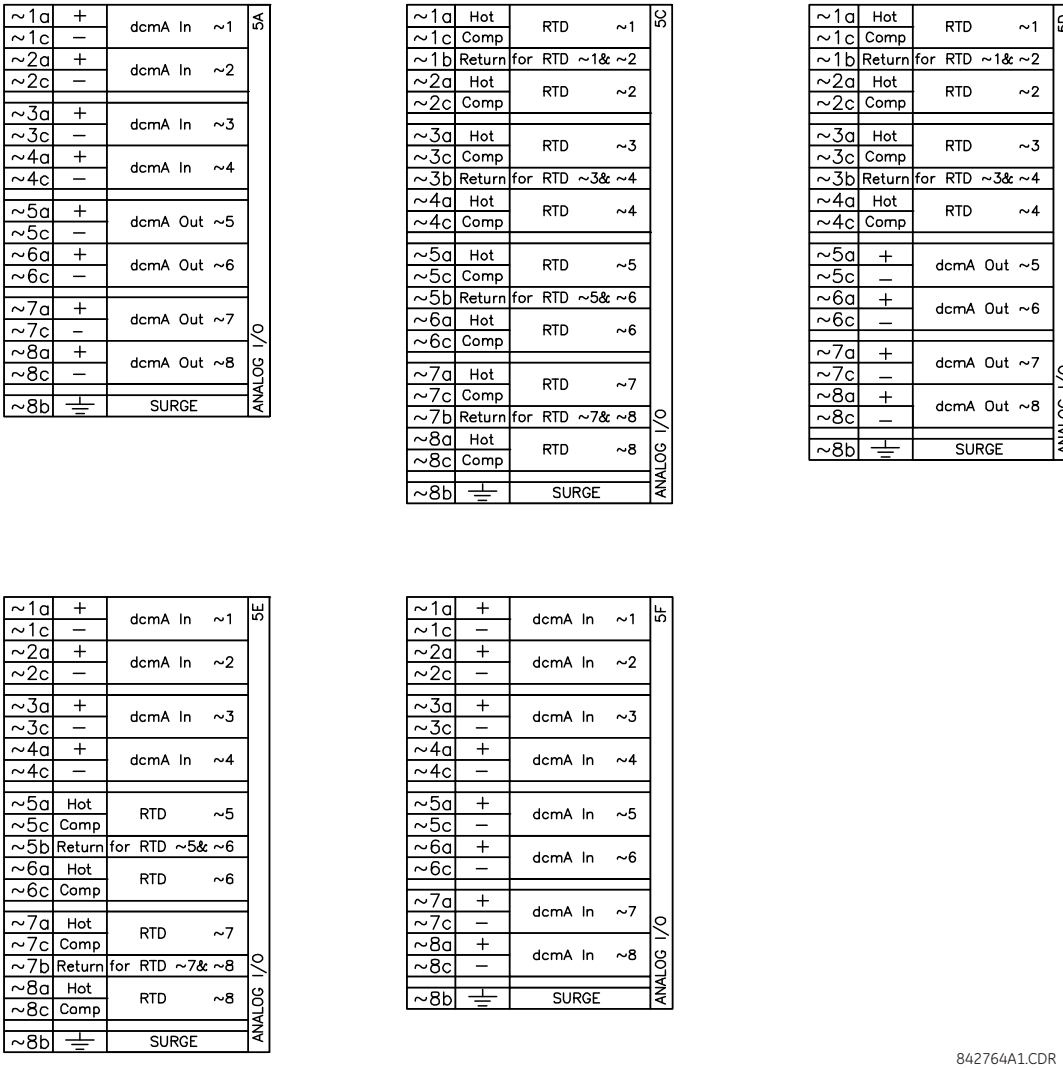
Every transducer input/output module has a total of 24 terminal connections. These connections are arranged as three terminals per row with a total of eight rows. A given row can be used for either inputs or outputs, with terminals in column "a" having positive polarity and terminals in column "c" having 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

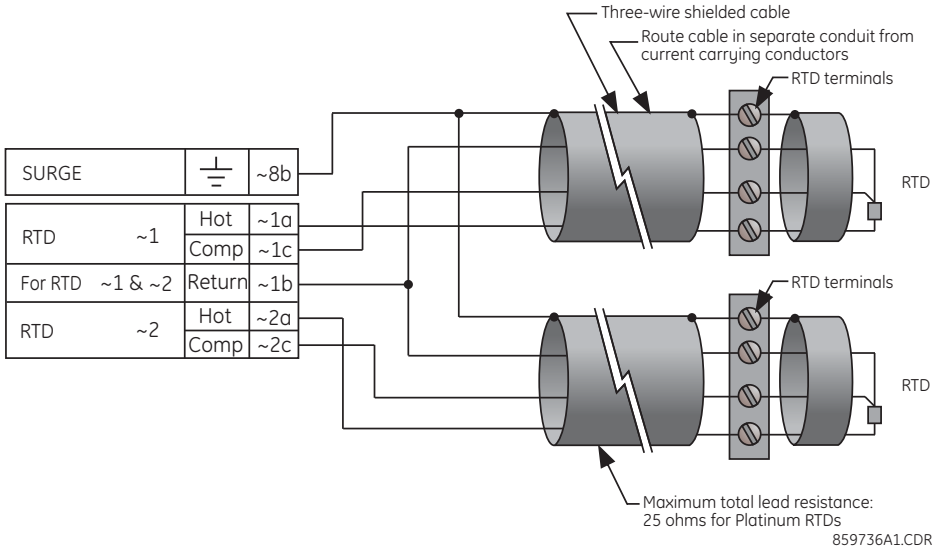
Where a tilde "~" symbol appears, substitute the slot position of the module.

Figure 3-24: Transducer input/output module wiring



The following figure show how to connect RTDs.

Figure 3-25: RTD connections

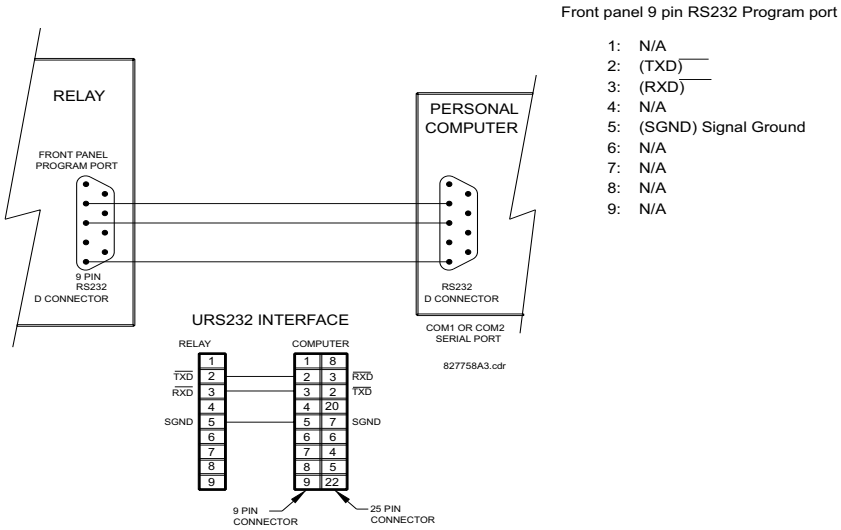


3.3.8 RS232 faceplate port

A nine-pin RS232C serial port is located on the 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.

The baud rate for this port can be set, with a default of 115200 bps.

Figure 3-26: RS232 faceplate port connection



3.3.9 CPU communication ports

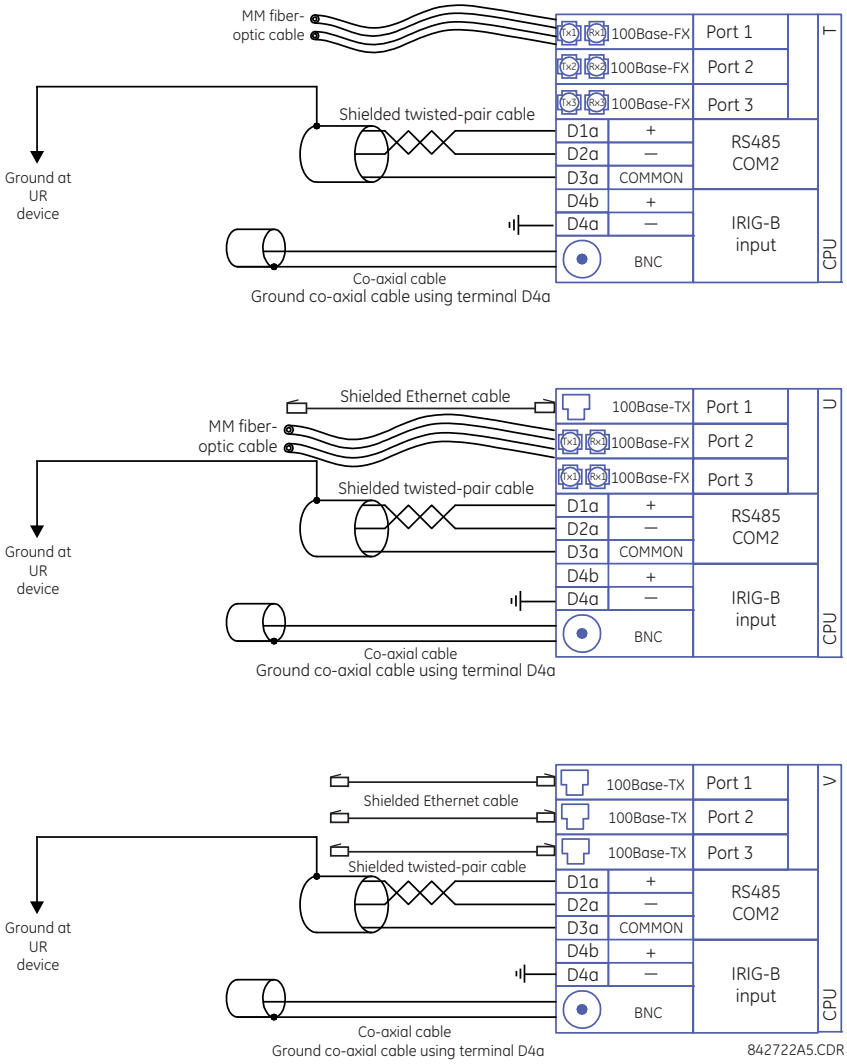
3.3.9.1 Overview

In addition to the faceplate RS232 port, there is a rear RS485 communication port.

The CPU modules do not require a surge ground connection.

3

Figure 3-27: CPU module communications wiring



3.3.9.2 RS485 port

RS485 data transmission and reception are accomplished over a single twisted-pair wire 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 Power Line Carrier (PLC) is possible.

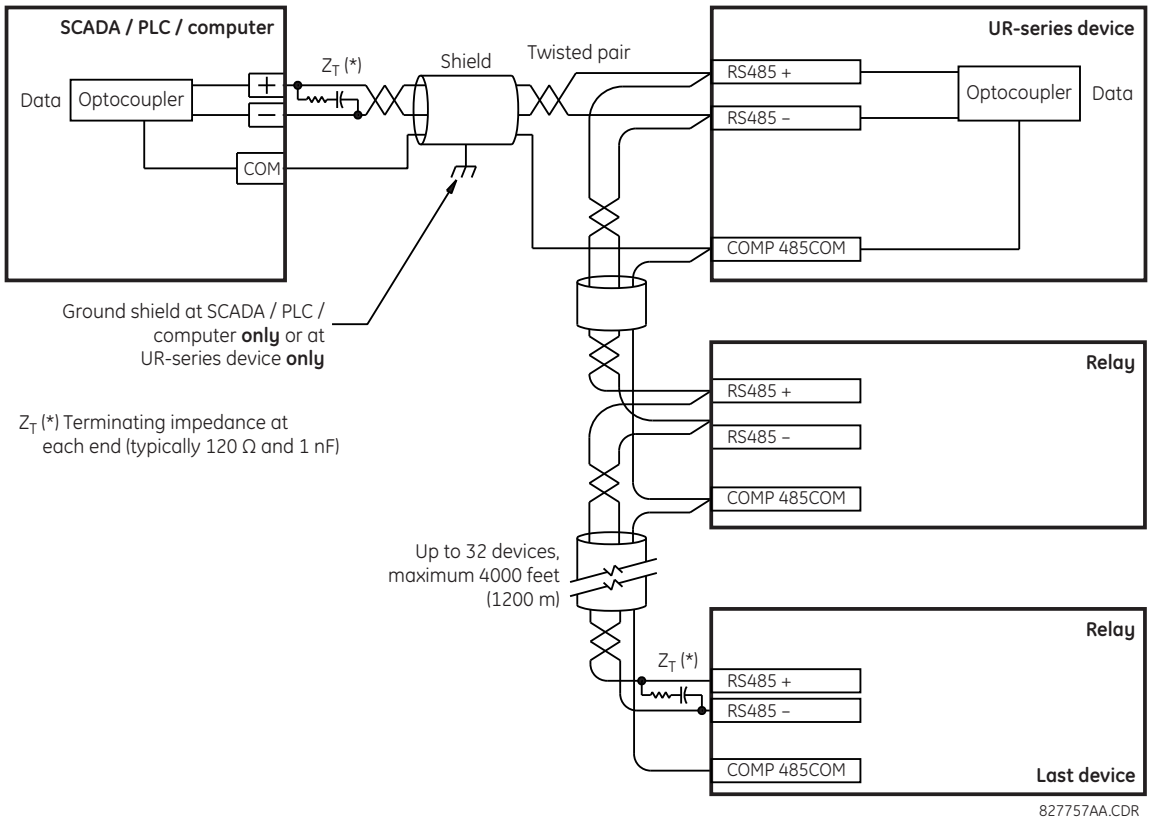
To minimize errors from noise, the use of shielded twisted-pair wire is recommended. Correct polarity must be observed. For instance, the relays must be connected with all RS485 "+" terminals connected together, and all RS485 "–" terminals connected together. Though data is transmitted over a two-wire 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 C70 COM terminal (#3); others function correctly only if the common wire is connected to the C70 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 provided internally at both communication ports. An isolated power supply with an optocoupled data interface also acts to reduce noise coupling. To ensure maximum reliability, ensure that all equipment has similar transient protection devices installed.

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

Figure 3-28: RS485 serial connection



3.3.9.3 100Base-FX fiber optic ports

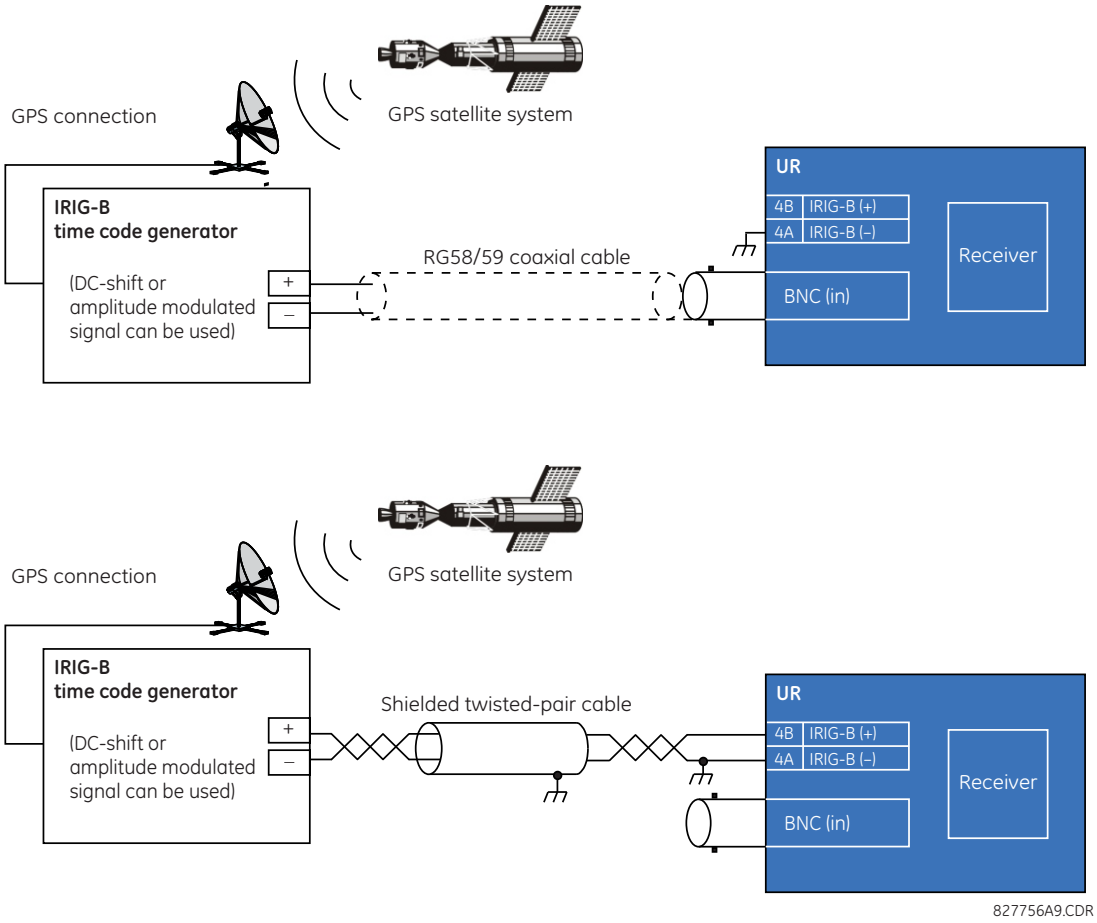
The fiber optic communication ports allow for fast and efficient communications between relays at 100 Mbps. Optical fiber can be connected to the relay supporting a wavelength of 1310 nm in multimode.

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.

3.3.10 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 C70 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 3-29: Options for the IRIG-B connection



NOTE

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

The C70 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.

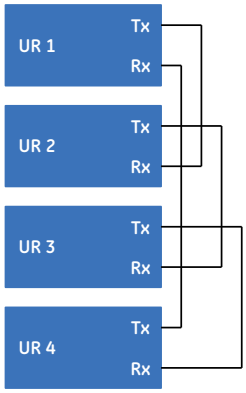
3.4 Direct input and output communications

3.4.1 Description

The direct inputs and outputs feature makes use of the type 7 series of communications modules and allows direct messaging between UR devices. The communications modules are outlined in the table later in this section.

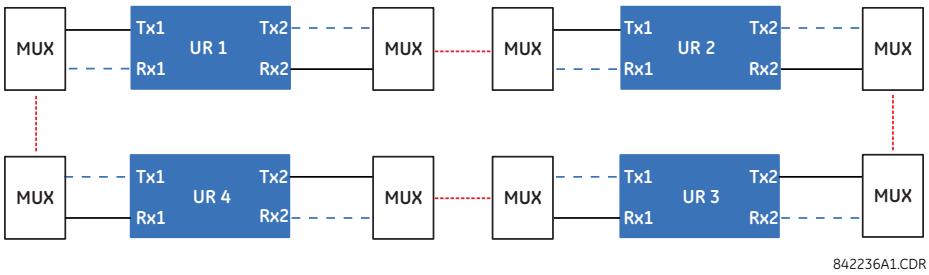
The communications channels are normally connected in a ring configuration, as shown in the following figure. The transmitter of one module is connected to the receiver of the next module. The transmitter of this second module is then connected to the receiver of the next module in the ring. This is continued to form a communications ring. The figure illustrates a ring of four UR-series relays with the following connections: UR1-Tx to UR2-Rx, UR2-Tx to UR3-Rx, UR3-Tx to UR4-Rx, and UR4-Tx to UR1-Rx. A maximum of 16 URs can be connected in a single ring.

Figure 3-30: Direct input and output single-channel connection



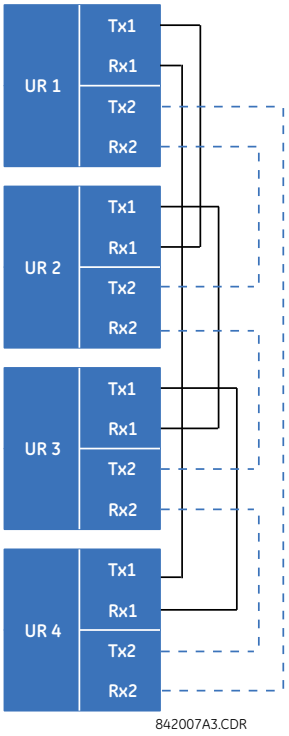
IRC modules with protocol C37.94 and G.703 are designed for back-to-back communication connections, so the ring configuration shown in the previous figure does not apply. To establish inter-relay communication in more than two URs, you need to have two channel IRC module and enable DIRECT I/O CHANNEL CROSSOVER function in all relays, as shown in the next figure. This configuration can be expanded to 16 URs, and this configuration does not provide redundancy ring since both channels are made into single ring by the channel crossover function. As per the figure Typical Pin Interconnection between Two G.703 Interfaces later in this chapter, the clock is supplied typically by multiplexer (MUX) and all URs are in Loop Timing Mode. If there is no MUX, then UR1 and UR3 can be in Internal Timing Mode and UR2 and UR4 can be in Loop Timing Mode. That is, connected channels must have opposite timing modes.

Figure 3-31: Ring configuration for C37.94 module (concept also applies to G.703)



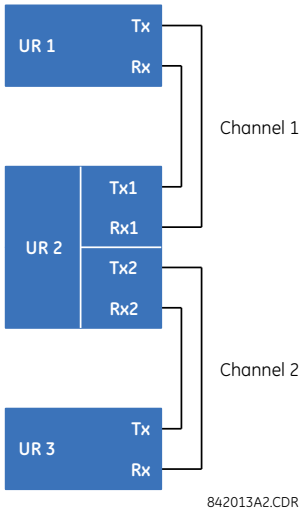
The interconnection for dual-channel type 7 communications modules is shown as follows. Two-channel modules allow for a redundant ring configuration. That is, two rings can be created to provide an additional independent data path. The required connections are: UR1-Tx1 to UR2-Rx1, UR2-Tx1 to UR3-Rx1, UR3-Tx1 to UR4-Rx1, and UR4-Tx1 to UR1-Rx1 for the first ring; and UR1-Tx2 to UR4-Rx2, UR4-Tx2 to UR3-Rx2, UR3-Tx2 to UR2-Rx2, and UR2-Tx2 to UR1-Rx2 for the second ring.

Figure 3-32: Direct input and output dual-channel connection



The following diagram shows the connection for three UR-series relays using two independent communication channels. UR1 and UR3 have single type 7 communication modules; UR2 has a dual-channel module. The two communication channels can be of different types, depending on the type 7 modules used. To allow the direct input and output data to cross-over from channel 1 to channel 2 on UR2, set the **DIRECT I/O CHANNEL CROSSOVER** setting to "Enabled" on UR2. This forces UR2 to forward messages received on Rx1 out Tx2, and messages received on Rx2 out Tx1.

Figure 3-33: Direct input and output single/dual channel combination connection

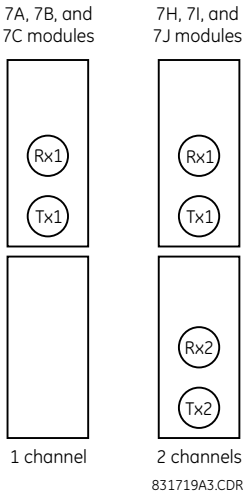


The inter-relay communications modules are available with several interfaces and some are outlined here in more detail. Those that apply depend on options purchased. The options are outlined in the Inter-Relay Communications section of the Order Code tables in Chapter 2. All of the fiber modules use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

3.4.2 Fiber: LED and ELED transmitters

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

Figure 3-34: LED and ELED fiber modules



3.4.3 G.703 interface

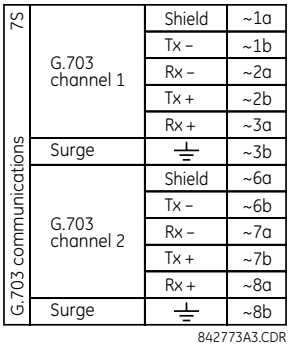
3.4.3.1 Description

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

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.

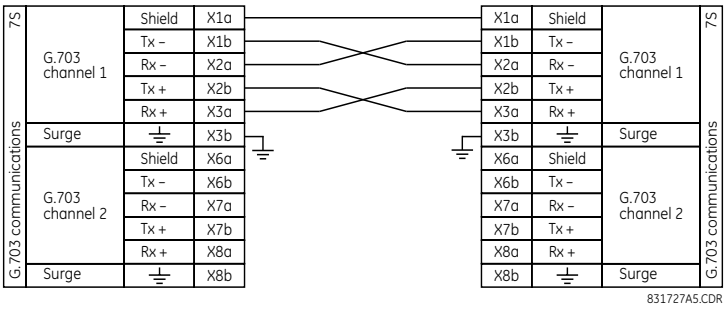
AWG 24 twisted shielded pair is recommended for external connections, with the shield grounded only at one end. Connecting the shield to pin X1a or X6a grounds the shield since these pins are connected internally to ground. Thus, if pin X1a or X6a is used to ground the shield at one end, do not ground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

Figure 3-35: 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 3-36: Typical pin interconnection between two G.703 interfaces



NOTE

Pin nomenclature differs from one manufacturer to another. It is not uncommon to see pinouts numbered TxA, TxB, RxA, and RxB. In such cases, assume that "A" is equivalent to "+" and "B" is equivalent to "–."

3.4.3.2 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. (For more information on accessing modules, see the Maintenance chapter.)
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 (channels 1 and 2) to the required 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 bottom of each module must be in the disengaged position as the module is inserted smoothly 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 inserted fully.

Figure 3-37: G.703 timing selection switch setting

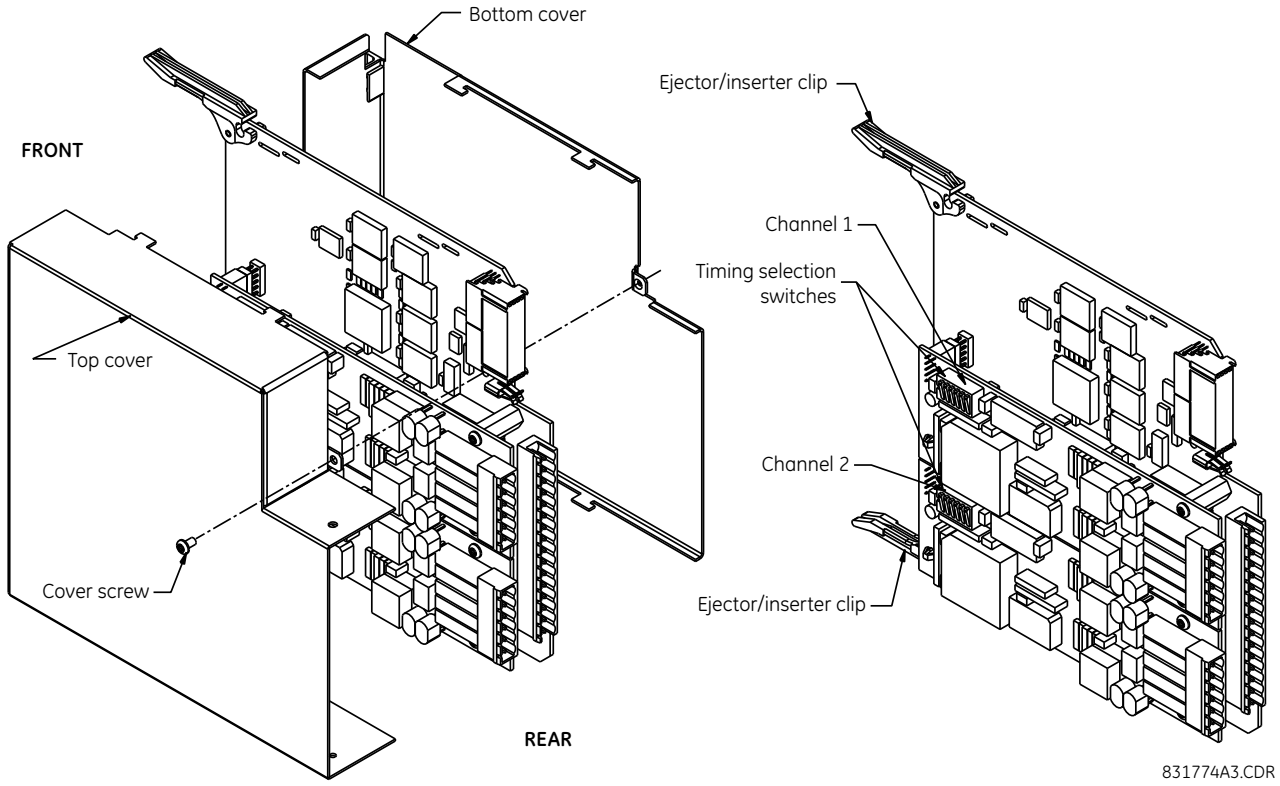


Table 3-6: G.703 timing selections

Switches	Function
S1	OFF → octet timing disabled ON → octet timing 8 kHz
S5 and S6	S5 = OFF and S6 = OFF → loop timing mode S5 = ON and S6 = OFF → internal timing mode S5 = OFF and S6 = ON → minimum remote loopback mode S5 = ON and S6 = ON → dual loopback mode

3.4.3.3 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 C70s are connected back-to-back, octet timing is disabled (OFF).

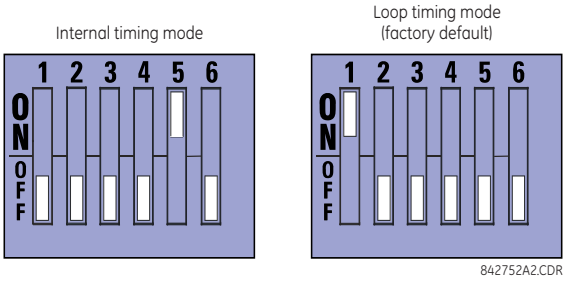
3.4.3.4 G.703 timing modes

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, set the G.703 timing selection to internal timing mode for back-to-back (UR-to-UR) connections. For back-to-back connections, set 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, set the G.703 timing selection to 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.

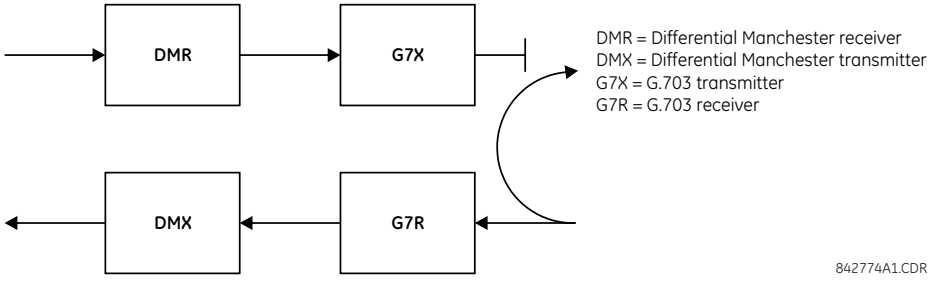
Figure 3-38: Switches



3.4.3.5 G.703 test modes

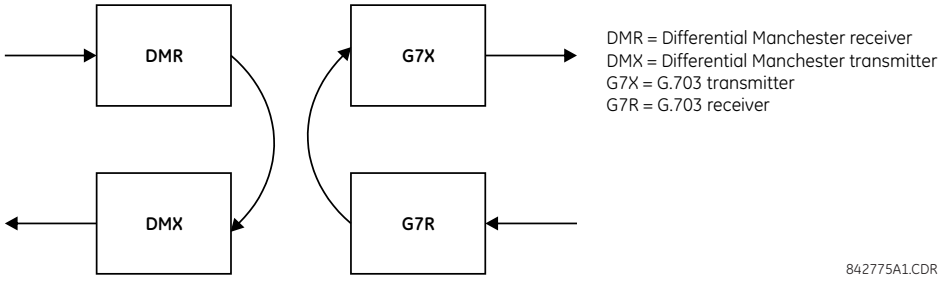
In *minimum remote loopback mode*, the multiplexer is enabled to return the data from the external interface without any processing to assist in diagnosing G.703 line-side problems irrespective of clock rate. Data enters from the G.703 inputs, passes through the data stabilization latch that also restores 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 3-39: 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 3-40: G.703 dual loopback mode



3.4.4 RS422 interface

3.4.4.1 Description

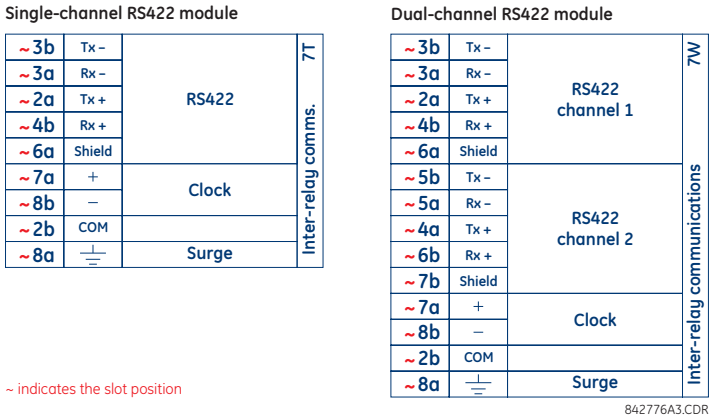
There are two RS422 inter-relay communications modules available: single-channel RS422 (module 7T) and dual-channel RS422 (module 7W). The modules can be configured to run at 64 kbps or 128 kbps. AWG 20-24 twisted shielded pair cable is recommended for external connections. These modules are protected by optically-isolated surge suppression devices.

The shield pins (6a and 7b) are connected internally 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

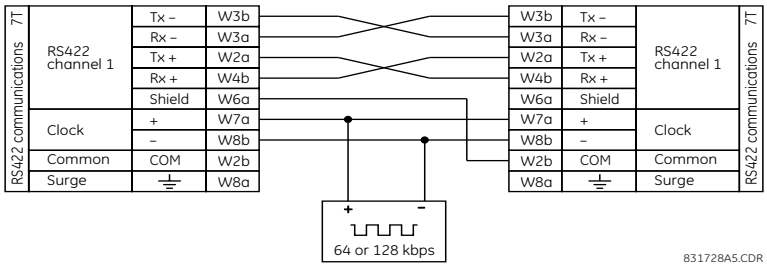
Match the clock terminating impedance with the impedance of the line.

Figure 3-41: 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 3-42: Typical pin interconnect between two RS422 interfaces

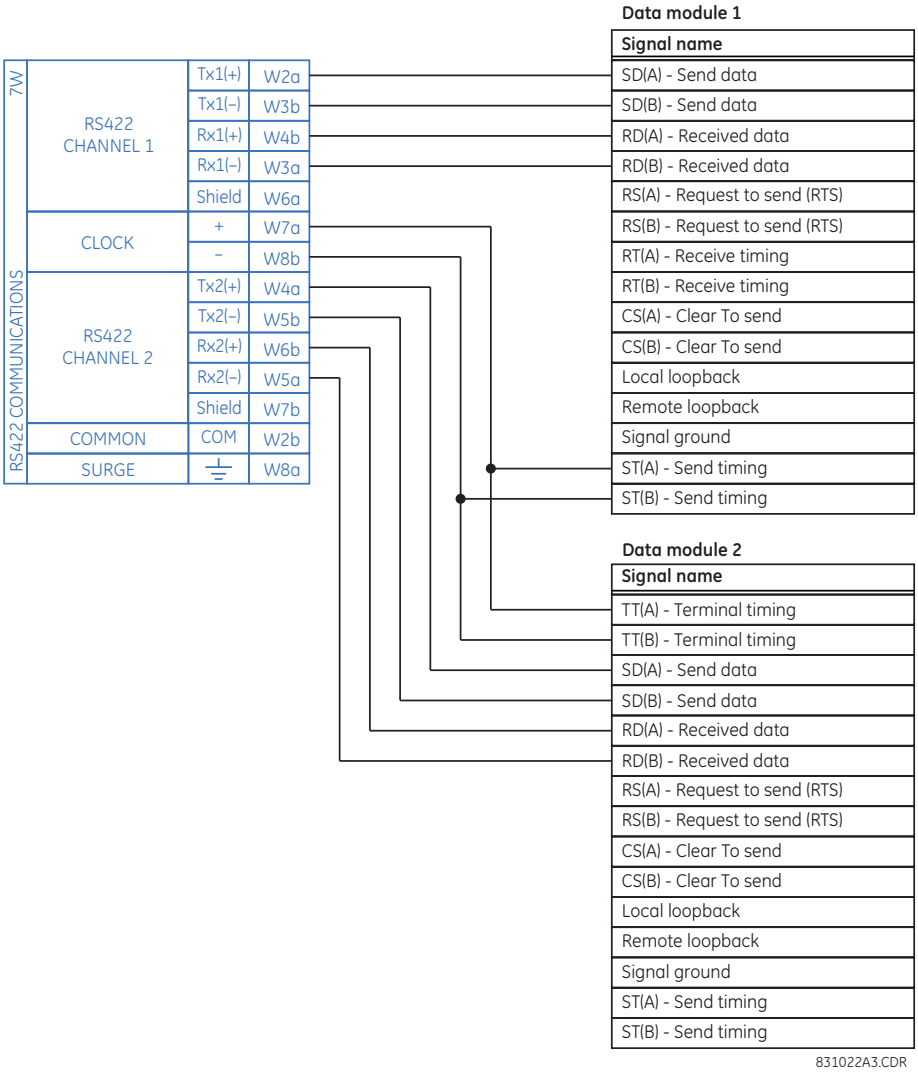


3.4.4.2 Two-channel application via multiplexers

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 way, 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 way. In addition, the send timing outputs of data module 1 are 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, shown as follows. If the terminal timing feature is not available or this type of connection is not wanted, the G.703 interface is a viable option that does not impose timing restrictions.

Figure 3-43: Timing configuration for RS422 two-channel, three-terminal application

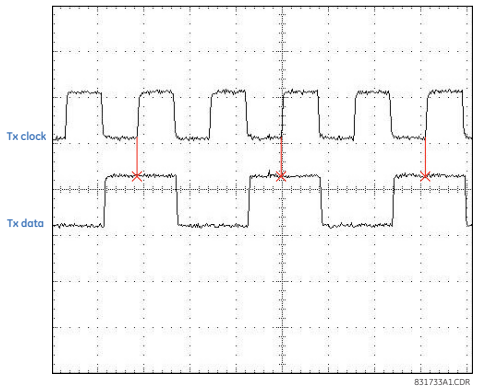


Data module 1 provides timing to the C70 RS422 interface via the ST(A) and ST(B) outputs. Data module 1 also provides timing to data module 2 TT(A) and TT(B) inputs via the ST(A) and AT(B) outputs. The data module pin numbers have been omitted in the figure because they vary by manufacturer.

3.4.4.3 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 3-44: Clock and data transitions



3.4.4.4 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 digital phase lock loop (DPLL) 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 serial communication controller (SCC) receive clock.

3.4.5 IEEE C37.94 interface

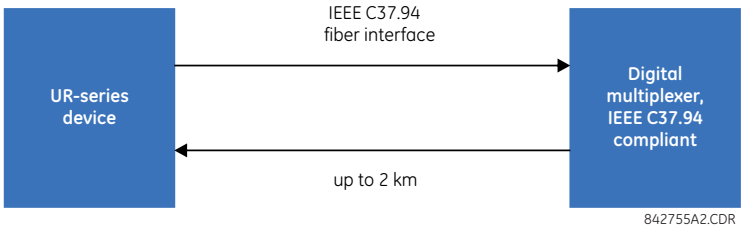
The UR-series IEEE C37.94 communication modules (module types 2I, 2J, 76, and 77) are designed to interface with IEEE C37.94 compliant digital multiplexers or an IEEE C37.94 compliant interface converter for use with direct input and output applications. The IEEE C37.94 standard defines a point-to-point 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

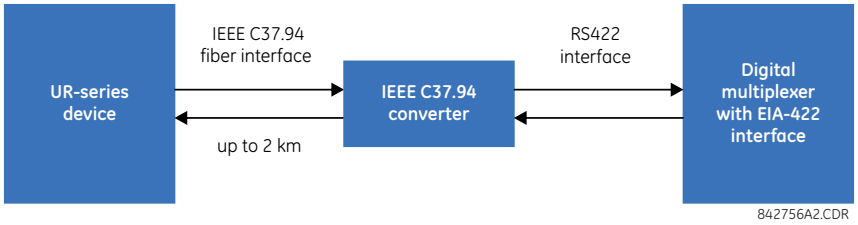
The UR-series C37.94 communication module can be connected directly to any compliant digital multiplexer that supports the IEEE C37.94 standard. The figure shows the concept.

Figure 3-45: IEEE C37.94 connection to compliant digital multiplexer



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. The following figure shows the concept.

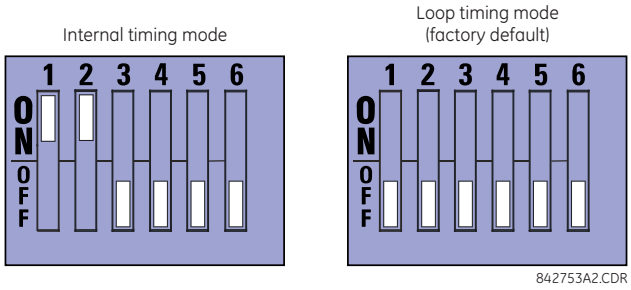
Figure 3-46: IEEE C37.94 connection to non-compliant digital multiplexer



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 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 C70 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.

Figure 3-47: Switches



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

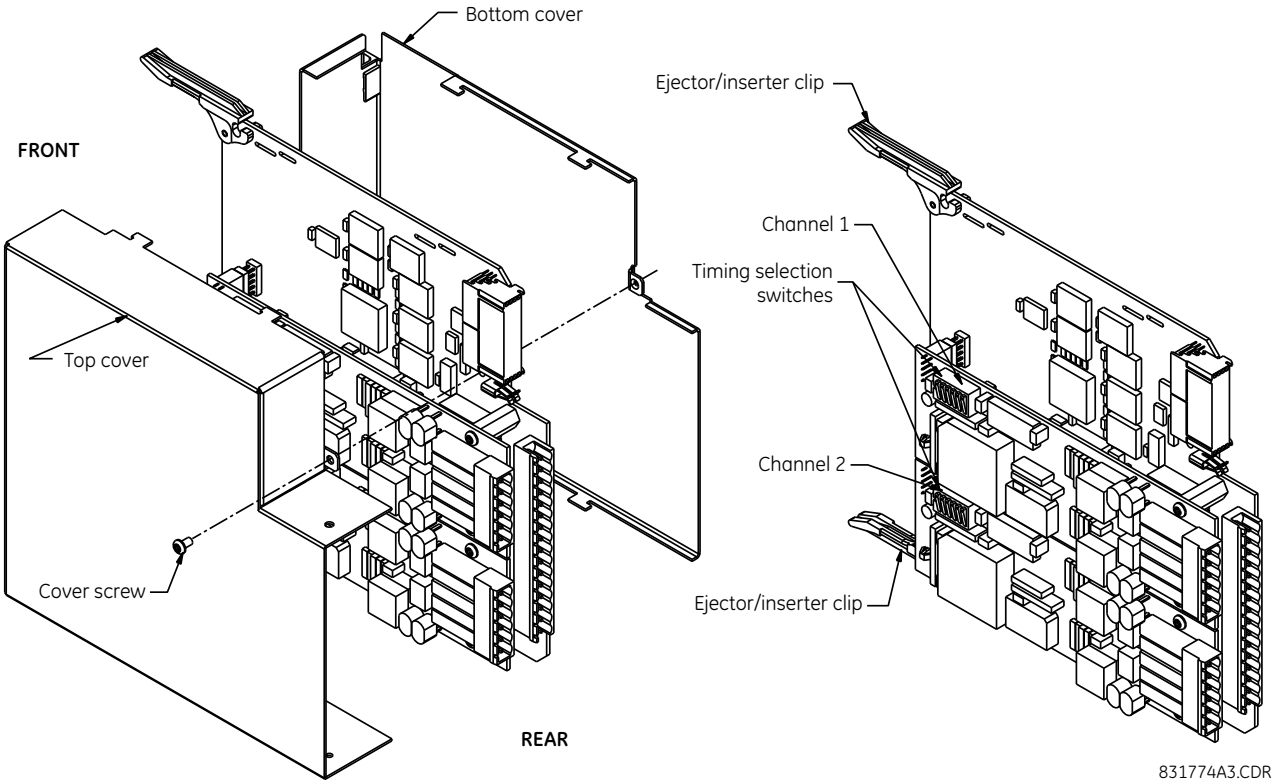
For the looped timing mode, the system clock is derived from the received line signal. Therefore, set the timing selection to loop timing mode for connections to higher order systems.

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 bottom of each module in order to release the module for removal.
3. Remove the module cover screw.

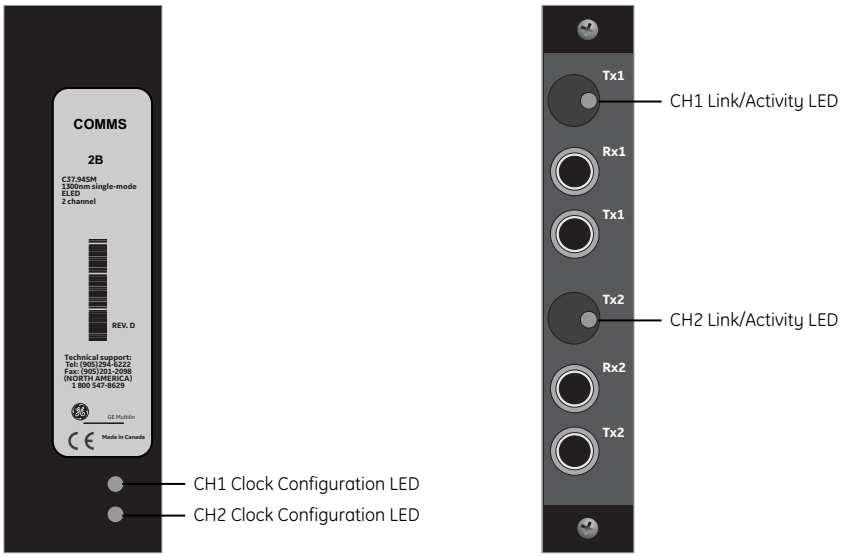
4. Remove the top cover by sliding it towards the rear and then lift it upwards.
5. Set the timing selection switches (channels 1 and 2) to the required timing modes (see description earlier).
6. Replace the top cover and the cover screw.
7. Re-insert the IEEE C37.94 module. Take care to ensure that 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 inserted smoothly 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 inserted fully.

Figure 3-48: 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 3-49: 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

3.5 Activate relay

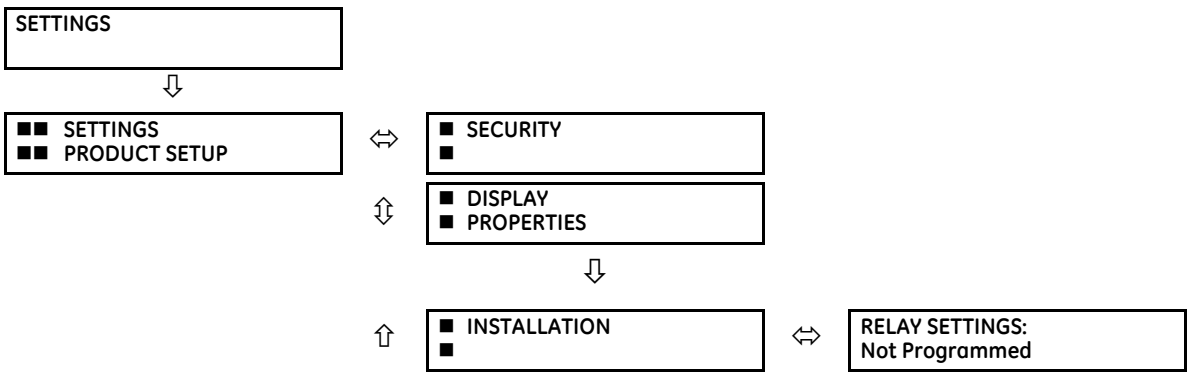
The relay is in the default "Not Programmed" state when it leaves the factory. When powered up successfully, the "Trouble" LED is on and the "In Service" LED is off. The relay in the "Not Programmed" state blocks signaling of any output relay. These conditions remain until the relay is explicitly put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

RELAY SETTINGS: **Not Programmed**	When the relay is powered up, the "Trouble LED" is on, the "In Service" LED is off, and this message displays, indicating that 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.

The relay can be activated on the front panel or in the EnerVista software.

To activate the relay using the front panel:

1. Press the **MENU** key until the **SETTINGS** header flashes momentarily and the **PRODUCT SETUP** message displays.
2. Press the **MESSAGE** right arrow until the **SECURITY** message displays.
3. Press the **MESSAGE** down arrow until the **INSTALLATION** message displays.
4. Press the **MESSAGE** right arrow until the **RELAY SETTINGS: Not Programmed** message displays.



5. After the **RELAY SETTINGS: Not Programmed** message displays, press a **VALUE** key to change the selection to "Programmed."
6. Press the **ENTER** key to save the change.



7. When the "NEW SETTING HAS BEEN STORED" message appears, the relay is in "Programmed" state and the "In Service" LED turns on.

To activate the relay using EnerVista software:

1. Navigate to **Settings > Product Setup > Installation** and change the **Relay Settings** field to "Programmed."
2. Save the change.

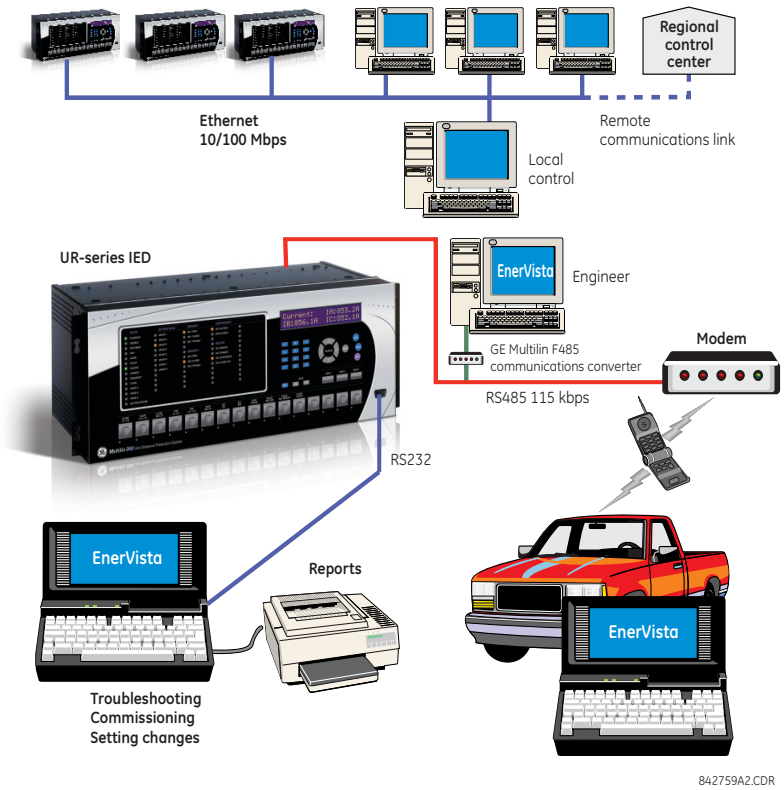
3.6 Install software

3.6.1 EnerVista communication overview

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, use a standard straight-through serial cable. Connect the DB-9 male end to the relay and the DB-9 or DB-25 female end to the computer COM2 port as described in the CPU Communication Ports section earlier in this chapter.

Figure 3-50: Relay communication options



To communicate through the C70 rear RS485 port from a computer RS232 port, the GE Grid Solutions 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 C70 rear communications port. The converter terminals (+, –, GND) are connected to the C70 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 this chapter.

3.6.2 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 software are as follows:

- Pentium 4 (Core Duo recommended)
- Windows XP with Service Pack 2 (Service Pack 3 recommended) or Windows 7, or Windows Server 2008 Release 2 64-bit, in the required EnerVista language
- 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 C70 and the EnerVista software:

- US Robotics external 56K FaxModem 5686

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

3.6.3 Install software

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

Install on a computer that has an operating system in the required language, for example a German operating system for use with EnerVista software in German.

To install the UR EnerVista software from the DVD:

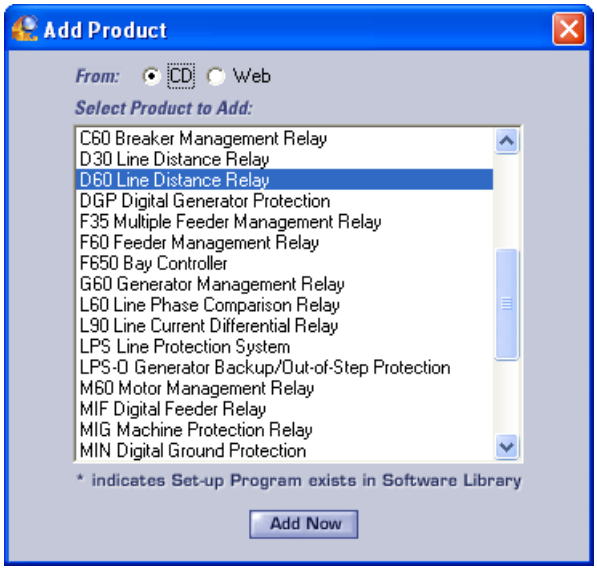
1. Insert the DVD into the DVD drive of your computer.
2. Click the **Install Now** button and follow the instructions.
3. When installation is complete, start the EnerVista Launchpad application.
4. Click the **IED Setup** section of the **Launch Pad** window.

Figure 3-51: 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 connection, 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 3-52: 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 3-53: UR device added to Launchpad window



3.7 Configure the C70 for software access

You connect remotely to the C70 through the rear RS485 or Ethernet port with a computer running the EnerVista UR Setup software. The C70 also can 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 C70 for remote access via the rear RS485 port, see the next section.
- To configure the C70 for remote access via the rear Ethernet port, see the Configure Ethernet Communication section.
- To configure the C70 for local access with a computer through either the front RS232 port or rear Ethernet port, see the Connect to the C70 section.
- To discover automatically UR devices and configure the software for them, see the Automatic Discovery of UR Devices section.

The devices are listed alphabetically in the main software window, for example B30, B90, T35. Use the **Device Name** to order them as required, for example B30 Odessa, B30 Truro, B90, T35.

Devices are listed in the order entered in the Device Setup window.

You cannot import a file to add a device to the software. You can import settings as outlined at the end of the chapter.

Implement IP addresses for the computer and a C70 device as follows.

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

Table 3-7: 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.

3.7.1 Configure serial communication

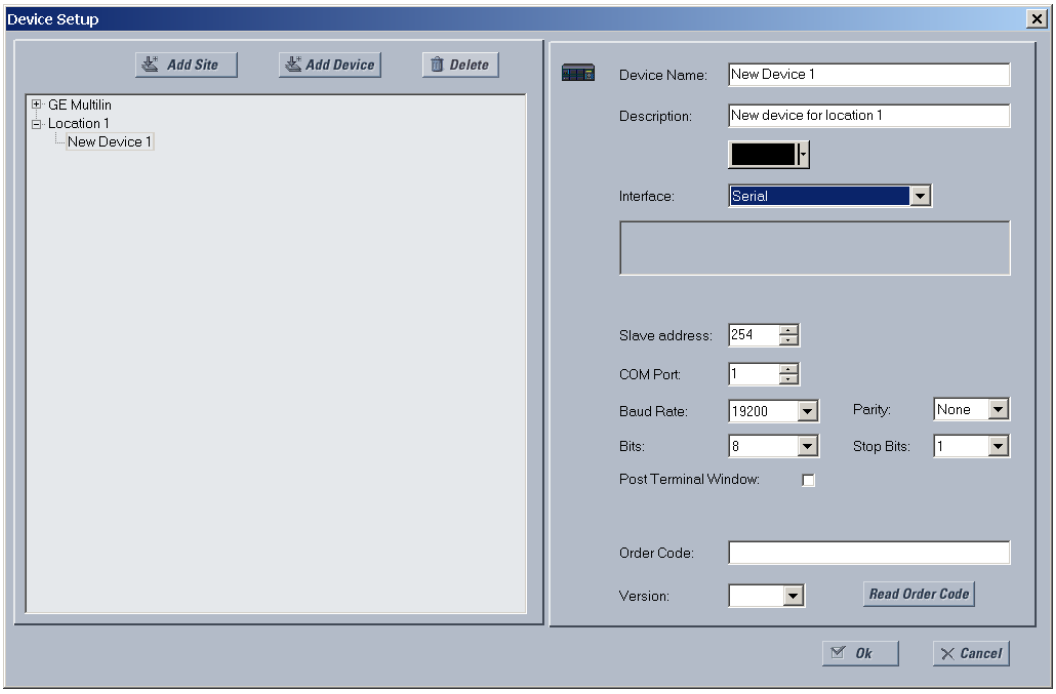
Two options are possible: local connection between computer and front RS232 port, and remote connection using the rear RS485 port.

For the RS232 connection, a computer with an RS232 port and a serial cable are required.

To use the RS485 port at the back of the relay, a GE Grid Solutions 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 3-54: Configuring serial communication



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.

   Baud Rate — Typically19200 for RS232 and higher for RS485

   Parity — Set to None if unsure

   Bits — Set to 8 if unsure

   Stop Bits — Set to 1 if unsure

10. Click the **Read Order Code** button to connect to the C70 and upload the order code to the software. 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 Connect to the C70 section to begin communication.

3.7.2 Configure Ethernet communication

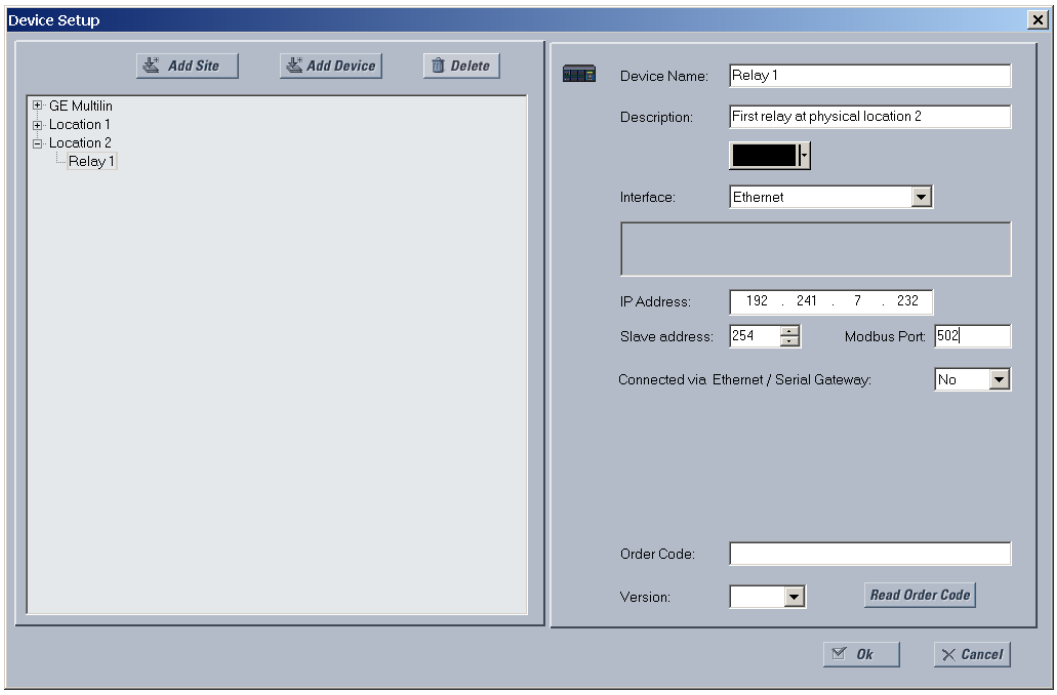
You connect the cable, define a site in the software, then add the relay as a device for the site. The computer and UR device must be on the same subnet.

1. Connect the Ethernet network cable to the Ethernet port on the back of the device.
2. On the computer, select the UR device from the EnerVista Launchpad to start EnerVista UR Setup.
3. Click the **Device Setup** button to open the Device Setup window, then click the **Add Site** button to define a new site.
4. Enter a site name in the "Site Name" field. If wanted, 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.

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

Figure 3-55: Configuring Ethernet communication



9. Enter the relay IP address specified in the front panel **SETTINGS** ⇨ **PRODUCT SETUP** ⇩⇨ **COMMUNICATIONS** ⇩⇨ **NETWORK** ⇨ **IP ADDRESS** in the **IP Address** field.
10. 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.
11. Click the **Read Order Code** button to connect to the C70 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.
12. 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 Connect to the C70 section to begin communications.

3.7.3 Automatic discovery of UR devices

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

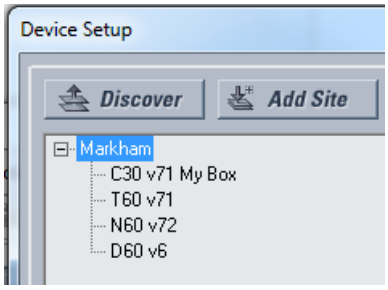
Using the **Discover** button in the **Device Setup** window, a single click of the mouse triggers the software to detect automatically any UR-series relays located on the network. The EnerVista UR Setup software then proceeds to configure all settings and order code options in the window. This feature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

To discover UR devices:

1. In EnerVista, click the **Device Setup** button.

2. In the window that opens, click the **Discover** button. If the required device is not found, add it manually as outlined earlier.

Figure 3-56: Discover button to detect UR devices in network



3.8 Connect to the C70

There are four ways to the connect to the device, as follows:

- RS232 port (outlined here)
- RS485 port
- Ethernet port (outlined here)
- LAN

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

NOTE

When multiple computers are connected to a C70 device, EnerVista settings windows are not updated automatically. They are refreshed when re-opened. If a user changes a setting on one computer, the other users need to refresh the display by closing and opening the settings window to see the change. To ensure that current settings are always viewed, close settings windows when not in use so that they are up-to-date when next accessed.

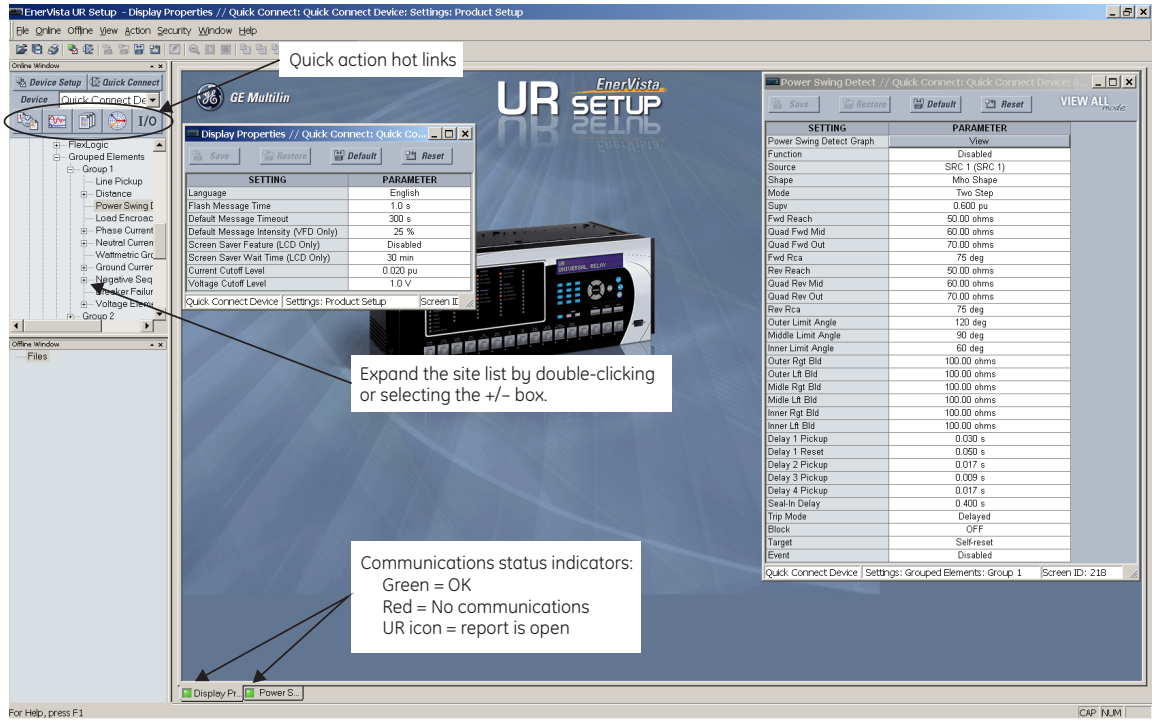
3.8.1 Connect to the C70 in EnerVista

For information on using the EnerVista software, see the Interfaces chapter.

To access the relay in EnerVista:

1. Open the **Settings > Product Setup > Display Properties** window as shown. The window opens with a status indicator on the lower left of the EnerVista UR Setup window.

Figure 3-57: EnerVista window



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 set up for communications (steps A and B earlier).
3. If a relay icon appears in place of the status indicator, then a report (such as an oscillography or event record) is open. Close the report to re-display the green status indicator.
4. The Display Properties settings can now be viewed, edited, or printed.

3.8.1.1 Quick action hot links

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

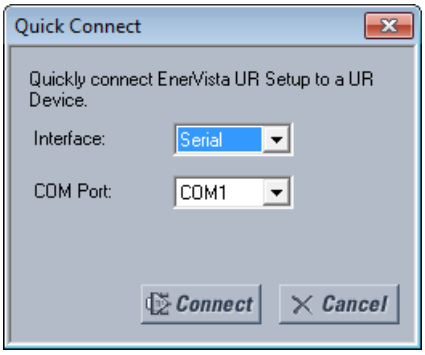
- View the event record
- View the last recorded oscillography record
- View the status of all C70 inputs and outputs
- View all of the C70 metering values
- View the C70 protection summary
- Generate a service report

3.8.2 Use Quick Connect via the front panel RS232 port

To connect to the UR from a computer using a serial cable:

1. Connect an RS232 serial cable to the computer and the front panel RS232 port.
2. Select the UR device from the EnerVista Launchpad to start EnerVista UR Setup.
3. Click the **Quick Connect** button to open the window.

Figure 3-58: Quick Connect window to access a device



3

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 on the left side of the screen. Expand the sections to view data directly from the C70 device. Use the **Device Setup** button to change the site names.

Each time that the EnerVista UR Setup software is initialized, click the **Quick Connect** button to establish direct communications to the C70. This ensures that configuration of the EnerVista UR Setup software matches the C70 model number.

3.8.3 Use Quick Connect via a rear Ethernet port

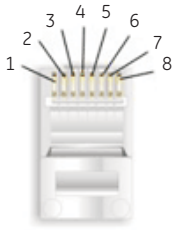
To use the Quick Connect feature to access the C70 from a computer through Ethernet, first assign an IP address to the relay using the front panel keyboard.

1. Press the **MENU** key until the **Settings** menu displays.
2. Navigate to **Settings** ⇨ **Product Setup** ⇩⇨ **Communications** ⇩⇨ **Network** ⇨ **IP Address Setting**.
3. Enter an IP address, for example "1.1.1.1," and press 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.

If using a blue or grey Ethernet cable, skip the rest of the this section. If using an orange cross-over Ethernet cable, the computer needs to be set up as follows.

1. Use an orange Ethernet cross-over cable to connect the computer to the rear Ethernet port. In case you need it, the following figure shows the pinout for an Ethernet cross-over cable.

Figure 3-59: Ethernet cross-over cable PIN layout



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	

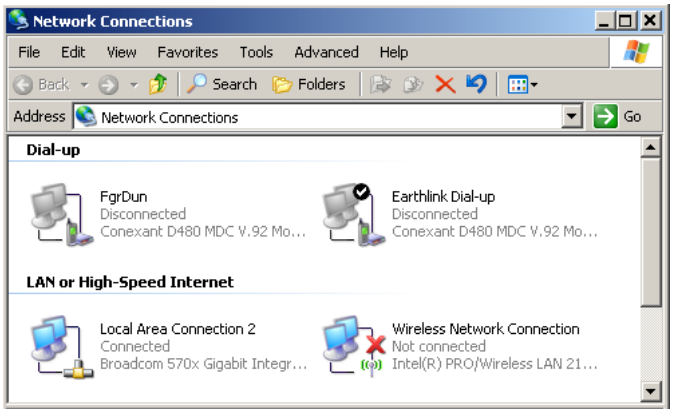
END 2		
Pin	**Wire color**	**Diagram**
1	White/green	
2	Green	
3	White/orange	
4	Blue	
5	White/blue	
6	Orange	
7	White/brown	
8	Brown	

842799A1.CDR

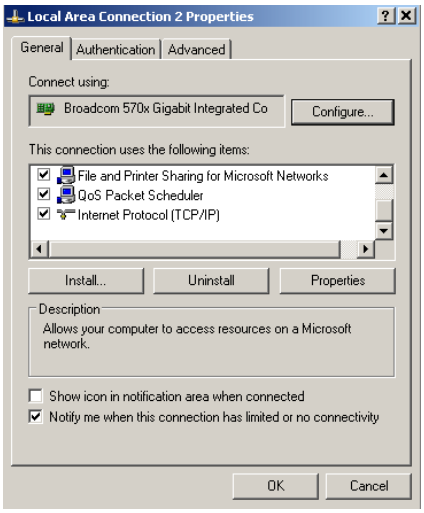
Next, assign the computer an IP address compatible with the relay's IP address.

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

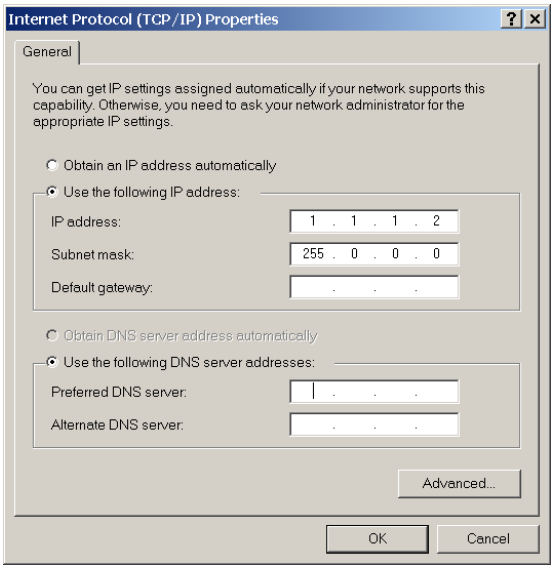
connections window. Or in Windows 7, access the **Network and Sharing Center** in the Control Panel.



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 C70 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 C70 (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, for example by selecting **Start > Run** from the Windows **Start** menu and typing "cmd" or clicking the **Start** button and entering "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 C70 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 C70 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.
```

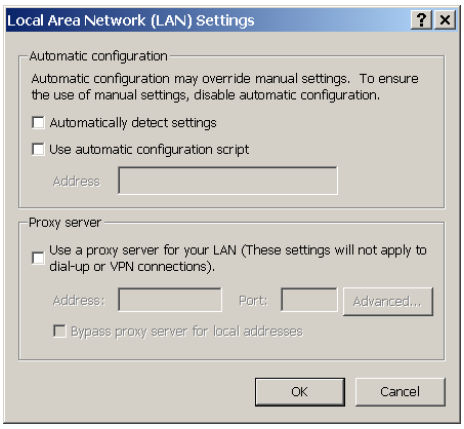
```
Ping statistics for 1.1.1.1:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
Approximate round trip time in milliseconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0 ms
Pinging 1.1.1.1 with 32 bytes of data:
```

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.

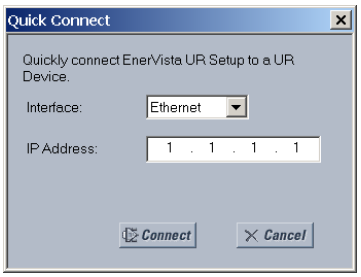


4. Ensure that the "Use a proxy server for your LAN" box is not checked.

If this computer is used to connect to the Internet, re-enable any proxy server settings after the computer has been disconnected from the C70 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 window.

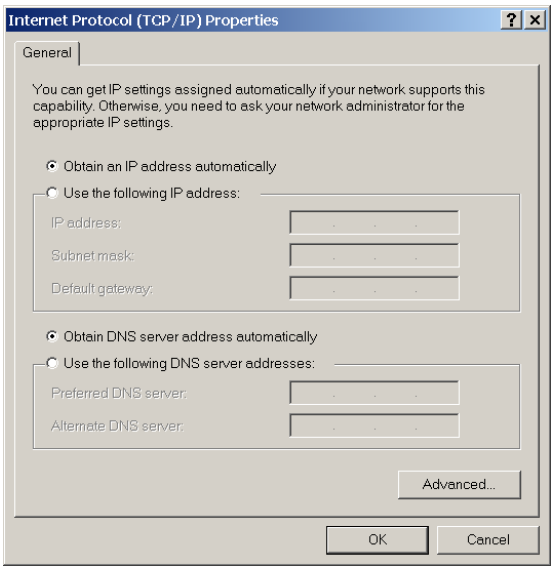


4. Select the **Ethernet** interface and enter the IP address assigned to the C70, then click the **Connect** button. The EnerVista UR Setup software creates a site named "Quick Connect" with a corresponding device also named "Quick Connect" and displays them on the left side of the screen.
5. Expand the sections to view data directly from the C70 device.

Each time that the EnerVista UR Setup software is initialized, click the **Quick Connect** button to establish direct communications to the C70. This ensures that configuration of the EnerVista UR Setup software matches the C70 model number.

When direct communications with the C70 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 the computer is used to connect to the Internet, re-enable any proxy server settings after the computer has been disconnected from the C70 relay.

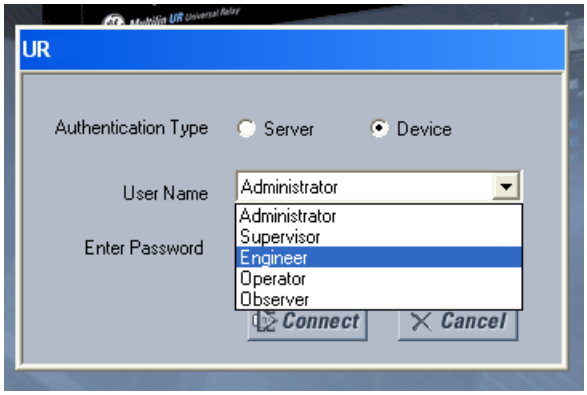
3.9 Set up CyberSentry and change default password

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 (see figure). 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. At the end of this instruction manual, the appendix called RADIUS Server Configuration gives an example of how to set up a simple RADIUS server. Once both the RADIUS server and the parameters for connecting the UR to the server have been configured, you can choose Server authentication on the login screen of EnerVista.

Figure 3-60: 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.

C70 Capacitor Bank Protection and Control System

Chapter 4: Interfaces

This chapter explains the EnerVista software interface, the front panel interface, and logic diagrams.

4.1 EnerVista software interface

4.1.1 Introduction

The EnerVista UR Setup software provides a single facility to configure, monitor, maintain, and troubleshoot 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 C70. This chapter outlines the EnerVista software interface features. The EnerVista UR Setup help file in the software also provides details for getting started and using the software interface.

4.1.2 Settings files

The EnerVista software supports the following three ways of handling changes to relay settings:

- In offline mode (relay disconnected) to create or edit relay settings files for later download to relays
- While connected to a relay to modify relay settings, and then save the settings to the relay
- Create/edit settings files and then write them to the relay while 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 C70 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 C70 that is in-service, the following sequence occurs:

1. The C70 takes itself out of service.
2. The C70 issues a UNIT NOT PROGRAMMED major self-test error.
3. The C70 closes the critical fail contact.

The Maintenance chapter outlines how to use a settings file in the .urs format for backup and restore.

4.1.3 Event viewing

While the interface is in online or offline mode, you can view and analyze data generated by triggered parameters as follows:

- **Event recorder** — The event recorder captures contextual data associated with the last 1024 events, listed chronologically 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

Event records are viewable at software and device-specific levels. Access the former under **Admin > Event Log > View**. Access the latter under **Actual Values > Records > Event Record**.

Event record entries for CyberSentry are explained in the next chapter. The following table outlines some software-level entries.

Table 4-1: Event record descriptions

Event	Description
EnerVista UR Setup SESSION STARTED	The EnerVista software was launched
Language was changed.	The user changed the software language using the **View > Language** menu item
DEFAULT USERS CREATED	The user management window was launched using the **Admin > User Management** menu item
: Successful upload of firmware END Firmware verified Firmware uploaded Firmware erased START: Upload new firmware	The firmware on a device was upgraded
EnerVista UR Setup EVENT LOG CLEARED	The event record was cleared. All event records were deleted using the **Admin > Event Log > Clear** menu item.

4.1.4 File support

The following support applies, where the Settings List is at the bottom left and the Site List is at the top left of the EnerVista window:

- **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 navigation menu, it is added back to the menu.
- **Drag and Drop** — The device settings and individual settings can be dragged and dropped between the Online and Offline Window areas. Also, any Windows Explorer directory folder is a file drag source and drop target.

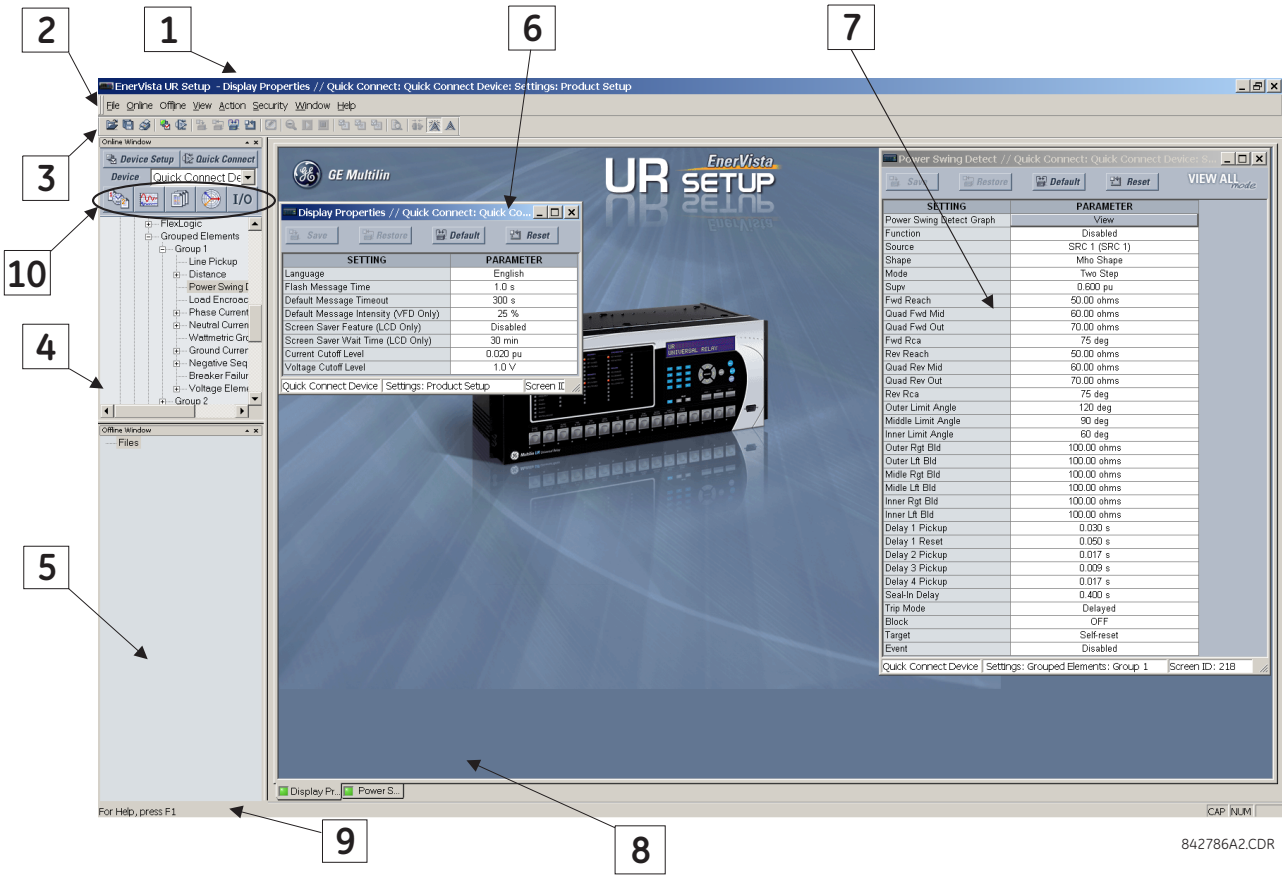
  New files that are dropped into the Offline Window are added to the tree, which is automatically sorted alphabetically with respect to settings file names. In the Online Window, files or individual menu items that are dropped in the selected device menu are sent automatically to the online device.

4.1.5 EnerVista main window

The EnerVista UR Setup software window has the following components:

1. Title bar that shows the pathname of the active data view or the name of the software
2. Main window menu bar
3. Main window tool bar
4. Site list / online window area
5. Settings list / offline window area
6. Software 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 window



4.1.6 Settings templates

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

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

The remaining settings (typically 10% or less) can be specified as editable and 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 the software. 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.

NOTE

Template mode is available in English only.

Settings file conversion from previous firmware versions is supported.

4.1.6.1 Enable the settings template

The settings file template feature is disabled by default. It can be enabled in offline or online mode.

The procedure outlines how to enable in offline mode the settings template for UR settings files.

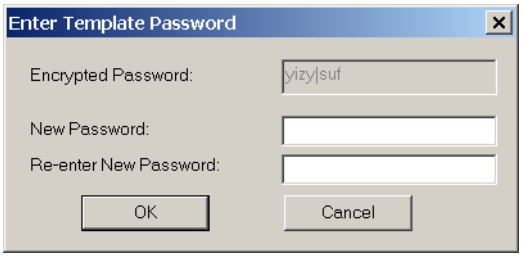
1. Locate the settings file from the Offline Window area of the EnerVista UR Setup software. If not there, a file can be added from an online device by right-clicking it and selecting the **Add Device to Offline Window** option.
2. In the Offline Window area, right-click the selected device or settings file and select the **Template Mode > Create Template** option.

   The settings file template is now enabled and the file menus display in light blue. A message displays. The settings file is now in template editing mode. To undo the action, select **Template Mode > Remove Template**.

Alternatively, the settings template can be applied to online settings, as follows.

1. Locate the device in the Online Window area of the EnerVista UR Setup software.
2. Right-click the 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.

Figure 4-2: Entering a settings file password



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.

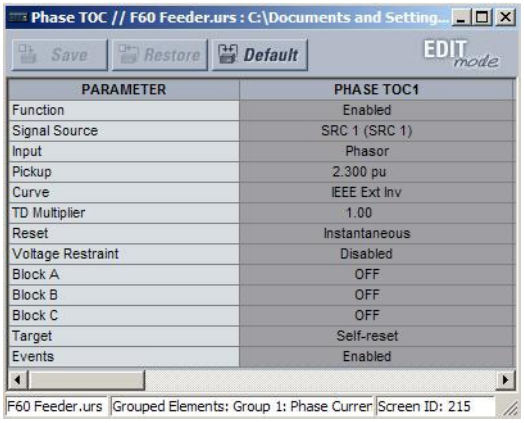
4.1.6.2 Edit the settings template

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.

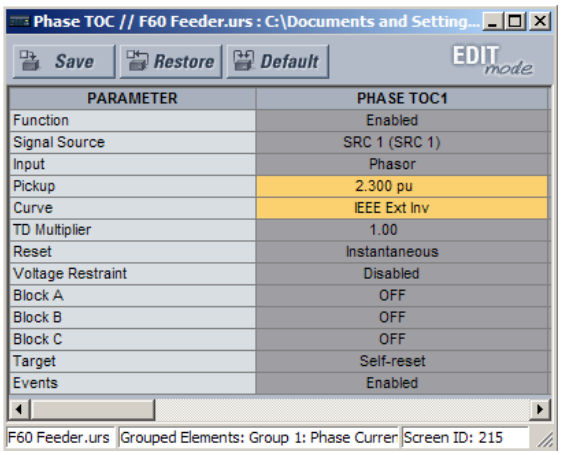
Figure 4-3: Settings template with all settings specified as locked



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

   A setting available to view is displayed against a yellow background.

Figure 4-4: Settings template with two settings specified as editable



5. Click the **Save** button to save changes to the settings template.
6. Continue through any other settings window 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.

4.1.6.3 Add password protection to a template

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

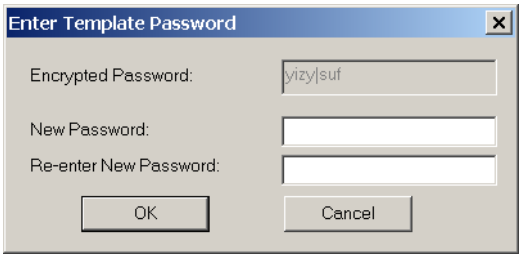
NOTE

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 **Template 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.

4.1.6.4 View 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:

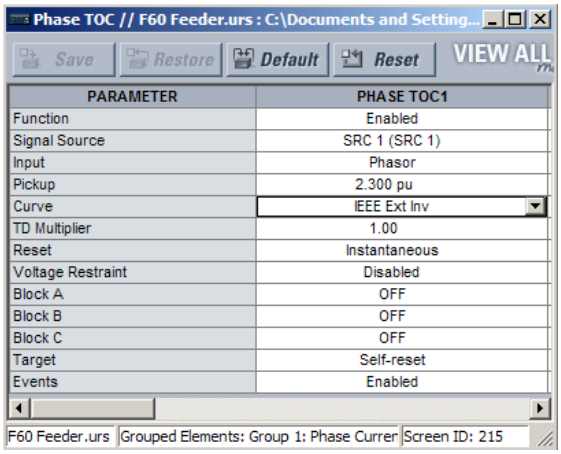
- Display only those settings available for editing
- Display all settings, with settings not available for editing greyed-out

To display only the settings available for editing:

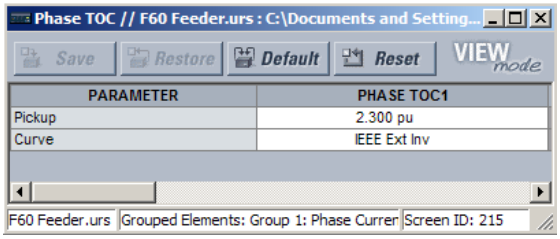
1. Right-click the device in the Online or Offline Window area and apply the template by selecting the **Template Mode > View In Template Mode** option.
2. Enter the template password then click **OK** to apply the template.

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.

Figure 4-5: Applying templates using the View in Template Mode command



Phase time overcurrent settings window without template applied.

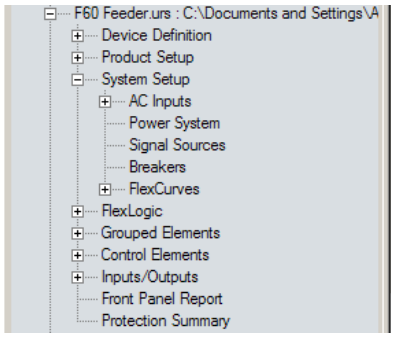


Phase time overcurrent window with template applied via the **Template Mode > View In Template Mode** command. The template specifies that only the Pickup and Curve settings be available.

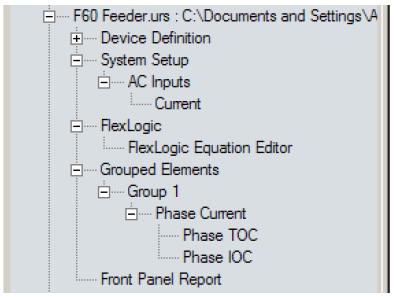
842858A1.CDR

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

Figure 4-6: Applying templates using the View in Template Mode settings command



Typical settings tree view without template applied.



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

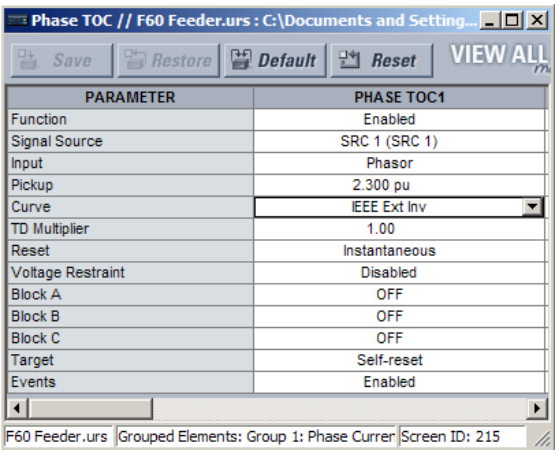
842860A1.CDR

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

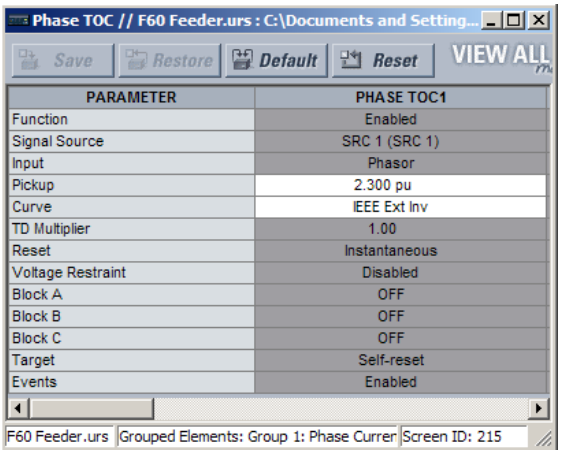
1. Right-click the device in the Online or Offline Window area and apply the template by selecting the **Template Mode > View All Settings** option.
2. Enter the template password then click **OK** to apply the template.

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 as follows.

Figure 4-7: Applying templates using the View All Settings command



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.

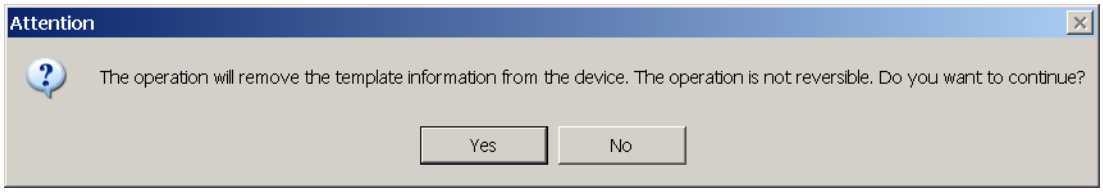
842859A1.CDR

4.1.6.5 Remove 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. Confirm that you want to remove the template by clicking **Yes**.



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

4.1.7 Secure and lock 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.

Locking can be tied to the serial number too.

4.1.7.1 Lock FlexLogic equations

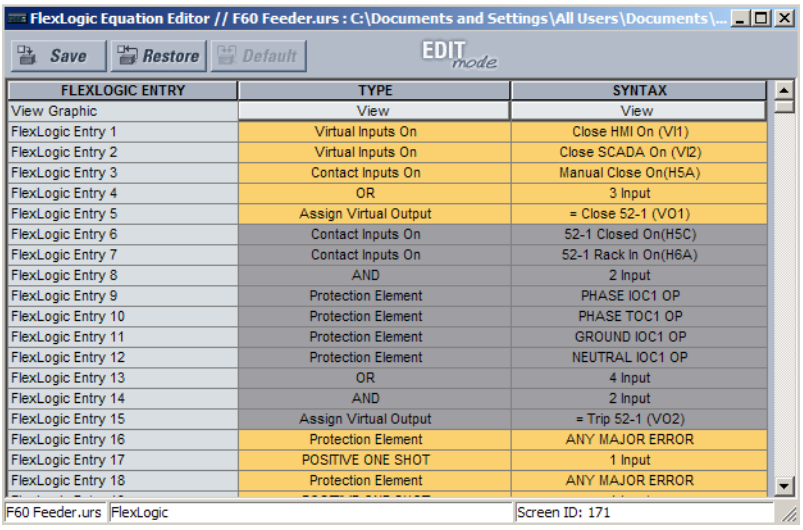
To lock individual entries of a FlexLogic equation:

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 them.

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

Figure 4-8: Locking FlexLogic equation entries in Edit Mode

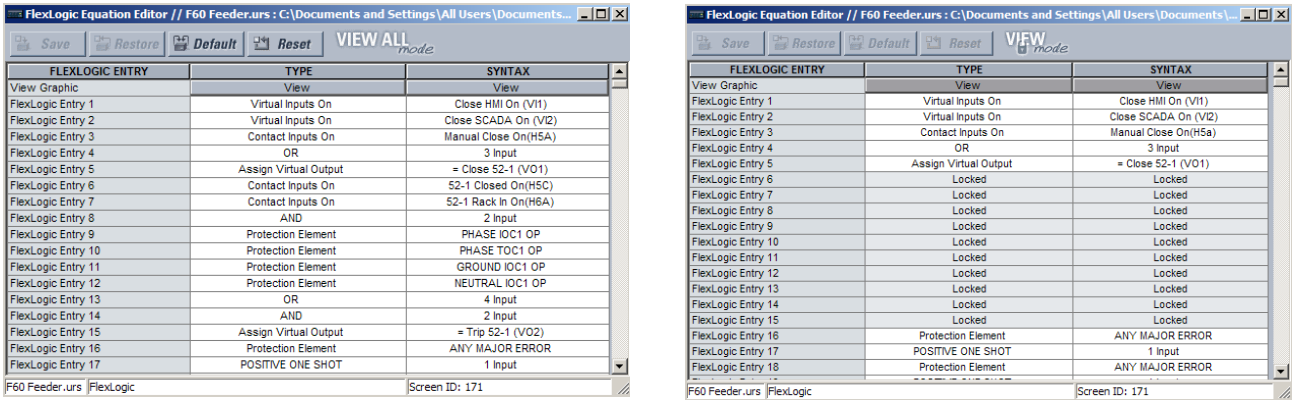


FLEXLOGIC ENTRY	TYPE	SYNTAX
View Graphic	View	View
FlexLogic Entry 1	Virtual Inputs On	Close HMI On (VI1)
FlexLogic Entry 2	Virtual Inputs On	Close SCADA On (VI2)
FlexLogic Entry 3	Contact Inputs On	Manual Close On(H5A)
FlexLogic Entry 4	OR	3 Input
FlexLogic Entry 5	Assign Virtual Output	= Close 52-1 (VO1)
FlexLogic Entry 6	Contact Inputs On	52-1 Closed On(H5C)
FlexLogic Entry 7	Contact Inputs On	52-1 Rack In On(H6A)
FlexLogic Entry 8	AND	2 Input
FlexLogic Entry 9	Protection Element	PHASE IOC1 OP
FlexLogic Entry 10	Protection Element	PHASE TOC1 OP
FlexLogic Entry 11	Protection Element	GROUND IOC1 OP
FlexLogic Entry 12	Protection Element	NEUTRAL IOC1 OP
FlexLogic Entry 13	OR	4 Input
FlexLogic Entry 14	AND	2 Input
FlexLogic Entry 15	Assign Virtual Output	= Trip 52-1 (VO2)
FlexLogic Entry 16	Protection Element	ANY MAJOR ERROR
FlexLogic Entry 17	POSITIVE ONE SHOT	1 Input
FlexLogic Entry 18	Protection Element	ANY MAJOR ERROR

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 is shown here.

Figure 4-9: Locking FlexLogic entries through settings templates



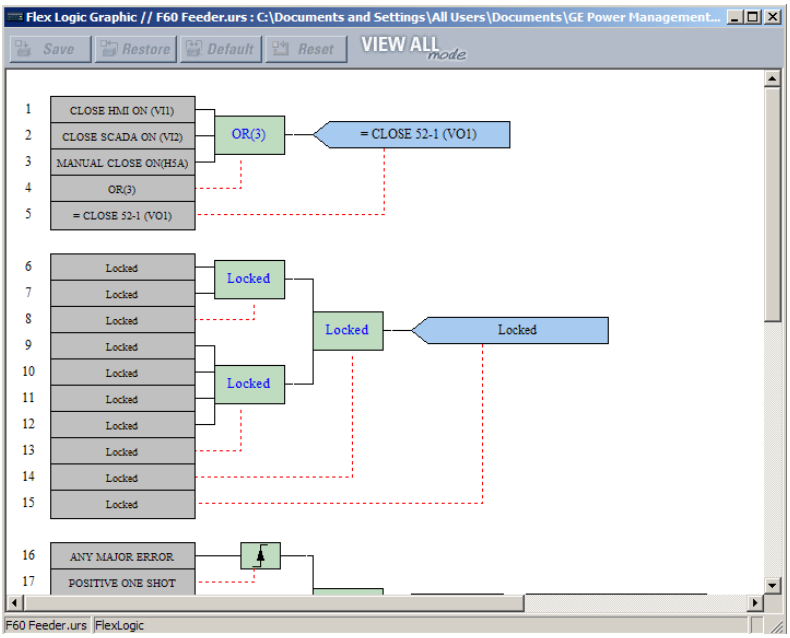
Typical FlexLogic™ entries without template applied.

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

842861A1.CDR

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

Figure 4-10: Secured FlexLogic in graphical view

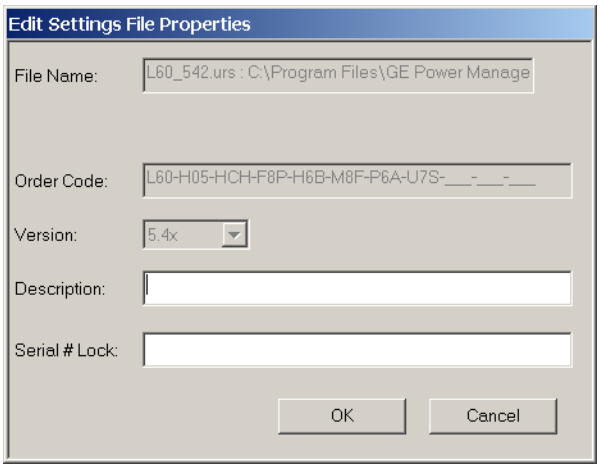


4.1.7.2 Lock FlexLogic equations to the serial number

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.

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

Figure 4-11: Settings file properties window



2. Enter the serial number of the C70 device to lock to the settings file in the **Serial # Lock** field.
3. Click the **OK** button to apply the change. The serial number is not validated.

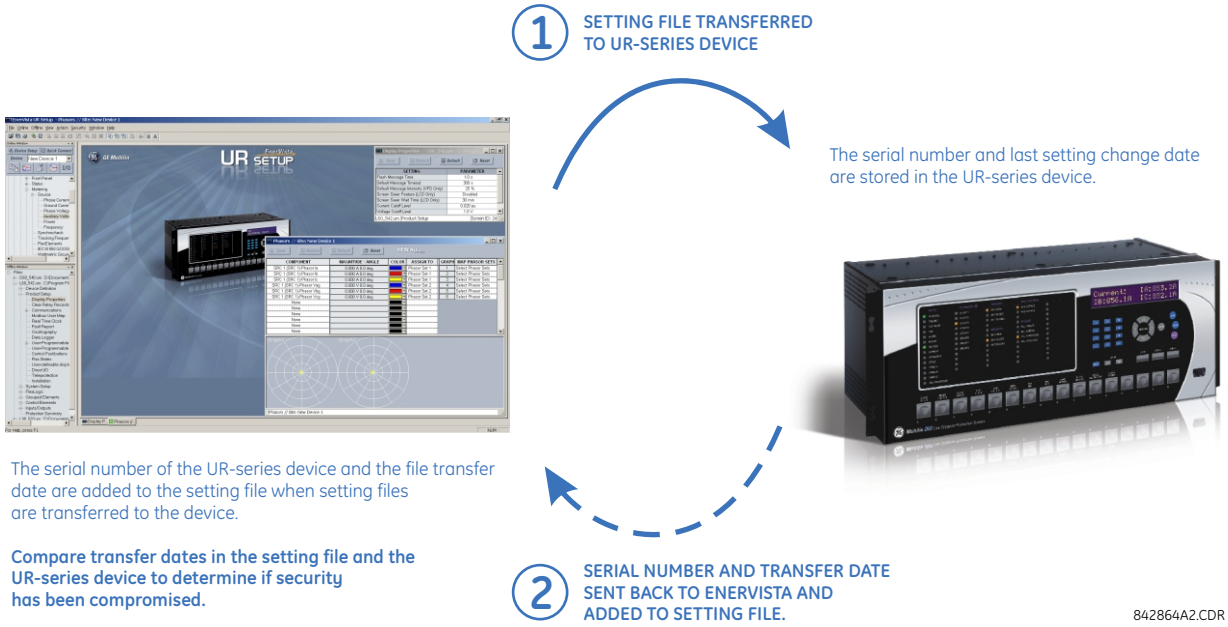
The settings file and corresponding secure FlexLogic equations are now locked to the C70 device specified by the serial number.

4.1.8 Settings file traceability

A traceability feature for settings files allows the user to quickly determine if the settings in a C70 device have been changed since the time of installation from a settings file. When a settings file is transferred to a C70 device, the date, time, and serial number of the C70 are sent back to EnerVista UR Setup and added to the settings file on the local computer. This information can be compared with the C70 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 C70 device or obtained from the C70 device. Any partial settings transfers by way of drag and drop do not add the traceability information to the settings file.

Figure 4-12: Settings file traceability



With respect to the figure, the traceability feature is used as follows.

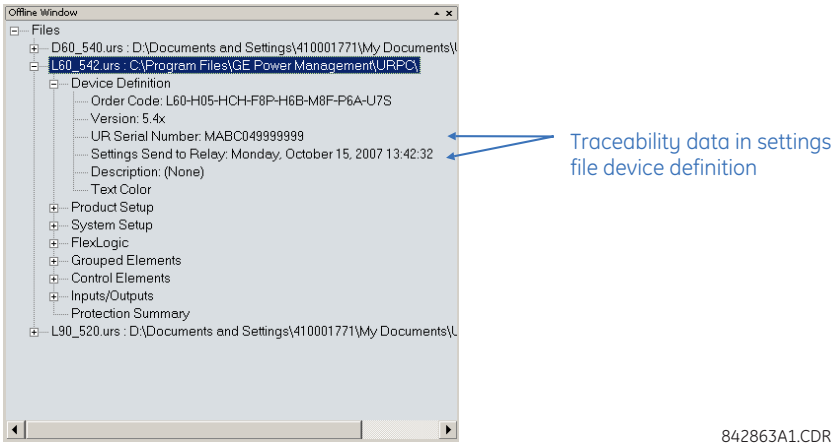
1. The transfer date of a settings file written to a C70 is logged in the relay and can be viewed in the EnerVista software or the front panel display. Likewise, the transfer date of a settings file saved to a local computer is logged in the EnerVista software.
2. Comparing the dates stored in the relay 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.

4.1.8.1 Settings file traceability information

The serial number and file transfer date are saved in the settings files when they are sent to a C70 device.

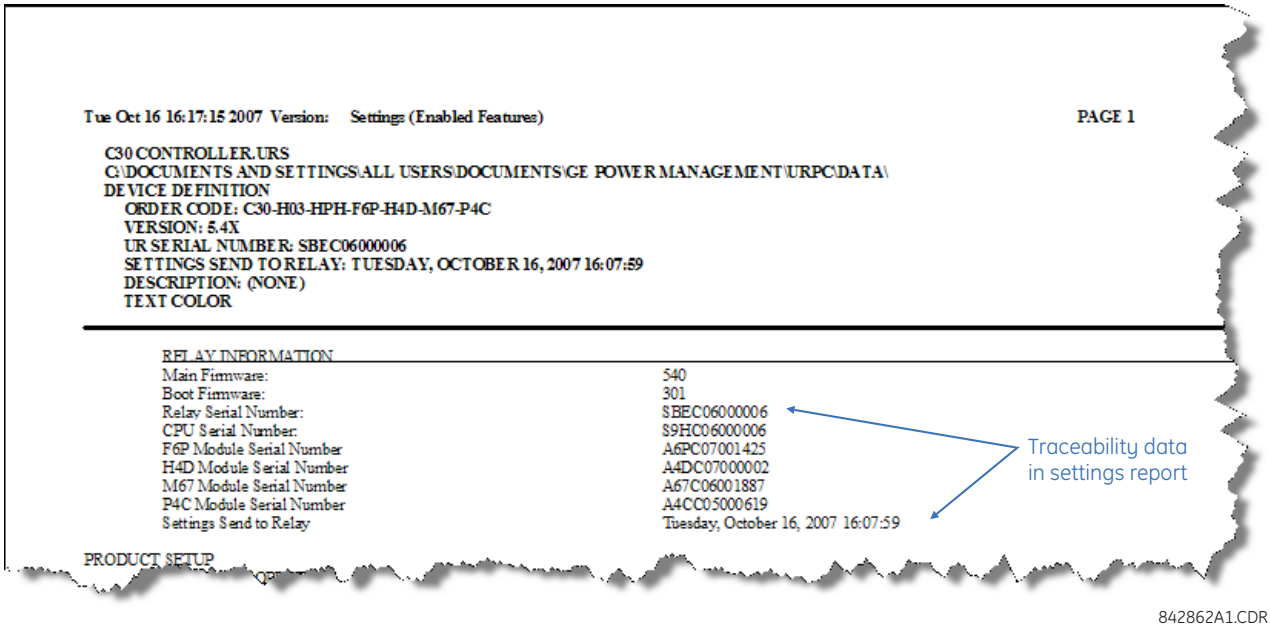
The C70 serial number and file transfer date are included in the settings file device definition within the EnerVista UR Setup offline window as shown in the example.

Figure 4-13: Device definition showing traceability data



This information is also available in printed settings file reports as shown in the example. A report is generated by right-clicking and selecting the **Print Settings** option.

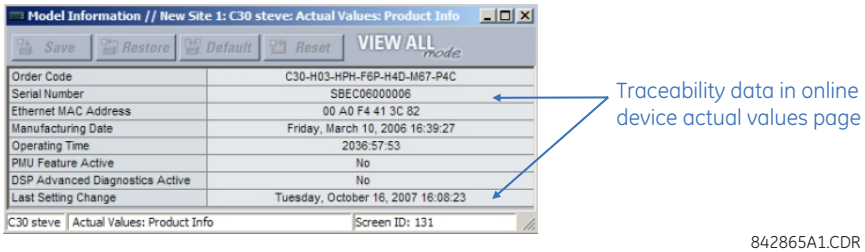
Figure 4-14: Settings file report showing traceability data



4.1.8.2 Online device traceability information

The C70 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 online window as shown in the example.

Figure 4-15: 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

4.1.8.3 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

4.2 Front panel interface

This section explains use of the front panel.

4.2.1 Front panel display

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

Settings files conversion from previous firmware versions is supported.

4.2.2 Front panel 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 further submenus.

The **MESSAGE** keys navigate through the submenus. 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.

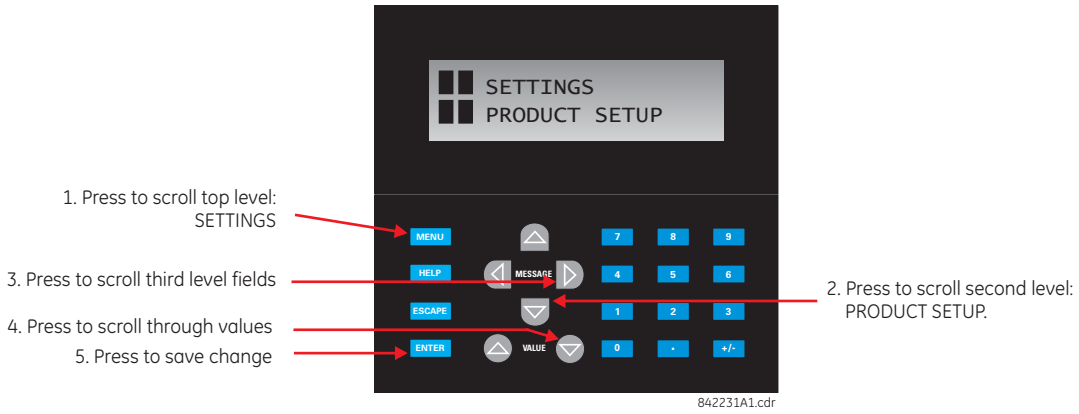
The **HELP** key can be pressed at any time for context-sensitive help messages.

The **ENTER** key stores 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.

The figure shows the sequence to use to enter a setting. Subsequent sections provide more detail.

Figure 4-16: Front panel keypad use



4.2.3 Menu navigation

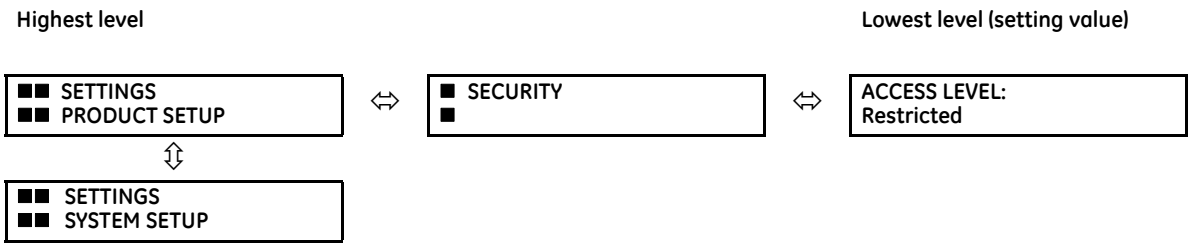
Press the **MENU** key to select a header display page (top-level menu). The header title appears momentarily followed by a header display page menu item. Each press of the **MENU** key advances through the following main headings:

- Actual Values
- Settings
- Commands
- Targets
- Factory Service
- User displays (when enabled)

4.2.4 Menu hierarchy

The setting and actual value messages are arranged hierarchically. The header display pages are indicated by double scroll bars (■■), while sub-header pages are indicated by single scroll bar (■). 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 arrow keys move within a group of headers, sub-headers, setting values, or actual values. Continually pressing the **MESSAGE** right arrow from a header display displays specific information for the category. Conversely, continually pressing the **MESSAGE** left arrow from a setting value or actual value display returns to the header display.

Default values are indicated in this instruction manual in mixed case. In the example shown here, the default access level is Restricted.



4.2.4.1 Example

■■ ACTUAL VALUES ■■ STATUS	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.
⇩	
■■ SETTINGS ■■ PRODUCT SETUP	Press the **MENU** key until the header for the first page of Settings appears. This page contains settings to configure the relay.
⇩	
■■ SETTINGS ■■ SYSTEM SETUP	Press the **MESSAGE** down arrow to move to the next Settings page. This page contains settings for System Setup. Repeatedly press the **MESSAGE** up and down arrows to display the other setting headers and then back to the first Settings page header.
⇩	
■ SECURITY ■	From the Settings page one header (Product Setup), press the **MESSAGE** right arrow once to display the first sub-header (Security).
⇩	
ACCESS LEVEL: Restricted	Press the **MESSAGE** right arrow once more and this displays the first setting for Security. Pressing the **MESSAGE** down arrow repeatedly displays the remaining setting messages for the Security sub-header.
⇩	
■ SECURITY ■	Press the **MESSAGE** left arrow once to move back to the first sub-header message.
⇩	
■ DISPLAY ■ PROPERTIES	Pressing the **MESSAGE** down arrow displays the second setting sub-header associated with the Product Setup header.
⇩	
FLASH MESSAGE TIME: 10.0 s	Press the **MESSAGE** right arrow once more to display the first setting for Display Properties.

4.2.5 Changing settings

4.2.5.1 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: 10.0 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 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 a 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 arrow or pressing the **ESCAPE** key, returns the original value to the display.
- **VALUE keys** — The **VALUE** up arrow increments the displayed value by the step value, up to the maximum value allowed. While at the maximum value, pressing the **VALUE** up arrow again allows the setting selection to continue upward from the minimum value. The **VALUE** down arrow decrements the displayed value by the step value, down to

the minimum value. While at the minimum value, pressing the **VALUE** down arrow 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. Press **ENTER** to store the new value in memory. This flash message momentarily appears as confirmation of the storing process. Numerical values that contain decimal places are rounded-off if more decimal place digits are entered than specified by the step value.

4.2.5.2 Entering enumeration data

Enumeration settings have data values that are part of a set, whose members are explicitly defined by a name. A set has 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 arrow displays the next selection while the **VALUE** down arrow displays the previous selection.

ACCESS LEVEL: **Setting**	If the **ACCESS LEVEL** needs to be "Setting," press the **VALUE** keys until the proper selection displays. 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.

4.2.5.3 Entering alphanumeric text

Text settings have data values that are fixed in length, but user-defined in characters. 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, 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.

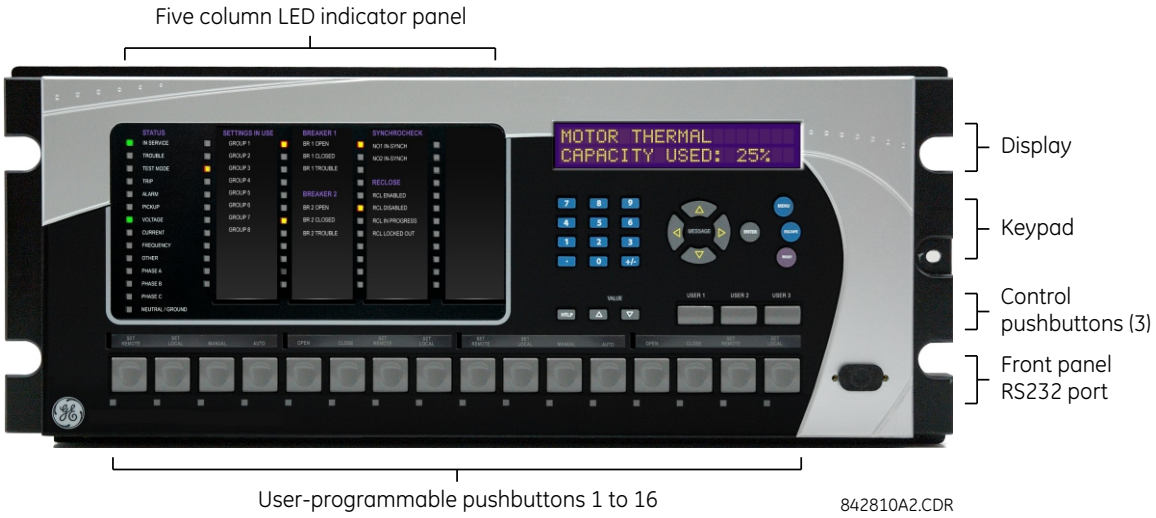
4.2.6 Faceplate

4.2.6.1 Enhanced faceplate

The front panel consists of LED panels, an RS232 port, keypad, LCD display, control pushbuttons, and optional user-programmable pushbuttons.

The faceplate is hinged to allow access to the removable modules.

Figure 4-17: Enhanced faceplate



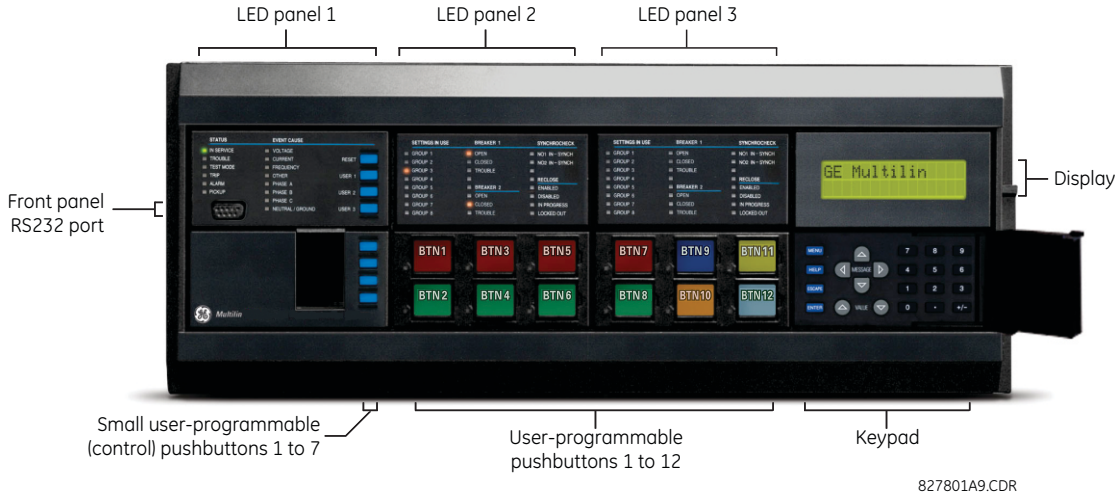
4

4.2.6.2 Basic faceplate

The front panel consists of LED panels, an RS232 port, keypad, LCD display, control pushbuttons, and optional user-programmable pushbuttons.

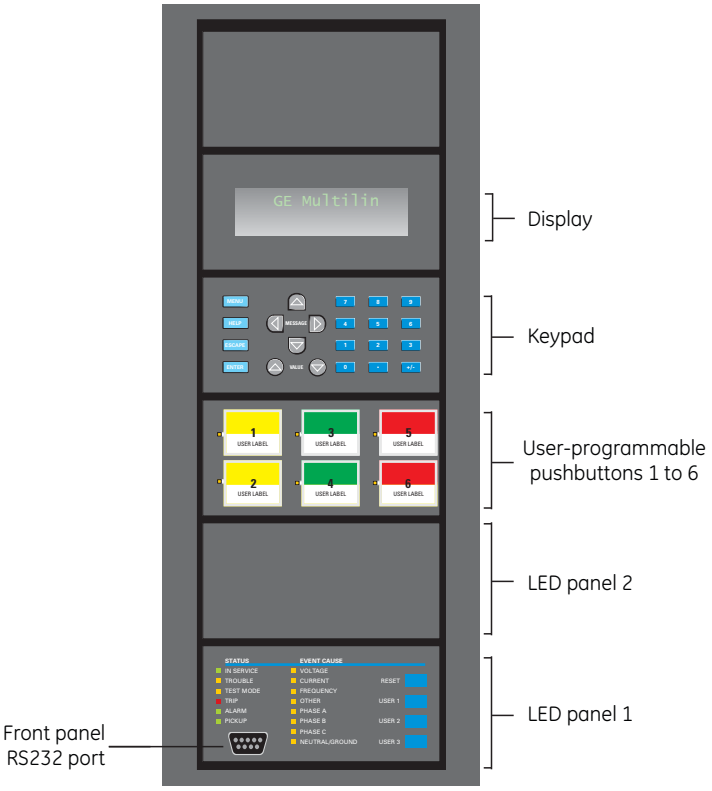
The faceplate is hinged to allow easy access to the removable modules. There is also a removable dust cover that fits over the faceplate that must be removed in order to access the keypad panel. The following figure shows the horizontal arrangement of the faceplate panel.

Figure 4-18: Standard horizontal faceplate



The following figure shows the vertical arrangement of the faceplate panel for relays ordered with the vertical option.

Figure 4-19: Standard vertical faceplate



4.2.7 LED indicators

4.2.7.1 Enhanced faceplate

The enhanced front panel display provides five columns of LED indicators. The first column contains 14 status and event-cause LEDs. 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 **USER** keys are used by the breaker control feature.

Figure 4-20: Typical LED panel for enhanced faceplate



The status indicators in the first column are as follows:

- **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 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 as follows.

Event-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 the 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, and so on. 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 C70, together with custom templates. The default labels can be replaced by user-printed labels.

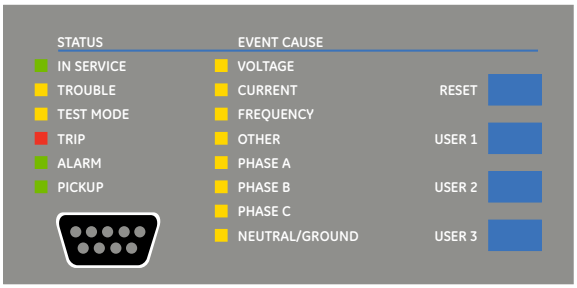
User customization of LED operation is of maximum benefit in installations where languages other than English are used to communicate with operators. See the User-Programmable LEDs section in chapter 5 for the settings used to program the operation of the LEDs on these panels.

4.2.7.2 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 4-21: LED panel 1



Status indicators

- **IN SERVICE** — Indicates that control power is applied, all monitored inputs/outputs and internal systems are fine, 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

Event-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 the 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, and so on. 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.

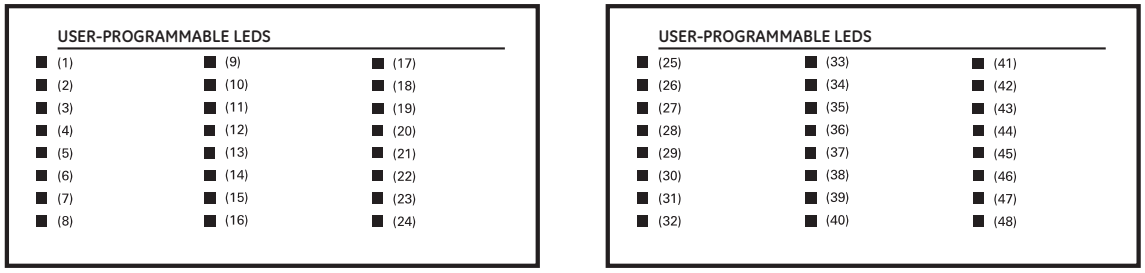
- **VOLTAGE** — Indicates voltage was involved
- **CURRENT** — Indicates current was involved
- **FREQUENCY** — Indicates frequency was involved
- **OTHER** — Indicates a composite function that is not solely current, voltage, or frequency based (distance or power for example) or a control function (digital 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 panels 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. See the User-programmable LEDs section in chapter 5 for the settings used to program the operation of the LEDs on these panels.

Figure 4-22: LED panels 2 and 3 (index template)



842782A1.CDR

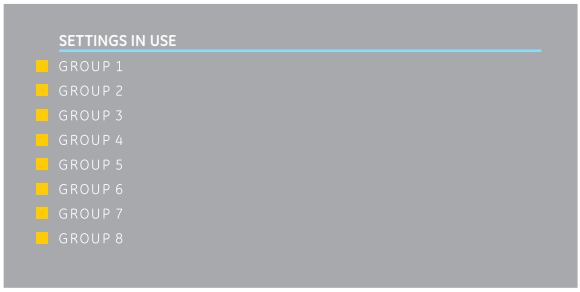
Default labels for LED panel 2

The default labels are intended to represent the following:

- **GROUP 1...6** — The illuminated GROUP is the active settings group

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 next section.

Figure 4-23: LED panel 2 (default labels)



842783A1.CDR

4.2.8 Custom LED labeling

4.2.8.1 Enhanced faceplate

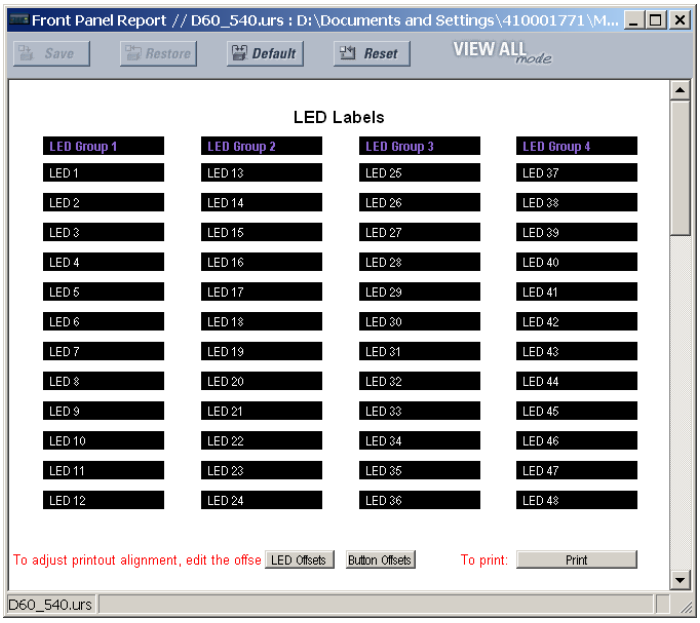
The following procedure requires these pre-requisites:

- EnerVista UR Setup software is installed and operational
- The C70 settings have been saved to a settings file
- The UR front panel label cutout sheet (GE 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 navigation menu for the settings file. The front panel report window displays.

Figure 4-24: Front panel report window



3. Enter the text to appear next to each LED and above each user-programmable pushbutton in the fields provided.
4. Feed the UR 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 UR 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

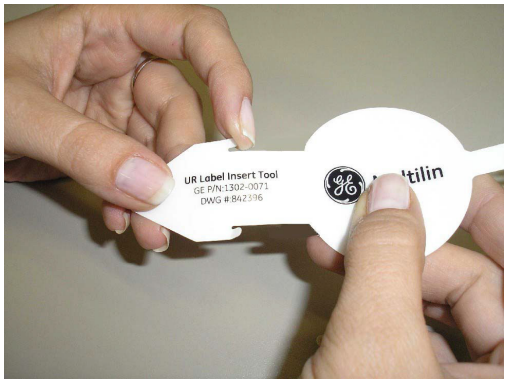
Use the tool EXACTLY as outlined as follows, with the printed side containing the GE part number facing the user.

The label package shipped with every C70 contains the three default labels, the custom label template sheet, and the label removal tool.

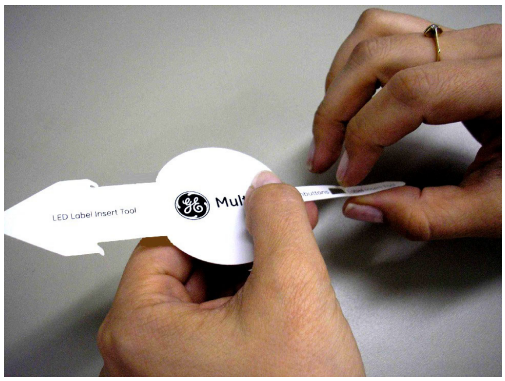
If the default labels are suitable for your application, insert them in the appropriate slots and program the LEDs to match them. If you require custom labels, use the following procedures to remove the original labels and insert the new ones.

To set up and use the label removal tool:

1. Bend the tabs at the left end of the tool upwards as shown.



Bend the tab at the center of the tool tail as shown.



To remove the LED labels from the C70 enhanced front panel and insert the custom labels:

1. Use the knife to lift the LED label and slide the label tool underneath. Ensure that 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. This attaches the label tool to the LED label.



3. Remove the tool and attached LED label as shown.

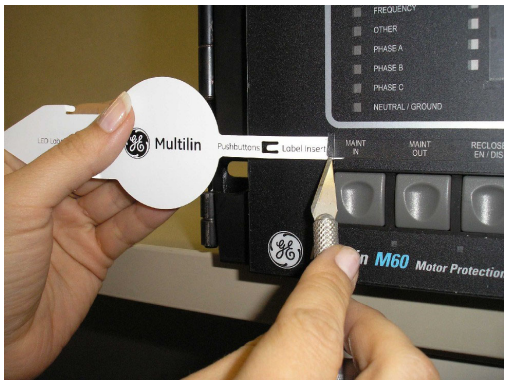


4. Slide the new LED label inside the pocket until the text is properly aligned with the LEDs, as shown.



To remove the user-programmable pushbutton labels from the C70 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. Ensure that the bent tab points away from the relay.



2. Slide the label tool under the user-programmable pushbutton label until the tabs snap out as shown. This attaches the

label tool to the user-programmable pushbutton label.



3. Remove the tool and attached user-programmable pushbutton label.



4. Slide the new user-programmable pushbutton label inside the pocket until the text is properly aligned with the

buttons.



4.2.9 Breaker control

The C70 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 the faceplate keypad or automatically initiated from a FlexLogic operand. A setting is provided to assign names to each breaker; this user-assigned name is 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.

It is assumed in the following discussion that the **SETTINGS** ⇨⇩ **SYSTEM SETUP** ⇨⇩ **BREAKERS** ⇨ **BREAKER 1(2)** ⇨ **BREAKER FUNCTION** setting is "Enabled" for each breaker.

4.2.9.1 Control mode selection and monitoring

Installations can require that a breaker be 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 that the **SETTINGS** ⇨⇩ **SYSTEM SETUP** ⇨⇩ **BREAKERS** ⇨ **BREAKER 1(2)** ⇨⇩ **BREAKER 1(2) PUSH BUTTON CONTROL** setting is “Enabled” for each breaker.

4.2.9.2 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.

4.2.9.3 Control of two breakers

For the following setup example, the **(Name)** field represents the user-programmed variable name.

For this example, 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 manually closes the breaker, and the **USER 3** key manually opens 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, that is, 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 displays 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 the following items (1), (2) and (3).
(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 cancels the breaker control function.

4.2.9.4 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 in the previous section for two breakers.

4.2.10 Change passwords

The information in this section refers to password security. For information on how to set the password for the first time or change CyberSentry passwords, see the previous chapter or the Settings > Product Setup > Security > CyberSentry section in the next chapter.

The C70 supports password entry from a local or remote connection.

Local access is defined as access to settings or commands via the faceplate. This includes both keypad entry and the RS232 port. Remote access is defined as access to settings or commands via any rear communications port. This includes both Ethernet and RS485 connections. Any change to the local or remote password 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 C70, the remote password must be used. If the connection is to the RS232 port of the faceplate, the local password must be used.

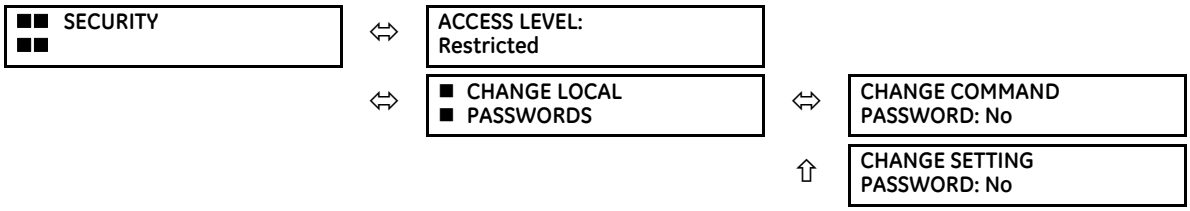
There are two user security access levels, setting and command, for which you can set a password for each. Use of a password for each level controls whether users can enter commands or change settings. Another option is to specify setting and/or command access for individual user accounts.

- **Setting** — Allows the user to make any changes to any of the setting values:
  - Changing any setting
  - Test mode operation
- **Command** — Restricts the user from making any settings changes, but allows the user to perform the following operations:
  - Changing the state of virtual inputs
  - Clearing the event records

- Clearing the oscillography records
- Changing the date and time
- Clearing the data logger
- Clearing the user-programmable pushbutton states

To enter the initial setting or command password:

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 arrow until the **ACCESS LEVEL** message appears on the display.
3. Press the **MESSAGE** down arrow until the **CHANGE LOCAL PASSWORDS** message appears on the display.
4. Press the **MESSAGE** right arrow 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 arrow 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 **VERIFY NEW PASSWORD** displays, re-type the password and press **ENTER**.



9. When the **NEW PASSWORD HAS BEEN STORED** message appears, your new Setting (or Command) password is active.

4.2.11 Invalid password entry

By default, when an incorrect Command or Setting password has been entered via the faceplate interface three times within five minutes, the LOCAL ACCESS DENIED FlexLogic operand is set to "On" and the C70 does not allow settings or command level access via the faceplate interface for five minutes.

By default, when an incorrect Command or Setting password has been entered via any external communications interface three times within five minutes, the REMOTE ACCESS DENIED FlexLogic operand is set to "On" and the C70 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**.

4.3 Logic diagrams

Logic diagrams in this instruction manual provide an overview of function and settings. A logic diagram is based on

- Inputs-on the left side, which are setting and operands

- Logical gates, which is Boolean algebra to combine logical lines using AND, OR, NOT, and other gates to get a new logical state
- Logical operators, which are timers, one-shot operations, latches, and so on
- Outputs-on the right side, which are products of the manipulations with inputs, logical gates, and logical operators to produce new operands and define the output state of the element

True and false values are denoted by 1 and 0 respectively. A function usually is high/on/enabled when 1.

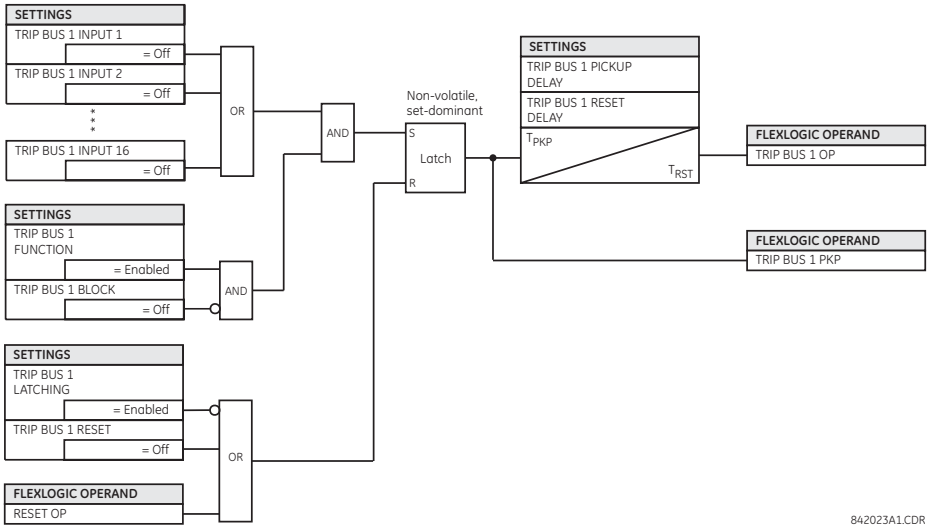
Reading from right to left in the following diagram, the TRIP BUS 1 OP and TRIP BUS 1 PKP FlexLogic operands on the right side are triggered when either the settings or reset latch in the middle of the diagram is triggered. When this applies, the TRIP BUS 1 OP operand is triggered after the delay set by the **TRIP BUS 1 PICKUP DELAY** or **TRIP BUS 1 RESET DELAY** setting, while the TRIP BUS 1 PKP operand initiates immediately. The settings or reset latch in the middle of the diagram is triggered as follows.

- For the reset, one of three conditions are required to meet the OR requirement shown at the bottom left. That is, the **TRIP BUS 1 LATCHING** setting must be 0=Disabled (which is negated by the NOT function to become 1=Enabled), output from the TRIP BUS 1 RESET FlexLogic operand must be 1, or output from the RESET OP FlexLogic operand must be 1.
- For the settings, one of 16 input conditions at the top left must be met for the OR, the **TRIP BUS 1 FUNCTION** must be Enabled, and the TRIP BUS 1 BLOCK output must output as 0, which is then negated/reversed by NOT to become 1.

Table 4-2: Logic diagram symbols

Symbol	Description
= Off	Output from FlexLogic operand, so user-defined
= Enabled	1 = Enabled and 0 = Disabled
OR	Any function input on the left side satisfies the condition
AND	All functions input on the left side are required to satisfy the condition
O	Not. Negates/reverses the output, for example 0 becomes 1.
●	Connection
S, R	Set, Reset
T_{PKP}	Timer pickup. Triggered by the settings latch in the diagram.
T_{RST}	Timer reset. Triggered by the reset latch in the diagram.

Figure 4-25: Logic diagram



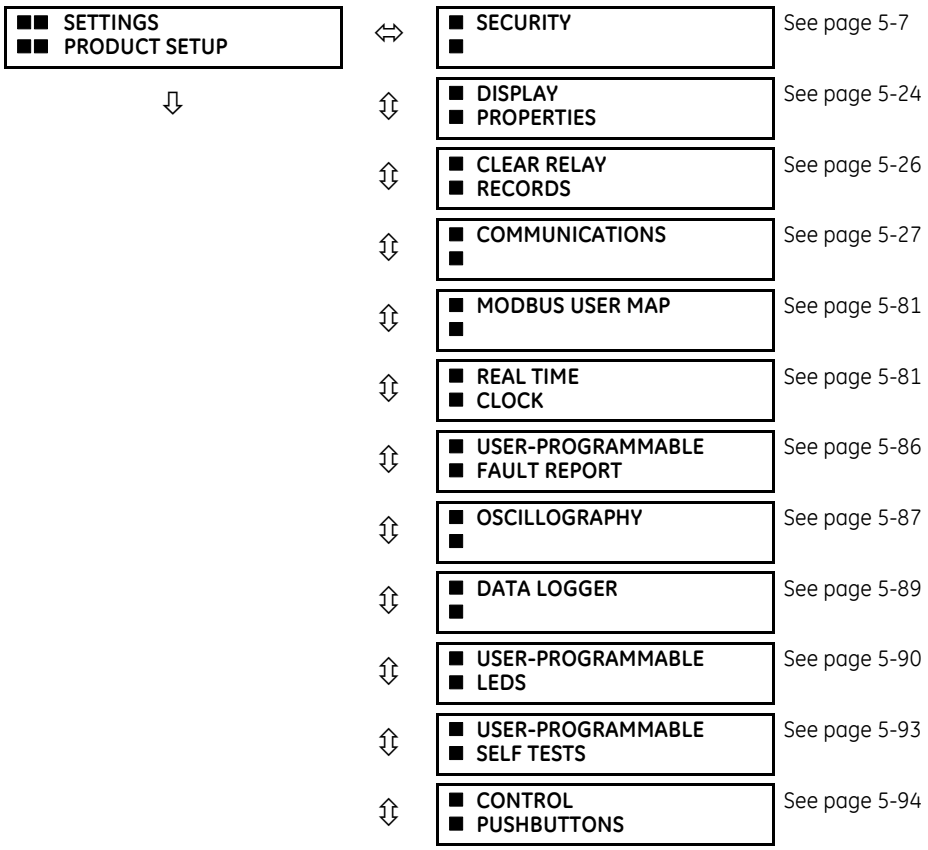
4

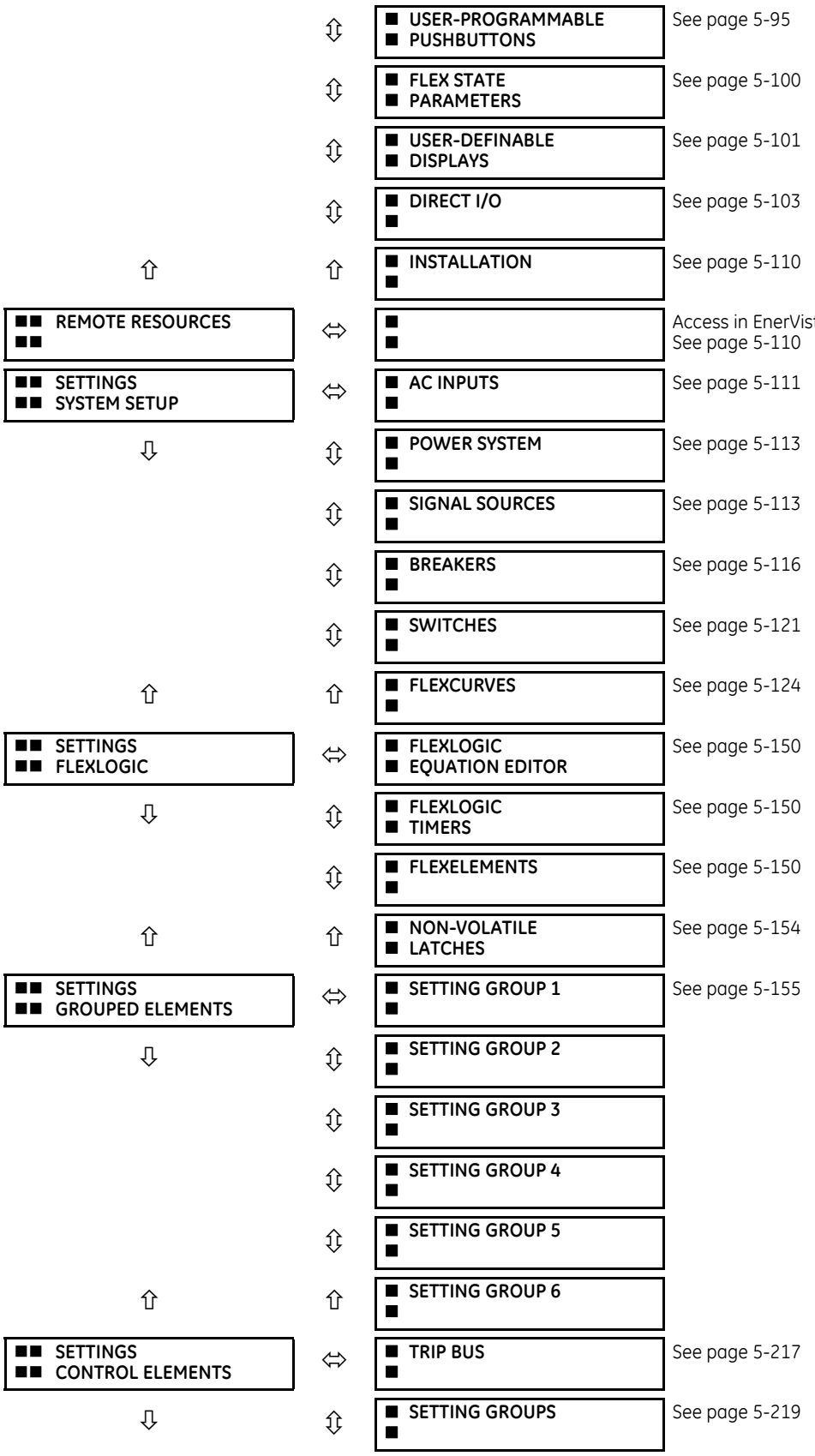
C70 Capacitor Bank Protection and Control System

Chapter 5: Settings

This chapter outlines front panel and/or software settings. The relay is not taken out of service when saving settings; the relay is taken out of service when a settings file is written to it.

5.1 Settings menu




■■ REMOTE RESOURCES
■■ SETTINGS
■■ SYSTEM SETUP
■■ SETTINGS
■■ FLEXLOGIC
■■ SETTINGS
■■ GROUPED ELEMENTS
■■ SETTINGS
■■ CONTROL ELEMENTS
■ USER-PROGRAMMABLE
■ PUSHBUTTONS
See page 5-95
■ FLEX STATE
■ PARAMETERS
See page 5-100
■ USER-DEFINABLE
■ DISPLAYS
See page 5-101
■ DIRECT I/O
■
See page 5-103
■ INSTALLATION
■
See page 5-110
■
■
Access in EnerVista
See page 5-110
■ AC INPUTS
■
See page 5-111
■ POWER SYSTEM
■
See page 5-113
■ SIGNAL SOURCES
■
See page 5-113
■ BREAKERS
■
See page 5-116
■ SWITCHES
■
See page 5-121
■ FLEXCURVES
■
See page 5-124
■ FLEXLOGIC
■ EQUATION EDITOR
See page 5-150
■ FLEXLOGIC
■ TIMERS
See page 5-150
■ FLEXELEMENTS
■
See page 5-150
■ NON-VOLATILE
■ LATCHES
See page 5-154
■ SETTING GROUP 1
■
See page 5-155
■ SETTING GROUP 2
■
■ SETTING GROUP 3
■
■ SETTING GROUP 4
■
■ SETTING GROUP 5
■
■ SETTING GROUP 6
■
■ TRIP BUS
■
See page 5-217
■ SETTING GROUPS
■
See page 5-219

	⇳	■ SELECTOR SWITCH ■	See page 5-220
	⇳	■ CAPACITOR CONTROL ■	See page 5-227
	⇳	■ TIME OF DAY TIMERS ■	See page 5-232
	⇳	■ AUTOMATIC VOLTAGE ■ REGULATOR	See page 5-233
	⇳	■ DIGITAL ELEMENTS ■	See page 5-237
	⇳	■ DIGITAL COUNTERS ■	See page 5-240
⇧	⇧	■ MONITORING ■ ELEMENTS	See page 5-242
■■ SETTINGS ■■ INPUTS / OUTPUTS	⇔	■ CONTACT INPUTS ■	See page 5-254
⇩	⇳	■ VIRTUAL INPUTS ■	See page 5-256
	⇳	■ CONTACT OUTPUTS ■	See page 5-257
	⇳	■ VIRTUAL OUTPUTS ■	See page 5-260
	⇳	■ RESETTING ■	See page 5-260
	⇳	■ DIRECT INPUTS ■	See page 5-261
⇧	⇧	■ DIRECT OUTPUTS ■	See page 5-261
■■ SETTINGS ■■ TRANSDUCER I/O	⇔	■ DCMA INPUTS ■	See page 5-265
⇩	⇳	■ RTD INPUTS ■	See page 5-266
⇧	⇧	■ DCMA OUTPUTS ■	See page 5-267
■■ SETTINGS ■■ TESTING	⇔	TEST MODE FUNCTION: Disabled	Range: Disabled, Test-Blocked, Test See page 5-270
⇩	⇳	TEST MODE FORCING: On	Range: FlexLogic operand See page 5-271
	⇳	■ FORCE CONTACT ■ INPUTS	See page 5-272
⇧	⇧	■ FORCE CONTACT ■ OUTPUTS	See page 5-272

5

5.2 Overview

5.2.1 Introduction to elements

For URs, 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 sets the output to logic 1, also referred to as *setting the flag*. A single comparator can 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.



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 a logic diagram. This includes the inputs, settings, fixed logic, and the output operands generated. The previous chapter explains how to read a logic diagram, and the abbreviations used in a diagram are defined in the Abbreviations chapter.

Some settings are specified in per-unit (pu) calculated quantities:

pu quantity = (actual quantity) / (base quantity)

Where the current source is from a single current transformer (CT), the *base quantity* is the nominal secondary or primary current of the CT. Use the secondary current base to convert per-unit 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:

$$\frac{13800}{14400} \times 120 = 115 \text{ V} \qquad \textbf{Eq. 5-1}$$

For wye-connected VTs, the primary and secondary base quantities are as before, but the secondary voltage setting (here a phase-to-ground value) is:

$$\frac{13800}{14400} \times \frac{120}{\sqrt{3}} = 66.4 \text{ V} \qquad \textbf{Eq. 5-2}$$

Many settings are common to most elements, outlined as follows:

- **FUNCTION setting** — This setting programs the element to operate when selected as "Enabled." The factory default is "Disabled." Once "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 can be provided to define the range of the measured parameters that cause the element to pick up.
- **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 remains 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 can happen when the element is in the operate state if the reset delay time is not zero.

  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.

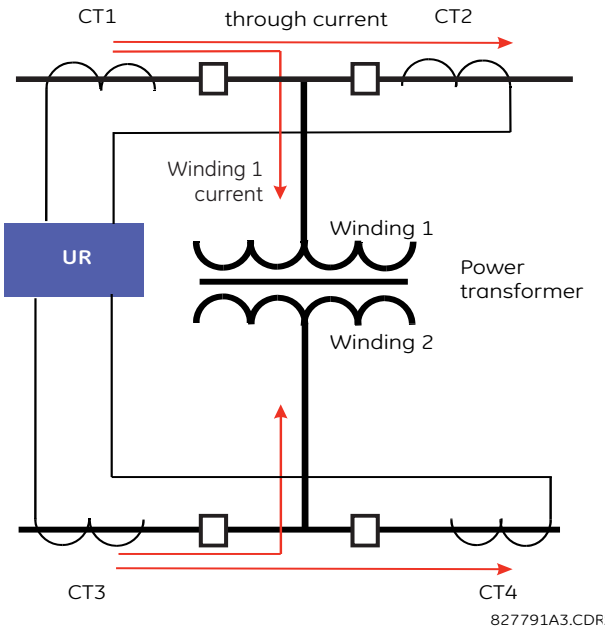
5.2.2 Introduction to AC sources

5.2.2.1 Background

A mechanism called a *source* configures the routing of CT and VT input channels to measurement sub-systems. Sources, in the context of UR 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 can contain all or some of the following signals: three-phase currents, single-phase ground current, three-phase voltages, and an auxiliary voltage from a single VT for checking for synchronism.

The basic idea of an AC source is to select a point on the power system where the voltages and currents are of interest. To illustrate the concept of sources, as applied to current inputs only, consider the breaker-and-a-half scheme that follows. (The breaker-and-a-half scheme is used for illustrative purposes and is available on select UR products.) In this application, the current flows as shown by the arrows. Some current flows through the upper bus bar to some other location or power equipment, and some current flows into transformer winding 1. The current into winding 1 is the phasor sum (or difference) of the currents in CT1 and CT2 (whether the sum or difference is used depends on the relative polarity of the CT connections). The same considerations apply to transformer winding 2. The protection elements require access to the net current for transformer protection, but some elements can need access to the individual currents from CT1 and CT2.

Figure 5-1: Breaker-and-a-half scheme



5

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 can flow. Auxiliary CTs are required to perform ratio matching if the ratios of the primary CTs to be summed are not identical. In the UR series of relays, provisions have been included for all the current signals to be brought to the UR device where grouping, ratio correction, and summation are applied internally via configuration settings.

A major advantage of using internal summation is that the individual currents are available to the protection device, for example as additional information to calculate a restraint current, or to allow the provision of additional protection 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 are to be added to form the net current into the protected device.

The internal grouping of current and voltage signals forms an AC source. This source can be given a specific name through the settings and becomes available to protection and metering elements in the UR platform. Individual names can be given to each source to help identify them for later use. For example, in the scheme shown in the preceding figure, the user configures one source to be the sum of CT1 and CT2 and can name this source as "Wdg1 I."

Once the sources have been configured, the user has them available as selections for the choice of input signal for the protection elements and as metered quantities.

5.2.2.2 CT/VT module configuration

CT and voltage transformer (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 can 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.

Increasing slot position letter -->		
CT/VT module 1	**CT/VT module 2**	**CT/VT module 3**
< bank 1 >	< bank 3 >	< bank 5 >
< bank 2 >	< bank 4 >	< bank 6 >

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 as follows.

Item	Maximum number
CT/VT Module	3
CT Bank (3 phase channels, 1 ground channel)	6
VT Bank (3 phase channels, 1 auxiliary channel)	6

5.2.2.3 CT/VT input channel configuration

Upon relay startup, configuration settings for every bank of current or voltage input channels in the relay are generated automatically from the order code. Within each bank, a channel identification label is assigned automatically 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 three channels.

Upon startup, the CPU configures the settings required to characterize the current and voltage inputs, and it displays them in the appropriate section in the sequence of the banks (as described earlier) as follows for a maximum configuration: F1, F5, M1, M5, U1, and U5.

5.3 Product setup

5.3.1 Security

5.3.1.1 Security overview

The following security features are available:

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

Lost password

If all passwords are lost, recovery is possible by resetting the unit to default values. Note that the relay is reset to default values, not just the passwords.

To reset the unit after a lost password:

1. Email GE customer service at multilin.tech@ge.com with the serial number and using a recognizable corporate email account. Customer service provides a code to reset the relay to the factory defaults.
2. Enter the reset code on the front panel, under **COMMANDS** ⇨⇩ **RELAY MAINTENANCE** ⇨ **SERVICE COMMAND**.

3. 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, ~, !, @, #, $,%, &)

5.3.1.2 Password security

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY

■ SECURITY ■	⇔	**ACCESS LEVEL:** **Restricted** — Range: Restricted, Command, Setting, Factory Service (for factory use only)
	⇳	■ **CHANGE LOCAL** ■ **PASSWORDS** — See page 5-9
	⇳	■ **CHANGE REMOTE** ■ **PASSWORDS** — See page 5-10
	⇳	■ **ACCESS** ■ **SUPERVISION** — See page 5-10
	⇳	■ **DUAL PERMISSION** ■ **SECURITY ACCESS** — See page 5-11
	⇧	**PASSWORD ACCESS:** **EVENTS: Disabled** — Range: Disabled, Enabled

The C70 supports password entry from a local or remote connection.

Local access is defined as access to settings or commands via the faceplate. This includes both keypad entry and the RS232 port. Remote access is defined as access to settings or commands via any rear communications port. This includes both Ethernet and RS485 connections. Any change to the local or remote password enables this functionality.

NOTE

For a relay without a CyberSentry software option, any user can activate the **RESET** button without password entry.

ACCESS LEVEL — The "Restricted" option means that settings and commands can be accessed, but there is no access to factory configuration. Access automatically reverts to the Restricted level according to the access level timeout setting values. The access level is set to Restricted when control power is cycled.

The "Factory Service" level is not available and intended for factory use only.

There are two user security access levels, setting and command, for which you can 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.

- **Setting** — Allows the user to make any changes to any of the setting values:
  - Changing any setting
  - Test mode operation

- **Command** — Restricts the user from making any settings changes, but allows the user to perform the following operations:
  - Changing the state of virtual inputs
  - Clearing the event records
  - Clearing the oscillography records
  - Changing the date and time
  - Clearing the data logger
  - Clearing the user-programmable pushbutton states

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 C70, the remote password must be used. If the connection is to the RS232 port of the faceplate, the local password must be used.

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 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.

PASSWORD ACCESS EVENTS — This setting allows recording of password access events in the event recorder.

Change local passwords

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ CHANGE LOCAL PASSWORDS

■ CHANGE LOCAL ■ PASSWORDS	⇔	CHANGE COMMAND PASSWORD: No	Range: No, Yes
	⇧	CHANGE SETTING PASSWORD: No	Range: No, Yes

As outlined in the previous section, there are two user security access levels, setting and command. Use of a password for each level controls whether users can enter commands or change settings.

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 and when power is cycled.

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.

Change remote passwords

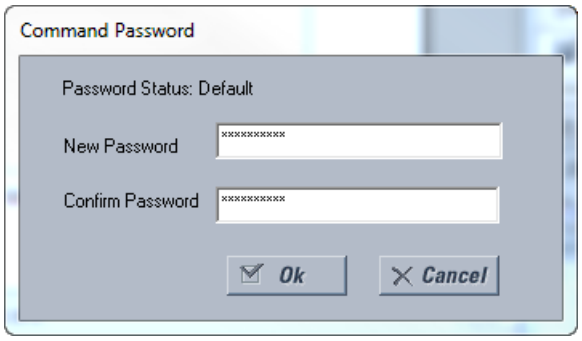
Proper passwords are required to enable each command or setting level access, which are explained in the previous section.

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ CHANGE REMOTE PASSWORDS

■ CHANGE REMOTE ■ PASSWORDS	⇔	CHANGE SETTING PASSWORD: No	Range: No, Yes
	⇧	CHANGE COMMAND PASSWORD: No	Range: No, Yes

To set the command or setting password:

1. In the EnerVista software or from the front panel, 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 earlier in this 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 it meets requirements.



NOTE

If you establish a local (serial) connection to the relay, you cannot view remote passcodes.

Access supervision

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ ACCESS SUPERVISION

■ ACCESS ■ SUPERVISION	⇔	■ ACCESS LEVEL ■ TIMEOUTS	See below
	⇕	INVALID ATTEMPTS BEFORE LOCKOUT: 3	Range: 2 to 5 in steps of 1

⇧ **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 that 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 C70 locks out password access after the number of invalid password entries specified by the **INVALID ATTEMPTS BEFORE LOCKOUT** setting has occurred.

The C70 provides a means to raise an alarm upon failed password entry. If password verification fails 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, password-protect the Command level. The operand does not generate events or targets.

If events or targets are required, the UNAUTHORIZED ACCESS operand can be assigned to a digital element programmed with event logs or targets enabled.

The following table outlines access level timeout settings.

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

⇧ **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 is set to Restricted when 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

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ DUAL PERMISSION SECURITY ACCESS

■ **DUAL PERMISSION SECURITY ACCESS**

⇔ **LOCAL SETTING AUTH: On** Range: selected FlexLogic operands (see below)

⇳ **REMOTE SETTING AUTH: On** Range: FlexLogic operand

⇧ **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.

This feature provides a mechanism to prevent unauthorized or unintended upload of settings to a relay through the local or remote 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 (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 displays on the front panel.

If this setting is "Off," firmware upgrades are blocked. If this setting is "On," firmware upgrades are allowed.

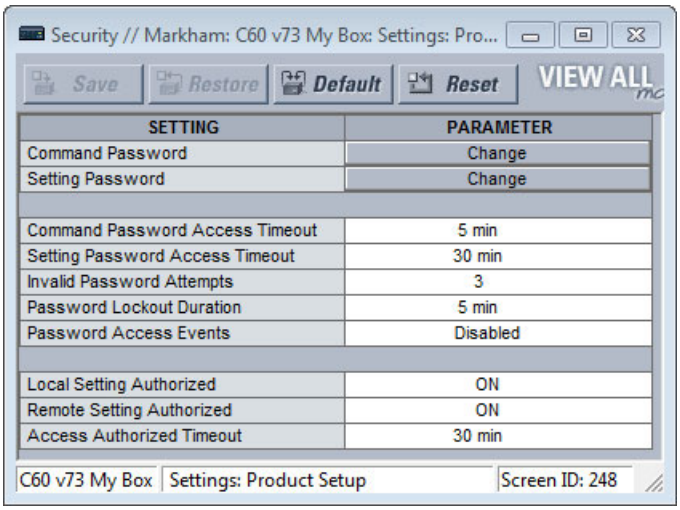
- **REMOTE SETTING AUTH** — This setting is used for remote (Ethernet or RS485 interface) setting access supervision.

  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 monitored continuously 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 updates 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 interface) 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 (on) prior to providing the remote setting password to gain setting access.

The **Access Authorized Timeout** setting represents the timeout delay remote setting access. It applies 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 denied immediately. 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 updates every five seconds.

5.3.1.3 EnerVista security

Enable the security management system

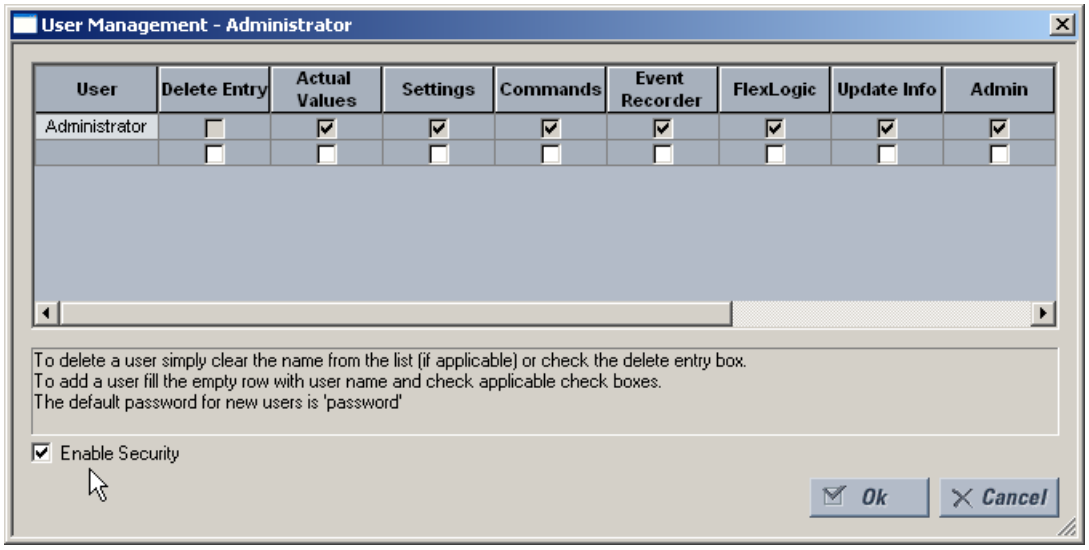
Access to files is controlled by the operating system and EnerVista software as follows:

- 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 to open the user management window.



2. Enable the **Enable Security** check box in the lower-left corner to enable the security management system.
3. Click the **Ok** button.

NOTE

If you force password entry by using this feature, ensure that you know the Administrator password. If you do not know the password and are locked out of the software, contact GE Grid Solutions for the default password of a UR device. 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.

Add a new user

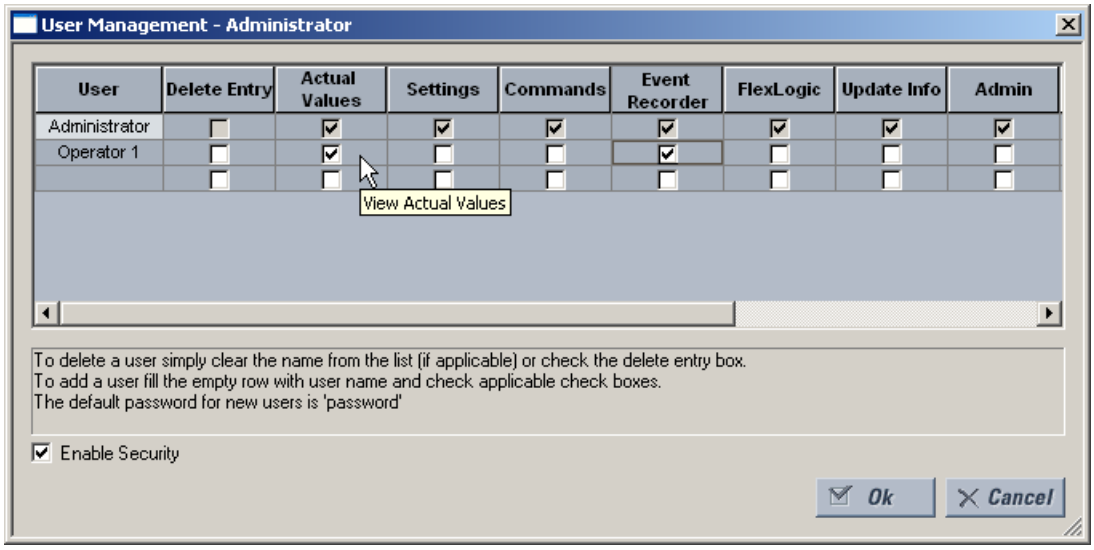
The following pre-requisites are required to add user accounts to the EnerVista security management system:

- The user adding the account must have administrator rights
- The EnerVista security management system must be enabled (previous section)

To add a user account:

1. Select the **Security > User Management** item from the top menu to open the user management window.
2. Enter a username in the **User** field. The username must be four to 20 characters in length.

3. Select the user access rights by enabling the check box of one or more 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 **Settings** values
Commands	Allows the user to execute **Commands**
Event Recorder	Allows the user to use the **Event 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 enabled, even if the **Update Info** field is enabled.
Admin	When the check box is enabled, the user becomes an EnerVista UR Setup administrator and has all administrative rights. Exercise caution when granting administrator rights.

4. Click **OK** to add the user account to the system.

Modify user privileges

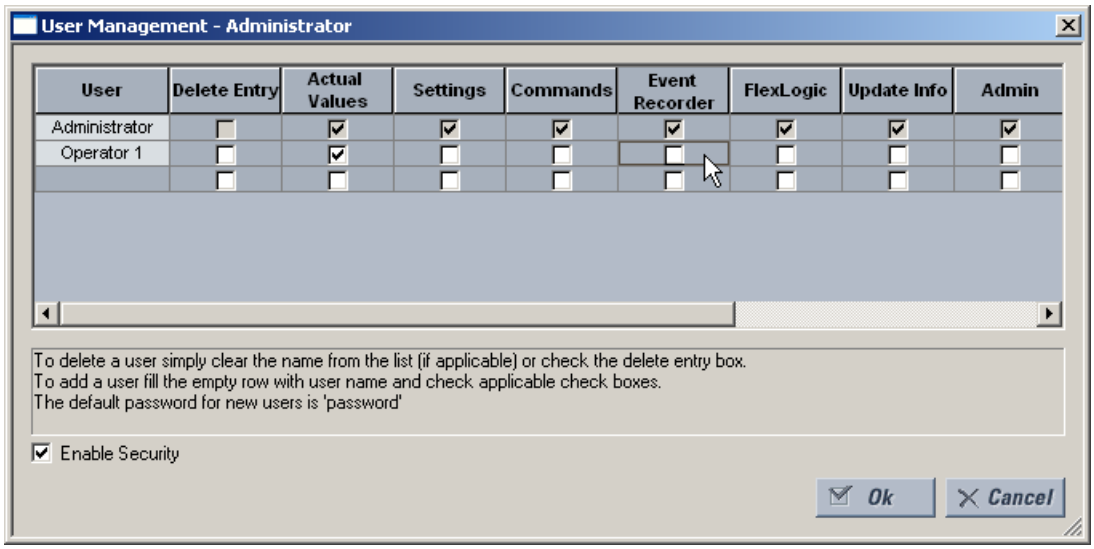
The following pre-requisites are required to modify user privileges in the EnerVista security management system:

- The user modifying the privileges must have administrator rights
- The EnerVista security management system must be enabled (the **Enable Security** check box enabled)

To modify user privileges:

1. Select the **Security > User Management** item from the top menu 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 enabled, even if the **Update Info** field is enabled.
Admin	When this check box is enabled, the user becomes an EnerVista UR Setup administrator and has all administrative rights. Exercise caution when granting administrator rights.

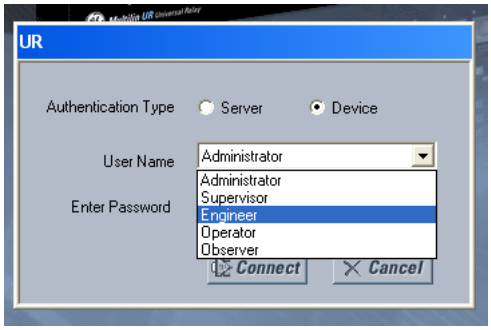
4. Click **OK** to save the changes.

5.3.1.4 CyberSentry security

The EnerVista software provides the means to configure and authenticate the C70 access using either a server or the device. Access to functions depends on user role.

The login screen of EnerVista has two options for access to the C70, these being Server and Device authentication.

Figure 5-2: Login screen for CyberSentry



When the "Server" **Authentication Type** is selected, the C70 uses the RADIUS server and not its local authentication database to authenticate the user.

When the "Device" button is selected, the C70 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 C70 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 the UR device, nor are they ever transmitted without cryptographic protection.

5

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 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.

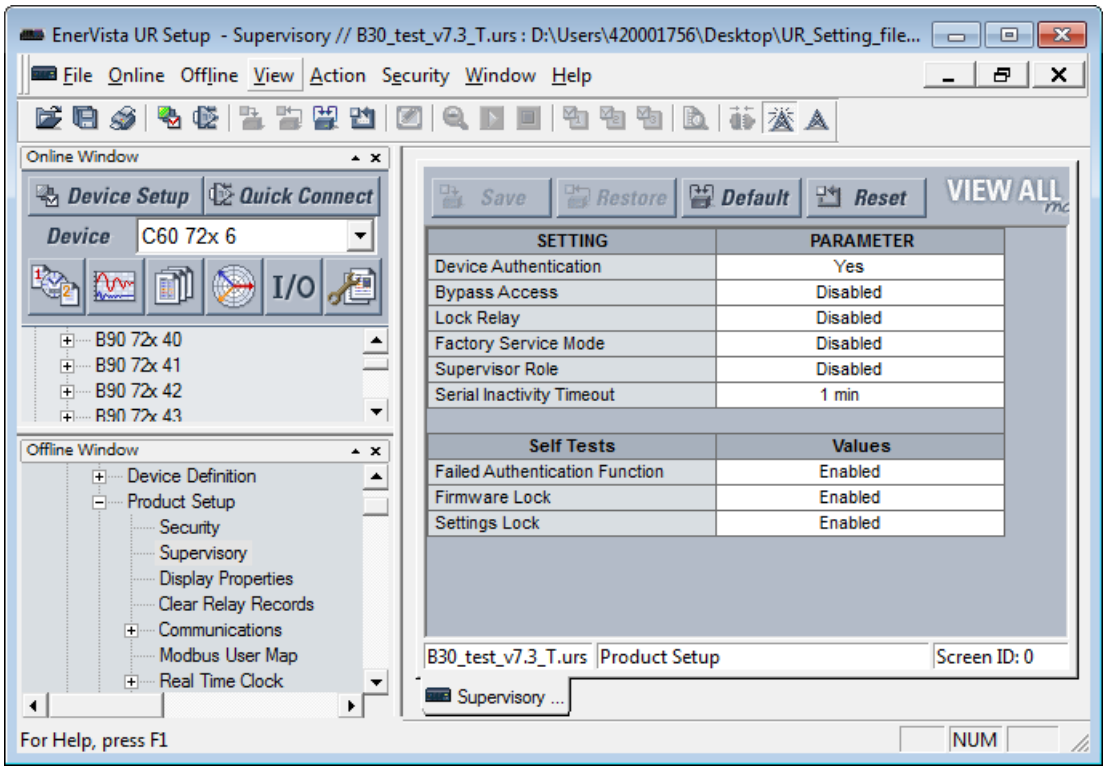
When using the rear RS485 port and CyberSentry, registers can be read with a maximum buffer of 64 bytes. Settings may or may not be written, so use another port or configure the **SERIAL INACTIVITY TIMEOUT** setting to a high value, such as eight minutes, to give the relay enough time to finish the task.

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.

Table 5-3: RADIUS server settings

Setting name	Description	Minimum	Maximum	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 earlier in this chapter	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

Table 5-4: General security settings

Setting name	Description	Minimum	Maximum	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 Lock (via Lock Relay)	Indicates if the device receives firmware upgrades. If Enabled 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. The Lock Relay setting blocks settings and firmware updates.	Disabled	Enabled	Enabled	-	Administrator
Factory Service Mode	When enabled, 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
Supervisor Role	When enabled, 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	Ensures that RADIUS user names are not the same as local/device role names	See RADIUS server documents	See RADIUS server document s		-	Administrator
Password	Local/device roles except for Observer are password-protected. All RADIUS users are password-protected.	See the Password Requirements section earlier in this chapter	See the following password section for requireme nts	Change Me1#	Text	The specified role and Administrator, except for Supervisor, where it is only itself

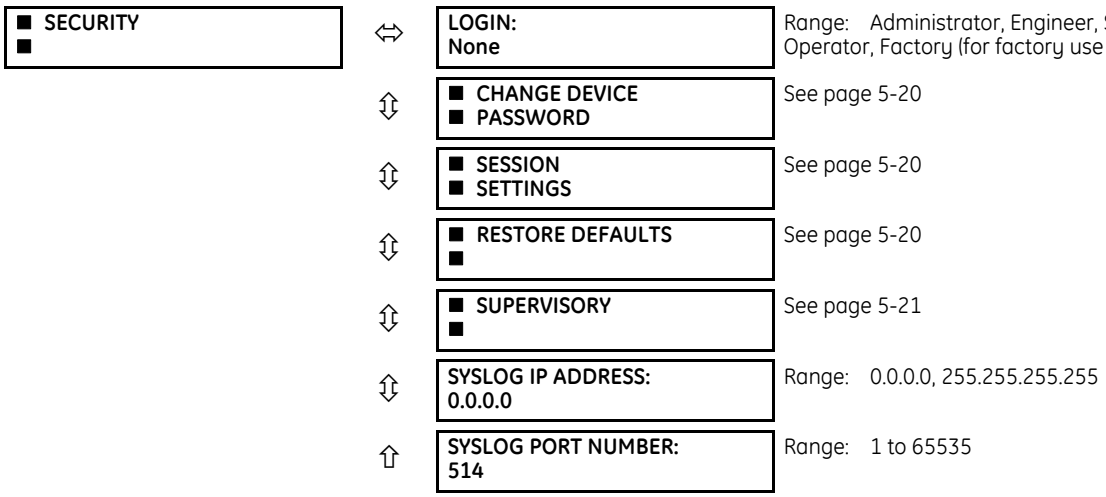
Table 5-5: Security alarm settings

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	Disabled	Enabled	Enabled	-	Administrator

Setting name	Description / Details	Min	Max	Default	Units	Minimum permissions
Firmware Lock	A value indicating if the device can receive a firmware upgrade. If Enabled and a firmware upgrade attempt is made, the device alarm activates. If Disabled, the device alarm does not activate. On each firmware upgrade this setting goes back to the default.	Disabled	Enabled	Enabled	-	Administrator
Settings Lock	A value indicating if the device can accept any settings changes. If Enabled and a settings change attempt is made, the device alarm activates. If Disabled, the device alarm does not activate.	Disabled	Enabled	Enabled	-	Supervisor (Administrator if Supervisor has been disabled)

CyberSentry settings through the front panel

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY



LOGIN — This setting is applicable for Device authentication only. This setting allows a user to log in with a specific role, as outlined here. For the Supervisor role, enable the "Supervisor Role" setting.

Whenever a new role is logged in, the user is prompted to enter a password. Passwords must obey the requirements specified earlier in the chapter in the Password Requirements section.The UR device supports five roles. Roles have their corresponding passwords, except the Observer role, which 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/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/write access to all settings and commands except 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 Commands 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 a Supervisor can set the Settings Lock and Firmware Lock in the Security settings. This role also has the ability to forcefully log off 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 C70 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. When local authentication is used, no password is required for this role. When RADIUS server authentication is used, a password is required.

NOTE

The Factory service role is not available. It is for factory use only.

Change device password

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ CHANGE DEVICE PASSWORD

■ CHANGE DEVICE PASSWORD	⇔	NEW PASSWORD:	Range: 20 alphanumeric characters
	⇧	CONFIRM PASSWORD:	Range: 20 alphanumeric characters

The menu displays on the front panel and in EnerVista upon successful login of the Administrator role.

Passwords are stored in text format. No encryption is applied.

NOTE

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.

If you are locked out of the software, contact GE Grid Solutions for the default password. When using CyberSentry, 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

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ SESSION SETTINGS

■ SESSION SETTINGS	⇔	SESSION LOCKOUT: 3	Range: 0 to 99
	⇧	SESSION LOCKOUT PERIOD: 3 min	Range: 0 to 9999 minutes

SESSION LOCKOUT — This setting specifies the number of failed authentications 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. A value of 0 means that there is no lockout period.

Restore defaults

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ RESTORE DEFAULTS

■ RESTORE DEFAULTS ■	⇔	LOAD FACTORY DEFAULTS: No	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

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ SUPERVISORY

■ SUPERVISORY ■	⇔	DEVICE AUTHENTICATION: Yes	Range: Yes, No
	⇩	BYPASS ACCESS: Disabled	Range: Local, Remote, Local and Remote, Disabled
	⇩	LOCK RELAY: Disabled	Range: Enabled, Disabled
	⇩	FACTORY SERVICE MODE: Disabled	Range: Enabled, Disabled
	⇩	■ SELF TESTS ■	See below
	⇩	SUPERVISOR ROLE: Disabled	Range: Enabled, Disabled
	⇧	SERIAL INACTIVITY TIMEOUT: 1 min	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 settings 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 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

LOCK RELAY — This setting uses a Boolean value (Enabled/Disabled) to indicate if the device accepts settings changes and whether the device can receive a firmware upgrade. This setting can be changed by the Supervisor role, if it is enabled, or by the Administrator if the Supervisor role is disabled. The Supervisor role disables this setting for the relay to start accepting settings changes, command changes, or firmware upgrade. After all the setting changes are applied or commands executed, the Supervisor enables to lock settings changes.

Example: If this setting is enabled and an attempt is made to change settings or upgrade the firmware, the UR device denies the settings changes or denies upgrading the firmware. If this setting is disabled, the UR device accepts settings changes and firmware upgrade.

This role is disabled by default.

FACTORY SERVICE MODE — When Enabled, 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, the Supervisor role is active. To Disable this setting a Supervisor authentication is necessary. If disabled, the Supervisor role is not allowed to log in. 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 their role after authentication, the Supervisor session remains valid until they switch to another role using MMI or until they end 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.

Self-tests

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ SUPERVISORY ⇨ SELF TESTS

■ SELF TESTS ■	⇔	■ FAILED ■ AUTHENTICATE	See below
	⇩	FIRMWARE LOCK: Enabled	Range: Enabled, Disabled
	⇧	SETTINGS LOCK: Enabled	Range: Enabled, Disabled

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.

SETTINGS ⇨ PRODUCT SETUP ⇨ SECURITY ⇨⇩ SUPERVISORY ⇨ SELF TESTS ⇨ FAILED AUTHENTICATE

■ FAILED ■ AUTHENTICATE	⇔	FAILED AUTHENTICATE: Enabled	Range: Enabled, Disabled

CyberSentry setup

When first using CyberSentry security, use the following procedure for setup.

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.
5. 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 at the end of this instruction manual gives an example of how to set up a simple RADIUS server. Once both the RADIUS server and the parameters for connecting the 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.

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.

For all user roles except Observer, only one instance can be logged in at a 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**.

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 5-6: 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

5.3.2 Display properties

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES

■ DISPLAY ■ PROPERTIES	⇔	LANGUAGE: English	Range: English; English, French; English, Russian; English, Chinese; English, German (examples; depends on order code) Visible when language other than English purchased

⇳	**FLASH MESSAGE TIME: 1.0 s**	Range: 0.5 to 10.0 s in steps of 0.1
⇳	**DEFAULT MESSAGE TIMEOUT: 300 s**	Range: 10 to 900 s in steps of 1
⇳	**DEFAULT MESSAGE INTENSITY: 25 %**	Range: 25%, 50%, 75%, 100% Visible when a VFD is installed
⇳	**SCREEN SAVER FEATURE: Disabled**	Range: Disabled, Enabled Visible when an LCD is installed
⇳	**SCREEN SAVER WAIT TIME: 30 min**	Range: 1 to 65535 min. in steps of 1 Visible when an LCD is installed
⇳	**CURRENT CUT-OFF LEVEL: 0.020 pu**	Range: 0.002 to 0.020 pu in steps of 0.001
⇧	**VOLTAGE CUT-OFF LEVEL: 1.0 V**	Range: 0.1 to 1.0 V secondary in steps of 0.1

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. This 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, and information messages displayed in response to certain key presses during settings programming. These messages override any normal messages. Use this setting to change the duration of flash messages on the display.

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 using this setting to ensure that 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 C70 has a liquid crystal display (LCD) and control its backlighting. When the **SCREEN SAVER FEATURE** is "Enabled," the LCD backlighting turns off after the **DEFAULT MESSAGE TIMEOUT** followed by the **SCREEN SAVER WAIT TIME**, provided that no keys have been pressed and no target messages are active. When a keypress occurs or a target becomes active, the LCD backlighting turns 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 to display even when the value reflects noise rather than the actual signal. The C70 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.

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 C70 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 to 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 using the following equations. 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** × **PHASE VT RATIO** = 66.4 V × 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 does not display. As well, the three-phase energy data do 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.

5.3.3 Clear relay records

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ CLEAR RELAY RECORDS

■ CLEAR RELAY ■ RECORDS	⇔	**CLEAR USER REPORTS:** **Off**	Range: FlexLogic operand
	⇩	**CLEAR EVENT RECORDS:** **Off**	Range: FlexLogic operand
	⇩	**CLEAR OSCILLOGRAPHY:** **Off**	Range: FlexLogic operand
	⇩	**CLEAR DATA LOGGER:** **Off**	Range: FlexLogic operand
	⇩	**RESET UNAUTH ACCESS:** **Off**	Range: FlexLogic operand
	⇩	**CLEAR DIR I/O STATS:** **Off**	Range: FlexLogic operand Visible only for units with Direct I/O module

RESET UNAUTH ACCESS — Resets the access restriction counter.

Selected records can be cleared from user-programmable conditions with FlexLogic operands. Assigning user-programmable pushbuttons to clear specific records is a typical application for these commands. Since the C70 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, apply the following settings.

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"

5.3.4 Communications

5.3.4.1 Menu

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS

■ COMMUNICATIONS ■	⇔	■ SERIAL PORTS ■	See below
	⇳	■ NETWORK ■	See page 5-28
	⇳	■ ROUTING ■	See page 5-33
	⇳	■ MODBUS PROTOCOL ■	See page 5-36
	⇳	PROTOCOL: DNP 3.0	Range: DNP 3.0, IEC 60870-5-104, IEC 60870-5-103 See page 5-36
	⇳	■ DNP PROTOCOL ■	See page 5-37
	⇳	■ DNP / IEC104 ■ POINT LISTS	See page 5-40
	⇳	■ IEC 61850 PROTOCOL ■	Access in EnerVista See page 5-41
	⇳	■ WEB SERVER ■ HTTP PROTOCOL	See page 5-73
	⇳	■ TFTP PROTOCOL ■	See page 5-74
	⇳	■ IEC 60870-5-104 ■ PROTOCOL	See page 5-74
	⇳	■ IEC103 ■ PROTOCOL	See page 5-76

5.3.4.2 Serial ports

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨ SERIAL PORTS

■ SERIAL PORTS ■	⇔	RS232 BAUD RATE: 115200	Range: 19200, 115200
	⇳	RS485 COM2 BAUD RATE: 19200	Range: 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, 115200 bit/s

⇳	**RS485 COM2 PARITY: Even**	Range: None, Odd, Even
⇧	**RS485 COM2 RESPONSE MIN TIME: 0 ms**	Range: 0 to 1000 ms in steps of 10

RS232 BAUD RATE, **RS485 COM2 BAUD RATE**, and **PARITY** — The C70 is equipped with two independent serial communication ports. The faceplate RS232 port is intended for local use and has two options for baud rate. 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 the EnerVista software. 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.

5.3.4.3 Ethernet network topology

The C70 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.

5

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

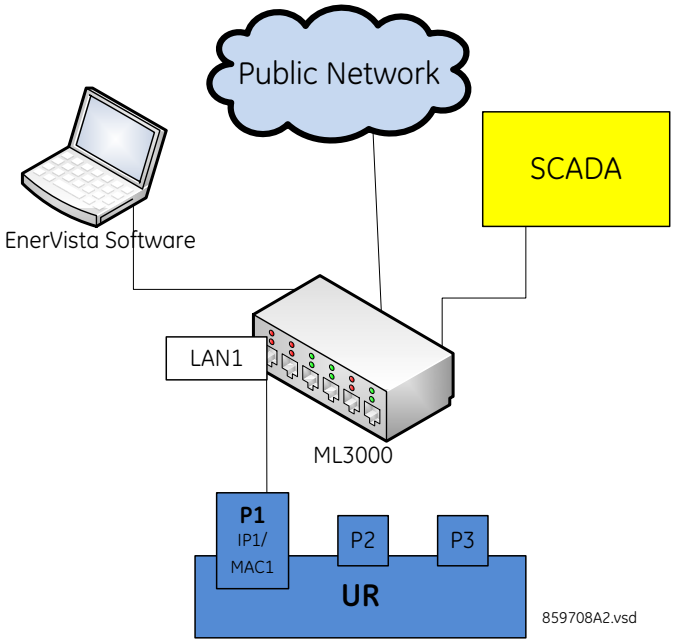
IP3/Mask3: 10.3.1.2/255.0.0.0

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.

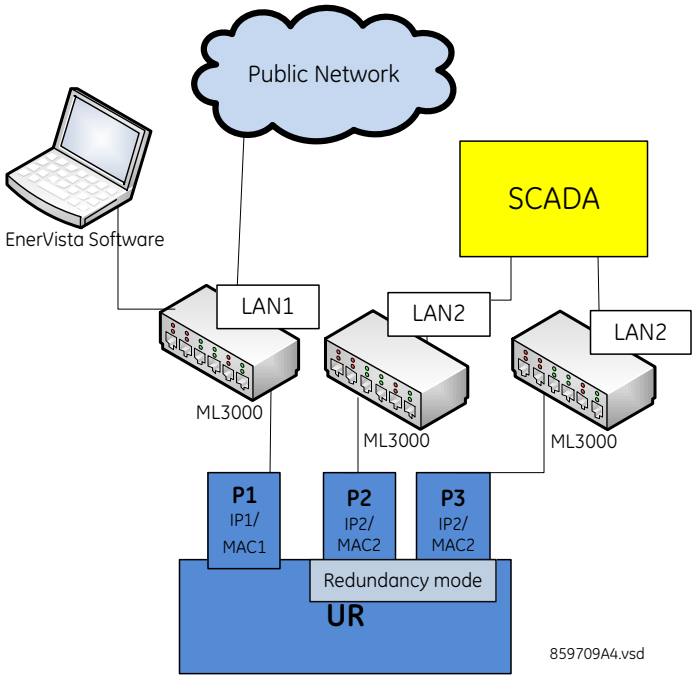
Figure 5-4: Network configuration for single LAN



Multiple LANS, with redundancy

The following topology 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 addresses of P2.

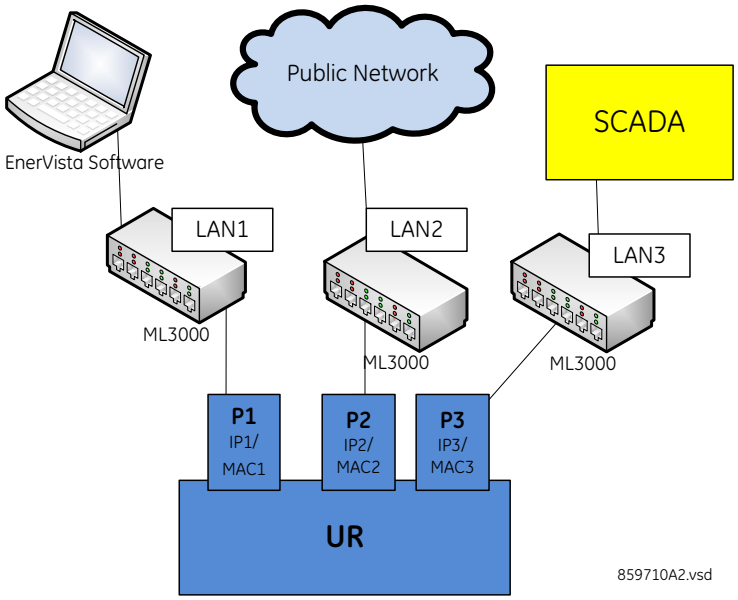
Figure 5-5: Multiple LANs, with redundancy



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



5

5.3.4.4 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.

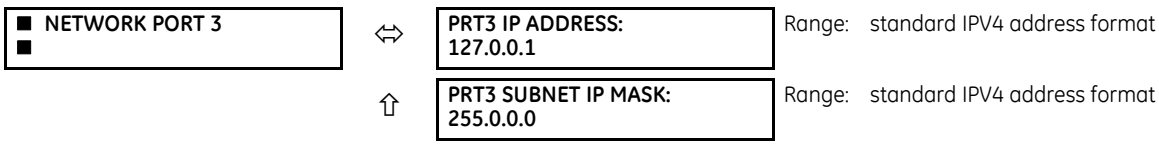
Follow the IP and subnet mask rules outlined in the Configuring the UR for Software Access section of the Installation chapter.

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.

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ NETWORK 1(3)

■ NETWORK PORT 1 ■	⇔	PRT1 IP ADDRESS: 127.0.0.1	Range: standard IPV4 address format
	⇧	PRT1 SUBNET IP MASK: 255.0.0.0	Range: standard IPV4 address format

■ NETWORK PORT 2 ■	⇔	PRT2 IP ADDRESS: 127.0.0.1	Range: standard IPV4 address format
	⇳	PRT2 SUBNET IP MASK: 255.0.0.0	Range: standard IPV4 address format
	⇳	PRT2 REDUNDANCY: None	Range: None, Failover, PRP Range if no PRP license: None, Failover
	⇧	PRP MCST ADDR: 01-15-4E-00-01-00	Range: 01-15-4E-00-01-00 to 01-15-4E-00-01-FF



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.

Use the front panel to change these settings. When online, the EnerVista software can be used to enable/disable each port only. In the Offline Window area, all settings can be changed except port 2 redundancy.

PRT1 (2 or 3) IP ADDRESS — This setting sets the port's 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 port's IPv4 subnet mask in standard IPV4 format. This setting is valid on port 3 if port 2 **REDUNDANCY** is set to None.

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 C70, 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 any changes to this setting to take effect, restart the unit.

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.

5.3.4.5 Far-End Fault Indication (FEFI)

Since 100BASE-FX does not support Auto-Negotiation, a Far-End Fault Indication (FEFI) feature is included since 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 for substation automation that support the Far-End Fault feature, especially when UR 7 redundancy Failover is selected for redundancy.

5.3.4.6 Parallel Redundancy Protocol (PRP)

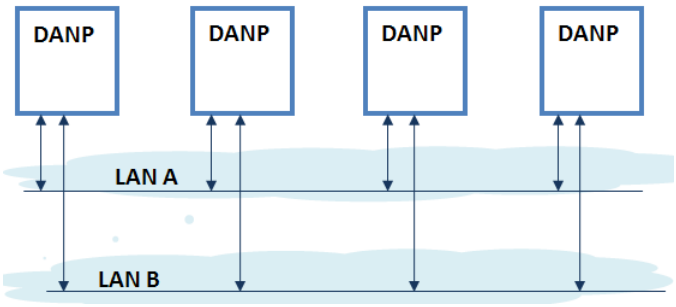


The C70 is provided with optional PRP capability. This feature is specified as a software option at the time of ordering. See the Order Codes section in chapter 2 for details.

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 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. 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 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. DANP devices have an additional module, called a 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.

In addition, 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 the DANP functionality. The RedBox functionality is not implemented.

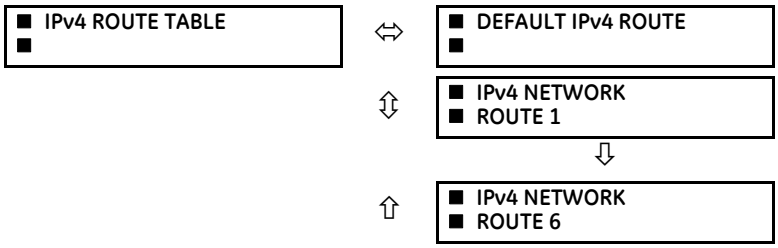
The original standard IEC 62439-3 (2010) was amended to align PRP with the High-availability Seamless Redundancy (HSR) protocol. To achieve this, the original PRP was modified at the cost of losing compatibility with the PRP 2010 version. The revised standard IEC 62439-3 (2012) is commonly referred to as PRP-1, while the original standard is PRP-0. The UR relays support PRP-1.

The relay implements PRP on two of its Ethernet ports, specifically Ports 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 (Ports 2 and 3) operate in redundant mode. In this mode, Port 3 uses the MAC, IP address, and mask of Port 2.

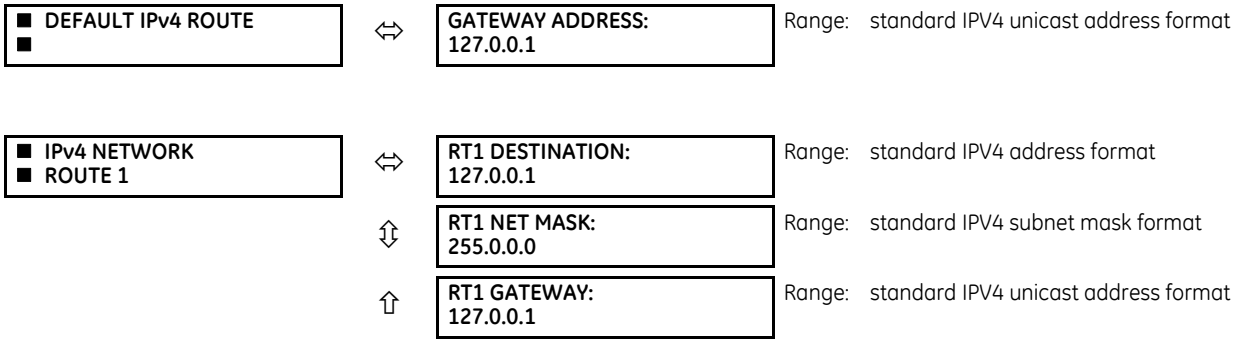
5.3.4.7 Routing

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IPv4 ROUTE TABLE 1(6)



A default route and up to 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.



Configure the network IP and subnet settings before configuring the routing settings.

Add and delete 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 C70.

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 also must be kept on default values.

By default, the value of the route gateway address is 127.0.0.1. This means that 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, where the route gateway must be on a connected network.

To delete a route:

1. Replace the route destination with the default loopback address of 127.0.0.1. When deleting a route, the mask and gateway also must be brought back to default values.
2. Delete the default route by replacing the default gateway with the default value of 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

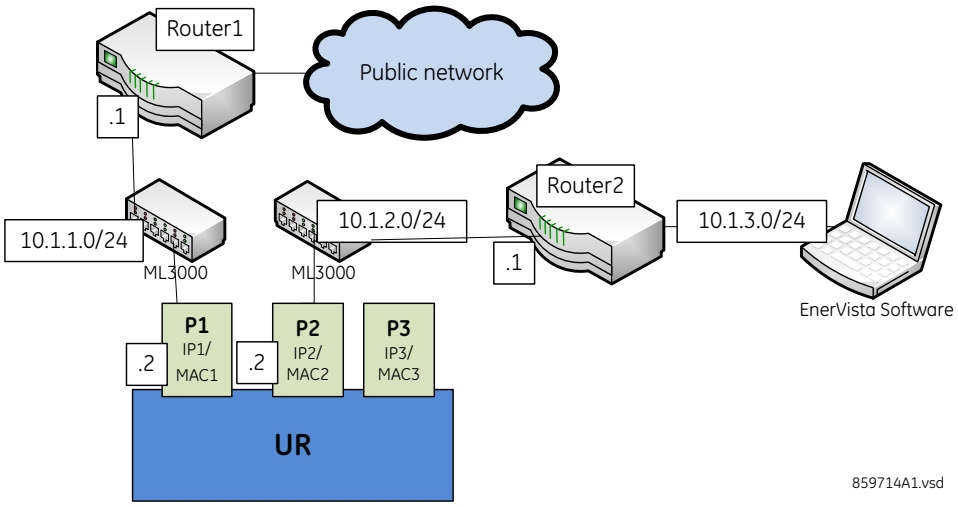
Routing behavior compared to previous releases

Prior to release 7.10, UR devices 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. Router1 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 Router2. Router2 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 Router1. Hence a destination unreachable message was received from the router.

The configuration starting with 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 Router2, which has knowledge about 10.1.3.0 and is able to route packets coming from the 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 5-7: Routing table information

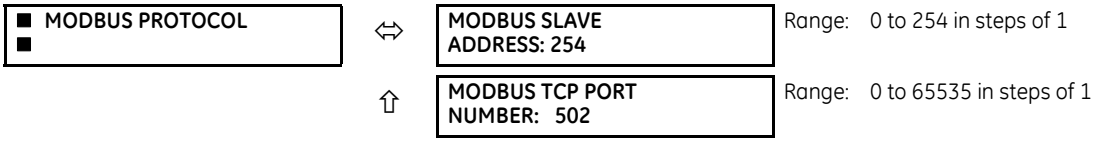
Field	Description
Destination	The IP address of the remote network to which this route points
Mask	The network mask for the destination
Gateway	The IP address of the next router to the remote network
Interface	Interface through which the specified network can be reached

Table 5-8: 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

5.3.4.8 Modbus protocol

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. UR devices operate as Modbus slave devices only.

For more information on the protocol, including the memory map table, see the UR Series Communications Guide.

MODBUS SLAVE ADDRESS — When using the Modbus protocol on the RS232 port, the C70 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 to which all Modbus slave devices listen. When **MODBUS SLAVE ADDRESS** is set to 0, the C70 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, starting at 1, set each device added to the link to use the next higher address. When using Modbus TCP/IP, the client must use the programmed **MODBUS SLAVE ADDRESS** value in the Unit Identifier field.

MODBUS TCP PORT NUMBER — 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 the port number is changed to 0, the change takes effect when the C70 is restarted. When it is set to 0, use the front panel or serial port to communicate with the relay.

NOTE

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

5.3.4.9 Protocol selection

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 5-9: Port and protocol combinations

PROTOCOL setting	DNP CHANNEL 1(2) PORT settings	RS232	RS485	Ethernet
DNP	Channel 1: Eth TCP Channel 2: Eth TCP	Modbus	Modbus	DNP, Modbus, IEC 61850
	Channel 1: Eth TCP Channel 2: none	Modbus	Modbus	DNP, Modbus, IEC 61850
	Channel 1: none Channel 2: Eth TCP	Modbus	Modbus	DNP, Modbus, IEC 61850
	Channel 1: Eth UDP Channel 2: none	Modbus	Modbus	DNP, Modbus, IEC 61850
	Channel 1: Eth TCP Channel 2: RS485	Modbus	DNP	DNP, Modbus, IEC 61850
	Channel 1: Eth TCP Channel 2: RS232	DNP	Modbus	DNP, Modbus, IEC 61850
	Channel 1: Eth UDP Channel 2: RS485	Modbus	DNP	DNP, Modbus, IEC 61850
	Channel 1: Eth UDP Channel 2: RS232	DNP	Modbus	DNP, Modbus, IEC 61850
	Channel 1: RS485 Channel 2: Eth TCP	Modbus	DNP	DNP, Modbus, IEC 61850
	Channel 1: RS232 Channel 2: Eth TCP	DNP	Modbus	DNP, Modbus, IEC 61850
	Channel 1: RS485 Channel 2: RS232	DNP	DNP	Modbus, IEC 61850
	Channel 1: RS232 Channel 2: RS485	DNP	DNP	Modbus, IEC 61850
	Channel 1: RS485 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

5.3.4.10 DNP protocol

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP PROTOCOL

■ DNP PROTOCOL ■	⇔	■ DNP CHANNELS ■	See below
	⇩	DNP ADDRESS: 1	Range: 0 to 65535 in steps of 1
	⇩	■ DNP NETWORK ■ CLIENT ADDRESSES	See below
	⇩	DNP TCP/UDP PORT NUMBER: 20000	Range: 0 to 65535 in steps of 1
	⇩	DNP UNSOL RESPONSE FUNCTION: Disabled	Range: Enabled, Disabled
	⇩	DNP UNSOL RESPONSE TIMEOUT: 5 s	Range: 0 to 60 s in steps of 1
	⇩	DNP UNSOL RESPONSE MAX RETRIES: 10	Range: 1 to 255 in steps of 1
	⇩	DNP UNSOL RESPONSE DEST ADDRESS: 1	Range: 0 to 65519 in steps of 1

⇳	**DNP CURRENT SCALE FACTOR: 1**	Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000
⇳	**DNP VOLTAGE SCALE FACTOR: 1**	Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000
⇳	**DNP POWER SCALE FACTOR: 1**	Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000
⇳	**DNP ENERGY SCALE FACTOR: 1**	Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000
⇳	**DNP PF SCALE FACTOR: 1**	Range: 0.001, 0.01. 0.1, 1, 10, 100, 1000, 10000, 100000
⇳	**DNP OTHER SCALE FACTOR: 1**	Range: 0 to 100000000 in steps of 1
⇳	**DNP CURRENT DEFAULT DEADBAND: 30000**	Range: 0 to 100000000 in steps of 1
⇳	**DNP VOLTAGE DEFAULT DEADBAND: 30000**	Range: 0 to 100000000 in steps of 1
⇳	**DNP POWER DEFAULT DEADBAND: 30000**	Range: 0 to 100000000 in steps of 1
⇳	**DNP ENERGY DEFAULT DEADBAND: 30000**	Range: 0 to 100000000 in steps of 1
⇳	**DNP PF DEFAULT DEADBAND: 30000**	Range: 0 to 100000000 in steps of 1
⇳	**DNP OTHER DEFAULT DEADBAND: 30000**	Range: 0 to 100000000 in steps of 1
⇳	**DNP TIME SYNC IIN PERIOD: 1440 min**	Range: 1 to 10080 min. in steps of 1
⇳	**DNP MESSAGE FRAGMENT SIZE: 240**	Range: 30 to 2048 in steps of 1
⇳	**DNP OBJECT 1 DEFAULT VARIATION: 2**	Range: 1, 2
⇳	**DNP OBJECT 2 DEFAULT VARIATION: 2**	Range: 1, 2, 3
⇳	**DNP OBJECT 20 DEFAULT VARIATION: 1**	Range: 1, 2, 5, 6
⇳	**DNP OBJECT 21 DEFAULT VARIATION: 1**	Range: 1, 2, 9, 10
⇳	**DNP OBJECT 22 DEFAULT VARIATION: 1**	Range: 1, 2, 5, 6
⇳	**DNP OBJECT 23 DEFAULT VARIATION: 1**	Range: 1, 2, 5, 6
⇳	**DNP OBJECT 30 DEFAULT VARIATION: 1**	Range: 1, 2, 3, 4, 5
⇳	**DNP OBJECT 32 DEFAULT VARIATION: 1**	Range: 1, 2, 3, 4, 5, 7
⇳	**DNP NUMBER OF PAIRED CONTROL POINTS: 0**	Range: 0 to 32 in steps of 1
⇧	**DNP TCP CONNECTION TIMEOUT: 120 s**	Range: 10 to 7200 s in steps of 1

The Distributed Network Protocol (DNP) allows for the optimization of control and data acquisition between the equipment in the substation and the central control center. The protocol is scalable; that is, it is designed to be compatible with the latest high speed LAN technology yet still be implemented over slower speed serial links.

The DNP improves upon many master-slave protocols by improving overall communication performance requirements and provides time-stamping with millisecond accuracy.

The C70 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 C70 can be used as a DNP slave device connected to multiple DNP masters (usually an RTU or a SCADA master station). Since the C70 maintains two sets of DNP data change buffers and connection information, two DNP masters can actively communicate with the C70 at one time.

See the UR Series Communications Guide for more information on DNP.

NOTE

For any change to DNP settings, restart the relay.

The DNP Channels sub-menu is shown.

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP PROTOCOL ⇨ DNP CHANNELS

■ DNP CHANNELS
■

⇔ **DNP CHANNEL 1 PORT: NONE**
Range: NONE, COM2 - RS485, FRONT PANEL - RS232, NETWORK - TCP, NETWORK - UDP

⇧ **DNP CHANNEL 2 PORT: NONE**
Range: NONE, COM2 - RS485, FRONT PANEL - RS232, NETWORK - TCP

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 this value is set to "Network - UDP," the DNP protocol can be used over UDP/IP on channel 1 only.

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 C70 on a DNP communications link. Assign a unique address to each DNP slave.

The C70 can specify a maximum of five clients for its DNP connections. These are IP addresses for the controllers to which the C70 can connect. The settings follow.

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP PROTOCOL ⇨ DNP NETWORK CLIENT ADDRESSES

■ DNP NETWORK
■ CLIENT ADDRESSES

⇔ **CLIENT ADDRESS 1: 0.0.0.0**
Range: standard IP address

⇩

⇧ **CLIENT ADDRESS 5: 0.0.0.0**
Range: standard IP address

The **DNP TCP/UDP PORT NUMBER** setting is for normal DNP operation. To close the port, set the port number to 0.

The **DNP UNSOL RESPONSE FUNCTION** is set to "Disabled" for RS485 applications since there is no collision avoidance mechanism. The **DNP UNSOL RESPONSE TIMEOUT** sets the time the C70 waits for a DNP master to confirm an unsolicited response. The **DNP UNSOL RESPONSE MAX RETRIES** setting determines the number of times the C70 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 C70 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 C70 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 are returned with values 1000 times smaller (for example, a value of 72000 V on the C70 is 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 is 10 times larger).

The **DNP DEFAULT DEADBAND** settings determine when to trigger unsolicited responses containing analog input data. These settings group the C70 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 C70 when any current values change by 15 A, the **DNP CURRENT DEFAULT DEADBAND** setting is 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 C70 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 C70. 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 provides more robust data transfer over noisy communication channels.

5

NOTE

Check the "DNP Points Lists" C70 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 C70 Ethernet port employed to access the C70 Main Menu, then by clicking the **Device Information Menu** item, then the **DNP Points Lists** item.

The **DNP OBJECT 1 DEFAULT VARIATION** to **DNP OBJECT 32 DEFAULT VARIATION** settings 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 UR Series Communications Guide.

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 C70 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 C70 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 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 is aborted by the C70. This frees up the connection to be re-used by a client.

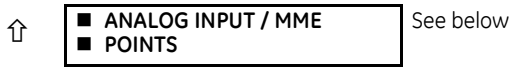
NOTE

For any change to DNP settings, restart the relay.

5.3.4.11 DNP / IEC 60870-5-104 point lists

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP / IEC104 POINT LISTS

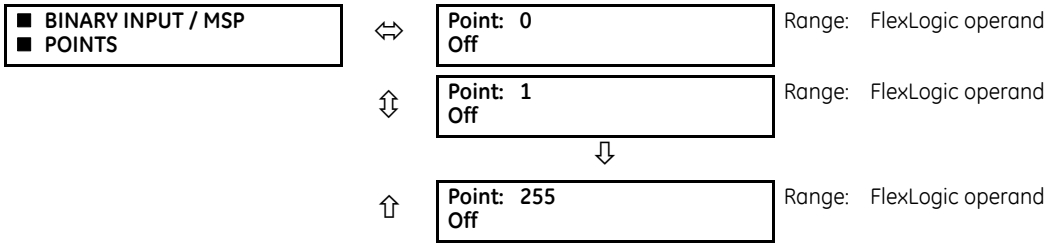
■ DNP / IEC104 ■ POINT LISTS	⇔	■ BINARY INPUT / MSP ■ POINTS	See below



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) follows.

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP / IEC104 POINT LISTS ⇨ BINARY INPUT / MSP POINTS

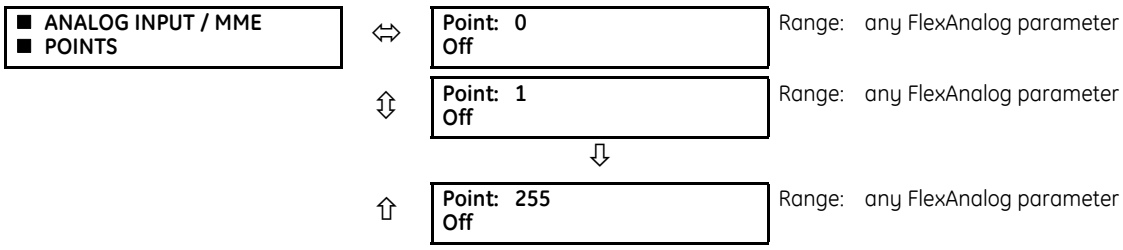


Up to 256 binary input points can be configured for the DNP or IEC 60870-5-104 protocols. The points are configured by assigning an appropriate FlexLogic operand. See the Introduction to FlexLogic section in this chapter for the range of assignable operands.

Changes to the DNP / IEC 60870-5-104 point lists take effect when the C70 is restarted.

The menu for the analog input points (DNP) or MME points (IEC 60870-5-104) follows.

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. See the FlexAnalog Parameters section in Appendix A for the range of assignable parameters.

Changes to the DNP / IEC 60870-5-104 point lists take effect when the C70 is restarted.

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.

5.3.4.12 IEC 61850 protocol

SOFTWARE OPTION

The C70 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 settings are accessible in EnerVista software or a substation configuration language (SCL) generating tool. The path is **Settings > Product Setup > Communications > IEC 61850**. The settings are not accessible from the front panel of the device.

NOTE

IEC 61850 messaging can form part of protection schemes. Consider IEC 61850 settings with the same criticality as protection element settings. To ensure reliable performance of protection schemes utilizing IEC 61850 messaging, route IEC 61850 traffic on a separate port from SCADA communications, or use redundant, independent ports, and a high speed network recovery method, such as PRP.

Overview

IEC 61850 is a series of international standards and technical reports applicable to power utility automation systems. It includes semantics, abstract communication services, specific communication services, performance specifications, network engineering guidelines, configuration description methodologies, and engineering processes. The standard enables interoperability among intelligent electronic devices (IEDs) from different suppliers and interoperability among software configuration tools from different suppliers. Interoperability in this case is the ability for IEDs to operate on the same network or communication path sharing information and commands, and for configuration tools to understand each other's configuration files.

The UR series supports a large subset of IEC 61850 features. These are detailed in the UR Series Communications Guide and include the information model, GOOSE publish, GOOSE subscribe, buffered report server, unbuffered report server, and Manufacturing Message Specification (MMS) query, read, write, and control services. In addition, the UR and EnerVista UR Setup software support IEC 61850 Substation Configuration Language (SCL) file import/export.

Whereas prior UR releases used edition 1.0 of IEC 61850, this release uses edition 2.0, with certain modifications according to IEC/TR 61850-90-5. Only edition 2.0 61850 configuration tools can interoperate with edition 2.0 devices such as the UR 7.3x release. The UR release uses edition 2.0 SCL, which differs from edition 1.0 SCL. GSSE, fixed GOOSE, and fixed report services of previous releases are no longer supported, and thus UR devices of previous releases using these features have to be converted to configurable GOOSE to communicate with a 7.3x device.

Many settings of UR protection, control, and monitoring elements, that is to say elements that are not concerned with the IEC 61850 protocol, can nevertheless be accessed via IEC 61850. These settings are documented elsewhere in this Settings chapter. This section of the Settings chapter deals solely with the settings that configure the IEC 61850 protocol itself.

The maximum number of simultaneous clients supported by the UR series is five.

EnerVista setup for IEC 61850

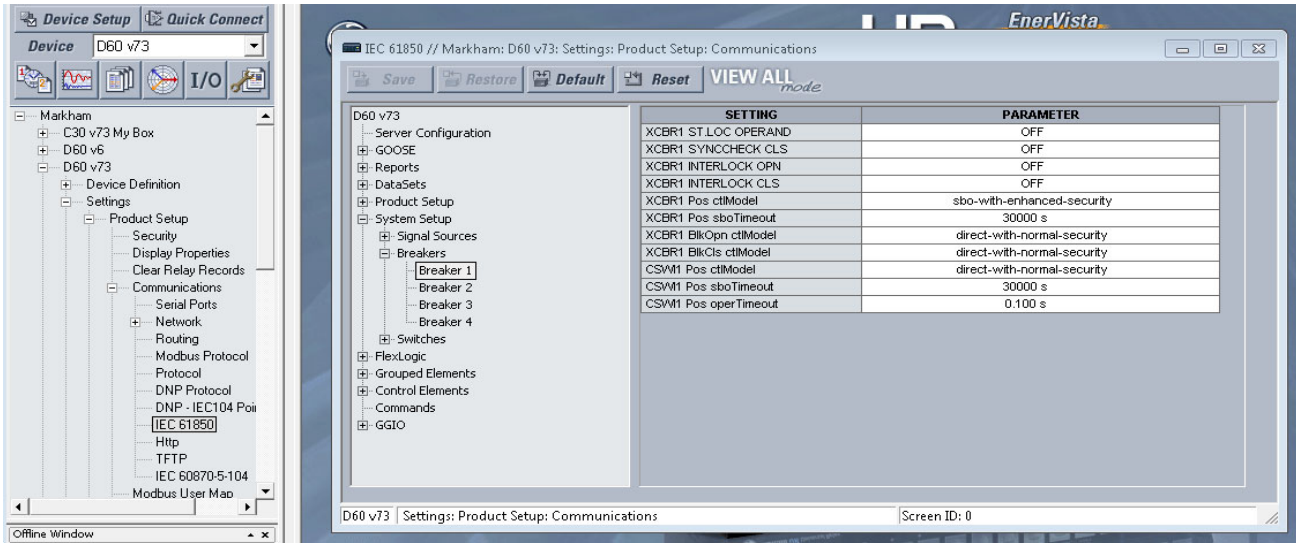
The EnerVista UR Setup software provides the interface to configure C70 settings for the IEC 61850 protocol. This section describes this interface. The software also supports import and export of IEC 61850 Substation Configuration Language (SCL) files as documented in the UR Series Communications Guide.

Unlike other UR settings, IEC 61850 protocol configuration settings cannot be accessed through the UR front panel. These settings are accessible with the EnerVista software, via MMS query, read, and write services, or via 61850 Substation Configuration Language (SCL) file transfer. Accordingly, whereas other settings are presented in this manual as they appear on the front panel, IEC 61850 settings are presented as they appear in the software. See the UR Series Communications Guide for MMS and SCL access. Note that if you update the IEC 61850 settings in the EnerVista software by writing to them by MMS while the corresponding IEC 61850 panel is open in EnerVista, you need to close then open the panel in EnerVista for the correct readings to display.

All IEC 61850 protocol configuration settings are accessed through software panels that are selected either in the **Online Window** area (see figure) or the **Offline Window** area in the EnerVista software.

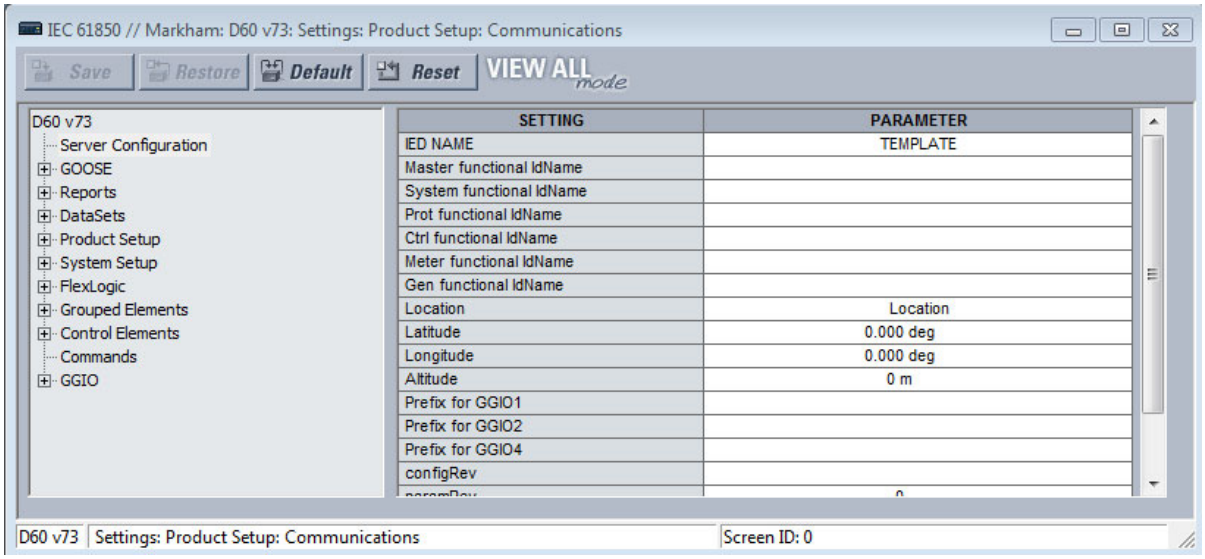
The EnerVista software also includes an interface that is compatible with firmware versions 5.0 to 7.2 to configure subscribers. Use the Simplified GOOSE Configurator in the Offline Window area.

Figure 5-9: IEC 61850 protocol panel in EnerVista software



The IEC 61850 window is divided into a navigation pane on the left and a settings panel on the right. You expand and click an option on the left to display its panel on the right. The following figure shows an example for Server Configuration. The setting entry panel contains in the **SETTING** column the names of the settings, and the settings entry boxes are in the **PARAMETER** column. Hovering the mouse over a setting name displays a tool-tip showing the 61850 information model name of the setting or its location in SCL files.

Figure 5-10: Main IEC 61850 panel



Opening the IEC 61850 window while online causes the UR Setup software to retrieve and import an SCL file from the connected C70. This SCD file contains all the settings in the UR at the time of the file request, both those that are mapped into the IEC 61850 information model (that is, the "public" sections) and those that are not in the model (that is, the "private" section). The UR Setup software imports all of these settings into the current session, not just those in the IEC 61850 window. To avoid loss of any unsaved setting changes made in other panels during the current session, all other panels for the C70 must be closed before the IEC 61850 panel can be opened; the software prompts for this when applicable. Panels for other devices can be open concurrently to facilitate parameter coordination.

When CyberSentry is enabled, editable settings depend on role logged in. For example, an Administrator and Engineer can change settings. If prompted for a "Settings password," it means Administrator or Engineer password.

The **Restore** button restores settings in the window to their last saved values. The **Default** button reverts settings in the window to factory default values or Oscillography, Data Logger, or FlexLogic Equation Editor pre-configured values. The **Reset** button reverts all IEC 61850 settings to the factory default values, not just the current window. (In other settings windows, the button reverts settings in the window to factory default values.)

Create CID and settings files

When the **Save** button in the online IEC 61850 window is clicked, UR Setup software prepares a configured IED description (CID) file containing all the device's settings and sends the CID file to the connected C70. On receipt of a CID file, the C70 checks it for correctness, and if no error is found, reboots using the settings in the CID file. UR Setup displays a message when the C70 is running the new settings, confirming successful transfer. This process can take a minute or so due to the extensive amount of processing required by the software and the C70.

Certain settings not related to IEC 61850 are indicated in this manual as taking effect only when the device is restarted. The reboot following CID file transfer described in the previous paragraph does not make these setting changes take effect, as the C70 does not accept the setting change until after the CID file transfer reboot. For any change in the indicated settings to take effect, after the automatic restart due to CID file transfer, you must perform a manual restart, for example by executing the **Maintenance > Reboot Relay Command** in the software.

When the **Save** button in the offline IEC 61850 window is clicked, UR Setup software saves to local storage, for example the hard drive, a .urs file containing all of the device's settings.

Server configuration

The Server Configuration panel contains IEC 61850 settings relevant to the server functions of the IED implementation.

The path is **Settings > Product Setup > Communications > IEC 61850 > Server Configuration**.

The following settings are available, where <iedName> is a syntactic variable representing the present value of the IED NAME setting.

IED NAME

Range: 1 to 58 VisibleString characters
Default: TEMPLATE

The value entered sets the IED name used by IEC 61850 for the C70. An IED name unique within the network must be entered for proper operation. Valid characters are upper and lowercase letters, digits, and the underscore (_) character. The first character must be a letter.

The **IED NAME** and the **Product LD inst name** comprise the <LDName> for a product. LD inst are fixed, with the longest being "Master" and "System" at six characters. So the IED NAME needs to be restricted to 58 characters to meet a 64 character limit.

Master functional ldName

Range: 0 to 64 VisibileString characters
Default:

The Master logical device contains the UR logical nodes modelling communications and setting group control. Valid characters are upper and lowercase letters, digits, and the underscore (_) character. If the number of characters entered is greater than zero, this setting sets the name used in communications for the Master logical device. If an ldName is entered, a name unique within the network must be entered for proper operation. The standard recommends choosing this name according to IEC 81346-1. If the number of characters entered is zero, the name used in communications for the Master logical device is "<iedName>Master", where <iedName> is the value of setting **IED NAME** described earlier.



Throughout the remainder of this section, <LDName> is a syntactic variable representing the present name of the master logical device. Depending on its context, <LDName> can be a product-related name or a function-related name. In SCL files, <LDName> is always the product-related name. In IEC 61850 messages, <LDName> is the function-related name if one is set by the Master functional ldName setting, otherwise <LDName> is again the product-related name. The product-related name of the Master logical device is "<iedName>Master". The function related name of the Master logical device is the value of the Master functional ldName setting.

System functional ldName

Range: 0 to 64 VisibileString characters
Default:

This setting is similar to setting **Master functional ldName**, but is for the System logical device, which contains the UR logical nodes modelling power system devices: breakers, switches, CTs, VTs, and so on, including interface to these such as AC inputs, contact I/O, transducer I/O, and HardFiber I/O.

Prot functional ldName

Range: 0 to 64 VisibileString characters
Default:

This setting is similar to setting **Master functional ldName**, but is for the Prot logical device instance, which contains the UR logical nodes modelling protection and protection related functions.

Ctrl functional ldName

Range: 0 to 64 VisibileString characters
Default:

This setting is similar to setting **Master functional ldName**, but is for the Ctrl logical device instance, which contains the UR logical nodes modelling control and monitoring functions.

Meter functional ldName

Range: 0 to 64 VisibileString characters
Default:

This setting is similar to setting **Master functional ldName**, but is for Meter the logical device instance, which contains the UR logical nodes modelling metering and measurement, including Signal Sources.

Gen functional ldName

Range: 0 to 64 VisibileString characters
Default:

This setting is similar to setting **Master functional ldName**, but is for the Gen logical device instance, which contains the UR logical nodes modelling FlexLogic, Virtual Outputs, non-volatile latches, FlexElements, recording (for example oscillography), security, front panel, and clock.

Location

Range: 0 to 255 ASCII characters
Default: Location

The value entered sets the value of the data attribute <LDName>/LPHD1.PhyNam.location. This data attribute is provided by the protocol to allow the user to declare where the equipment is installed.

Latitude

Range: -90.000 to 90.000 degrees in steps of 0.001 degree
Default: 0.000 deg

The value entered sets the value of the data attribute <LDName>/LPHD1.PhyNam.latitude. This data attribute is provided by the protocol to allow the user to declare the geographical position of the device in WGS84 coordinates -latitude. Negative values indicate a southern latitude. WGS refers to the world geodetic system, which is used in global positioning systems (GPS), and 84 is the current version of the standard.

Longitude

Range: -180.000 to 180.000 degrees in steps of 0.001 degree
Default: 0.000 deg

The value entered sets the value of the data attribute <LDName>/LPHD1.PhyNam.longitude. This data attribute is provided by the protocol to allow the user to declare the geographical position of the device in WGS84 coordinates - longitude. Negative values indicate a western longitude.

Altitude

Range: 0 to 10,0000 m in steps of 1 m
Default: 0 m

The value entered sets the value of the data attribute <LDName>/LPHD1.PhyNam.altitude. This data attribute is provided by the protocol to allow the user to declare the geographical position of the device in WGS84 coordinates - altitude.

Prefix for GGIO1

Range for Edition 2: 0 to 11 VisibleString characters
Range for Edition 1: 0 to 6 VisibleString characters
Default:

This setting sets the LN Prefix of the logical node GGIO1 that is described in the GGIO1 section later. Valid characters are upper and lowercase letters, digits, and the underscore (_) character. The first character must be a letter.

Prefix for GGIO2

Range for Edition 2: 0 to 11 VisibleString characters
Range for Edition 1: 0 to 6 VisibleString characters
Default:

This setting sets the LN Prefix of logical node GGIO2 that is described in the GGIO2 section later. Valid characters are upper and lowercase letters, digits, and the underscore (_) character. The first character must be a letter.

Prefix for GGIO4

Range for Edition 2: 0 to 11 VisibleString characters
Range for Edition 1: 0 to 6 VisibleString characters
Default:

This setting sets the LN Prefix of logical node GGIO4 that is described in the GGIO4 section later. Valid characters are upper and lowercase letters, digits, and the underscore (_) character. The first character must be a letter.

Master configRev

Range: 0 to 255 ASCII characters
Default:

This data attribute is provided by the protocol to allow the user to declare changes to the semantic of the data model of the UR. The intent is that the user changes Master configRev each time that the semantic or data model changes, so that clients can readily detect the change. A semantic change is a logical node getting a new semantic use; for example, an instance of logical node CSWI is now serving a different physical switch, or an instance of a logical node PDIS is now used for another zone. A data model change is a change in the presence of logical nodes, data objects, data attributes, or instance names.

The scope of Maser configRev is the entire relay configuration as the Master logical device is the root logical device. Similar settings are provided for the other logical nodes; the scope of these other configRev settings is limited to the corresponding logical device configuration.

paramRev

Range: -2,147,483,648 to 2,147,483,647 in steps of 1
Default: 0

This data attribute is provided by the protocol to make changes to the settings of the C70 apparent to clients. The Substation Configuration Tool and UR Setup software advance the value of paramRev each time any setting changes. The C70 increments the value of parmRev when a setting change is made other than through CID file download.

LLN0.Mod.ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security
Default: sbo-with-normal-security

This setting specifies the control service that clients must use to control the TEST MODE FUNCTION of the C70. An "on" control to <LDName>/LLN0.Mod changes TEST MODE FUNCTION to Disabled, an "on-blocked" control changes it to Forcible, and a "test/blocked" changes it to Isolated.

IEC/MMS TCP PORT NUMBER

Range: 0 to 65535 in steps of 1

Default: 102

This setting allows the user to change the TCP port number for Manufacturing Message Specification (MMS) connections. It is recommended that this setting be left at the default value.

NOTE

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

Configuration Type

Range: G2, E3-2.0

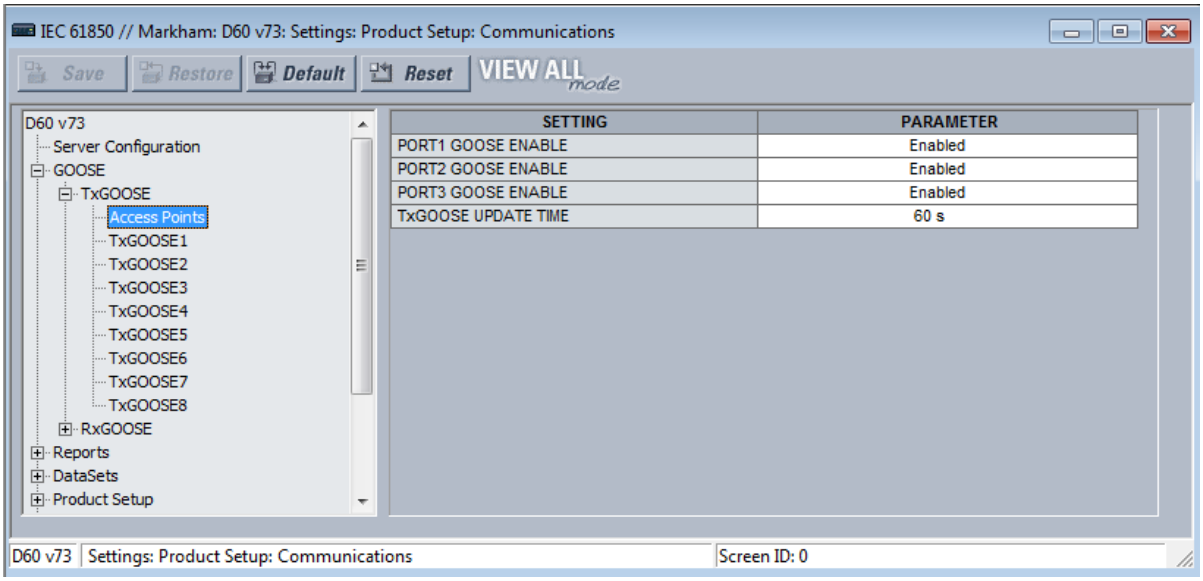
Default: G2

This setting specifies the method used to describe GOOSE subscription configuration in SCL. See the UR Series Communications Guide for details. Basically, in the G2 mode, the CID file contains IED elements for IEDs subscribed to by this IED containing GOOSE subscription information. In the E3 2.0 mode, the CID file has only one IED element and GOOSE subscription information is coded in data objects in the standard LGOS logical node used to monitor reception of the subscribed GOOSE. UR 7.30 or later accepts either mode.

GOOSE

The path is **Settings > Product Setup > Communications > IEC 61850 > GOOSE**.

Figure 5-11: IEC 61850 TxGOOSE Access Points panel



Support for Routable GOOSE

Routable GOOSE (R-GOOSE) is supported in firmware releases 7.4 and later. Routable GOOSE allows UR and other devices to be located in separate networks. Encryption/decryption of messages is performed by a separate gateway device. Messages are routed using a separate router, using IP addresses.

Conversion can be required for R-GOOSE and GOOSE message exchange. Examples include the following:

- A v7.4 device can send an R-GOOSE message to another v7.4 device when both have R-GOOSE active as the protocol. No conversion is required.
- A v7.4 device can send a GOOSE message to another v7.4 device when both have GOOSE active as the protocol. No conversion is required.

- For a v7.4 device to send an R-GOOSE message to a v7.3 or v5.9 device, for example, a C30 Controller System with the GOOSE Protocol Converter (software option 99) is required to transform the R-GOOSE to GOOSE for the other devices
- Similarly, a device that sends GOOSE messages to a v7.4 device that is expecting R-GOOSE requires the C30 with the converter

See the GOOSE Protocol Converter section in firmware version 7.4 or later C30 instruction manual for more information.

TxGOOSE

IEC 61850 GOOSE is an efficient method for simultaneous high-speed delivery of a set of generic substation event information in a publishing physical device to more than one subscribing physical device. A TxGOOSE is a UR element implementing a single IEC 61850 GOOSE message publishing service. The subscribing function in URs is performed by RxGOOSE elements, as described in the next section. Each UR with IEC 61850 order code options has eight TxGOOSE elements. Each TxGOOSE element can publish the values of up to 64 attributes of the IEC 61850 nodes in the UR.

Published TxGOOSE messages configured in the EnerVista UR Setup software can be subscribed by and the published operand values understood by other UR devices. In fact, they can be subscribed to and understood by any device of any manufacturer that implements the IEC 61850 edition 1.0 or 2.0 GOOSE subscription mechanism. The messages are published with a multicast address so that the network sends the messages to all devices; any number of devices that want to subscribe can.

The entities whose values are published in GOOSE messages are known as members. The members are itemized in an ordered list known as a data set. Each TxGOOSE can use any one of the data sets provided. See the DataSets section later for details.

Each enabled TxGOOSE transmits its message whenever a value change is detected in one or more of its members. To guard against the possibility that such a message is lost in the network before it reaches all subscribers, the message is quickly retransmitted several times. To allow subscribers to verify that their link to the publisher and the publisher itself are healthy, each message is also periodically retransmitted even while the values are unchanging. These latter messages are known as heartbeat messages, while the former are known as event messages. Heartbeat messages also provide means for a subscriber newly online to receive the published values in the absence of an event.

TxGOOSE1 and TxGOOSE2 scan for value changes in its FlexLogic operand members as frequently as such a change can occur. TxGOOSE1 and TxGOOSE2 are therefore suitable for highly time critical signals, such as tripping and dynamic blocking. FlexAnalog members are scanned for value changes only every 250 ms. See the Deadband Settings section later for a description of what is considered a value change in an analog member.

The remaining TxGOOSE, meaning TxGOOSE3 and up, scan both their FlexLogic and FlexAnalog members for value changes every 250 ms. They are suited for control applications, such as voltage control or power factor regulation.

The details of TxGOOSE message construction are contained in the UR Series Communications Guide. Knowledge of these details is not required to configure GOOSE.

The UR does not implement the Fixed-Length encoded GOOSE messages option specified in IEC 61850-8-1:2011 clause A.3; the UR always uses the ASN.1 Basic encoding rules (as specified in ISO/IEC 8825-1) as specified in IEC 61850-8-1:2004 and as optional in IEC 61850-8-1:2011 clause A.3. So do not try to configure the UR for fixed-offset TxGOOSE.

TxGOOSE

Navigate to **Settings > Product Setup > Communications > IEC 61850 > GOOSE > TxGOOSE > Access Points** to access the settings that are common to all GOOSE messages published.

The following settings are available.

PORT1 GOOSE ENABLE

Range: Enabled, Disabled

Default: Enabled

When set to Disabled, no GOOSE messages are published on C70 Ethernet port 1, and any GOOSE messages received on port 1 are ignored. When set to Enabled, all enabled GOOSE messages are published on C70 Ethernet port 1, and any GOOSE messages received on port 1 are listened to.

C70 Ethernet ports 2 and 3 each have a similar setting.

TxGOOSE UPDATE TIME

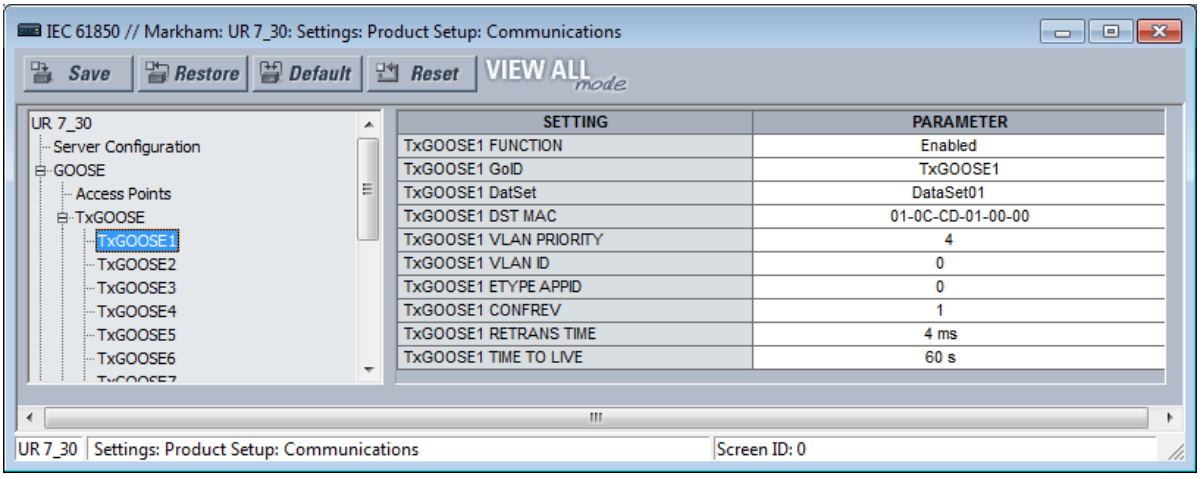
Range: 1 to 60 s in steps of 1 s

Default: 60 s

This setting specifies the time interval between heartbeat messages, which are messages that are sent periodically while no events are detected. The standard suggests that the heartbeat time be less than (actually half) of the timeAllowedtoLive parameter, which is set by the **TxGOOSE TIME TO LIVE** settings described later.

Navigate to **Settings > Product Setup > Communications > IEC 61850 > GOOSE > TxGOOSE > TxGOOSE1** to access the settings for the first TxGOOSE. The settings and functionality for the others are similar.

Figure 5-12: IEC 61850 TxGOOSE panel



TxGOOSE1 FUNCTION

Range: Enabled, Disabled

Default: Enabled

When set to Disabled, TxGOOSE1 messages are not published. When set to Enabled, TxGOOSE1 messages are published.

When TxGOOSE1 to 8 are set to Disabled in EnerVista and subsequently Enabled by writing via MMS, the panel continues to read Disabled until relaunched. There is no polling capability to update automatically the IEC 61860 readings, so the panel needs to be closed then opened for the correct status to display.

TxGOOSE1 GoID

Range for Edition 2: 0 to 129 VisibleString characters

Range for Edition 1: 0 to 65 VisibleString characters

Default: TxGOOSE1

The entered value sets the goID value published in TxGOOSE1 messages, and can be used by subscribers to discriminate the TxGOOSE1 messages from other GOOSE messages.

TxGOOSE1 DatSet

Range: None, DataSet01, DataSet02,...

Default: None

This setting selects the published data set using the UR Setup software designator for the data set. The IEC 61850 name of the data sets are configured in the Datasets panel, as described later.

An ObjectReference to the data set, which consists of the concatenation of the string "<LDName>/LLN0." and the data set name, is published in the datSet field of TxGOOSE1 messages and can be used by subscribers to discriminate TxGOOSE1 messages from other GOOSE messages.

TxGOOSE1 DST MAC

Range: any 12 digit hexadecimal number

Default: 01-0C-CD-01-00-00

The value entered sets the Ethernet destination Media Access Control (MAC) address in published TxGOOSE1 messages. As the standard requires that the address have the multicast bit set TRUE, that is to say the second digit is set to an odd number, messages transmitted have the multicast bit set TRUE no matter its value in this setting.

The destination MAC address can be used by the network to restrict message delivery to selected devices that need to receive them, reducing network loading. This address also can be used by hardware in receiving devices to filter out messages that are of no interest to them, reducing processor burden. Different filtering algorithms are implemented by different devices. The standard recommends that the algorithm used by hardware of the receiving device be considered when assigning destination multicast addresses.

Subscribers can use this address to discriminate TxGOOSE1 messages from other GOOSE messages.

TxGOOSE1 VLAN PRIORITY

Range: 0, 1, 2, 3, 4, 5, 6, 7, 5-4, 6-4, 6-5, 7-4, 7-5, 7-6

Default: 4

When the value entered is 0, 1, 2, 3, 4, 5, 6, or 7, the User Priority value in the IEEE 802.1Q VLAN tag included in published TxGOOSE1 messages is set to that value. When one of the two-digit values is entered, the dynamic priority feature is selected: the first event message has the User Priority value of the first digit, and User Priority is decremented in each following message until reaching the value of the second digit. For instance, if the selected value is 7-5, then the User Priority values in successive messages beginning with the message triggered by an event is 7, 6, 5, 5, 5, 5, 5, and so on. Do not make a dynamic priority selection when standard behavior is required.

Network devices can forward a message with a higher priority value before a message with a lower priority value, which speeds delivery of high priority messages in heavily loaded networks. The standard recommends that higher priority messages, such as GOOSE, have priority values in the range of 4 to 7.

TxGOOSE1 VLAN ID

Range: 0 to 4095 in steps of 1

Default: 0

The value entered sets the VID value in the IEEE 802.1Q VLAN tag included in published TxGOOSE1 messages. VID can be used by network devices to direct messages to only selected devices, reducing network burden. VID values of 0 and 1 are assigned by IEEE 802.1Q to other functions and are not to be used for GOOSE.

TxGOOSE1 ETYPE APPID

Range: 0 to 65535 in steps of 1

Default: 0

The value entered sets the APPID value in published GOOSE messages and can be used by subscribers to discriminate TxGOOSE1 messages from other GOOSE messages.

The standard reserves the value range 0 to 16383 for GOOSE Type 1 (Fast messages), and reserves the value range 32768 to 41151 for GOOSE Type 1A (Trip messages). Some subscribers can process messages in the Type 1A range faster than messages in the Type 1 range. The standard reserves the default value (0) to indicate lack of configuration. The standard strongly recommends unique, source-orientated APPIDs within a given system.

TxGOOSE1 ConfRev

Range: 0 to 4294967295 in steps of 1

Default: 1

The value entered sets the confRev value in published GOOSE messages, and can be used by subscribers to discriminate TxGOOSE messages of the expected configuration revision from messages of a different revision. The standard requires that confRef be incremented each time the members or the order of the members published is changed, and each time the data set name is changed. The standard states that the value of 0 is reserved.

TxGOOSE1 RETRANS TIME

Range: 0 to 100 ms in steps of 1 ms

Default: 4 ms

If the entered time is non-zero, when a member value change is detected, four event transmissions are sent, then heartbeat transmissions resume. The interval between the first and second event transmissions, and between the second and third, is the time set here. The interval between the third and the fourth event transmission is double the set time. If the entered time is zero, only a single event transmission occurs, then heartbeat transmissions resume.

TxGOOSE1 TIME TO LIVE

Range: 1 to 300 s in steps of 1 s

Default: 300 s

The value entered sets the timeAllowedtoLive value in published TxGOOSE1 messages. The standard requires subscribers to assume a failure has occurred when another TxGOOSE1 message is not received within the published timeAllowedtoLive time.

Base this setting on the **TxGOOSE UPDATE TIME** and the tolerable number of contiguous message delivery misses. For example, if the heartbeat time is 10 s, and missing up to three successive messages is tolerable, make the setting 10*3 + 1 = 31 s. The extra second is to ensure that arrival of the third heartbeat transmission beats the timeAllowedtoLive timer. The standard suggests that the heartbeat time be less than (actually half) of the timeAllowedtoLive parameter.

RxGOOSE

Navigate to **Settings > Product Setup > Communications > IEC 61850 > GOOSE > RxGOOSE > RxGOOSE Messages**.

IEC 61850, GOOSE is an efficient method for simultaneous high-speed delivery of the same generic substation event information in a publishing physical device to more than one subscribing physical device. An RxGOOSE is a UR element implementing a single IEC 61850 GOOSE message subscribing service. The publishing function in URs is performed by TxGOOSE elements, as described in the previous section. Each C70 has 16 RxGOOSE elements. Each RxGOOSE element can subscribe to GOOSE messages from a specified publisher. Subscribed messages can contain up to 64 of any set of data attributes with basic types BOOLEAN, FLOAT32, INT32, Dbpos, TimeStamp, or Quality. Messages containing data objects, that is to say structured data, are not accepted.

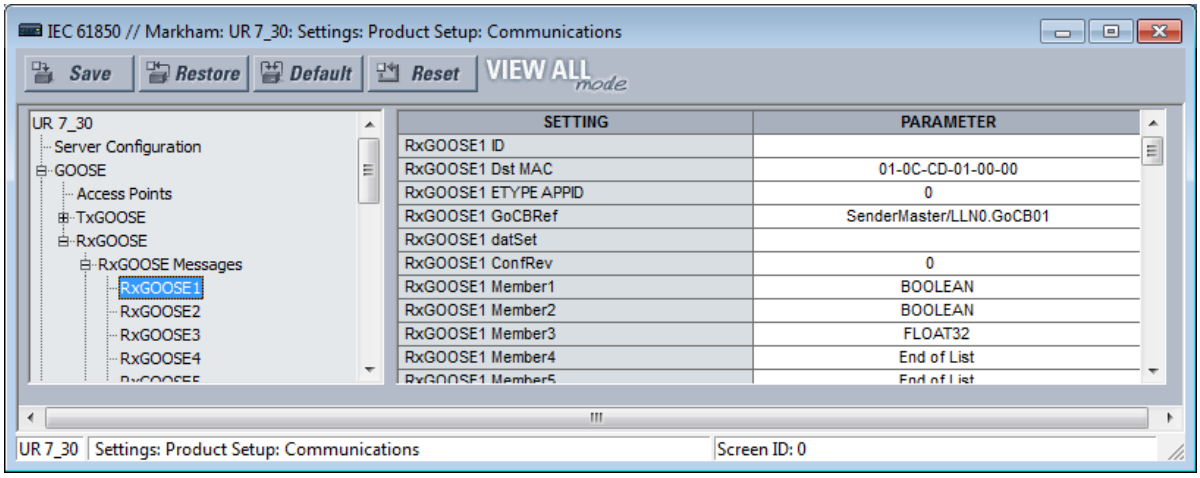
With these conditions, GOOSE messages from any device of any manufacturer that implements the IEC 61850 edition 1.0 or 2.0 GOOSE publish service can be subscribed to. The UR accepts both the variable-length encoded GOOSE messages specified in IEC 61850-8-1:2004 and the Fixed-Length encoded GOOSE messages as specified in IEC 61850-8-1:2011 clause A.3.

Each enabled RxGOOSE monitors for interruption of the GOOSE messages that it subscribes to based on the value in the timeAllowedtoLive field of the last message received. If a new message is not received within that time interval, the RxGOOSE assumes that connectivity is lost. FlexLogic operands (for example, RxGOOSE1 On, RxGOOSE1 Off) reflect the status of each RxGOOSE connectivity. RxGOOSE connectivity of an RxGOOSE with non-zero MAC address is also considered lost after the C70 finishes restart until a message is received. When RxGOOSE connectivity is lost, a common RxGOOSE Fail self-test activates.

Navigate to **Settings > Product Setup > Communications > IEC 61850 > GOOSE > RxGOOSE > RxGOOSE Messages > RxGOOSE1** to access the settings that specify the messages to be accepted by the first RxGOOSE element. Messages that contain the value true in the ndsCom field are never accepted. Messages that contain the value true in the simulation field (test field in edition 1.0 messages) are accepted only when the UR test mode is Forcible or Isolated; see the Testing section at the end of this chapter for details. The settings and functionality for the other RxGOOSE are similar.

Navigate to **Settings > Product Setup > Communications > IEC 61850 > GOOSE > RxGOOSE > RxGOOSE Messages > RxGOOSE1**. The following settings are available.

Figure 5-13: IEC 61850 RxGOOSE Messages panel



RxGOOSE1 ID

Range: 0 to 129 VisibleString characters

Default:

If the value entered has one or more characters, the goID field of incoming GOOSE messages must exactly match this value for the message to be accepted as a valid RxGOOSE1 message. If the entered value is the empty string, RxGOOSE1 does not check the value received in the goID field.

RxGOOSE1 Dst MAC

Range: any 12 digit hexadecimal number

Default: 00-00-00-00-00-00

Set this setting to the MAC address of the publisher. Only received GOOSE messages having a Media Access Control (MAC) address equal to this value are accepted as valid RxGOOSE1 messages. An entered address of zero disables RxGOOSE1.

If the publisher is a UR Series 7.3x device, the setting needs to match the value of the publisher's **TxGOOSE Dst MAC** setting.

RxGOOSE1 ETYPE APPID

Range: 0 to 65535 in steps of 1

Default: 0

If the value entered is non-zero, the APPID field of incoming GOOSE messages must exactly match this value for the message to be accepted as a valid RxGOOSE1 message. If the value entered is zero, RxGOOSE1 does not check the value received in the APPID field.

If the publisher is a UR Series 7.3x device, the setting needs to match the value of the publisher's **TxGOOSE ETYPE APPID** setting.

RxGOOSE1 GoCBRef

Range for Edition 2: 0 to 129 alphanumeric, underscore, slash and period characters, beginning with an alpha character

Range for Edition 1: 0 up to 65 alphanumeric, underscore, slash and period characters, beginning with an alpha character

Default:

The gocbRef field of incoming GOOSE messages must match this value for the message to be accepted as a valid RxGOOSE1 message. If the entered value is the empty string, RxGOOSE1 is disabled. If not the empty string, the entry needs to be an ACSI ObjectReference to the publishing control block in the format:

<LDName>/LLN0.<GoCBName>

where <LDName> is the function-related name if the logical device containing the publishing control block has "ldName" configured, otherwise the product-related name of that logical device, and <GoCBName> is the name of the publishing control block.

The C70 translates the ACSI format required for this setting to the MMS format used in GOOSE messages:

<LDName>/LLN0GO<GoCBName>

If the publisher is a UR 7.3x series device, <LDName> is the value of the publisher's Master functional ldName setting if that setting is not empty, otherwise it is the value of the publisher's IED NAME suffixed with "Master". If the publisher is a UR 7.3x series device, <GoCBName> is "GoCB" suffixed with the two digit TxGOOSE instance number, for example "GoCB01".

RxGOOSE1 datSet

Range for Edition 2: 0 to 32 alphanumeric and underscore characters, beginning with an alpha character
Range for Edition 1: 0 to 32 alphanumeric and underscore characters, beginning with an alpha character
Default:

If the entered value has one or more characters, the datSet field of incoming GOOSE messages must exactly match this value prefixed by <LDName>/LLN0$ for the message to be accepted as a valid RxGOOSE1 message. <LDName> is as specified in the RxGOOSE GoCBRef setting above. If the entered value is the empty string, RxGOOSE1 does not check the value received in the datSet field.

If the publisher is a UR 7.3x series device, set this setting to the value of the publisher's DataSetxx name setting, where xx is the instance number of the data set selected by the publisher's **TxGOOSE datSet** setting.

RxGOOSE1 ConfRev

Range: 0 to 4294967295 in steps of 1
Default: 1

If the value entered is non-zero, the confRev field of incoming GOOSE messages must exactly match this value for the message to be accepted as a valid RxGOOSE1 message. If the entered value is zero, RxGOOSE1 does not check the value received in the confRev field.

If the publisher is a UR 7.3x series device, set this setting to match the value of the publisher's **TxGOOSE ConfRev** setting.

RxGOOSE1 Member 1

Range: End of List, BOOLEAN, Dbpos (DPS), FLOAT32, INT32, Quality, TimeStamp
Default: End of List

This setting specifies the type that the first member of incoming GOOSE messages must be for the message to be accepted as a valid RxGOOSE1 message. There are similar settings for each of the members that the UR is able to subscribe to in a given GOOSE message. The member before the first member setting set to "End of List" must be the last member of the message for the message to be accepted as a valid RxGOOSE1 message.

If the publisher is a UR 7.3x series device, set these settings to match the basic type of the members of the publisher's data set selected by the publisher's **TxGOOSE datSet** setting.

RxGOOSE inputs

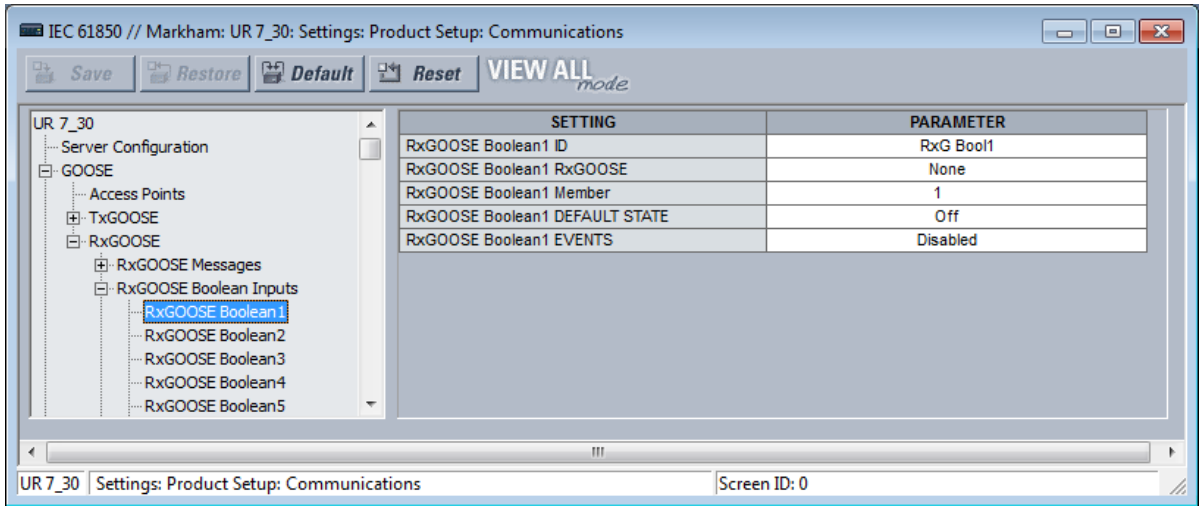
The values received by RxGOOSE elements need to be converted to FlexLogic or FlexAnalog operands so that they can be used by other UR elements. This conversion is done by RxGOOSE Boolean, RxGOOSE DPS, and RxGOOSE Analog elements. Each RxGOOSE Boolean can convert the value of a specified Boolean member received by a specified RxGOOSE to a FlexLogic operand. Each RxGOOSE DPS can convert the value of a specified Dbpos (Double bit position) member to four FlexLogic operands, one for each of the four possible Dbpos states. Each RxGOOSE Analog can convert the value of a specified FLOAT32 member to a FlexAnalog operand. Each of these operands reverts to its default state when the RxGOOSE connectivity is lost. INT32, Quality, and TimeStamp members cannot be converted to operands, and thus although they can be accepted in GOOSE messages, they have no effect on the UR.

RxGOOSE Boolean, RxGOOSE DPS, and RxGOOSE Analog elements are mapped to various data objects in <iedName>Master/GGIO3. This is to allow reading of their values via MMS and to allow references to them in SCL files. GGIO3 has no settings, nor is it visible via UR Setup software. See the UR Communications Guide for more information on GGIO3.

RxGOOSE Boolean inputs

Navigate to **Settings > Product Setup > Communications > IEC 61850 > GOOSE > RxGOOSE > RxGOOSE Boolean Inputs > RxGOOSE Boolean1** to access the settings for the first RxGOOSE Boolean. The settings and functionality for the others are similar.

Figure 5-14: RxGOOSE Boolean panel



RxGOOSE Boolean1 ID

Range: 0 to 12 characters
Default: RxG Bool1

This setting allows the user to assign descriptive text to the name of the RxGOOSE Boolean1 FlexLogic operand. The full operand name is the value of this setting appended with " On". This descriptive text also appears in the SCL files associated with the UR.

RxGOOSE Boolean1 RxGOOSE

Range: None, RxGOOSE1, RxGOOSE2, and so on
Default: None

This setting selects the RxGOOSE containing the value that drives the RxGOOSE Boolean1 FlexLogic operand. If set to None, the RxGOOSE Boolean1 FlexLogic operand assumes its default state.

RxGOOSE Boolean1 Member

Range: 1 to 64 in steps of 1
Default: 1

This setting selects the GOOSE message member that drives the RxGOOSE Boolean1 FlexLogic operand. A setting of 1 selects the first member, 2 selects the second member, and so on. Entering a number greater than the number of members in the message and entering the number of a member that is not a BOOLEAN results in the RxGOOSE Boolean1 FlexLogic operand assuming its default state.

RxGOOSE Boolean1 DEFAULT STATE

Range: On, Off, Latest/On, Latest/Off
Default: On

This setting selects the logic state for the RxGOOSE Boolean1 FlexLogic operand if the UR has just completed startup and the selected RxGOOSE has not yet received a message, or the selected RxGOOSE has lost its connectivity with the publisher. The following choices are available:

- "On" value defaults the input to logic 1
- "Off" value defaults the input to logic 0
- "Latest/On" freezes the input in case of lost connectivity. If the latest state is unknown, such as after UR power-up but before the first communication, the input defaults to logic 1. When communication resumes, the input becomes fully operational.
- "Latest/Off" freezes the input in case of lost connectivity. If the latest state is unknown, such as after UR power-up but before the first communication, the input defaults to logic 0. When communication resumes, the input becomes fully operational.

RxGOOSE Boolean1 EVENTS

Range: Disabled, Enabled

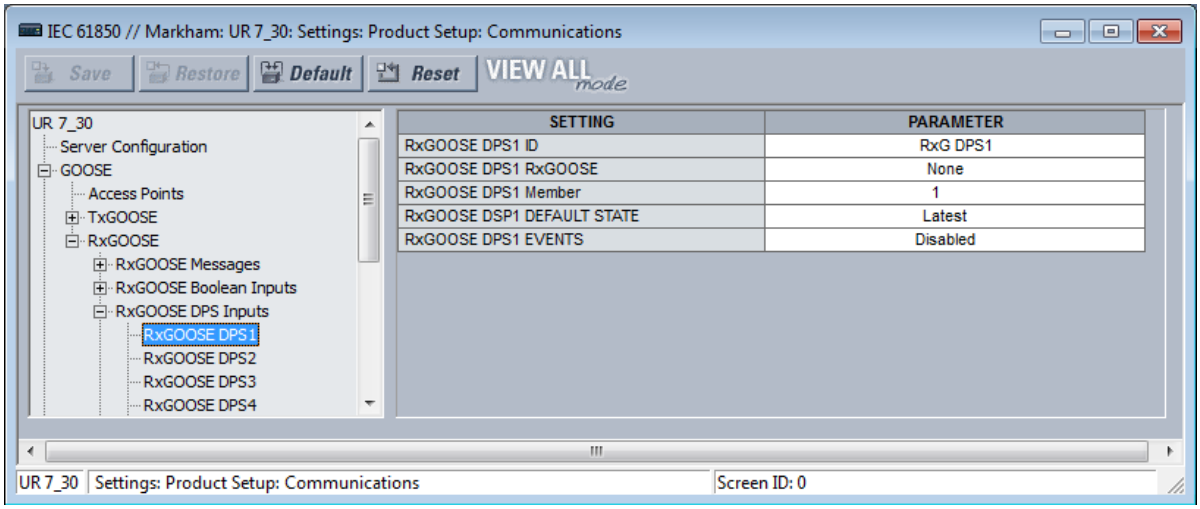
Default: Disabled

This setting selects whether Off to On transitions of the RxGOOSE Boolean1 FlexLogic operand are recorded by the event recorder. If set to Enabled, Off to On transitions are recorded. On to Off transitions are not recorded, even if events are enabled.

RxGOOSE DPS inputs

Navigate to **Settings > Product Setup > Communications > IEC 618560 > GOOSE > RxGOOSE > RxGOOSE DPS Inputs > RxGOOSE DPS1** to access the settings for the first RxGOOSE Boolean. The settings and functionality for the others are similar.

Figure 5-15: RxGOOSE DPS Inputs panel



RxGOOSE DPS1 ID

Range: 0 to 12 characters

Default: RxG DPS1

This setting allows the user to assign descriptive text to the names of the four RxGOOSE DPS1 FlexLogic operands. The full operand name is the value of this setting appended with "Intermediate," "On," "Off," or "Bad." This descriptive text also appears in the SCL files associated with the C70.

RxGOOSE DPS1 RxGOOSE

Range: None, RxGOOSE1, RxGOOSE2, and so on

Default: None

This setting selects the RxGOOSE containing the value that drives the RxGOOSE DPS1 FlexLogic operand. If set to None, the RxGOOSE DPS1 FlexLogic operand assumes its default state.

RxGOOSE DPS1 Member

Range: 1 to 64 in steps of 1

Default: 1

This setting selects the GOOSE message member that drives the RxGOOSE DPS1 FlexLogic operand. A setting of 1 selects the first member, 2 selects the second member, and so on. Entering a number greater than the number of members in the message and entering the number of a member that is not a Dbpos results in the RxGOOSE DPS1 FlexLogic operand assuming its default state.

RxGOOSE DPS1 DEFAULT STATE

Range: intermediate-state, off, on, bad-state, Latest

Default: Latest

This setting selects the logic state for the data attribute @Master/GGIO3.IndPos01.stVal when the UR has just completed start-up and the selected RxGOOSE has not yet received a message, and when the RxGOOSE has lost its connectivity with the publisher. When this setting is selected to Latest, the value of @Master/GGIO3.IndPosψψ.stVal is intermediate-state when the UR has just completed start-up and the selected RxGOOSE has not yet received a message, and the latest received value when the RxGOOSE loses its connectivity with the publisher.

RxGOOSE DPS1 EVENTS

Range: Disabled, Enabled

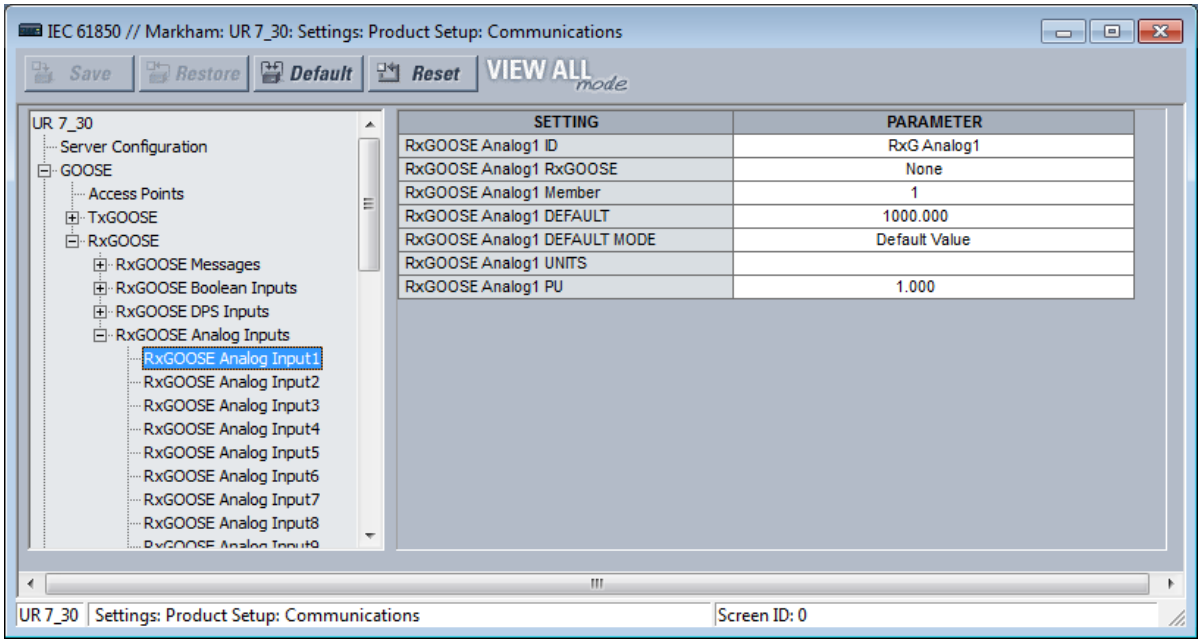
Default: Disabled

This setting selects whether Off to On transitions of the RxGOOSE DPS1 FlexLogic operands are recorded by the event recorder. If set to Enabled, Off to On transitions are recorded. On to Off transitions are not recorded, even if events are enabled.

RxGOOSE analog inputs

Navigate to **Settings > Product Setup > Communications > IEC 61850 > GOOSE > RxGOOSE > RxGOOSE Analog Inputs > RxGOOSE Analog Input1** to access the settings for the first RxGOOSE Boolean. The settings and functionality for the others are similar.

Figure 5-16: RxGOOSE Analog Inputs panel



RxGOOSE Analog1 ID

Range: 0 to 12 characters

Default: RxG Analog1

This setting allows the user to assign descriptive text to RxGOOSE Analog1. This descriptive text also appears in the SCL files associated with the C70. Unlike RxGOOSE Booleans and RxGOOSE DPS, the RxGOOSE Analog operands have fixed names, for example RxGOOSE Analog1.

RxGOOSE Analog1 RxGOOSE

Range: None, RxGOOSE1, RxGOOSE2, and so on

Default: None

This setting selects the RxGOOSE containing the value that drives the RxGOOSE Analog1 FlexAnalog operand. If set to None, the RxGOOSE Analog1 FlexAnalog operand assumes its default state.

RxGOOSE Analog1 Member

Range: 1 to 64 in steps of 1

Default: 1

This setting selects the GOOSE message member that drives the RxGOOSE Analog1 FlexAnalog operand. A setting of 1 selects the first member, 2 selects the second member, and so on. Entering a number greater than the number of members in the message and entering the number of a member that is not a FLOAT32 results in the RxGOOSE Analog1 FlexAnalog operand assuming its default state.

RxGOOSE Analog1 DEFAULT

Range: -1000000.000 to 1000000.000 in steps of 0.001

Default: 1000.000

This setting specifies the value of the GOOSE analog input when the selected RxGOOSE has lost its connectivity with the publisher and the RxGOOSE Analog1 DEFAULT MODE is set to "Default Value." Otherwise this setting has no effect. 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 can be rounded to the closest possible floating point number.

RxGOOSE Analog1 DEFAULT MODE

Range: Default Value, Last Known

Default: Default Value

When the selected RxGOOSE has lost its connectivity with the publisher and this setting is "Last Known," the value of the RxGOOSE Analog1 FlexLogic operand remains at the last received value. When the selected RxGOOSE has lost its connectivity with the publisher and this setting value is "Default Value," then the RxGOOSE Analog1 FlexLogic operand is defined by the RxGOOSE Analog1 DEFAULT setting. After restart, until a message is received, the operand value is the default value.

RxGOOSE Analog1 UNITS

Range: up to 4 characters

Default:

This setting specifies a four-character string that can is used in the actual values display of RxGOOSE Analog1.

RxGOOSE Analogs are floating-point values, with no units. The RxGOOSE UNIT and PU base settings allow the user to configure RxGOOSE Analog, so that it can be used in a FlexElement.

RxGOOSE 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.

RxGOOSE Analogs can be compared to other RxGOOSE Analogs with any character string or no string.

RxGOOSE Analog1 PU

Range: 0.000 to 1000000000.000 in steps of 0.001

Default: 1.000

This setting specifies the per-unit base value for other C70 features to use with the RxGOOSE Analog1 operand. A FlexElement for instance subtracts two quantities after converting their values to integers rescaled to a common base, the common base being the largest of the base values of the two quantities. If one of quantities is RxGOOSE Analog1 and its per-unit base value is not appropriate, the rescaling operation can result in unnecessary loss of precision or overflow in the integer result. The FlexElement Base Units table in the Settings > FlexLogic > FlexElements section later, which tabulates the per-unit base value used by its pickup setting and implies the per-unit base used by other FlexAnalogs, can be of use in selecting a value for the **RxGOOSE Analog1 PU** setting.

Some UR elements have requirements for the type of input operands, for instance current type or voltage type. These elements assume that RxGOOSE Analog operands are of whatever type is necessary to meet these requirements.

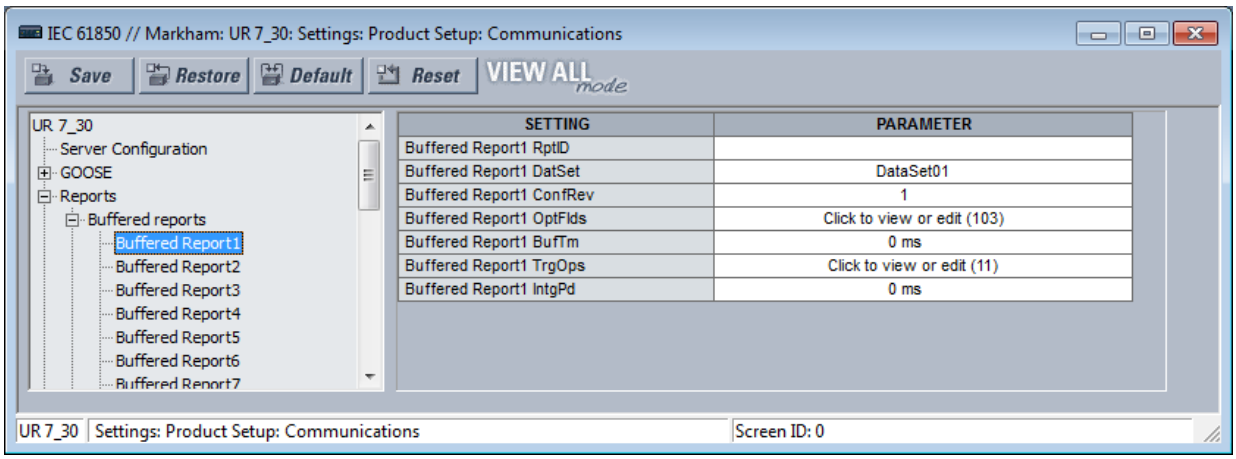
The per-unit base setting represents thousands, not single units. For example, a PU base of 1.000 is actually 1000 and a PU base of 0.001 is 1.

When using RxGOOSE Analogs and PU base in FlexElements, the largest value that can be displayed in the FlexElement actual values is 2,140,000.000.

Reports

Navigate to **Settings > Product Setup > Communications > IEC 61850 > Reports**.

Figure 5-17: IEC 61850 buffered report panel



5

An IEC 61850 Report server is an efficient method for delivery of generic substation event information in a single server to a single client, such as a supervisory control IED. A Configurable Report is a UR element implementing an IEC 61850 Report server, either of the buffered or unbuffered kind. The following table lists the number of Configurable Report elements. Each Configurable Report element can report the values of up to 64 FlexLogic or FlexAnalog operands. Buffered report elements queue value changes that occur while the client is offline and delivered when the client re-connects. Up to 512 events can be queued. Unbuffered control blocks purge all value change events when the connection to the client is lost; any events that occur while the client is not connected are lost.

Table 5-10: Number of report elements

	Number
Buffered reports	20
Unbuffered reports	14

Configurable Reports interoperate with any client device of any manufacturer that conforms to the IEC 61850 edition 1.0 or 2.0 report client requirements.

The entities whose values are reported by a Configurable Report are known as members. The members are itemized in an ordered list known as a data set. Each Configurable Report can use any one of the data sets provided.

Each enabled Configurable Report transmits an update to its client whenever a value change is detected in one or more of its members. Also, the control block can be configured to send integrity reports containing the present value of all members either on demand from the client or periodically. A TCP handshaking mechanism causes messages that are not read and acknowledged by the client to be retransmitted.

For a Configurable Report to operate, its members must be selected (that is, its data set configured) and a client must open a connection to, configure, and enable its report control block. Control blocks and data sets can be pre-configured by sending the C70 a CID file. See the UR Series Communications Guide for details. EnerVista UR Setup also can be used to select the data set members and to pre-configure the control blocks.

Each buffered report has the following settings.

Buffered Report1 RptID

Range: 0 to 129 VisibleString characters

Default: empty string

The name of the report. The entered value sets the RptID value in Buffered Report1 messages, and it can be used by the client to discriminate Buffered Report1 messages from other messages. If the number of characters entered is zero, the value used for RptID in messages is an ObjectReference to the report's control block, that is, "<LDName>/LLN0BR"BRCB01".

Buffered Report1 DatSet

Range: None, DataSet01, DataSet02, ...

Default: None

This setting selects the data set whose members' status is reported in Buffered Report1 messages using the UR Setup software designator for the data set. The IEC 61850 name of the data sets are configured in the Datasets panel, as described later.

An ObjectReference to the data set, which consists of the concatenation of the string "<LDName>/LLN0$" and the data set name, is used in the datSet field of report messages, and it can be used by the client to discriminate Buffered Report1 messages from other messages.

Buffered Report1 ConfRev

Range: 0 to 4294967295 in steps of 1

Default: 1

The entered value sets the confRev value in Buffered Report1 messages, and it can be used by clients to discriminate report messages of the expected configuration revision from messages of a different revision. The standard requires that confRef be incremented each time the members or the order of the members is changed, and each time the data set name is changed. The standard states that the value of 0 is reserved.

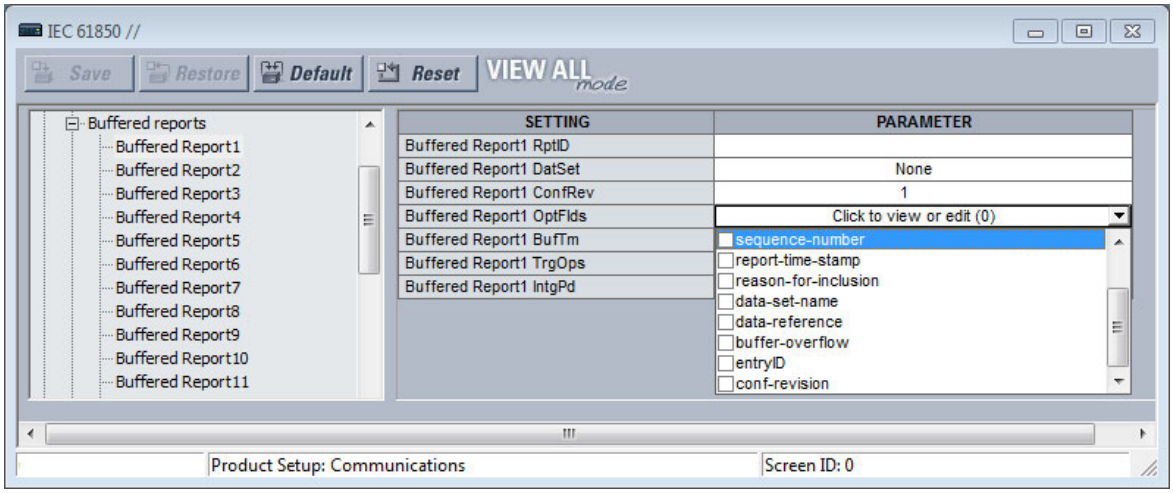
Buffered Report1 OptFlds

Range: The check box for each individual bit can be enabled or not (see figure)

Default: All bits true

The OptFlds setting is bitstring that controls which of the optional fields are included in report messages. The figure shows the available option bits.

Figure 5-18: Options for buffered report messages



Buffered Report1 BufTm

Range: 0 to 4294967295 in steps of 1

Default: 0

The entered value sets the time interval in milliseconds for the buffering of events for inclusion in a single report.

Buffered Report1 TrgOps

Range: The check box for an individual bit can be enabled or not
Default: All bits true

The TrgOps setting is bitstring that controls which trigger conditions are monitored in this report. The options are as follows:

- data-change
- quality-change
- integrity
- general interrogation

Buffered Report1 IntgPd

Range: 0 to 4294967295 in steps of 1
Default: 0

The entered value sets the period in milliseconds for generating Buffered Report1 integrity reports. An integrity report includes the values of all members of the referenced data set, whether a change has occurred or not.

Each unbuffered report has the following settings.

Unbuffered Report1 RptID

Range: 0 to 129 VisibleString characters
Default:

The name of the report. The entered value sets the RptID value in Unbuffered Report1 messages, and it can be used by the client to discriminate Unbuffered Report1 messages from other messages. If the number of characters entered is zero, the value used for RptID in messages is an ObjectReference to the report's control block, that is, "<LDName>/LLN0RP"URCB01".

Unbuffered Report1 DatSet

Range: None, DataSet01, DataSet02, ...
Default: None

This setting selects the data set whose members' status is reported in Unbuffered Report1 messages using the UR Setup software designator for the data set. The IEC 61850 name of the data sets are configured in the Datasets panel, as described later.

An ObjectReference to the data set, which consists of the concatenation of the string "<LDName>/LLN0$" and the data set name, is used in the datSet field of report messages, and it can be used by the client to discriminate Unbuffered Report1 messages from other messages.

Unbuffered Report1 ConfRev

Range: 0 to 4294967295 in steps of 1
Default: 0

The entered value sets the confRev value in Unbuffered Report1 messages, and it can be used by clients to discriminate report messages of the expected configuration revision from messages of a different revision. The standard requires that confRef be incremented each time the members or the order of the members is changed, and each time the data set name is changed.

Unbuffered Report1 OptFlds

Range: The check box for an individual bit can be enabled or not
Default: All bits true

The OptFlds setting is bitstring that controls which of the optional fields are included in report messages. The options are as follows:

- sequence-number
- report-time-stamp
- reason-for-inclusion
- data-set-name

- data-reference
- conf-revision

Notice that OptFlds bits buffer-overflow and entryID are not applicable to unbuffered reports even though the bits exist in the protocol. They are therefore labelled N/A (not applicable) on the display.

Unbuffered Report1 BufTm

Range: 0 to 4294967295 in steps of 1

Default: 0

The entered value sets the time interval in milliseconds for the buffering of events for inclusion into a single report.

Unbuffered Report1 TrgOps

Range: The check box for an individual bit can be enabled or not

Default: All bits true

The TrgOps setting is bitstring that controls which trigger conditions are monitored in this report. The options are as follows:

- data-change
- quality-change
- integrity
- general interrogation

Unbuffered Report1 IntgPd

Range: 0 to 4294967295 in steps of 1.

Default: 0

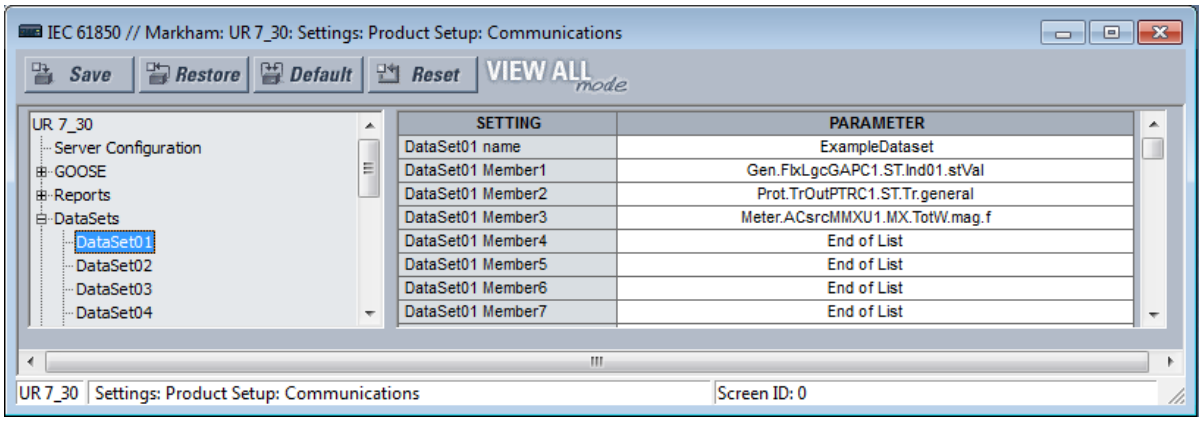
The entered value sets the period in milliseconds for generating Unbuffered Report1 integrity reports. An integrity report includes the values of all members of the referenced data set, whether a change has occurred or not.

DataSets

Navigate to **Settings > Product Setup > Communications > IEC 61850 > DataSets**.

As mentioned in the preceding GOOSE and Reports sections, the members whose values are communicated by these services are itemized in an ordered list known as a data set. Each UR with the IEC 61850 option has 12 data sets. Each data set can contain as many as 64 members. Any data set can be used simultaneously by any number of TxGOOSE elements and/or by any number of Configurable Report elements. UR Setup software can configure any FlexLogic operands and any FlexAnalog operands as members.

Figure 5-19: IEC 61850 DataSets



UR Setup requires data set members to be IEC 61850 data objects or data attributes with Functional Constraint ST or MX. Certain FlexLogic and FlexAnalog operands have factory assigned data attributes as tabulated in the UR Series Communications Guide. All FlexLogic and FlexAnalog operands can be user-assigned to GGIO1 or GGIO4 data attributes, so that operands without factory assigned data attributes can still have their values published. See the GGIO1 and GGIO4 sections later for details.

Datasets used by TxGOOSE1, TxGOOSE2, and/or by reports also provide a chatter suppression service for their Boolean members. Oscillation in a value, also known as chatter, can be caused by errors in logic programming, inadequate hysteresis (deadband) on a threshold, or a failed station component. Chatter can flood a communications network with GOOSE messages, degrading response time for all users. If chatter is detected in a Boolean member, TxGOOSE suspends GOOSE event message triggering and report message triggering from that member for as long as the condition exists, and for a minimum period of one second. While sending is suspended, a self-test message identifying the specific data item detected as oscillating is activated.

Navigate to **Settings > Product Setup > Communications > IEC 61850 > DataSets > DataSet01** to access the settings for the first data set. The settings and functionality for the others are similar.

DataSet01 name

Range: 0 to 32 VisibleString characters

Default: DataSet01

The value entered sets the name of the data set, which is required to be unique within the UR for proper operation. An ObjectReference to the data set consists of a string that is the concatenation of "<LDName>/LLN0$" and the DataSet01 name setting value. An ObjectReference to the data set is published in the datSet field of TxGOOSE messages, and it can be used by subscribers to discriminate the messages of that TxGOOSE from other GOOSE messages. An ObjectReference to the data set is optionally published in the DatSet field of Report messages. Valid characters are upper and lowercase letters, digits, and the underscore (_) character. The first character must be a letter.

DataSet01 Member1

Range: End of List or any instantiated 61850 data object or data attribute with Functional Constraint ST or MX

Default: End of List

This setting specifies the first member in TxGOOSE1 messages. There is a similar setting for each of the up to 64 members that the UR allows in a Dataset. Only values of members before the first set to End of List are published.

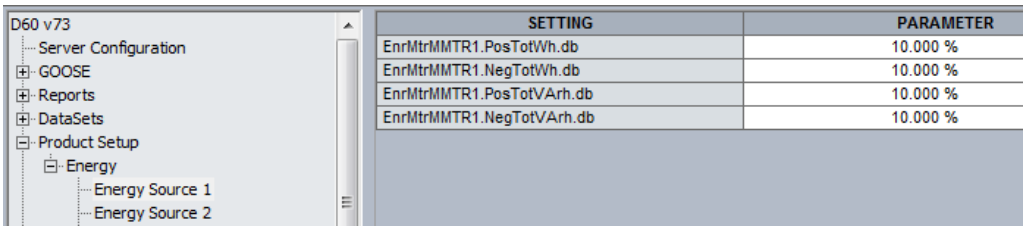
Deadband settings

A deadband is a range in which no action occurs, expressed as a percentage.

The IEC 61850 panels contain hundreds of deadband settings, such as in the following panels: System Setup > Signal Sources, FlexLogic, Grouped Elements, Control Elements, and GGIO4. Each panel is not outlined here.

Deadband setting names all end either with "DEADBAND" or .db. As they all work the same way, but each on a different analog value, a single description applicable to all deadband settings is given here. The analog value that each deadband setting applies to is usually obvious from the name of the setting. However, a tabulation of the analog values and their associated deadband setting can be found in the UR Series Communications Guide.

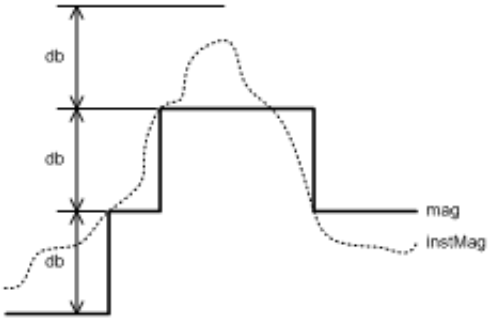
Figure 5-20: Deadband settings with .db suffix



GOOSE, buffered report, and unbuffered report messages are for the most part transmitted only when there is a value change in one or more of their members. Most analog values continuously dither by an amount that is not significant. Were a report to be sent each time an insignificant analog value change occurred, then the communications network floods with GOOSE and report messages, degrading response time for all users.

To control this, a deadband setting is provided for each analog value. Also, in addition to the present actual value of each analog ("instMag" in the following figure), there is a deadbanded value ("mag" in the figure), which is updated with the present value only when the difference between the two exceeds the deadband setting (db in the figure). Changes to this deadbanded value trigger transmissions when included in GOOSE and report data sets.

Figure 5-21: Deadband settings



Deadband settings are entered in UR Setup in units of percent of the difference between the "max." and "min." of the associated analog value. A zero deadband setting suppresses transmission triggering. The range of deadband settings is 0.000 to 100.000% in steps of 0.001. The default value is 10.000%.

GGIO4 elements have individual settings for "min." and "max." The min. and max. for FlxEIGAPC#.OpSig.db (FLEXELEMENT # OpSig) are -50 pu and +50 pu respectively. The min. value for all other quantities is 0. The max. values are as follows:

- Phase current — 46 x phase CT primary setting
- Neutral current — 46 x ground CT primary setting
- Phase and phase-to-phase voltage — 275 x VT ratio setting
- Power (real, reactive, apparent, 3-phase, and 1-phase) — 46 x phase CT primary setting x 275 x VT ratio setting
- Energy (real or imaginary) — 46 x phase CT primary setting x 275 x VT ratio setting x 1 hour
- Frequency — 90 Hz
- Frequency rate of change — 90 Hz/s
- Power factor — 2
- Angle — 360 degrees

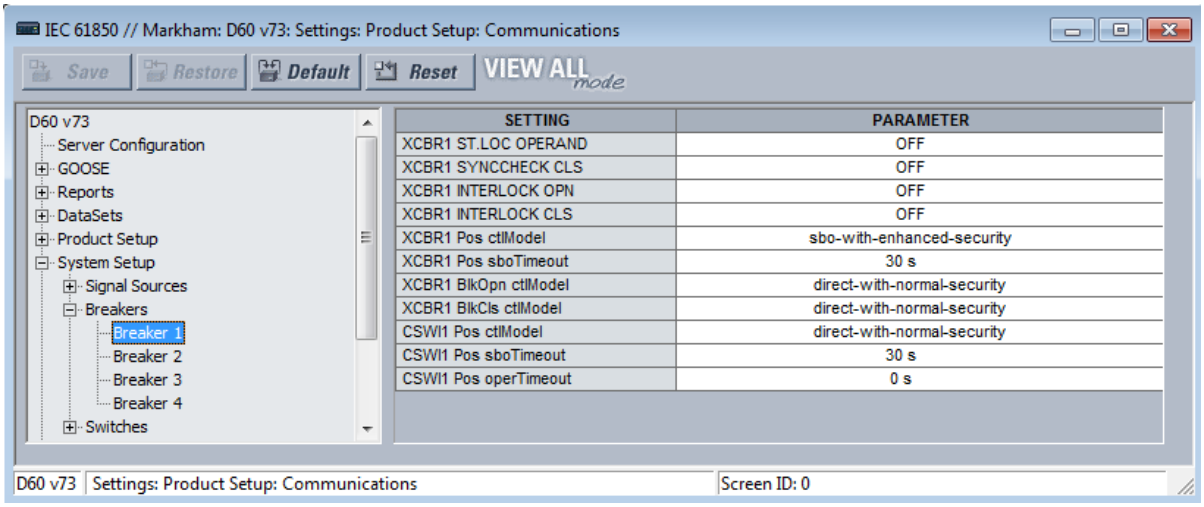
Select the deadband settings from knowledge of the characteristics of the power system quantity measured and knowledge of the demands of the applications receiving the measurement via GOOSE or report such that changes of significance to the application are promptly reported, yet the network is not overly burdened with event messages.

Breaker 1

The UR breaker control and status monitoring elements have certain settings that configure how the IEC 61850 protocol interacts with these elements. These settings are described in this section. See the Breakers section in the System Setup section of this chapter for details on the operation of breaker control elements.

Navigate to **Settings > Communications > IEC 61850 > System Setup > Breakers > Breaker 1** to access the settings that configure the IEC 61850 protocol interface with the first breaker control and status monitoring element. The settings and functionality for the others are similar.

Figure 5-22: IEC 61850 Breaker panel



XCBR1 ST.LOC OPERAND

Range: any FlexLogic operand

Default: OFF

This setting is used to select a FlexLogic operand that declares to IEC 61850 services that breaker 1 is selected for local control. While the selected operand is asserted, Bkr0XCBR1.Loc.stVal is true and IEC 61850 commands to BkrCSWI1.Pos and Bkr0XCBR1.Pos are not accepted, and a Negative Response (-Rsp) is issued with the REASON CODE of Blocked-by-switching-hierarchy.

XCBR1 SYNCCHECK CLS

Range: any FlexLogic operand

Default: ON

This setting is used to select a FlexLogic operand that declares to IEC 61850 services that synchrocheck conditions are acceptable for closing breaker 1. If a SelectWithValue or Operate service with ctlVal true and with Check.SynchroCheck true is requested of either BkrCSWI1.Pos or Bkr0XCBR1.Pos and the selected operand is not asserted, a Negative Response (-Rsp) is issued with the REASON CODE of Blocked-by-synchrocheck.

XCBR1 INTERLOCK OPN

Range: any FlexLogic operand

Default: ON

This setting is used to select a FlexLogic operand that declares to IEC 61850 services that interlocking conditions are not acceptable for opening breaker 1. While the selected operand is asserted, the value of BkrCILO.EnaOpn.stVal is false. If a SelectWithValue or Operate service with ctlVal false and with Check.Interlock-check true is requested of either BkrCSWI1.Pos or Bkr0XCBR1.Pos, and the selected operand is not activated, a Negative Response (-Rsp) is issued with the REASON CODE of Blocked-by-interlocking.

XCBR1 INTERLOCK CLS

Range: any FlexLogic operand

Default: ON

This setting is used to select a FlexLogic operand that declares to IEC 61850 services that interlocking conditions are not acceptable for closing breaker 1. While the selected operand is asserted, the value of BkrCILO.EnaCls.stVal is false. If a SelectWithValue or Operate service with ctlVal true and with Check.Interlock-check true is requested of either BkrCSWI1.Pos or Bkr0XCBR1.Pos and the selected operand is not activated, a Negative Response (-Rsp) is issued with the REASON CODE of Blocked-by-interlocking.

XCBR1 Pos ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security, direct-with-enhanced-security, sbo-with-enhanced-security
Default: sbo-with-enhanced-security

This setting selects the control model clients must use to successfully control the breaker 1 signals marked Bkr0XCBR1.PosOpn.ctlVal and Bkr0XCBR1.PosCls.ctlVal on the Breaker Control Logic (Sheet 1 of 2) diagram in the Settings > System Setup section later in this chapter. These signals force a breaker 1 three-phase trip or close control while the operand selected by setting XCBR1 ST.LOC OPERAND is not active.

"sbo" here is select-before-operate. Enhanced security means that the UR reports to the client the breaker 1 position at the end of the command sequence.

XCBR1 Pos sboTimeout

Range: 2.000 to 60.000 s in steps of 0.001s
Default: 30.000 s

This setting specifies the maximum time between a select and an operate command to breaker 1 signals marked Bkr0XCBR1.PosOpn.ctlVal and Bkr0XCBR1.PosCls.ctlVal in order for the operand to be successful. This setting is only relevant when XCBR1 Pos ctlModel is sbo-with-normal-security or sbo-with-enhanced-security.

XCBR1 BlkOpn ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control the breaker 1 signal marked Bkr0XCBR1.BlkOpn.ctlVal signal on the Breaker Control Logic (Sheet 1 of 2) diagram in the Settings > System Setup section later. This signal when true blocks breaker 1 trip control while the operand selected by setting XCBR1 ST.LOC OPERAND is not active.

XCBR1 BlkCls ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control the breaker 1 signal marked Bkr0XCBR1.BlkCls.ctlVal signal on the Breaker Control Logic (Sheet 1 of 2) diagram in the Settings > System Setup section later. This signal when true blocks breaker 1 close control while the operand selected by setting XCBR1 ST.LOC OPERAND is not active.

CSWI1 Pos ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security, direct-with-enhanced-security, sbo-with-enhanced-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control the breaker 1 signals marked BkrCSWI1.PosOpn.ctlVal and BkrCSWI1.PosCls.ctlVal on the Breaker Control Logic (Sheet 1 of 2) diagram in the Settings > System Setup section earlier. These signals force a breaker 1 three-phase trip or close control while the operand selected by setting XCBR1 ST.LOC OPERAND is not active.

CSWI1 Pos sboTimeout

Range: 2.000 to 60.000 s in steps of 0.001s
Default: 30.000 s

This setting specifies the maximum time between a select and an operate command to breaker 1 via BkrCSWI1.Pos in order for the operand to be successful. This setting is only relevant when CSWI1 Pos ctlModel is sbo-with-normal-security or sbo-with-enhanced-security.

CSWI1 Pos operTimeout

Range: 0.000 to 2.000 s in steps of 0.001s
Default: 0.100 s

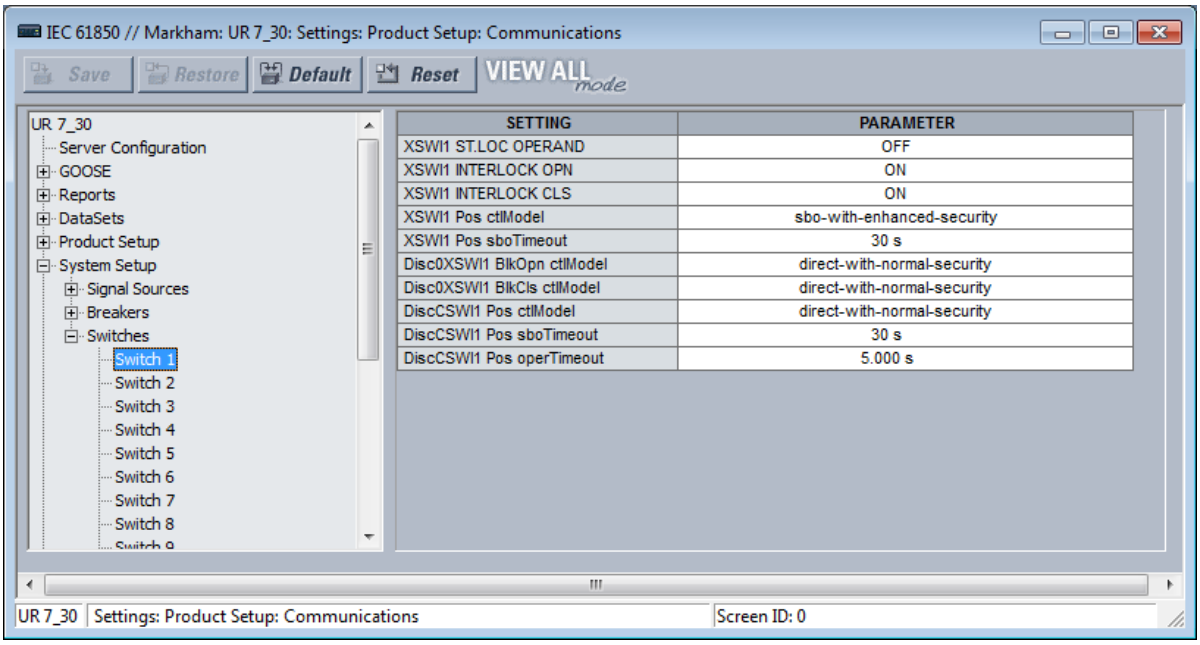
This setting specifies the maximum time between an operate command to breaker 1 via BkrCSWI1.Pos until BkrCSWI1.Pos.stVal enters the commanded state. The command terminates if the commanded state is not reached in the set time.

Switch 1

The UR disconnect switch control and status monitoring elements have certain settings that configure how the IEC 61850 protocol interacts with these elements. These settings are described in this section. See the Settings > System Setup > Disconnect Switches section later in this chapter for details on the operation of the disconnect switch control elements.

Navigate to **Settings > Product Setup > Communications > IEC 61850 > System Setup > Switches > Switch 1** to access the settings that configure the IEC 61850 protocol interface with the first disconnect switch control and status monitoring element. The settings and functionality for the others are similar.

Figure 5-23: Switches panel



XSWI1 ST.LOC OPERAND

Range: any FlexLogic operand
Default: Off

This setting is used to select a FlexLogic operand that declares to IEC 61850 services that disconnect switch 1 is selected for local control. While the selected operand is asserted, Disc0XSWI1.Loc.stVal is true and IEC 61850 commands to DiscCSWI1.Pos and Disc0XSWI1.Pos are not accepted, and a Negative Response (-Rsp) is issued with the REASON CODE of Blocked-by-switching-hierarchy.

XSWI1 INTERLOCK OPN

Range: any FlexLogic operand
Default: On

This setting is used to select a FlexLogic operand that declares to IEC 61850 services that interlocking conditions are not acceptable for opening disconnect switch 1. While the selected operand is asserted, the value of DiscCILO.EnaOpn.stVal is false. If a SelectWithValue or Operate service with ctlVal false and with Check.Interlock-check true is requested of DiscCSWI1.Pos or Disc0XSWI1.Pos and the selected operand is not activated, a Negative Response (-Rsp) is issued with the REASON CODE of Blocked-by-interlocking.

XSWI1 INTERLOCK CLS

Range: any FlexLogic operand

Default: On

This setting is used to select a FlexLogic operand that declares to IEC 61850 services that interlocking conditions are not acceptable for closing disconnect switch 1. While the selected operand is asserted, the value of DiscCILO.EnaCls.stVal is false. If a SelectWithValue or Operate service with ctlVal true and with Check.Interlock-check true is requested of DiscCSWI1.Pos or Disc0XSWI1.Pos and the selected operand is not activated, a Negative Response (-Rsp) is issued with the REASON CODE of Blocked-by-interlocking.

XSWI1 Pos ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security, direct-with-enhanced-security, sbo-with-enhanced-security

Default: sbo-with-enhanced-security

This setting selects the control model that clients must use to successfully control the disconnect switch 1 signals marked Disc0XCBR1.PosOpn.ctlVal and Disc0XCBR1.PosCls.ctlVal on the Disconnect Switch Logic diagram in the Settings > System Setup section later. These signals force a disconnect switch trip or close control while the operand selected by setting XSWI1 ST.LOC OPERAND is not active.

"sbo" here is select-before-operate. Enhanced security means that the C70 reports to the client the disconnect switch 1 position the end of the command sequence.

XSWI1 Pos sboTimeout

Range: 2.000 to 60.000 s in steps of 0.001s

Default: 30.000 s

This setting specifies the maximum time between a select and an operate command to disconnect switch 1 signals marked Disc0XCBR1.PosOpn.ctlVal and Disc0XCBR1.PosCls.ctlVal in order for the operand to be successful. This setting is only relevant when XSWI1 Pos ctlModel is sbo-with-normal-security or sbo-with-enhanced-security.

XSWI1 BlkOpn ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security

Default: sbo-with-normal-security

This setting selects the control model clients must use to successfully control the disconnect switch 1 signal marked DiscCSWI1.BlkOpn.ctlVal signal on the Disconnect Switch Logic diagram in the Settings > System Setup section later. This signal when true blocks disconnect switch 1 trip control while the operand selected by setting XSWI1 ST.LOC OPERAND is not active.

XSWI1 BlkCls ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security

Default: sbo-with-normal-security

This setting selects the control model clients must use to successfully control the disconnect switch 1 signal marked DiscCSWI1.BlkCls.ctlVal signal on the Disconnect Switch Logic diagram in the Settings > System Setup section later. This signal when true blocks disconnect switch 1 close control while the operand selected by setting XSWI1 ST.LOC OPERAND is not active.

CSWI1 Pos ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security, direct-with-enhanced-security, sbo-with-enhanced-security

Default: sbo-with-normal-security

This setting selects the control model clients must use to successfully control the disconnect switch 1 signals marked DiscCSWI1.PosOpn.ctlVal and DiscCSWI1.PosCls.ctlVal on the Disconnect Switch Logic diagram in the Settings > System Setup section later. These signals force a disconnect switch trip or close control while the operand selected by setting XSWI1 ST.LOC OPERAND is not active.

CSWI1 Pos sboTimeout

Range: 2.000 to 60.000 s in steps of 0.001s

Default: 30.000 s

This setting specifies the maximum time between a select and an operate command to disconnect switch 1 via BkrCSWI1.Pos in order for the operand to be successful. This setting is only relevant when CSWI1 Pos ctlModel is sbo-with-normal-security or sbo-with-enhanced-security.

CSWI1 Pos operTimeout

Range: 0.000 to 65.535 s in steps of 0.001s

Default: 5.000 s

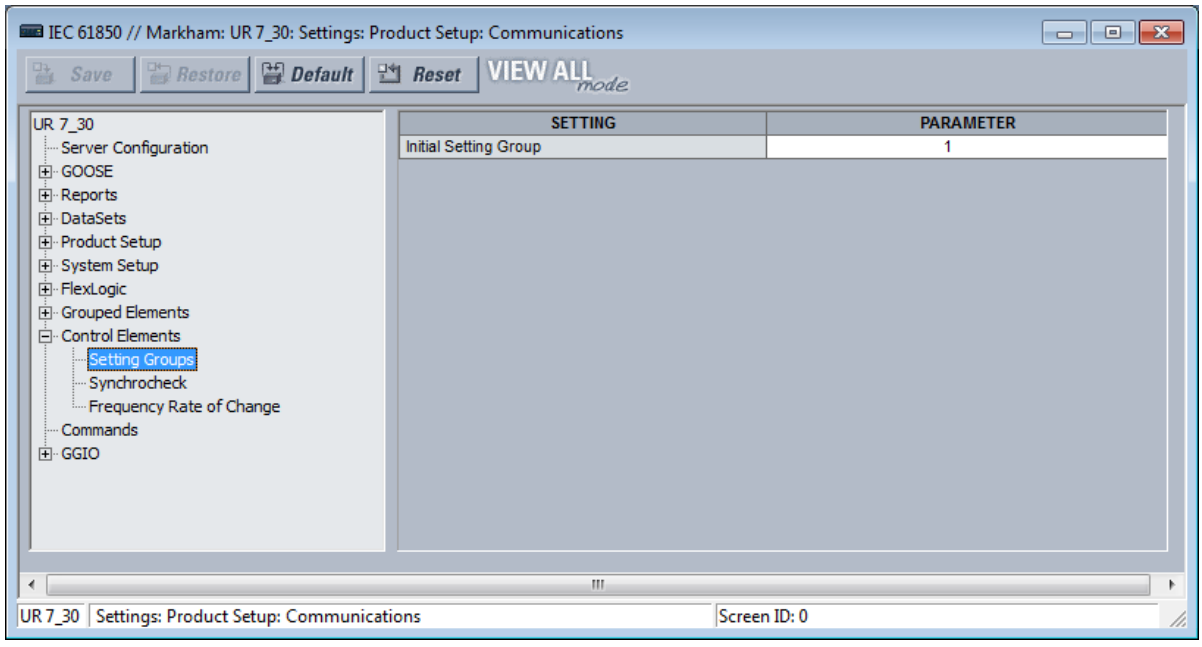
This setting specifies the maximum time between an operate command to disconnect switch 1 via BkrCSWI1.Pos until BkrCSWI1.Pos.stVal enters the commanded state. The command terminates if the commanded state is not reached in the set time.

Setting Groups

The UR implements a setting groups element as detailed in the Control Elements > Setting Groups section of this chapter. The active setting group and the setting group open for edits can be selected via MMS commands SelectActiveSG and SelectEditSG. The setting related to these IEC 61850 commands are described here.

Navigate to **Settings > Product Setup > Communications > IEC 61850 > Control Elements > Setting Groups** to access the setting that configures the IEC 61850 setting group commands.

Figure 5-24: Setting Groups panel



Initial Setting Group

Range: 1 to 6 in steps of 1

Default: 1

The entered value sets the initial value of the non-volatile register normally controlled by the service SelectActiveSG. This initialization occurs only on the UR reboot immediately following the receipt of a valid CID file.

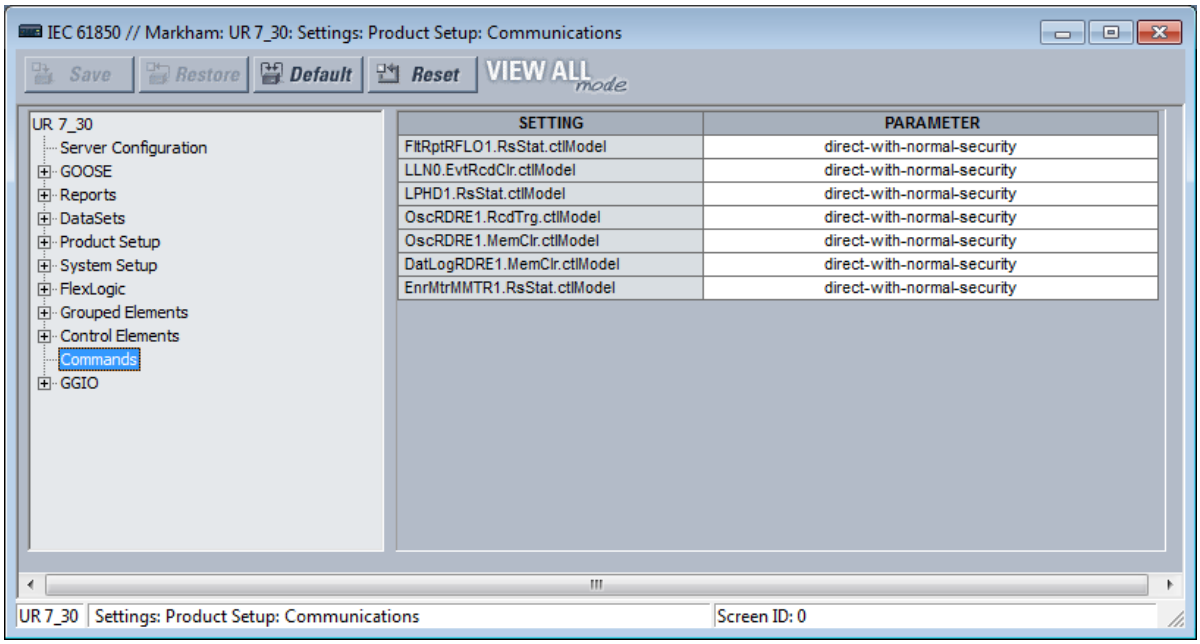
This setting is not mapped into the IEC 61850 information model, but sets the value of SettingControl element attribute actSG in SCL files.

Commands

The UR implements a number of clear records commands as detailed in the Commands and Targets chapter of this manual. Several of these commands also can be issued via IEC 61850. The settings related to these IEC 61850 commands are described here.

Navigate to **Settings > Product Setup > Communications > IEC 61850 > Commands** to access the settings that configure the IEC 61850 protocol interface for record clear commands.

Figure 5-25: Commands panel



FltRptRFLO1.RsStat.ctlModel

Range: direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control the command CLEAR FAULT REPORTS. "sbo" here is select-before-operate. Enhanced security means that the C70 reports to the client the breaker 1 position at the end of the command sequence.

LLN0.EvtRcdClr.ctlModel

Range: direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control the command CLEAR EVENT RECORDS.

LPHD1.RsStat.ctlModel

Range: direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control the command CLEAR ALL RELAY RECORDS.

OscRDRE1.RcdTrg.ctlModel

Range: direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control the command FORCE TRIGGER.

OscRDRE1.MemClr.ctlModel

Range: direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control the command CLEAR OSCILLOGRAPHY.

DatLogRDRE1.MemClr.ctlModel

Range: direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control the command CLEAR DATA LOGGER.

EnrMtrMMTR.RsStat.ctlModel

Range: direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control the command CLEAR ENERGY.

GGIO1

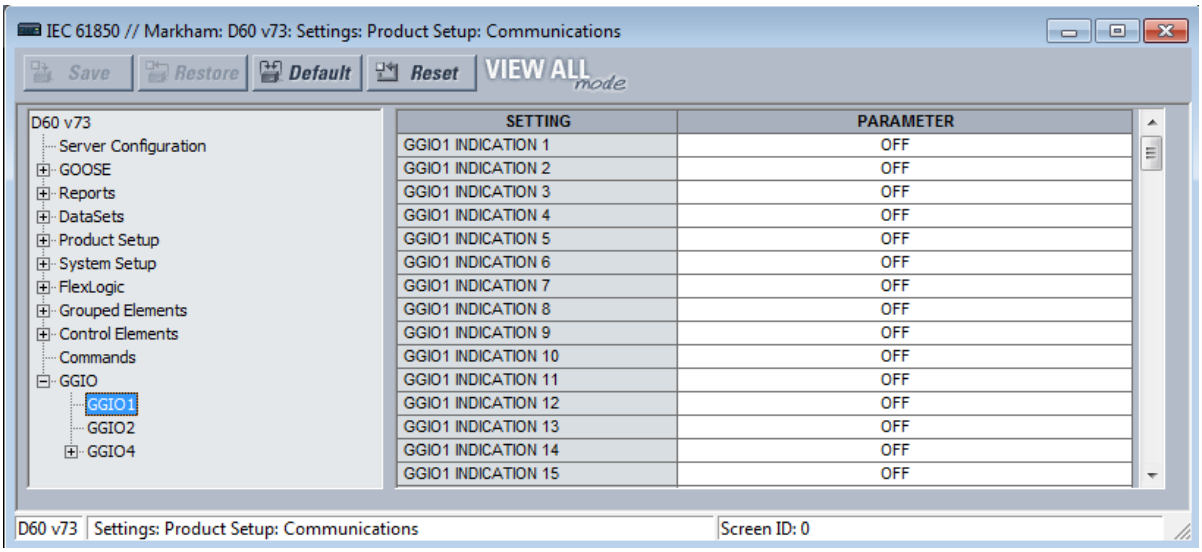
GGIO1 is a UR feature that allows up to 128 UR FlexLogic operands to be user-mapped to IEC 61850 information model data attributes.

For the value of a FlexLogic operand to be read via MMS, included in TxGOOSE messages, or included in buffered/unbuffered reports, the value must be assigned to a data attribute. GGIO1 allows those FlexLogic operands that have not yet been factory-assigned to a data attribute to be user-assigned to a generic data attribute, and thus have their values included in IEC 61850 communications.

Navigate to **Settings > Product Setup > Communications > IEC 61850 > GGIO > GGIO1** to access the settings for GGIO1.

5

Figure 5-26: IEC 61850 GGIO1 panel



GGIO1 INDICATION 1

Range: any FlexLogic operand
Default: OFF

This setting selects the FlexLogic operand whose value is mapped into the IEC 61850 data attribute <LDName>/GGIO1.Ind001.stVal. See the FlexLogic section in this chapter for a list of FlexLogic operands.

GGIO1 INDICATION 2

Range: any FlexLogic operand
Default: OFF

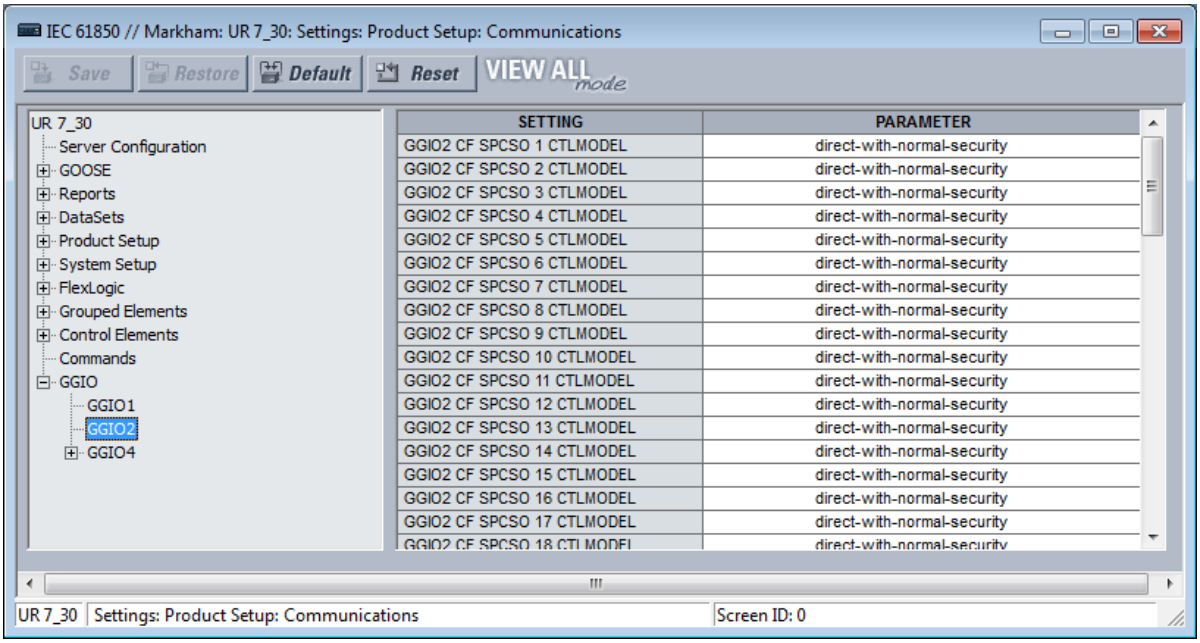
Selects the FlexLogic operand mapped to <LDName>/GGIO1.Ind002.stVal, and so on.

GGIO2

Virtual Inputs are controllable FlexLogic operands that can be controlled via IEC 61850 commands to GGIO2, by DNP, by Modbus, and by the UR front panel. The settings related to these IEC 61850 commands are described here.

Navigate to **Settings > Product Setup > Communications > IEC 61850 > GGIO > GGIO2** to access the settings that configure the IEC 61850 protocol interface for Virtual Input commands.

Figure 5-27: GGIO2 panel



GGIO2 CF SPCSO 1 ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

This setting selects the control model clients must use to successfully control Virtual Input 1. "sbo" here is select-before-operate.

GGIO2 CF SPCSO 2 ctlModel

Range: status-only, direct-with-normal-security, sbo-with-normal-security
Default: direct-with-normal-security

Selects the control model for Virtual Input 2, and so on.

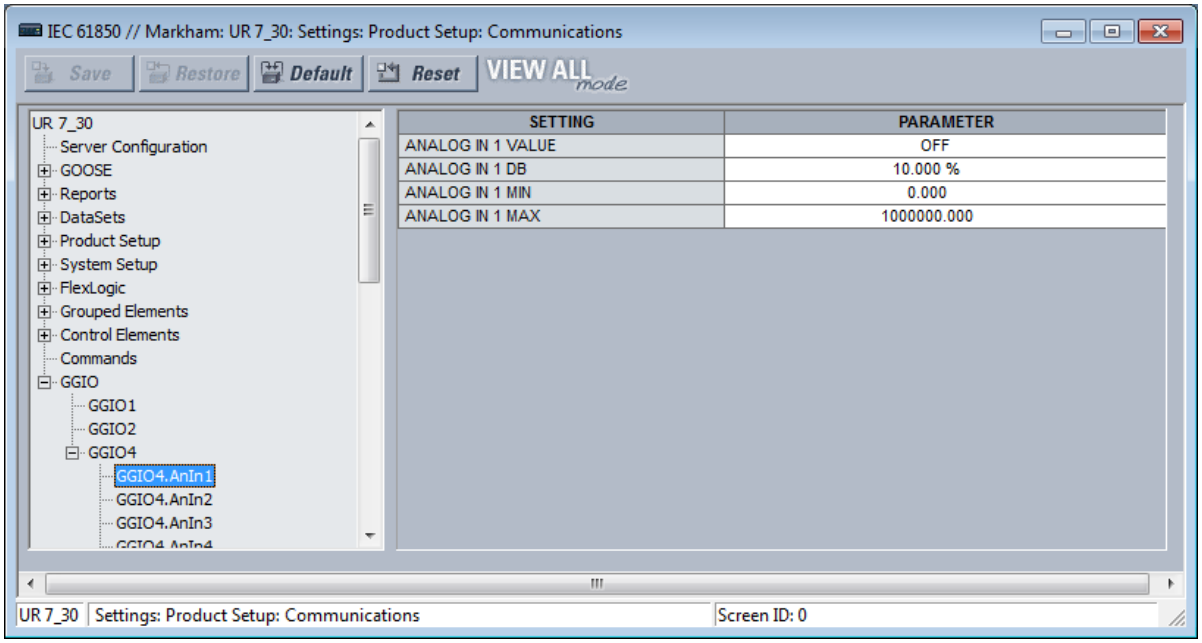
GGIO4

GGIO4 is a UR feature that allows any of up to 32 UR FlexAnalog operands to be user-mapped to an IEC 61850 information model data attribute.

For the value of a FlexAnalog operand to be read via MMS, included in TxGOOSE messages, or included in buffered/unbuffered reports, the value must be assigned to a data attribute. GGIO4 allows those FlexAnalog operands that have not yet been factory assigned to a data attribute to be user-assigned to a generic data attribute, and thus have their values included in IEC 61850 communications.

Navigate to **Settings > Product Setup > Communications > IEC 61850 > GGIO > GGIO4 > GGIO4.AnIn1** to access the settings for the first GGIO4 value. The settings and functionality for the others are similar.

Figure 5-28: GGIO4 panel



5

ANALOG IN 1 VALUE

Range: any FlexAnalog operand
Default: OFF

This setting selects the FlexAnalog operand whose value is mapped into the IEC 61850 data attribute <LDName>/GGIO4.AnIn01.instMag.f. The value of the FlexAnalog operand is converted automatically to the format and scaling required by the standard, that is to say primary amperes, primary volts, and so on. See Appendix A for a list of FlexAnalog operands.

ANALOG IN 1 DB

Range: 0.000 to 100.000% in steps of 0.001
Default: 10.000%

This setting specifies the deadband for the **ANALOG IN 1 VALUE**. 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 "max." and "min." values. Here, the "max." and "min." are as specified by the settings **ANALOG IN 1 MAX** and **ANALOG IN 1 MIN**.

See the Deadband Settings section earlier for a description of deadbanded values.

ANALOG IN 1 MIN

Range: -1000000000.000 to 1000000000.000 in steps of 0.001
Default: 1000.000

This setting specifies the "min." value used in deadband calculations. The scaling of this setting is the same as used by <LDName>/GGIO4.AnIn01.instMag.f. 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 are rounded to the closest possible floating point number.

ANALOG IN 1 MAX

Range: -1000000000.000 to 1000000000.000 in steps of 0.001
Default: 0.000

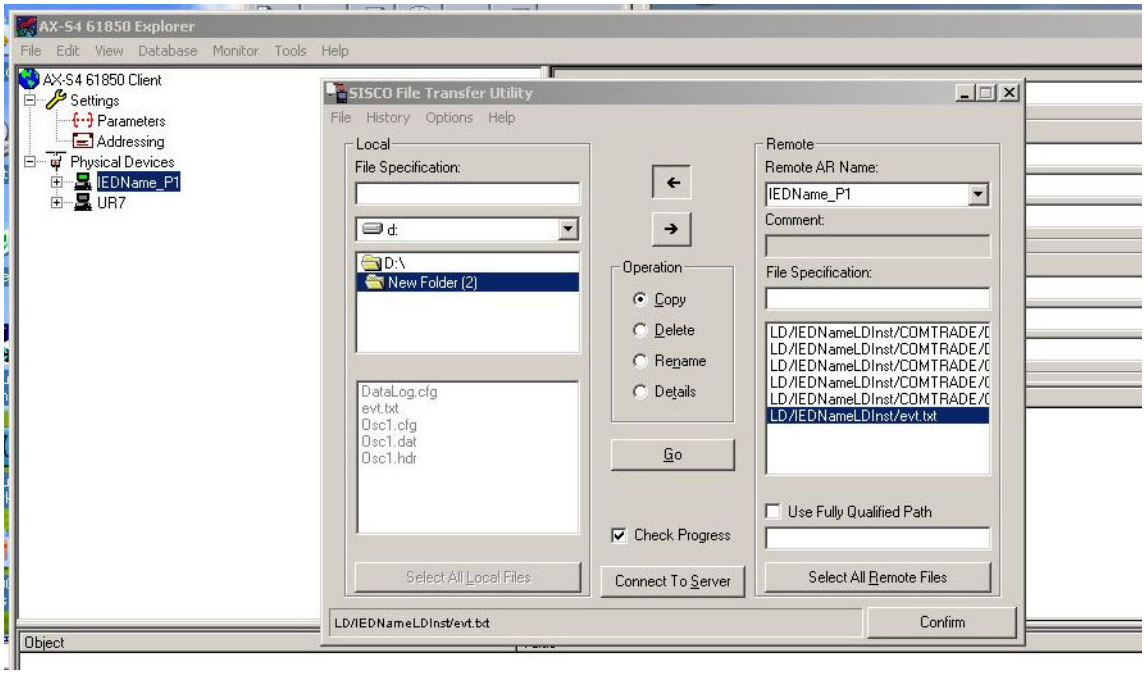
This setting specifies the "max." value used in deadband calculations. The scaling of this setting is the same as used by <LDName>/GGIO4.AnIn01.instMag.f. This setting is stored as an IEEE 754 / IEC 60559 floating point number. Because of the large range of this setting, not all possible values can be stored. Some values are rounded to the closest possible floating point number.

File transfer by IEC 61850

The C70 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 5-29: File transfer by IEC 61850



5.3.4.13 Web server HTTP protocol

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ WEB SERVER HTTP PROTOCOL

■ WEB SERVER ■ HTTP PROTOCOL	⇔	HTTP TCP PORT NUMBER: 80

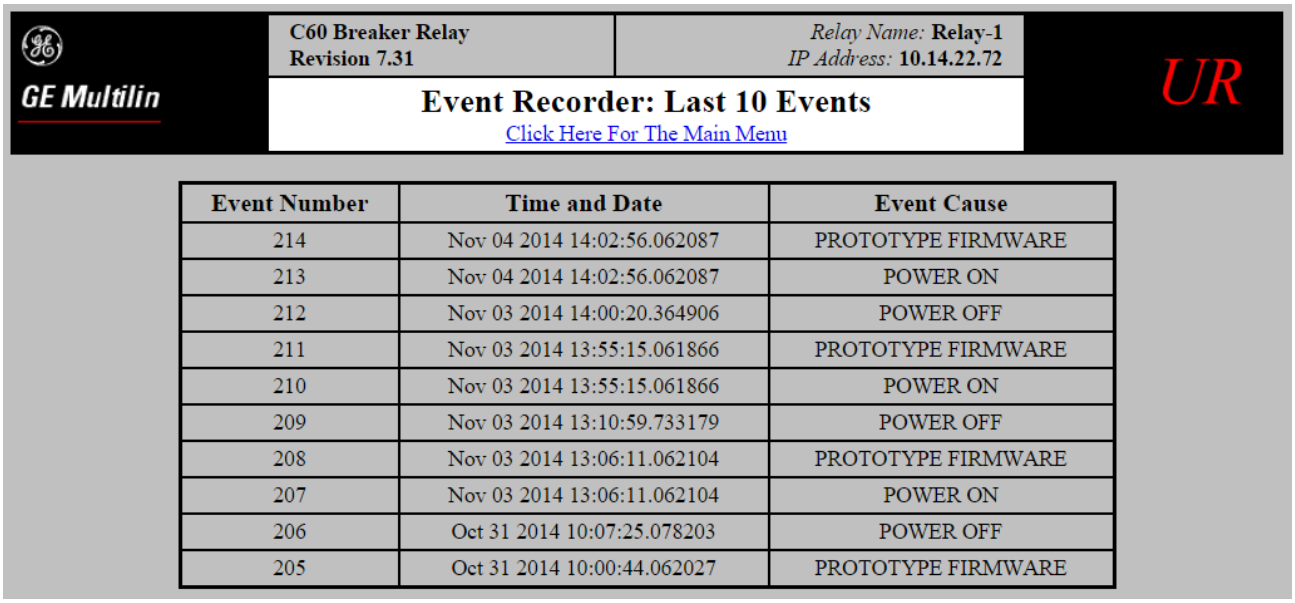
Range: 0 to 65535 in steps of 1

The C70 contains an embedded web server and can display pages in a web browser. The web pages are organized as a series of menus that can be accessed starting at the C70 "Main Menu." Web pages are read-only and are available showing DNP and IEC 60870-5-104 points lists, Modbus registers, event records, fault reports, and so on. First connect the C70 and a computer to an Ethernet network, then enter the IP address of the C70 Ethernet port in a web browser.

To close the port, set the port number to 0.

Any change takes effect when the C70 is restarted.

Figure 5-30: Example of UR web page showing event records



GE Multilin

C60 Breaker Relay
Revision 7.31

Relay Name: **Relay-1**
IP Address: **10.14.22.72**

UR

Event Recorder: Last 10 Events

Click Here For The Main Menu

Event Number	Time and Date	Event Cause
214	Nov 04 2014 14:02:56.062087	PROTOTYPE FIRMWARE
213	Nov 04 2014 14:02:56.062087	POWER ON
212	Nov 03 2014 14:00:20.364906	POWER OFF
211	Nov 03 2014 13:55:15.061866	PROTOTYPE FIRMWARE
210	Nov 03 2014 13:55:15.061866	POWER ON
209	Nov 03 2014 13:10:59.733179	POWER OFF
208	Nov 03 2014 13:06:11.062104	PROTOTYPE FIRMWARE
207	Nov 03 2014 13:06:11.062104	POWER ON
206	Oct 31 2014 10:07:25.078203	POWER OFF
205	Oct 31 2014 10:00:44.062027	PROTOTYPE FIRMWARE

NOTE

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

5

5.3.4.14 TFTP protocol

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ TFTP PROTOCOL

■ TFTP PROTOCOL ■	⇔	TFTP MAIN UDP PORT NUMBER: 69	Range: 0 to 65535 in steps of 1
	⇩	TFTP DATA UDP PORT 1 NUMBER: 0	Range: 0 to 65535 in steps of 1
	⇩	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 C70 over a network. The C70 operates as a TFTP server. TFTP client software is available from various sources, including Microsoft Windows NT. The dir.txt file obtained from the C70 contains a list and description of all available files, for example event records and oscillography.

While TFTP is supported, the put function is not for security reasons. For example, you can enter a "get" command but not a "put" command.

TFTP MAIN UDP PORT NUMBER — To close the port, set the port number to 0. Any change takes effect when the C70 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.

5.3.4.15 IEC 60870-5-104 protocol

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

⇳	■ IEC NETWORK ■ CLIENT ADDRESSES	See below
⇳	IEC COMMON ADDRESS OF ASDU: 0	Range: 0 to 65535 in steps of 1
⇳	IEC CYCLIC DATA PERIOD: 60 s	Range: 1 to 65535 s in steps of 1
⇳	IEC CURRENT DEFAULT THRESHOLD: 30000	Range: 0 to 65535 in steps of 1
⇳	IEC VOLTAGE DEFAULT THRESHOLD: 30000	Range: 0 to 65535 in steps of 1
⇳	IEC POWER DEFAULT THRESHOLD: 30000	Range: 0 to 65535 in steps of 1
⇳	IEC ENERGY DEFAULT THRESHOLD: 30000	Range: 0 to 65535 in steps of 1
⇳	IEC PF DEFAULT THRESHOLD: 1.00	Range: 0.00 to 1.00
⇳	IEC OTHER DEFAULT THRESHOLD: 30000	Range: 0 to 65535 in steps of 1
⇧	IEC REDUNDANCY ENABLED: No	Range: No, Yes

IEC 60870-5-104 is a transmission protocol for network access, specifically for communication between a control station and substation over a TCP/IP network.

The C70 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 C70 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 C70 maintains two sets of IEC 60870-5-104 data change buffers, ideally no more than two masters actively communicate with the C70 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 C70 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 C70 when any current values change by 15 A, the **IEC CURRENT DEFAULT THRESHOLD** setting is 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 C70, 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 — To close the port, set the port number to 0. Any change takes effect when the C70 is restarted.

IEC COMMON ADDRESS OF ASDU — The change takes effect when the C70 is restarted.

IEC CYCLIC DATA PERIOD — The change takes effect when the C70 is restarted.

NOTE

The C70 relay does not support energy metering. As such, the **IEC ENERGY DEFAULT THRESHOLD** setting is not applicable.

NOTE

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 60870-5-104 PROTOCOL ⇨⇩ IEC NETWORK CLIENT ADDRESSES

■ IEC NETWORK ■ CLIENT ADDRESSES	⇔	CLIENT ADDRESS 1: 0.0.0.0	Range: standard IPV4 address format
	⇩		
	⇧	CLIENT ADDRESS 5: 0.0.0.0	Range: standard IPV4 address format

The C70 can specify a maximum of five clients for its IEC 104 connections. These are IP addresses for the controllers to which the C70 can connect. A maximum of two simultaneous connections are supported at any given time.

5.3.4.16 IEC 60870-5-103 protocol

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 60870-5-103

■ IEC103 ■ PROTOCOL	⇔	IEC103 COMMON ADDRESS OF ASDU: 0	Range: 0 to 254 in steps of 1
	⇳	IEC103 SYNC TIMEOUT: 1	Range: 1 to 1440 min in steps of 1
	⇳	■ IEC103 INPUTS ■ BINARY	See below
	⇳	■ IEC103 INPUTS ■ MEASURANDS	See below
	⇧	■ IEC103 COMMANDS ■	See below



The C70 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.

IEC 60870-5-103 is a companion standard to the IEC 60870-5 suite 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 protocol is enabled when the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨ PROTOCOL** setting is set to IEC 60870-5-103.

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.

The UR Series Communications Guide contains more information on the protocol.

IEC103 COMMON ADDRESS OF ASDU — This setting uniquely defines this C70 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 C70 waits for a synchronization message. The C70 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 C70 sets the invalid bit in the time stamp of a time-tagged message.

The settings for the remaining menus are outlined as follows.

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 60870-5-103 ⇨⇩ IEC103 INPUTS BINARY

■ IEC103 INPUTS BINARY	⇔	■ POINT 0 ■ — See below
	⇳	■ POINT 1 ■ — See below
	⇩	
	⇧	■ POINT 95 ■ — See below

■ POINT 0 ■	⇔	POINT 0 FUN 0 — Range: 0 to 255 in steps of 1
	⇳	POINT 0 INF 0 — Range: 0 to 255 in steps of 1
	⇧	POINT 0 Input Off — Range: FlexLogic operand
	⇩	

■ POINT 95 ■	⇔	POINT 95 FUN 0 — Range: 0 to 255 in steps of 1
	⇳	POINT 95 INF 0 — Range: 0 to 255 in steps of 1
	⇧	POINT 95 Input Off — Range: FlexLogic operand

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 IEC 60870-5-103 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.

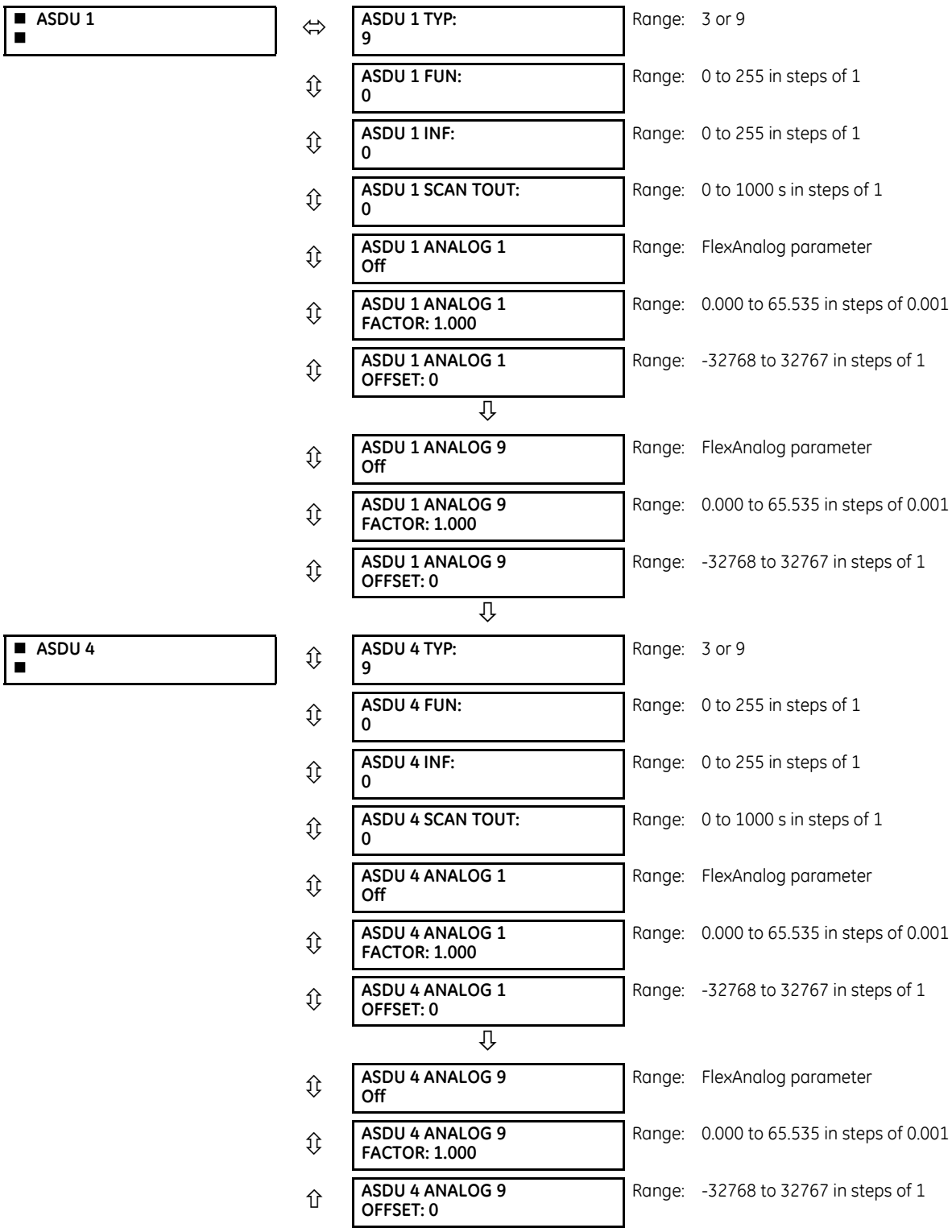
For each defined point, set appropriate values for the Function Type (FUN) and Information Number (INF), which form the Information Object Identifier field of the ASDU, as defined in IEC 60870-5-103.

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 C70 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.

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 60870-5-103 ⇨⇩ IEC103 INPUTS MEASURANDS

■ IEC103 INPUTS MEASURANDS	⇔	■ ASDU 1 ■ — See below
	⇩	
	⇧	■ ASDU 4 ■



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).

FUNCTION TYPE (FUN) and **INFORMATION NUMBER (INF)** — These two fields form the Information Object Identifier of the ASDU as defined in IEC 60870-103.

SCAN TIMEOUT (SCAN TOUT) — This is the cyclic period used by the C70 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 C70 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 IEC 60870-5-103 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 ASDU 2 and configure measurands in ASDU 3.

For any change to take effect, restart the relay.

ANALOG # FACTOR and **OFFSET** — For each measurand included in the ASDU, a factor and offset also can be configured. The factor and offset allow for scaling to be performed on measurands. The final measurement sent to the IEC 60870-103 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 IEC 103. 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 IEC 60870-5-103 chapter of the UR Series Communications Guide. Two examples follow, where you decide factors a and b.

  Example 1: Nominal power Pn = 100 MW = 100000 KW (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 100000 KW * 2.4 = 240000 KW, we transmit

  Pt = 0.017 * 240000 = 4080

  A value above 240 MW is indicated by overflow.

  Example 2: Nominal voltage Vn = 500000 V

  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

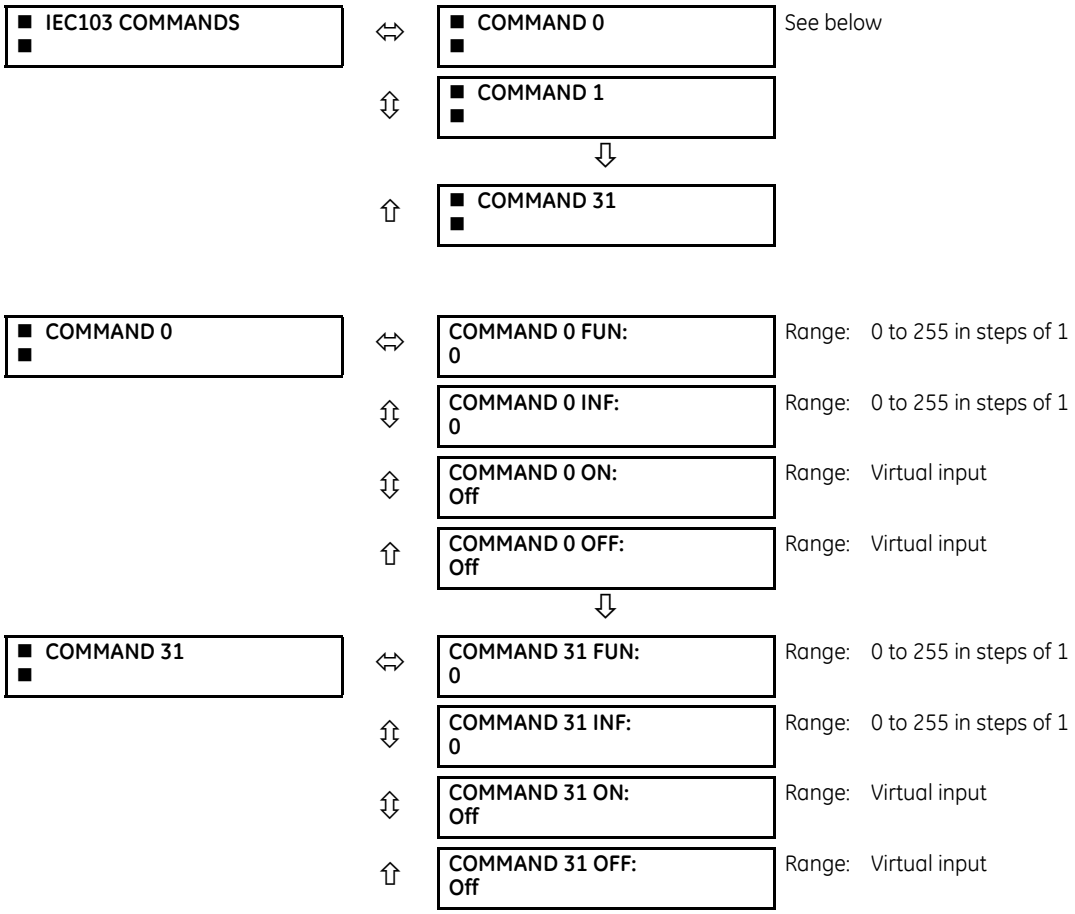
  b = -4096

Vt = 0.006 * V - 4096

For max voltage 500000 V * 2.4 = 1200000 V, we transmit

Vt = 0.006 * 1200000 - 4096 = 7200 - 4096 = 3104

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 60870-5-103 ⇨⇩ IEC103 COMMANDS



Commands are received as General Command (Type Identification 20). The user can configure the action to perform when an ASDU command comes.

A list of available mappings is provided on the C70. 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.

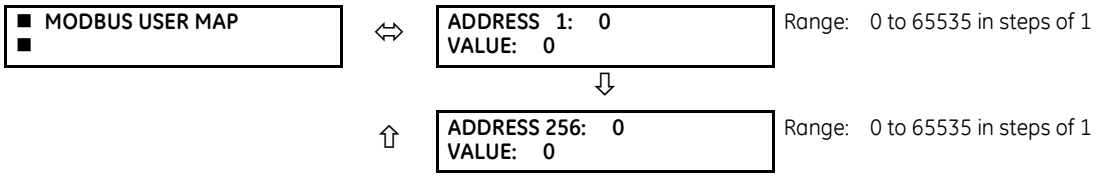
Table 5-11: Commands mapping table

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.

5.3.5 Modbus user map

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ MODBUS USER MAP



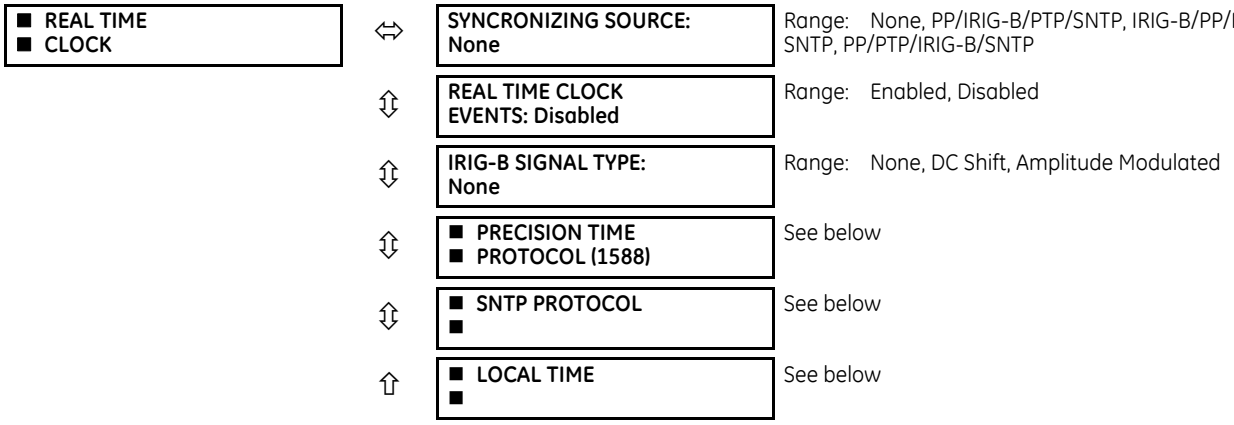
The Modbus user map provides read-only access for up to 256 registers. To obtain a memory map value, enter the address in the **ADDRESS** line (converted from hex to decimal format). The corresponding value (if programmed) displays in the **VALUE** line. A value of "0" in subsequent register **ADDRESS** 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.

The UR Series Communications Guide outlines the Modbus memory map. The map is also viewable in a web browser; enter the IP address of the C70 in a web browser and click the option.

5.3.6 Real-time clock

5.3.6.1 Menu

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.

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, and the clock can be 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.

Setup for IRIG-B is illustrated in the Installation chapter.

Whenever a time synchronization message is received through any of the active protocols, the C70 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. If IRIG-B or PTP is used to update the relay clock, the other protocols (such as SNTP) are not allowed to update, even if active.

For version 7.32 and later in 7.3x, the SNTP priority includes other protocols, such as IEC 60870-5-103, IEC 60870-5-104, and DNP.

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.

To configure and enable PTP and/or SNTP, or to set local time parameters (for example time zone, daylight savings), use the following sections.

5.3.6.2 Precision time protocol (1588)

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK ⇨⇩ PRECISION TIME PROTOCOL (1588)

■ PRECISION TIME ■ PROTOCOL (1588)	⇔	STRICT POWER PROFILE: Disabled	Range: Enabled, Disabled
	⇳	PTP DOMAIN NUMBER: 0	Range: 0 to 255
	⇳	PTP VLAN PRIORITY: 4	Range: 0 to 7
	⇳	PTP VLAN ID: 0	Range: 0 to 4095
	⇧	■ PTP PORT 1 ■	See below

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK ⇨⇩ PRECISION TIME PROTOCOL (1588) ⇨⇩ PTP PORT 1(3)

■ PTP PORT 1 ■	⇳	PORT 1 PTP FUNCTION: Disabled	Range: Enabled, Disabled
	⇳	PORT 1 PATH DELAY ADDER: 0 ns	Range: 0 to 60 000 ns in steps of 1
	⇧	PORT 1 PATH DELAY ASYMMETRY: 0 ns	Range: –1 000 to +1 000 ns in steps of 1



The C70 is provided with optional Precision Time Protocol capability. This feature is specified as the IEEE 1588 software option at the time of ordering. See the Order Codes section in chapter 2 for details.

The C70 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.

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 that 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 can 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. When a clock on start-up discovers that it is "better" than the present grandmaster, it assumes the grandmaster role and the previous grandmaster reverts to slave. The C70 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. If one of the network devices in the hierarchy does not fully implement PP, the associated propagation delay and/or latency may not be compensated for, and the time received at the end-device can be in error by more than 100 µs.

See the preceding Real Time Clock section 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. The PTP menu displays only when the option was purchased.

STRICT POWER PROFILE — Power profile (IEEE Std C37.238 2011) requires that the relay only select a power profile compliant clock as a grandmaster, 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 only selects as master the clocks displaying the IEEE_C37_238 identification codes. It uses a port only when the peer delay mechanism is operational. With the strict power profile setting disabled, the relay uses clocks without the power profile identification when no power profile clocks are present, and uses 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 — Set this setting to the domain number of the grandmaster-capable clock(s) to be synchronized to. A network can 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 it be set to 7 in accordance with PTP. Depending on the characteristics of the device to which the relay is linked directly, VLAN Priority can 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 can be left at its default value. Depending on the characteristics of the device to which the relay is linked directly, VLAN ID can 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, make this setting 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 is 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 always and completely corrects for uncompensated delay. A setting can be chosen that reduces the worst-case error to half of the range between minimum and maximum uncompensated delay, if these values are known.

PORT 1 ... 3 PATH DELAY ASSYMMETRY — 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 make this setting zero.

In unusual cases where the length of the link is different in different directions, set this setting 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 9000 ns and that the delay from the switch to the relay is 11000 ns, then the mean delay is 10000 ns, and the path delay asymmetry is 11000 - 10000 = +1000 ns.

5.3.6.3 SNTP protocol

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK ⇨⇩ SNTP PROTOCOL

■ SNTP PROTOCOL ■	⇔	**SNTP FUNCTION: Disabled**	Range: Enabled, Disabled
	⇳	**SNTP SERVER IP ADDR: 0.0.0.0**	Range: standard IP address format
	⇧	**SNTP UDP PORT NUMBER: 123**	Range: 0 to 65535 in steps of 1

The C70 supports the Simple Network Time Protocol specified in RFC-2030. With SNTP, the C70 can obtain clock time over an Ethernet network. The C70 acts as an SNTP client to receive time values from an SNTP/NTP server, usually a dedicated product using a GPS receiver. UR series relays support unicast, broadcast, multicast, and anycast SNTP functionality.

The **SNTP FUNCTION** setting enables or disables the SNTP feature on the C70.

To use SNTP in unicast mode, set **SNTP SERVER IP ADDR** to the SNTP/NTP server IP address. Once this address is set and **SNTP FUNCTION** is "Enabled," the C70 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 C70 clock is closely synchronized with the SNTP/NTP server. It takes up to two minutes for the C70 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 C70 then listens to SNTP messages sent to the "all ones" broadcast address for the subnet. The C70 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 the port number to 0, after which the change takes effect when the C70 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.

5.3.6.4 Local time

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK ⇨⇩ LOCAL TIME

■ LOCAL TIME ■	⇔	LOCAL TIME OFFSET FROM UTC: 0.0 hr	Range: –24.0 to 24.0 hr in steps of 0.5
	⇩	DAYLIGHT SAVINGS TIME: Disabled	Range: Disabled, Enabled
	⇩	DST START MONTH: January	Range: January to December (all months)
	⇩	DST START DAY: Sunday	Range: Sunday to Saturday (all days of the week)
	⇩	DST START DAY INSTANCE: First	Range: First, Second, Third, Fourth, Last
	⇩	DST START HOUR: 2:00	Range: 0:00 to 23:00
	⇩	DST STOP MONTH: January	Range: January to December (all months)
	⇩	DST STOP DAY: Sunday	Range: Sunday to Saturday (all days of the week)
	⇩	DST STOP DAY INSTANCE: First	Range: First, Second, Third, Fourth, Last
	⇩	DST STOP HOUR: 2:00	Range: 0:00 to 23:00

The C70 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 timestamps 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.

LOCAL TIME OFFSET FROM UTC — 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.

DAYLIGHT SAVINGS TIME and **DST** — 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.

5.3.7 User-programmable fault report

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE FAULT REPORTS ⇨⇩ USER-PROGRAMMABLE FAULT REPORT 1(2)

■ USER-PROGRAMMABLE ■ FAULT REPORT 1	⇔	FAULT REPORT 1 FUNCTION: Disabled	Range: Disabled, Enabled
	⇳	PRE-FAULT 1 TRIGGER: Off	Range: FlexLogic operand
	⇳	FAULT 1 TRIGGER: Off	Range: FlexLogic operand
	⇳	FAULT REPORT 1 # 1: Off	Range: Off, any actual value analog parameter
	⇩		
	⇧	FAULT REPORT 1 #32: Off	Range: Off, any actual value analog parameter

When enabled, this function monitors the pre-fault trigger. The pre-fault data are stored in the memory for prospective creation of the fault report on the rising edge of the pre-fault trigger. The element waits for the fault trigger as long as the pre-fault trigger is asserted, but not shorter than 1 second. When the fault trigger occurs, the fault data is stored and the complete report is created. If the fault trigger does not occur within 1 second after the pre-fault trigger drops out, the element resets and no record is created.

The user programmable record contains the following information: the user-programmed relay name, detailed firmware revision (x.xx, for example) and relay model (C70), the date and time of trigger, the name of pre-fault trigger (a specific FlexLogic operand), the name of fault trigger (a specific FlexLogic operand), the active setting group at pre-fault trigger, the active setting group at fault trigger, pre-fault values of all programmed analog channels (one cycle before pre-fault trigger), and fault values of all programmed analog channels (at the fault trigger).

Each fault report is stored as a file to a maximum capacity of ten files. An eleventh trigger overwrites the oldest file. The EnerVista software is required to view all captured data. A FAULT RPT TRIG event is automatically created when the report is triggered.

The relay includes two user-programmable fault reports to enable capture of two types of trips (for example, trip from thermal protection with the report configured to include temperatures, and short-circuit trip with the report configured to include voltages and currents). Both reports feed the same report file queue.

The last record is available as individual data items via communications protocols.

PRE-FAULT 1 TRIGGER — Specifies the FlexLogic operand to capture the pre-fault data. The rising edge of this operand stores one cycle-old data for subsequent reporting. The element waits for the fault trigger to actually create a record as long as the operand selected as **PRE-FAULT 1 TRIGGER** is "On." If the operand remains "Off" for 1 second, the element resets and no record is created.

FAULT 1 TRIGGER — Specifies the FlexLogic operand to capture the fault data. The rising edge of this operand stores the data as fault data and results in a new report. The trigger (not the pre-fault trigger) controls the date and time of the report.

FAULT REPORT 1 # 1 to **FAULT REPORT 1 #32** — These settings specify an actual value such as voltage or current magnitude, true RMS, phase angle, frequency, temperature, and so on, to be stored when the report is created. Up to 32 channels can be configured. Two reports are configurable to cope with variety of trip conditions and items of interest.

5.3.8 Oscillography

5.3.8.1 Menu

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ OSCILLOGRAPHY

■ OSCILLOGRAPHY ■	⇔	NUMBER OF RECORDS: 15	Range: 3 to 64 in steps of 1
	⇩	TRIGGER MODE: Automatic Overwrite	Range: Automatic Overwrite, Protected
	⇩	TRIGGER POSITION: 50%	Range: 0 to 100% in steps of 1
	⇩	TRIGGER SOURCE: Off	Range: FlexLogic operand
	⇩	AC INPUT WAVEFORMS: 16 samples/cycle	Range: Off; 8, 16, 32, 64 samples/cycle
	⇩	■ DIGITAL CHANNELS ■	See below
	⇧	■ ANALOG CHANNELS ■	See below

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 5-12: 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

TRIGGER MODE — A new record automatically overwrites an older record when **TRIGGER MODE** is set to "Automatic Overwrite."

TRIGGER POSITION — Set this 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.

TRIGGER SOURCE — 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.

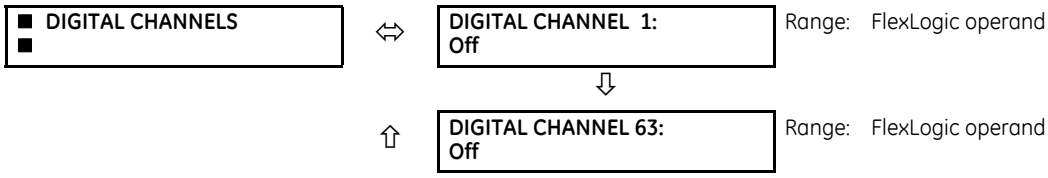
AC INPUT WAVEFORMS — Determines the sampling rate at which AC input signals (that is, current and voltage) are stored. Reducing the sampling rate allows longer records to be stored. This setting has no effect on the internal sampling rate of the relay, which is always 64 samples per cycle. That is, it 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.

5.3.8.2 Digital channels

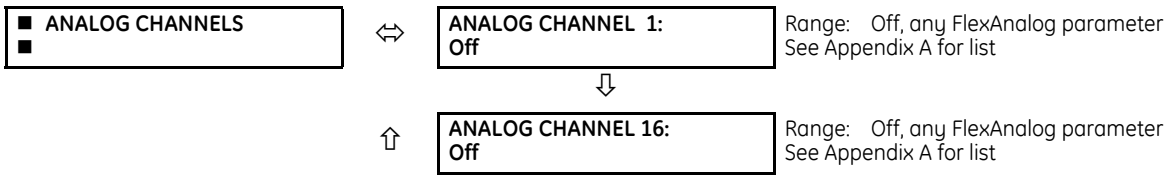
SETTINGS ⇨ PRODUCT SETUP ⇨⇩ OSCILLOGRAPHY ⇨⇩ DIGITAL CHANNELS



DIGITAL 1(63) CHANNEL — This 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.

5.3.8.3 Analog channels

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 depend 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

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 time-consuming to scan through the list of parameters via the relay keypad and display — entering this number via the relay keypad causes the corresponding parameter to display.

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.

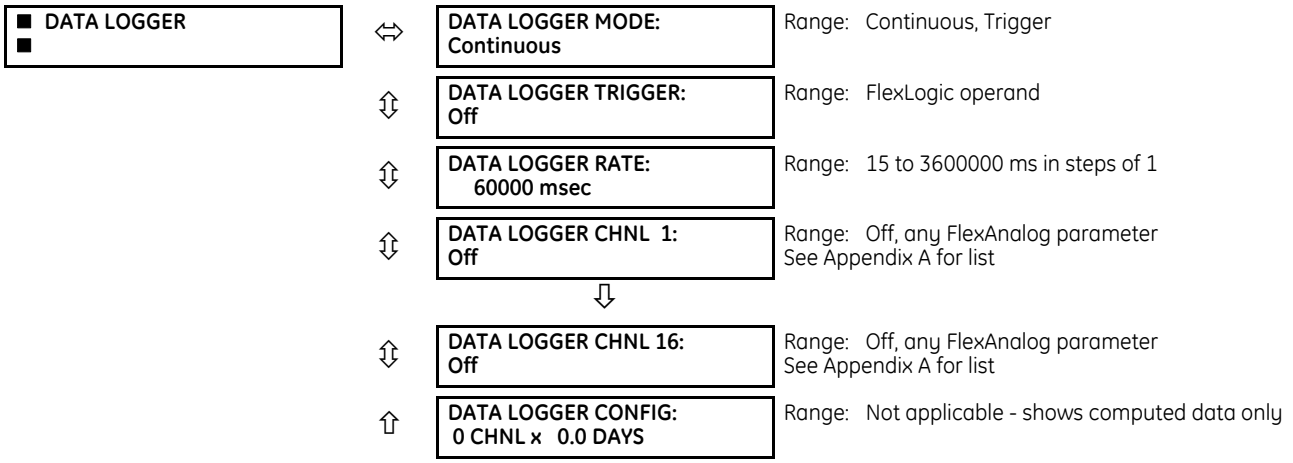
If there are no CT/VT modules and analog input modules, no analog traces appear in the file; only the digital traces appear.

The source harmonic indices appear as oscillography analog channels numbered from 0 to 23. These correspond directly to the to the 2nd to 25th harmonics in the relay as follows:

Analog channel 0 ↔ 2nd harmonic
Analog channel 1 ↔ 3rd harmonic
...
Analog channel 23 ↔ 25th harmonic

5.3.9 Data logger

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 can 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, so 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. The following table outlines examples of storage capacities for a system frequency of 60 Hz.

Table 5-13: 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 data in the log.

DATA LOGGER MODE — This setting configures the mode in which the data logger operates. When set to "Continuous," the data logger actively records any configured channels at the rate as defined by the **DATA LOGGER RATE**. The data logger is idle in this mode when no channels are configured. When set to "Trigger," the data logger records any configured channels at the instance of the rising edge of the **DATA LOGGER TRIGGER** source FlexLogic operand. The data logger ignores all

subsequent triggers and continues 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 also stops the current record and resets 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. This 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 is recorded.

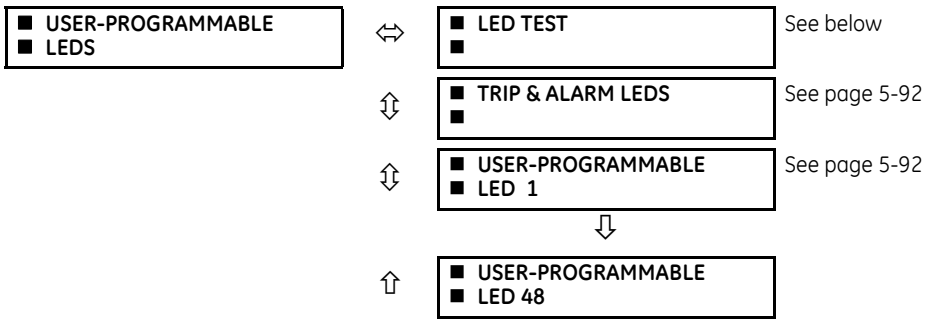
DATA LOGGER CHNL 1(16) — This setting selects the metering actual value that is to be recorded in Channel 1(16) of the data log. The parameters available in a given relay are dependent on: the type of relay, the type and number of CT/VT hardware modules installed, and the type and number of Analog Input hardware modules installed. Upon startup, the relay automatically prepares 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 time-consuming to scan through the list of parameters via the relay keypad/display—entering this number via the relay keypad causes the corresponding parameter to display.

DATA LOGGER CONFIG — This display presents the total amount of time that the Data Logger can record the channels not selected to "Off" without overwriting old data.

5.3.10 User-programmable LEDs

5.3.10.1 Menu

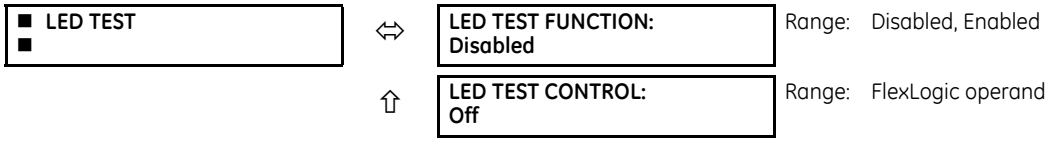
SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE LEDS



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.

5.3.10.2 LED test

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 a 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 the following 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 ends.
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.

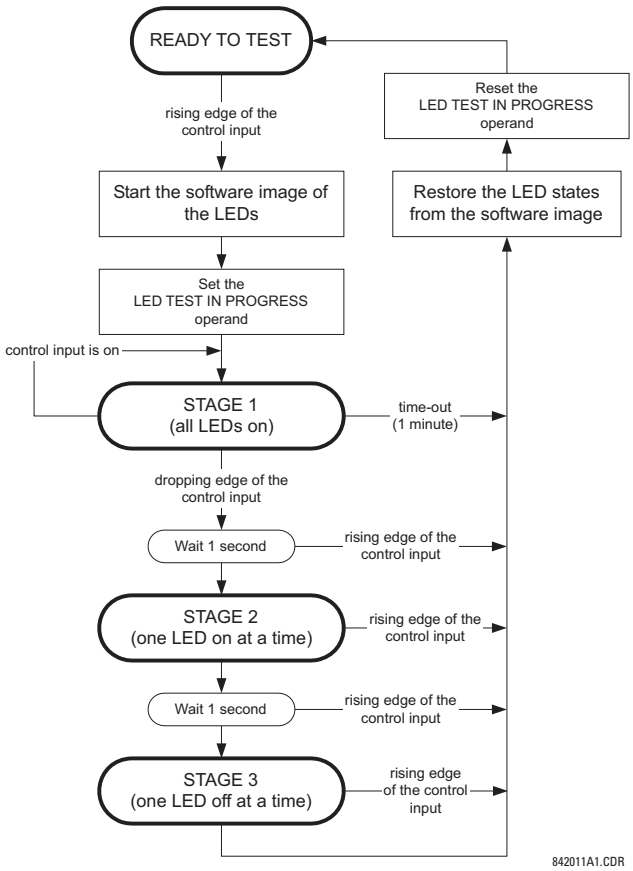
3. All the LEDs are turned on. One LED at a time turns off for 1 second, then back on. The test routine starts at the top left panel moving from top to bottom of each column of the LEDs. This test checks for hardware failures that lead to more than one LED being turned off from a single logic point. 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 does 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 5-31: LED test sequence



Application example 1

Assume one needs to check if any of the LEDs is "burned" through user-programmable pushbutton 1. Apply the following settings.

Configure user-programmable pushbutton 1 by making the following entries in the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE PUSHBUTTONS ⇨ USER PUSHBUTTON 1** menu. (The option does not display when not purchased.)

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 is initiated when the user-programmable pushbutton 1 is pressed. Keep the pushbutton pressed for as long as the LEDs are being visually inspected. When finished, release the pushbutton. The relay then automatically starts stage 2. At this point, test can be cancelled 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. When finished, release the pushbutton so that the relay then automatically starts stage 2. When stage 2 is completed, stage 3 starts automatically. The test can be cancelled at any time by pressing the pushbutton.

5.3.10.3 Trip and alarm LEDs

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE LEDS ⇨⇩ TRIP & ALARMS LEDS

■ TRIP & ALARM LEDS ■	⇔	TRIP LED INPUT: Off	Range: FlexLogic operand
	⇧	ALARM LED INPUT: Off	Range: FlexLogic operand

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.

5.3.10.4 User-programmable LED 1(48)

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE LEDS ⇨⇩ USER-PROGRAMMABLE LED 1(48)

■ USER-PROGRAMMABLE ■ LED 1	⇔	LED 1 OPERAND: Off	Range: FlexLogic operand
	⇧	LED 1 TYPE: Self-Reset	Range: Self-Reset, Latched

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 tracks 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 5-14: Recommended settings for user-programmable LEDs

Setting	Parameter	Setting	Parameter
LED 1 operand	SETTING GROUP ACT 1	LED 13 operand	Off
LED 2 operand	SETTING GROUP ACT 2	LED 14 operand	Off
LED 3 operand	SETTING GROUP ACT 3	LED 15 operand	Off
LED 4 operand	SETTING GROUP ACT 4	LED 16 operand	Off
LED 5 operand	SETTING GROUP ACT 5	LED 17 operand	Off
LED 6 operand	SETTING GROUP ACT 6	LED 18 operand	Off
LED 7 operand	Off	LED 19 operand	Off
LED 8 operand	Off	LED 20 operand	Off
LED 9 operand	Off	LED 21 operand	Off
LED 10 operand	Off	LED 22 operand	Off
LED 11 operand	Off	LED 23 operand	Off
LED 12 operand	Off	LED 24 operand	Off

See the figure in the Setting Groups section of the Control Elements section later in this chapter for an example of group activation.

5.3.11 User-programmable self tests

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMALBE SELF TESTS

■ USER-PROGRAMMABLE ■ SELF TESTS	⇔	**DIRECT RING BREAK FUNCTION: Enabled** — Range: Disabled, Enabled. Valid for units equipped with Direct Input/Output module.
	⇩	**DIRECT DEVICE OFF FUNCTION: Enabled** — Range: Disabled, Enabled. Valid for units equipped with Direct Input/Output module.
	⇩	**REMOTE DEVICE OFF FUNCTION: Enabled** — Range: Disabled, Enabled
	⇩	**FIRST ETHERNET FAIL FUNCTION: Disabled** — Range: Disabled, Enabled
	⇩	**SEC. ETHERNET FAIL FUNCTION: Disabled** — Range: Disabled, Enabled
	⇩	**THIRD ETHERNET FAIL FUNCTION: Disabled** — Range: Disabled, Enabled
	⇩	**BATTERY FAIL FUNCTION: Enabled** — Range: Disabled, Enabled
	⇩	**SNTP FAIL FUNCTION: Enabled** — Range: Disabled, Enabled
	⇩	**IRIG-B FAIL FUNCTION: Enabled** — Range: Disabled, Enabled
	⇩	**PTP FAIL FUNCTION: Enabled** — Range: Disabled, Enabled
	⇧	**SFP MODULE FAIL FUNCTION: Disabled** — Range: Disabled, Enabled

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 so wanted.

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.

5.3.12 Control pushbuttons

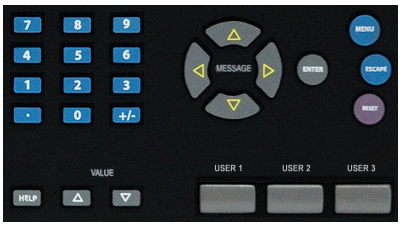
SETTINGS ⇨ PRODUCT SETUP ⇨⇩ CONTROL PUSHBUTTONS ⇨ CONTROL PUSHBUTTON 1(7)

■ CONTROL ■ PUSHBUTTON 1	⇔	CONTROL PUSHBUTTON 1 FUNCTION: Disabled	Range: Disabled, Enabled
	⇧	CONTROL PUSHBUTTON 1 EVENTS: Disabled	Range: Disabled, Enabled

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.

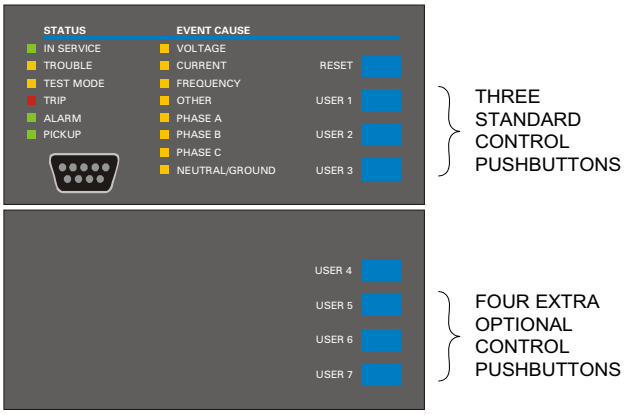
Figure 5-32: Control pushbuttons (enhanced faceplate)



5

An additional four control pushbuttons are included on the basic faceplate when the C70 is ordered with the 12 user-programmable pushbutton option.

Figure 5-33: Control pushbuttons (basic faceplate)

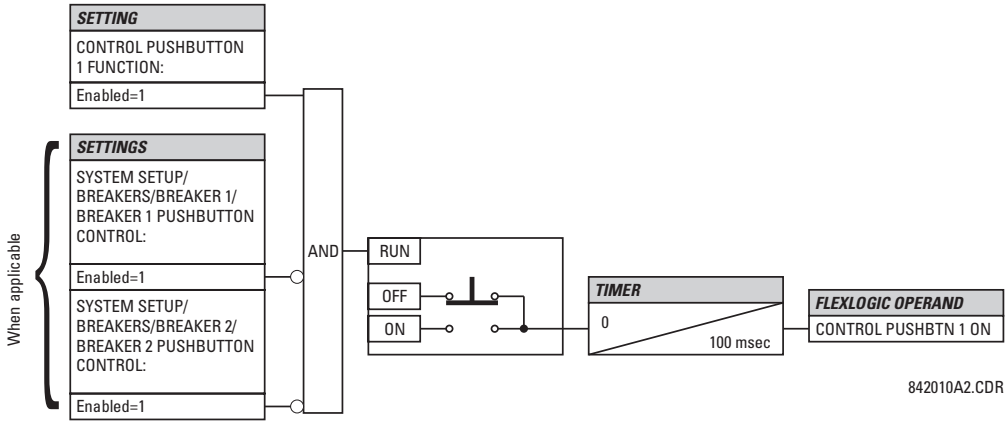


Control pushbuttons are not typically used for critical operations and are not protected by the control password. However, by supervising their output operands, the user can dynamically enable or disable control pushbuttons for security reasons.

Each control pushbutton asserts its own FlexLogic operand. Each operand need to be configured appropriately to perform the required function. Each 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 is recognized by various features that can 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.

Figure 5-34: Control pushbutton logic



5.3.13 User-programmable pushbuttons

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE PUSHBUTTONS ⇨ USER PUSHBUTTON 1(16)

■ USER PUSHBUTTON 1 ■	⇔	**PUSHBUTTON 1 FUNCTION: Disabled**	Range: Self-Reset, Latched, Disabled
	⇩	**PUSHBTN 1 ID TEXT: USER PB 1**	Range: up to 20 alphanumeric characters
	⇩	**PUSHBTN 1 ON TEXT: PUSHBTN 1 ON**	Range: up to 20 alphanumeric characters
	⇩	**PUSHBTN 1 OFF TEXT: PUSHBTN 1 OFF**	Range: up to 20 alphanumeric characters
	⇩	**PUSHBTN 1 HOLD: 0.1 s**	Range: 0.0 to 10.0 s in steps of 0.1
	⇩	**PUSHBTN 1 SET: Off**	Range: FlexLogic operand
	⇩	**PUSHBTN 1 RESET: Off**	Range: FlexLogic operand
	⇩	**PUSHBTN 1 AUTORST: Disabled**	Range: Disabled, Enabled
	⇩	**PUSHBTN 1 AUTORST DELAY: 1.0 s**	Range: 0.2 to 600.0 s in steps of 0.1
	⇩	**PUSHBTN 1 REMOTE: Off**	Range: FlexLogic operand
	⇩	**PUSHBTN 1 LOCAL: Off**	Range: FlexLogic operand
	⇩	**PUSHBTN 1 DROP-OUT TIME: 0.00 s**	Range: 0 to 60.00 s in steps of 0.05
	⇩	**PUSHBTN 1 LED CTL: Off**	Range: FlexLogic operand
	⇩	**PUSHBTN 1 MESSAGE: Disabled**	Range: Disabled, Normal, High Priority
	⇩	**PUSHBUTTON 1 EVENTS: Disabled**	Range: Disabled, Enabled

This option is available when an Inter-Relay Communications card is specified at the time of ordering (see the Order Code tables). With the option, direct inputs/outputs display by default. When you enable the teleprotection feature, direct I/O is not visible.

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

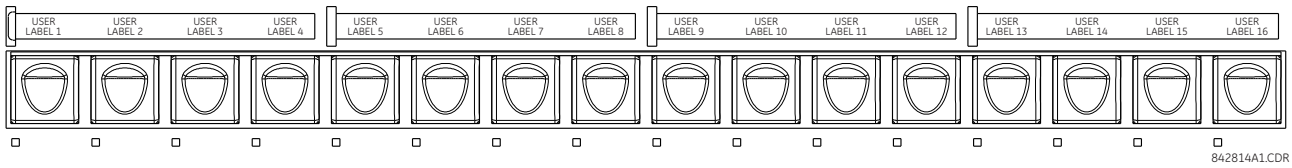
NOTE

User-programmable pushbuttons require a front panel with that option. If the front panel was ordered separately, update the EnerVista software under **Maintenance > Change Front Panel**.

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.

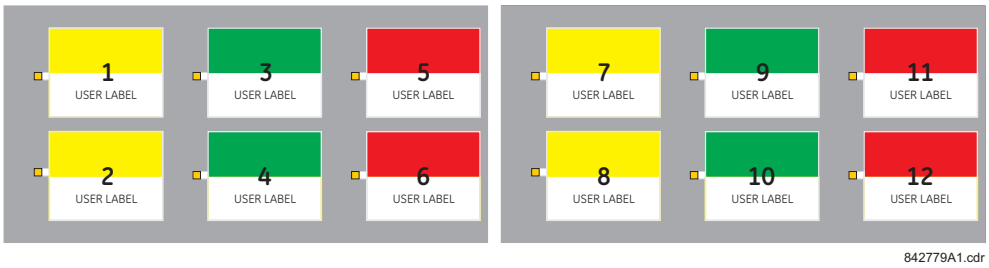
The figure shows user-configurable pushbuttons for the enhanced front panel.

Figure 5-35: User-programmable pushbuttons (enhanced front panel)



The following figure shows user-configurable pushbuttons for the basic front panel.

Figure 5-36: 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 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 assigned to the **PUSHBTN 1 SET** setting remains On has no effect on the pulse duration.



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 de-asserted.

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 pushbutton 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 50 ms. 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 50 ms.

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 on message 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 **PUSHBTN 1 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 5-37: User-programmable pushbutton logic (Sheet 1 of 2)

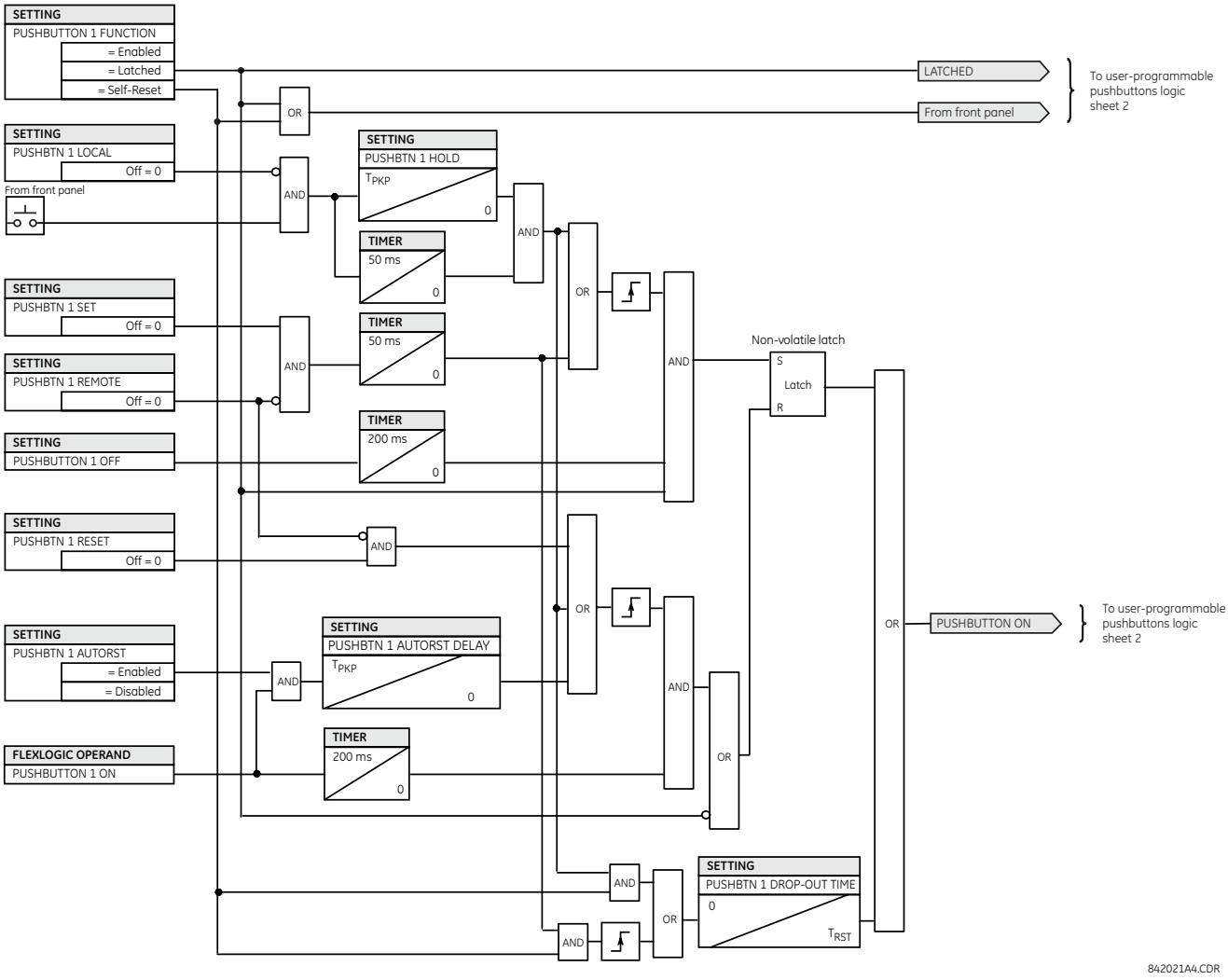
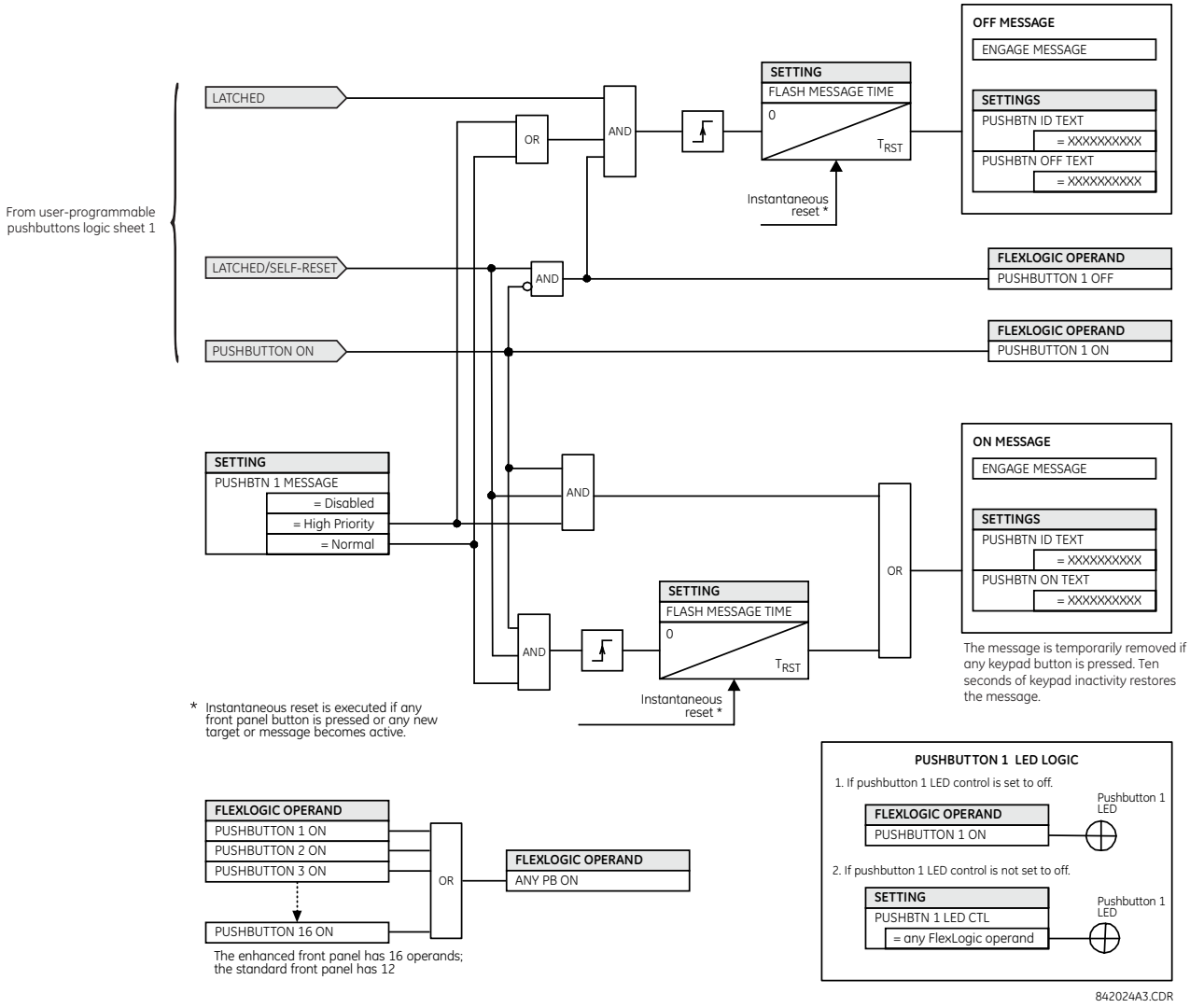
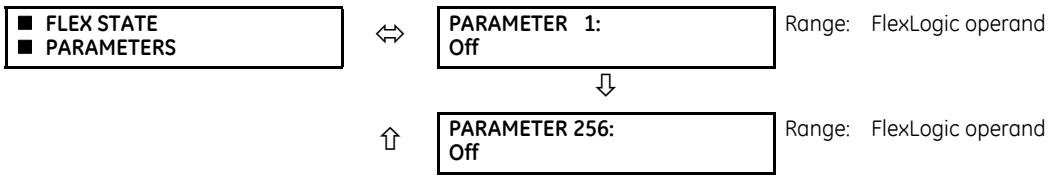


Figure 5-38: User-programmable pushbutton logic (Sheet 2 of 2)



5.3.14 Flex state parameters

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FLEX STATE PARAMETERS



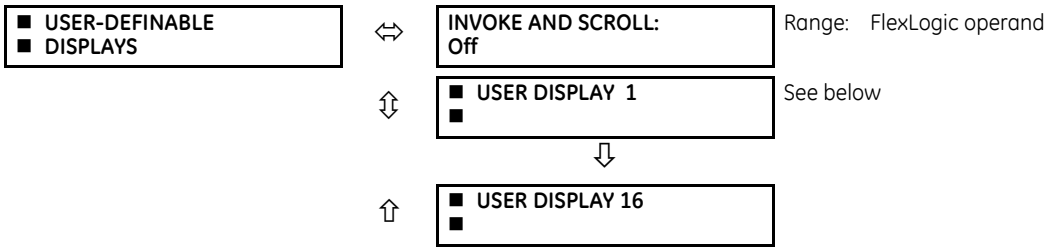
This feature provides a mechanism where any of 256 selected FlexLogic operand states can be used for efficient monitoring. The feature allows user-customized access to the FlexLogic operand states in the relay. The state bits are packed so that 16 states are readable in a single Modbus register. The state bits can be configured so that all states of interest are available in a minimum number of Modbus registers.

The state bits can 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. Sixteen registers accommodate the 256 state bits.

5.3.15 User-definable displays

5.3.15.1 Menu

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 DISPLAY** 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.

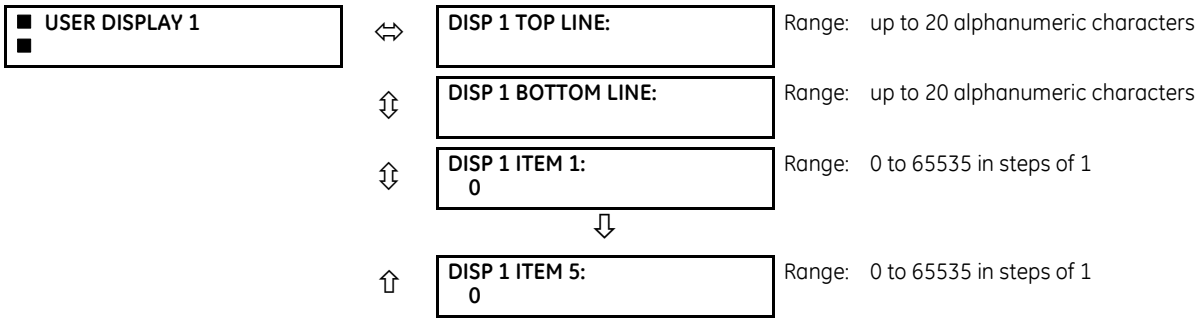
- **Keypad** — Use the **MENU** key to select the **USER DISPLAY** menu item to access the first user-definable display (note that only the programmed screens are displayed). The screens can be scrolled using the up and down arrow keys. The display disappears after the default message time-out period 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 arrow key operate concurrently.

  When the default timer expires (set by the **DEFAULT MESSAGE TIMEOUT** setting), the relay starts 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.

5.3.15.2 User display 1(16)

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 then prompts with 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 can be edited subsequently.

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 can be entered from the faceplate keypad or the EnerVista 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 can 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 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 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 as follows.

■ USER DISPLAY 1 ■	⇔	DISP 1 TOP LINE: Current X ~ A	Shows user-defined text with first tilde marker
	⇳	DISP 1 BOTTOM LINE: Current Y ~ A	Shows user-defined text with second tilde marker
	⇳	DISP 1 ITEM 1: 6016	Shows decimal form of user-selected Modbus register address, corresponding to first tilde marker
	⇳	DISP 1 ITEM 2: 6357	Shows decimal form of user-selected Modbus register address, corresponding to second tilde marker
	⇳	DISP 1 ITEM 3: 0	This item is not being used. There is no corresponding tilde marker in top or bottom lines.
	⇳	DISP 1 ITEM 4: 0	This item is not being used. There is no corresponding tilde marker in top or bottom lines.
	⇧	DISP 1 ITEM 5: 0	This item is not being used. There is no corresponding tilde marker in top or bottom lines.
USER DISPLAYS	⇨	Current X 0.850 Current Y 0.327 A	Shows the resultant display content

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.

5.3.16 Direct inputs and outputs

5.3.16.1 Menu

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DIRECT I/O

■ DIRECT I/O ■	⇔	DIRECT OUTPUT DEVICE ID: 1	Range: 1 to 16 in steps of 1
	⇩	DIRECT I/O CH1 RING CONFIGURATION: Yes	Range: Yes, No
	⇩	DIRECT I/O CH2 RING CONFIGURATION: Yes	Range: Yes, No
	⇩	DIRECT I/O DATA RATE: 64 kbps	Range: 64 kbps, 128 kbps
	⇩	DIRECT I/O CHANNEL CROSSOVER: Disabled	Range: Disabled, Enabled
	⇩	■ CRC ALARM CH1 ■	See page 5-108
	⇩	■ CRC ALARM CH2 ■	
	⇩	■ UNRETURNED ■ MESSAGES ALARM CH1	See page 5-109
	⇩	■ UNRETURNED ■ MESSAGES ALARM CH2	



This option is available when an Inter-Relay Communications card is specified at the time of ordering (see the Order Code tables).

Direct inputs and outputs exchange status information (inputs and outputs) between UR-series relays connected directly via type 7 digital communications cards. The mechanism is very similar to IEC 61850 GOOSE, except that communications takes place over a non-switchable isolated network and is optimized for speed. On type 7 cards that support two channels, direct output messages are sent from both channels simultaneously. This effectively sends direct output messages both ways around a ring configuration. On type 7 cards that support one channel, direct output messages are sent only in one direction. Messages are resent (forwarded) when it is determined that the message did not originate at the receiver.

For the direct I/Os to function properly, all UR devices sending I/Os using an Inter-Relay Communications card must have identical firmware revisions.

Direct output message timing is similar to GOOSE message timing. Integrity messages (with no state changes) are sent at least every 1000 ms. Messages with state changes are sent within the main pass scanning the inputs and asserting the outputs unless the communication channel bandwidth has been exceeded. Two self-tests are performed and signaled by the following FlexLogic operands:

- DIRECT RING BREAK (direct input/output ring break). This FlexLogic operand indicates that direct output messages sent from a UR-series relay are not being received back by the relay.
- DIRECT DEVICE 1 OFF to DIRECT DEVICE 16 OFF (direct device offline). These FlexLogic operands indicate that direct output messages from at least one direct device are not being received.

Direct input and output settings are similar to remote input and output settings. The equivalent of the remote device name strings for direct inputs and outputs is the **DIRECT OUTPUT DEVICE ID** setting, which identifies the relay in all direct output messages. All UR-series IEDs in a ring need to have unique numbers assigned. The IED ID is used to identify the sender of the direct input and output message.

If the direct input and output scheme is configured to operate in a ring (**DIRECT I/O CH1 RING CONFIGURATION** or **DIRECT I/O CH2 RING CONFIGURATION** is "Yes"), all direct output messages are received back. If not, the direct input/output ring break self-test is triggered. The self-test error is signaled by the DIRECT RING BREAK FlexLogic operand.

Select the **DIRECT I/O DATA RATE** to match the data capabilities of the communications channel. All IEDs communicating over direct inputs and outputs must be set to the same data rate. UR-series IEDs equipped with dual-channel communications cards apply the same data rate to both channels. Delivery time for direct input and output messages is approximately 0.2 of a power system cycle at 128 kbps and 0.4 of a power system cycle at 64 kbps, per each "bridge."

Table 5-15: Direct input and output data rates

Module	Channel	Supported data rates
74	Channel 1	64 kbps
	Channel 2	64 kbps
7L	Channel 1	64 kbps, 128 kbps
	Channel 2	64 kbps, 128 kbps
7M	Channel 1	64 kbps, 128 kbps
	Channel 2	64 kbps, 128 kbps
7P	Channel 1	64 kbps, 128 kbps
	Channel 2	64 kbps, 128 kbps
7T	Channel 1	64 kbps, 128 kbps
7W	Channel 1	64 kbps, 128 kbps
	Channel 2	64 kbps, 128 kbps
7V	Channel 1	64 kbps, 128 kbps
	Channel 2	64 kbps, 128 kbps
2A	Channel 1	64 kbps
2B	Channel 1	64 kbps
	Channel 2	64 kbps
2G	Channel 1	128 kbps
2H	Channel 1	128 kbps
2I	Channel 1	64 kbps, 128 kbps
	Channel 2	64 kbps, 128 kbps
2J	Channel 1	64 kbps, 128 kbps
	Channel 2	64 kbps, 128 kbps
76	Channel 1	64 kbps
77	Channel 1	64 kbps
	Channel 2	64 kbps
75	Channel 1	64 kbps
	Channel 2	64 kbps
7E	Channel 1	64 kbps
	Channel 2	64 kbps
7F	Channel 1	64 kbps
	Channel 2	64 kbps
7G	Channel 1	64 kbps
	Channel 2	64 kbps
7Q	Channel 1	64 kbps
	Channel 2	64 kbps
7R	Channel 1	64 kbps
7S	Channel 1	64 kbps
	Channel 2	64 kbps

NOTE

The G.703 modules are fixed at 64 kbps. The **DIRECT I/O DATA RATE** setting is not applicable to these modules.

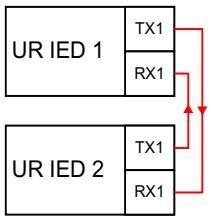
The **DIRECT I/O CHANNEL CROSSOVER** setting applies to C70s with dual-channel communication cards and allows crossing over messages from channel 1 to channel 2. This places all UR-series IEDs into one direct input and output network regardless of the physical media of the two communication channels.

The following application examples illustrate the basic concepts for direct input and output configuration. See the Inputs and Outputs section in this chapter for information on configuring FlexLogic operands (flags, bits) to be exchanged.

Example 1: Extending the input/output capabilities of a UR-series relay

Consider an application that requires additional quantities of contact inputs or output contacts or lines of programmable logic that exceed the capabilities of a single UR-series chassis. The problem is solved by adding an extra UR-series IED, such as the C30, to satisfy the additional input and output and programmable logic requirements. The two IEDs are connected via single-channel digital communication cards as shown in the figure.

Figure 5-39: Input and output extension via direct inputs and outputs



842711A1.CDR

In this application, apply the following settings. For UR-series IED 1:

DIRECT OUTPUT DEVICE ID: "1"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O DATA RATE: "128 kbps"

For UR-series IED 2:

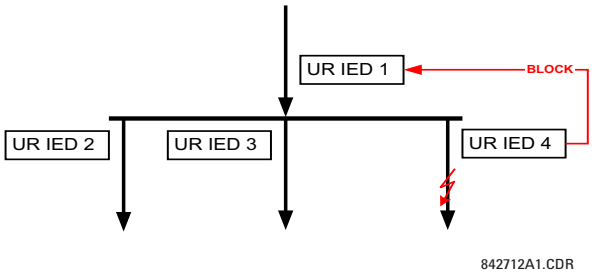
DIRECT OUTPUT DEVICE ID: "2"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O DATA RATE: "128 kbps"

The message delivery time is about 0.2 of power cycle in both ways (at 128 kbps); that is, from device 1 to device 2, and from device 2 to device 1. Different communications cards can be selected by the user for this back-to-back connection (for example: fiber, G.703, or RS422).

Example 2: Interlocking busbar protection

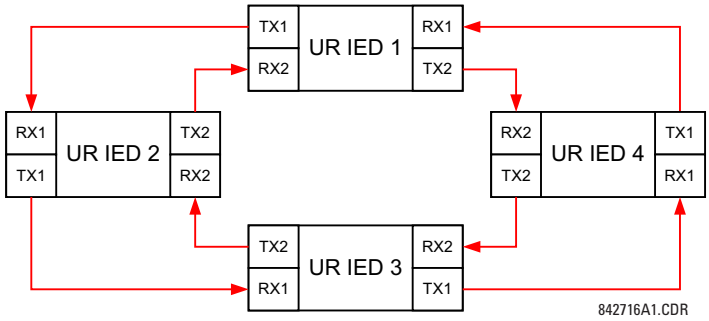
A simple interlocking busbar protection scheme could be accomplished by sending a blocking signal from downstream devices, say 2, 3, and 4, to the upstream device that monitors a single incomer of the busbar, as shown.

Figure 5-40: Sample interlocking busbar protection scheme



For increased reliability, a dual-ring configuration (shown as follows) is recommended for this application.

Figure 5-41: Interlocking bus protection scheme via direct inputs/outputs



In this application, apply the following settings. For UR-series IED 1:

DIRECT OUTPUT DEVICE ID: "1"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O CH2 RING CONFIGURATION: "Yes"

For UR-series IED 2:

DIRECT OUTPUT DEVICE ID: "2"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O CH2 RING CONFIGURATION: "Yes"

For UR-series IED 3:

DIRECT OUTPUT DEVICE ID: "3"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O CH2 RING CONFIGURATION: "Yes"

For UR-series IED 4:

DIRECT OUTPUT DEVICE ID: "4"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O CH2 RING CONFIGURATION: "Yes"

Message delivery time is approximately 0.2 of power system cycle (at 128 kbps) times number of 'bridges' between the origin and destination. Dual-ring configuration effectively reduces the maximum 'communications distance' by a factor of two.

In this configuration the following delivery times are expected (at 128 kbps) if both rings are healthy:

IED 1 to IED 2: 0.2 of power system cycle
IED 1 to IED 3: 0.4 of power system cycle
IED 1 to IED 4: 0.2 of power system cycle
IED 2 to IED 3: 0.2 of power system cycle
IED 2 to IED 4: 0.4 of power system cycle
IED 3 to IED 4: 0.2 of power system cycle

If one ring is broken (say TX2-RX2) the delivery times are as follows:

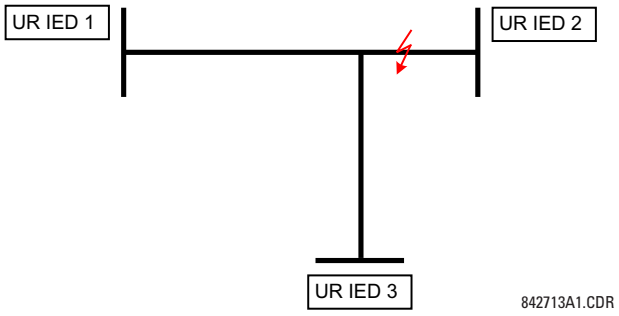
IED 1 to IED 2: 0.2 of power system cycle
IED 1 to IED 3: 0.4 of power system cycle
IED 1 to IED 4: 0.6 of power system cycle
IED 2 to IED 3: 0.2 of power system cycle
IED 2 to IED 4: 0.4 of power system cycle
IED 3 to IED 4: 0.2 of power system cycle

A coordinating timer for this bus protection scheme could be selected to cover the worst case scenario (0.4 of a power system cycle). Upon detecting a broken ring, the coordination time is adaptively increased to 0.6 of a power system cycle. The complete application requires addressing a number of issues, such as failure of both the communications rings, failure or out-of-service conditions of one of the relays, and so on. Self-monitoring flags of the direct inputs and outputs feature primarily are used to address these concerns.

Example 3: Pilot-aided schemes

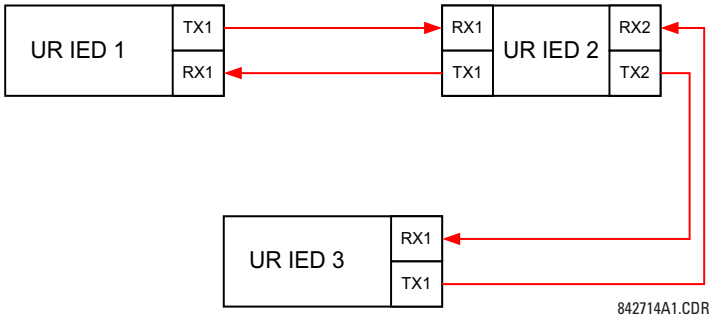
Consider the three-terminal line protection application shown.

Figure 5-42: Three-terminal line application



A permissive pilot-aided scheme can be implemented in a two-ring configuration, shown as follows (IEDs 1 and 2 constitute a first ring, while IEDs 2 and 3 constitute a second ring).

Figure 5-43: Single-channel open loop configuration



In this application, apply the following settings. For UR-series IED 1:

DIRECT OUTPUT DEVICE ID: "1"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O CH2 RING CONFIGURATION: "Yes"

For UR-series IED 2:

DIRECT OUTPUT DEVICE ID: "2"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O CH2 RING CONFIGURATION: "Yes"

For UR-series IED 3:

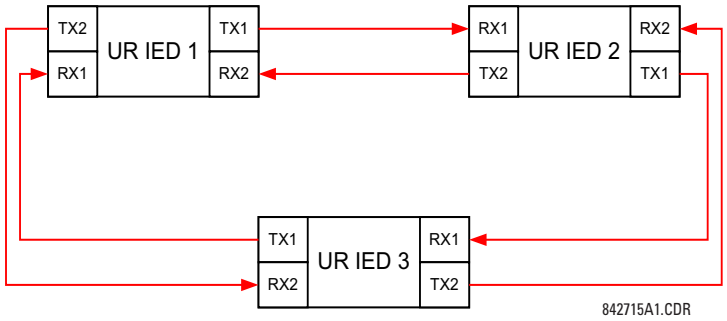
DIRECT OUTPUT DEVICE ID: "3"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O CH2 RING CONFIGURATION: "Yes"

In this configuration the following delivery times are expected (at 128 kbps):

IED 1 to IED 2: 0.2 of power system cycle
IED 1 to IED 3: 0.5 of power system cycle
IED 2 to IED 3: 0.2 of power system cycle

In this scheme, IEDs 1 and 3 do not communicate directly. IED 2 must be configured to forward the messages as explained in the Inputs and Outputs section. Implement a blocking pilot-aided scheme with more security and, ideally, faster message delivery time. This is accomplished using a dual-ring configuration as shown here.

Figure 5-44: Dual-channel closed loop (dual-ring) configuration



5

In this application, apply the following settings. For UR-series IED 1:

DIRECT OUTPUT DEVICE ID: "1"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O CH2 RING CONFIGURATION: "Yes"

For UR-series IED 2:

DIRECT OUTPUT DEVICE ID: "2"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O CH2 RING CONFIGURATION: "Yes"

For UR-series IED 3:

DIRECT OUTPUT DEVICE ID: "3"
DIRECT I/O CH1 RING CONFIGURATION: "Yes"
DIRECT I/O CH2 RING CONFIGURATION: "Yes"

In this configuration the following delivery times are expected (at 128 kbps) if both the rings are healthy:

IED 1 to IED 2: 0.2 of power system cycle
IED 1 to IED 3: 0.2 of power system cycle
IED 2 to IED 3: 0.2 of power system cycle

The two communications configurations can be applied to both permissive and blocking schemes. Take speed, reliability, and cost into account when selecting the required architecture.

5.3.16.2 CRC alarm CH1(2)

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DIRECT I/O ⇨⇩ CRC ALARM CH1(2)

■ CRC ALARM CH1 ■	⇔	**CRC ALARM CH1 FUNCTION: Disabled**	Range: Enabled, Disabled
	⇕	**CRC ALARM CH1 MESSAGE COUNT: 600**	Range: 100 to 10000 in steps of 1
	⇕	**CRC ALARM CH1 THRESHOLD: 10**	Range: 1 to 1000 in steps of 1

⇧ **CRC ALARM CH1 EVENTS: Disabled** Range: Enabled, Disabled

The C70 checks integrity of the incoming direct input and output messages using a 32-bit CRC. The CRC alarm function is available for monitoring the communication medium noise by tracking the rate of messages failing the CRC check. The monitoring function counts all incoming messages, including messages that failed the CRC check. A separate counter adds up messages that failed the CRC check. When the failed CRC counter reaches the user-defined level specified by the **CRC ALARM CH1 THRESHOLD** setting within the user-defined message count **CRC ALARM 1 CH1 COUNT**, the DIR IO CH1 CRC ALARM FlexLogic operand is set.

When the total message counter reaches the user-defined maximum specified by the **CRC ALARM CH1 MESSAGE COUNT** setting, both the counters reset and the monitoring process is restarted.

Configure the operand to drive an output contact, user-programmable LED, or selected communication-based output. Latching and acknowledging conditions—if required—are programmed accordingly.

The CRC alarm function is available on a per-channel basis. The total number of direct input and output messages that failed the CRC check is available as the **ACTUAL VALUES ⇨ STATUS ⇨⇩ DIRECT INPUTS ⇨⇩ CRC FAIL COUNT CH1** actual value.

- **Message count and length of the monitoring window** — To monitor communications integrity, the relay sends 1 message per second (at 64 kbps) or 2 messages per second (128 kbps) even if there is no change in the direct outputs. For example, setting the **CRC ALARM CH1 MESSAGE COUNT** to "10000," corresponds a time window of about 160 minutes at 64 kbps and 80 minutes at 128 kbps. If the messages are sent faster as a result of direct outputs activity, the monitoring time interval shortens. Take this into account when determining the **CRC ALARM CH1 MESSAGE COUNT** setting. For example, if the requirement is a maximum monitoring time interval of 10 minutes at 64 kbps, then the **CRC ALARM CH1 MESSAGE COUNT** is set to $10 \times 60 \times 1 = 600$.
- **Correlation of failed CRC and bit error rate (BER)** — The CRC check can fail if one or more bits in a packet are corrupted. Therefore, an exact correlation between the CRC fail rate and the BER is not possible. Under certain assumptions an approximation can be made as follows. A direct input and output packet containing 20 bytes results in 160 bits of data being sent and therefore, a transmission of 63 packets is equivalent to 10,000 bits. A BER of 10^{-4} implies 1 bit error for every 10000 bits sent or received. Assuming the best case of only 1 bit error in a failed packet, having 1 failed packet for every 63 received is about equal to a BER of 10^{-4}.

5.3.16.3 Unreturned messages alarm CH1(2)

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DIRECT I/O ⇨⇩ UNRETURNED MESSAGES ALARM CH1(2)

■ **UNRETURNED MESSAGES ALARM CH1**

⇔ **UNRET MSGS ALARM CH1 FUNCTION: Disabled** Range: Enabled, Disabled

⇳ **UNRET MSGS ALARM CH1 MESSAGE COUNT: 600** Range: 100 to 10000 in steps of 1

⇳ **UNRET MSGS ALARM CH1 THRESHOLD: 10** Range: 1 to 1000 in steps of 1

⇧ **UNRET MSGS ALARM CH1 EVENTS: Disabled** Range: Enabled, Disabled

The C70 checks integrity of the direct input and output communication ring by counting unreturned messages. In the ring configuration, all messages originating at a given device should return within a pre-defined period of time. The unreturned messages alarm function is available for monitoring the integrity of the communication ring by tracking the rate of unreturned messages. This function counts all the outgoing messages and a separate counter adds the messages have failed to return. When the unreturned messages counter reaches the user-definable level specified by the **UNRET MSGS ALARM CH1 THRESHOLD** setting and within the user-defined message count **UNRET MSGS ALARM CH1 COUNT**, the DIR IO CH1 UNRET ALM FlexLogic operand is set.

When the total message counter reaches the user-defined maximum specified by the **UNRET MSGS ALARM CH1 MESSAGE COUNT** setting, both the counters reset and the monitoring process is restarted.

Configure the operand to drive an output contact, user-programmable LED, or selected communication-based output. Latching and acknowledging conditions, if required, are programmed accordingly.

The unreturned messages alarm function is available on a per-channel basis and is active only in the ring configuration. The total number of unreturned input and output messages is available as the **ACTUAL VALUES ⇨ STATUS ⇨⇩ DIRECT INPUTS ⇨⇩ UNRETURNED MSG COUNT CH1** actual value.

5.3.17 Installation

SETTINGS ⇨ PRODUCT SETUP ⇨⇩ INSTALLATION

■ **INSTALLATION** ■	⇔	**RELAY SETTINGS: Not Programmed**	Range: Not Programmed, Programmed
	⇧	**RELAY NAME: Relay-1**	Range: up to 20 alphanumeric characters

To safeguard against the installation of a relay without any entered settings, the unit does not allow signaling of any output relay until **RELAY SETTINGS** is set to "Programmed." This setting is "Not Programmed" by default. The UNIT NOT PROGRAMMED self-test error message displays until the relay is put into the "Programmed" state.

The **RELAY NAME** setting allows the user to uniquely identify a relay. This name appears on generated reports.

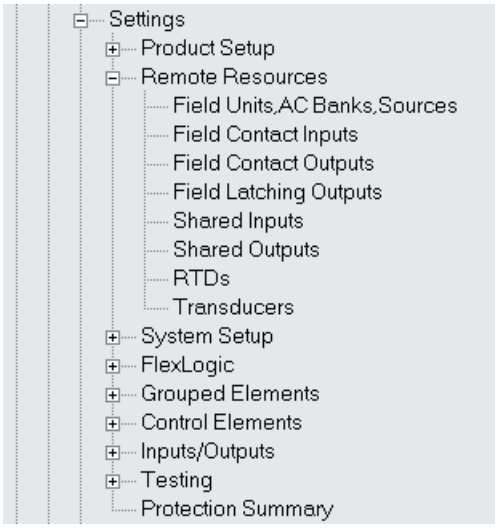
5.4 Remote resources

5.4.1 Remote resources configuration

5

When the C70 is ordered with a process card module as a part of HardFiber system, an additional **Remote Resources** menu tree is available in the EnerVista software to allow configuration of the HardFiber system.

Figure 5-45: Remote Resources configuration menu



The remote resources settings configure a C70 with a process bus module to work with HardFiber Bricks. Remote resources configuration is only available through the EnerVista software, and is not available through the C70 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 C70 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 C70 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 C70 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 the HardFiber Process Bus System Instruction Manual.

5.5 System setup

5.5.1 AC inputs

5.5.1.1 Current banks

SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨ CURRENT BANK F1(U5)

■ CURRENT BANK F1 ■	⇔	PHASE CT F1 PRIMARY: 1 A	Range: 1 to 65000 A in steps of 1
	⇩	PHASE CT F1 SECONDARY: 1 A	Range: 1 A, 5 A
	⇩	GROUND CT F1 PRIMARY: 1 A	Range: 1 to 65000 A in steps of 1
	⇩	GROUND CT F1 SECONDARY: 1 A	Range: 1 A, 5 A

Six 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, M, U} 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. See 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
- M1: CT bank with 800:1 ratio

The following rule applies:

Eq. 5-6

where C70 allows CT bank summation in SRC 3 or 4.

$$SRC\ 1 = F1 + F5 + M1 \quad \textbf{Eq. 5-7}$$

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 are 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 operates on 1000 A primary.

The same rule applies for current sums from CTs with different secondary taps (5 A and 1 A).

5.5.1.2 Voltage banks

SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK F5(U5)

■ VOLTAGE BANK F5 ■	⇔	PHASE VT F5 CONNECTION: Wye	Range: Wye, Delta
	⇩	PHASE VT F5 SECONDARY: 66.4 V	Range: 25.0 to 240.0 V in steps of 0.1
	⇩	PHASE VT F5 RATIO: 1.00 :1	Range: 1.00 to 24000.00 in steps of 0.01
	⇩	AUXILIARY VT F5 CONNECTION: Vag	Range: Vn, Vag, Vbg, Vcg, Vab, Vbc, Vca
	⇩	AUXILIARY VT F5 SECONDARY: 66.4 V	Range: 25.0 to 240.0 V in steps of 0.1
	⇩	AUXILIARY VT F5 RATIO: 1.00 :1	Range: 1.00 to 24000.00 in steps of 0.01

Three bank 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, M, U} 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 is 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 is 115; that is, (13800 / 14400) × 120. For a wye connection, the voltage value entered must be the phase to neutral voltage, which is 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 is 120; that is, 14400 / 120.

NOTE

If the **PHASE VT F5 CONNECTION** is set to "Delta", the relay does not calculate voltage harmonics.

5.5.2 Power system

SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM

■ POWER SYSTEM ■	⇔	**NOMINAL FREQUENCY:** **60 Hz**	Range: 25 to 60 Hz in steps of 1
	⇩	**PHASE ROTATION:** **ABC**	Range: ABC, ACB
	⇩	**FREQUENCY AND PHASE REFERENCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇧	**FREQUENCY TRACKING:** **Enabled**	Range: Disabled, Enabled

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 can 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**.

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 and 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 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 ($V_{ANGLE\ REF} = V_A$), while Clarke transformation of the phase signals is used for frequency metering and tracking ($V_{FREQUENCY} = (2V_A - V_B - V_C)/3$) 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.

FREQUENCY TRACKING is set to "Disabled" only in unusual circumstances; consult GE Grid Solutions for special variable-frequency applications.

NOTE

The frequency tracking feature functions only when the C70 is in the "Programmed" mode. If the C70 is "Not Programmed," then metering values are available but can exhibit significant errors.

5.5.3 Signal sources

SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES ⇨ SOURCE 1(6)

■ SOURCE 1 ■	⇔	**SOURCE 1 NAME:** **SRC 1**	Range: up to six alphanumeric characters
	⇩	**SOURCE 1 PHASE CT:** **None**	Range: None, F1, F5, F1+F5,... up to a combination of any 6 CTs. Only Phase CT inputs are displayed.
	⇩	**SOURCE 1 GROUND CT:** **None**	Range: None, F1, F5, F1+F5,... up to a combination of any 6 CTs. Only Ground CT inputs are displayed.

⇳	**SOURCE 1 PHASE VT:** **None**	Range: None, F5, M1, M5, U5 Only phase voltage inputs are displayed
⇧	**SOURCE 1 AUX VT:** **None**	Range: None, F5, M1, M5, U5 Only auxiliary voltage inputs are displayed

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.

It is possible to select the sum of all CT combinations. The first channel displayed is the CT to which all others are 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 primary current rating. 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.

5.5.3.1 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 can 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.

5.5.3.2 AC input actual values

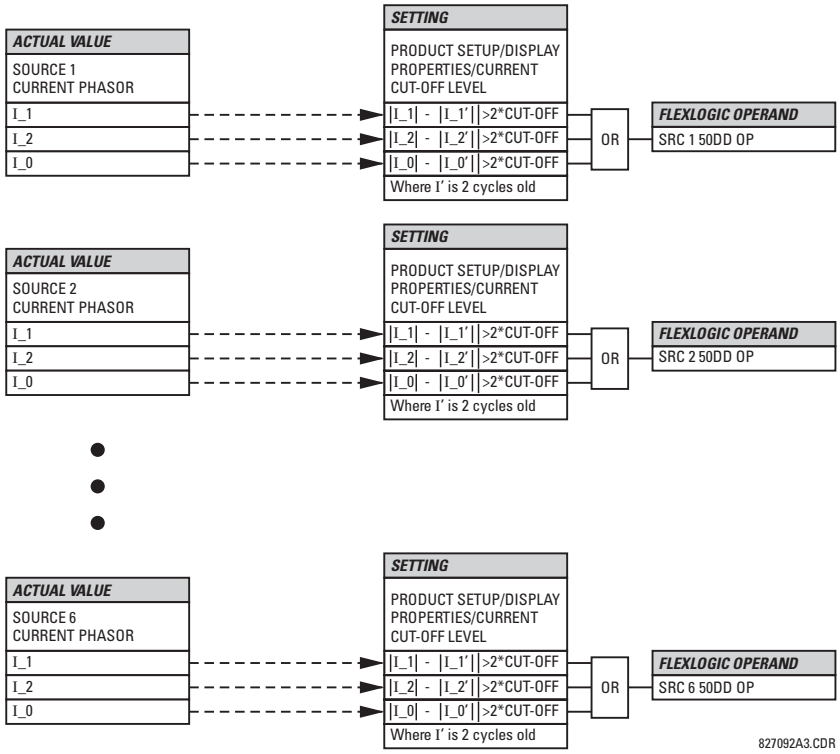
The calculated parameters associated with the configured voltage and current inputs are displayed in the current and voltage sections of actual values. Only the phasor quantities associated with the actual AC physical input channels display here. All parameters contained within a configured source are displayed in the sources section of the actual values.

5.5.3.3 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 logic is as follows.

Figure 5-46: Disturbance detector logic



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.

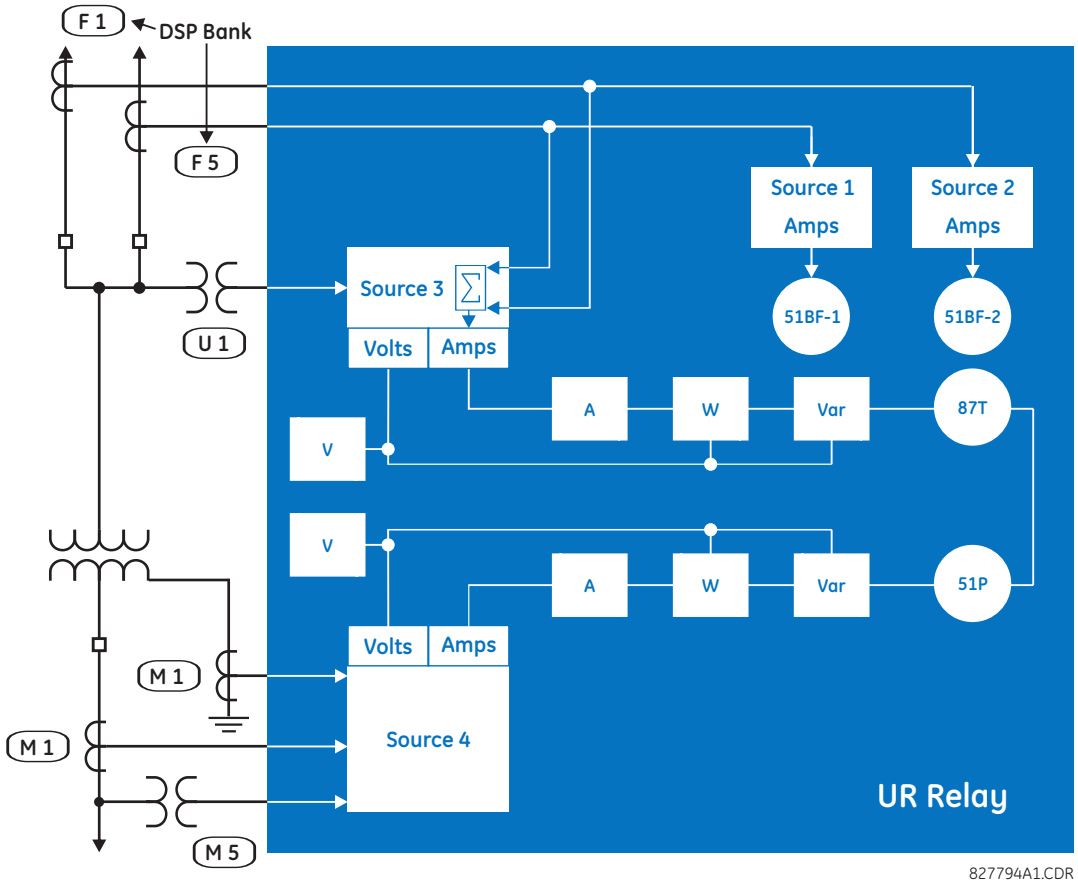
5.5.3.4 Example for use of sources

An example of the use of sources is shown in the following figure. A relay can have the following hardware configuration:

	Increasing slot position letter -->		
UR	**CT/VT module 1**	**CT/VT module 2**	**CT/VT module 3**
B30, B90, C70, F35, N60, T35	8 CTs	4 CTs, 4 VTs	4 CTs, 4 VTs
C60, D60, G30, G60, L30, L90, M60, T60	CTs	VTs	not applicable

This configuration can 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 5-47: Example of 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

5.5.4 Breakers

SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ BREAKERS ⇨ BREAKER 1(6)

■ BREAKER 1 ■	⇔	**BREAKER 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇩	**BREAKER1 PUSH BUTTON CONTROL: Disabled**	Range: Disabled, Enabled
	⇩	**BREAKER 1 NAME: Bkr 1**	Range: up to six alphanumeric characters
	⇩	**BREAKER 1 MODE: 3-Pole**	Range: 3-Pole, 1-Pole
	⇩	**BREAKER 1 OPEN: Off**	Range: FlexLogic operand

⇳	**BREAKER 1 BLK OPEN:** **Off**	Range: FlexLogic operand
⇳	**BREAKER 1 CLOSE:** **Off**	Range: FlexLogic operand
⇳	**BREAKER 1 BLK CLOSE:** **Off**	Range: FlexLogic operand
⇳	**BREAKER1 ΦA/3P CLSD:** **Off**	Range: FlexLogic operand
⇳	**BREAKER1 ΦA/3P OPND:** **Off**	Range: FlexLogic operand
⇳	**BREAKER 1 ΦB CLOSED:** **Off**	Range: FlexLogic operand
⇳	**BREAKER 1 ΦB OPENED:** **Off**	Range: FlexLogic operand
⇳	**BREAKER 1 ΦC CLOSED:** **Off**	Range: FlexLogic operand
⇳	**BREAKER 1 ΦC OPENED:** **Off**	Range: FlexLogic operand
⇳	**BREAKER 1 TOPERATE:** **70 ms**	Range: 0 to 65535 s in steps of 1
⇳	**BREAKER 1 EXT ALARM:** **Off**	Range: FlexLogic operand
⇳	**BREAKER 1 ALARM DELAY: 0.000 s**	Range: 0.000 to 65.535 s in steps of 0.001
⇳	**MANUAL CLOSE RECAL1 TIME: 0.000 s**	Range: 0.000 to 65.535 s in steps of 0.001
⇳	**BREAKER 1 OUT OF SV:** **Off**	Range: FlexLogic operand
⇧	**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. Information to program the settings is covered here. These features are provided for two or more breakers; a user can use only those portions of the design relevant to a single breaker, which must be breaker 1.

The number of breaker control elements depends on the number of CT/VT modules specified with the C70. 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 pushbutton operations.

BREAKER 1 NAME — Assign a user-defined name (up to six characters) to the breaker. This name is used in flash messages related to breaker 1.

BREAKER 1 MODE — 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 — Selects an operand that creates a programmable signal to operate an output relay to open breaker 1.

BREAKER 1 BLK OPEN — 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 — Selects an operand that creates a programmable signal to operate an output relay to close breaker 1.

BREAKER 1 BLK CLOSE — 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 — Selects an operand, usually a contact input connected to a breaker auxiliary position tracking mechanism. This input is 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 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 — Selects an operand, usually a contact input, that is 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 outlined 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 outlined 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 outlined 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 outlined 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 does 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.



IEC 61850 functionality is permitted when the C70 is in "Programmed" mode and not in local control mode.

Figure 5-48: Dual breaker control logic (Sheet 1 of 2)

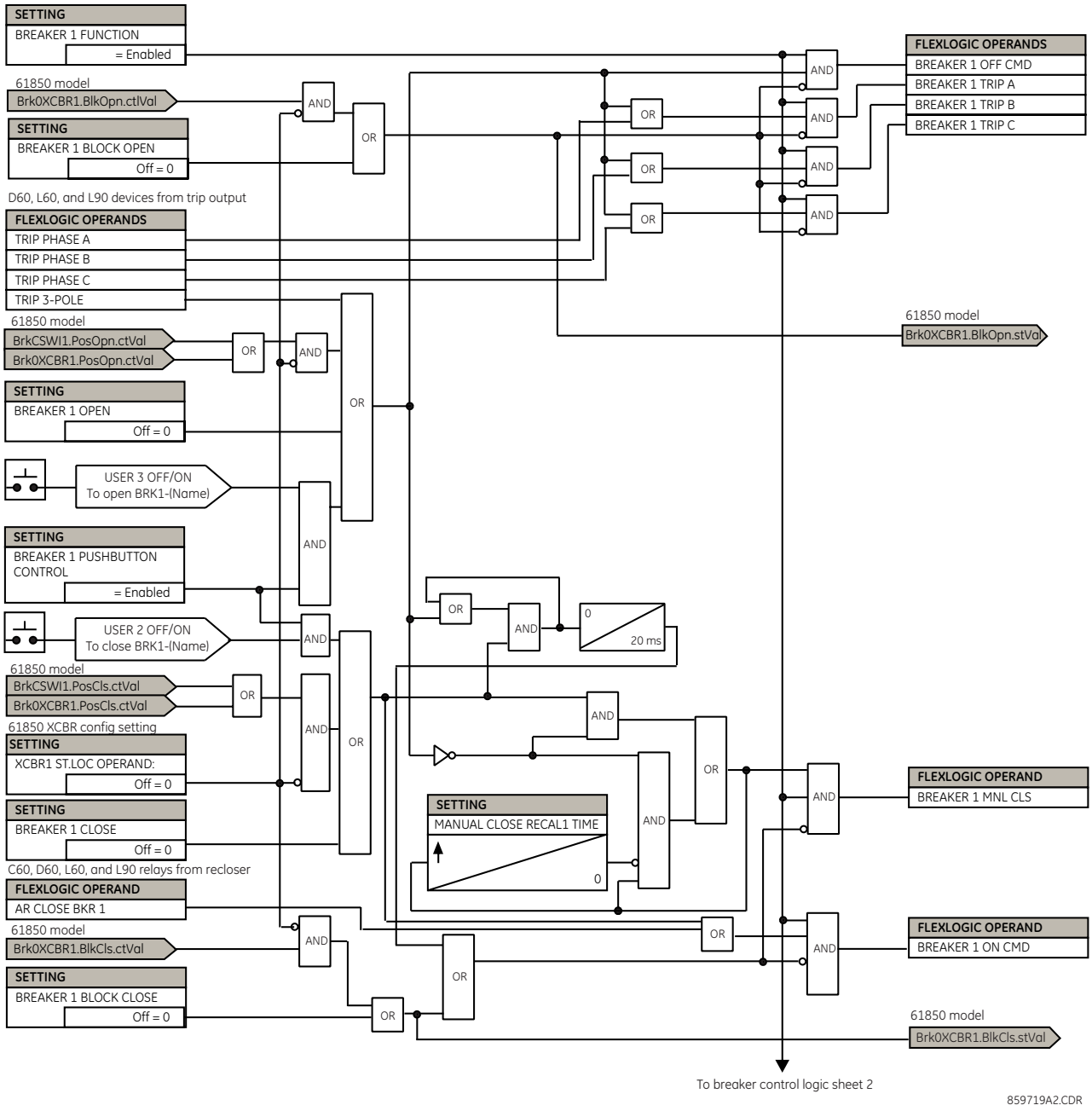
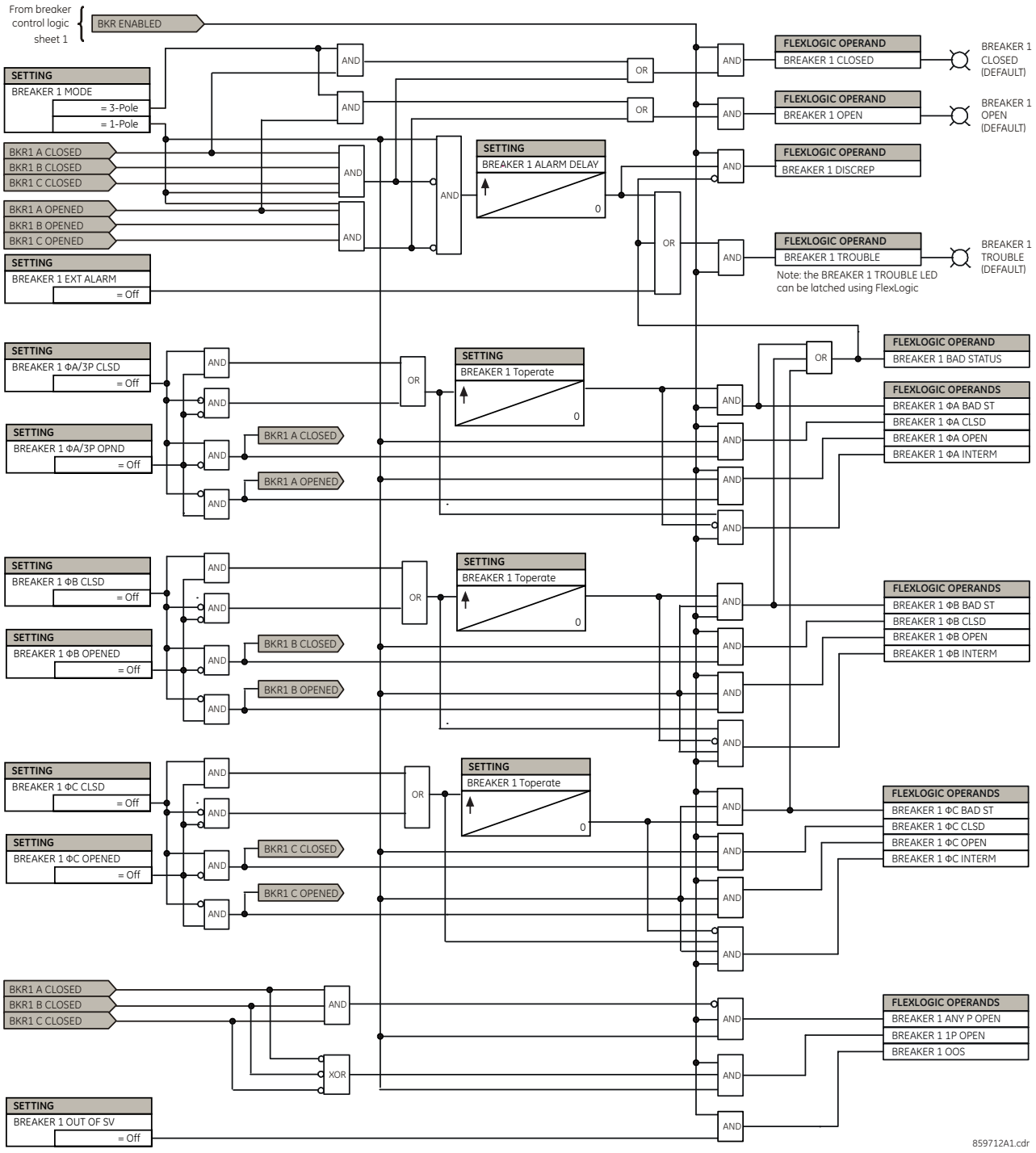


Figure 5-49: Dual breaker control logic (Sheet 2 of 2)



The breaker element has direct hard-coded connections to the 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 blocking of open/close commands are provided. Note that the dwell time for the IEC 61850 trip and close commands shown is one protection pass only. To maintain the close/open command for a certain time, do so on the contact outputs using the "Seal-in" setting, in the Trip Output element, or in FlexLogic.

5.5.5 Disconnect switches

SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SWITCHES ⇨⇩ SWITCH 1(24)

■ SWITCH 1 ■	⇔	**SWITCH 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇕	**SWITCH 1 NAME: SW 1**	Range: up to six alphanumeric characters
	⇕	**SWITCH 1 MODE: 3-Pole**	Range: 3-Pole, 1-Pole
	⇕	**SWITCH 1 OPEN: Off**	Range: FlexLogic operand
	⇕	**SWITCH 1 BLK OPEN: Off**	Range: FlexLogic operand
	⇕	**SWITCH 1 CLOSE: Off**	Range: FlexLogic operand
	⇕	**SWITCH 1 BLK CLOSE: Off**	Range: FlexLogic operand
	⇕	**SWTCH 1 ΦA/3P CLSD: Off**	Range: FlexLogic operand
	⇕	**SWTCH 1 ΦA/3P OPND: Off**	Range: FlexLogic operand
	⇕	**SWITCH 1 ΦB CLOSED: Off**	Range: FlexLogic operand
	⇕	**SWITCH 1 ΦB OPENED: Off**	Range: FlexLogic operand
	⇕	**SWITCH 1 ΦC CLOSED: Off**	Range: FlexLogic operand
	⇕	**SWITCH 1 ΦC OPENED: Off**	Range: FlexLogic operand
	⇕	**SWITCH 1 TOPERATE: 70 ms**	Range: 0 to 65535 ms in steps of 1
	⇕	**SWITCH 1 ALARM DELAY: 0.000 s**	Range: 0.000 to 65.535 s in steps of 0.001
	⇧	**SWITCH 1 EVENTS: Disabled**	Range: Disabled, Enabled

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 operation of the disconnect switch element.

SWITCH 1 NAME — Assign a user-defined name (up to six characters) to the disconnect switch. This name is 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 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 outlined 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 outlined 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 outlined 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 outlined for phase A.

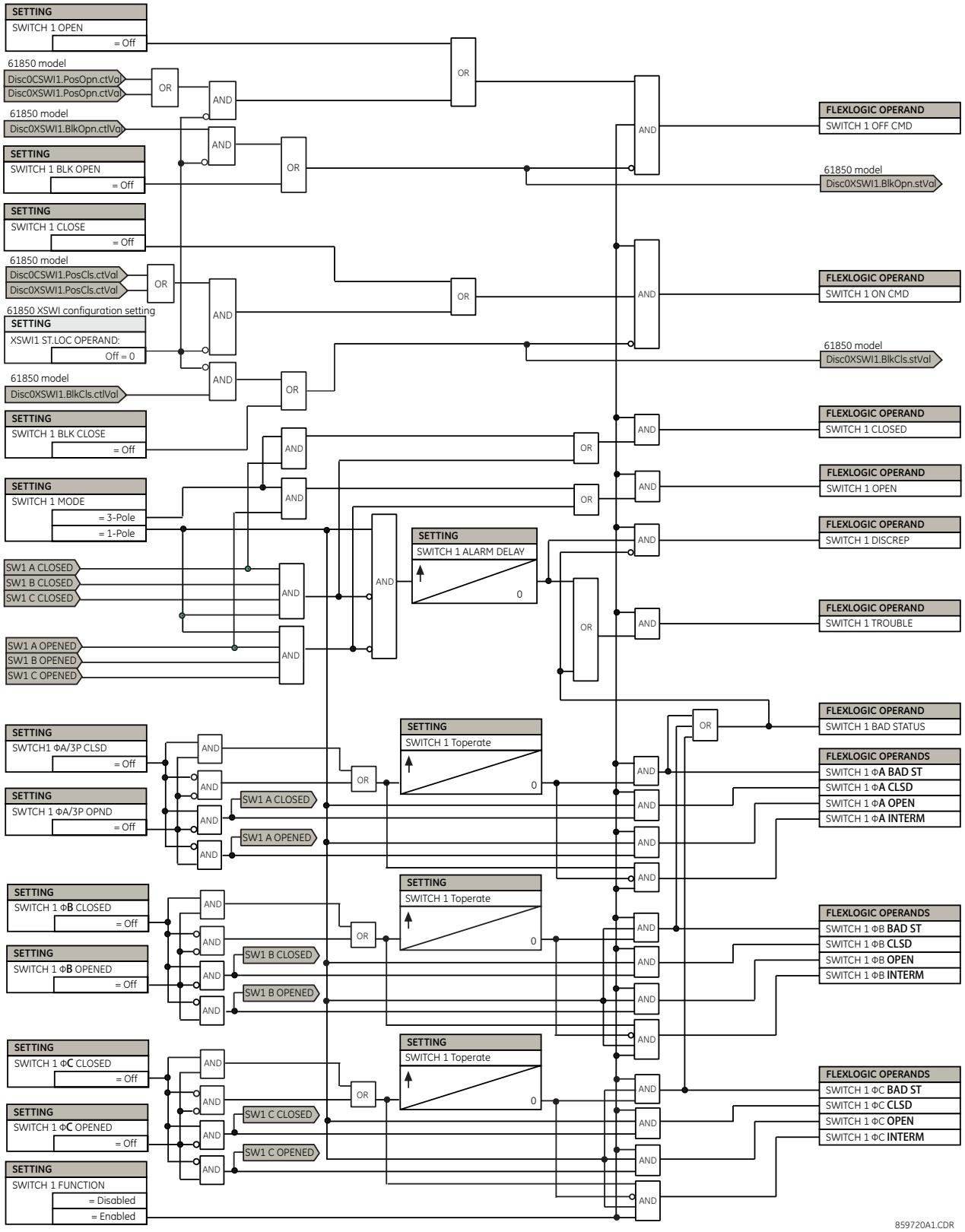
SWITCH 1 TOPERATE — This setting specifies the required interval to overcome transient disagreement between the 89/a and 89/b auxiliary contacts during disconnect switch operation. If transient disagreement still exists after this time has expired, the SWITCH 1 BAD STATUS FlexLogic operand is asserted 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 do not declare a pole disagreement. This allows for non-simultaneous operation of the poles.



IEC 61850 functionality is permitted when the C70 is in "Programmed" mode and not in local control mode.

Figure 5-50: Disconnect switch logic

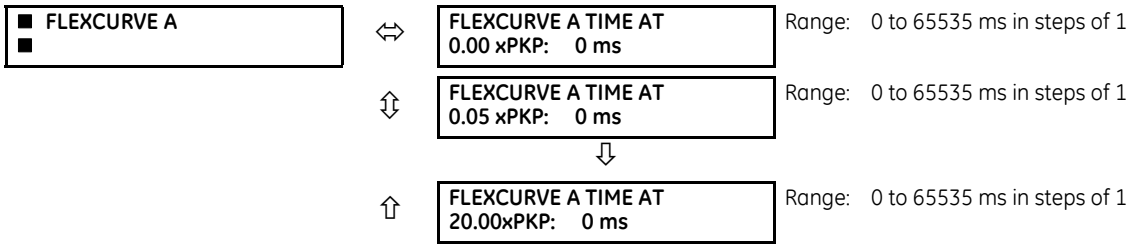


The switch element has direct hard-coded connections to the IEC 61850 model as shown in the logic diagram. This allows remote open/close operation of each switch, using either CSWI or XSWI IEC 61850 logical nodes. IEC 61850 select-before-operate functionality, local/remote switch functionality, along with blocking open/close commands are provided. Note that the dwell time for the IEC 61850 trip and close commands shown is one protection pass only. To maintain close/open command for a certain time, do so either on the contact outputs using the "Seal-in" setting or in FlexLogic.

5.5.6 FlexCurves

5.5.6.1 Settings

SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ FLEXCURVES ⇨⇩ FLEXCURE 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 required protection curve (A, B, C, or D).

Table 5-16: 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. Take care 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 can result in undesired behavior for the operating quantity that is close to 1.00 pu.

5.5.6.2 FlexCurve configuration with EnerVista software

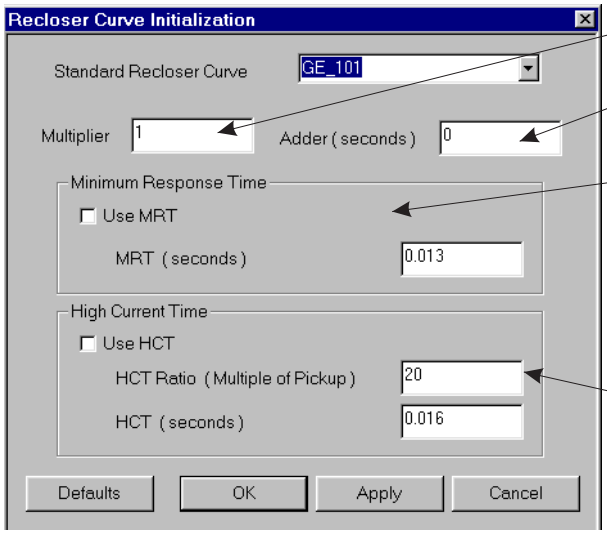
The EnerVista software allows for easy configuration and management of FlexCurves and their associated data points. Prospective FlexCurves can be configured from a selection of standard curves to provide the best approximate fit, then specific data points can be edited afterwards. Alternately, curve data can be imported from a specified file (.csv format) by selecting the EnerVista **Import Data From** setting (**Settings > System Setup > FlexCurves > FlexCurve**).

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.

5.5.6.3 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 protective devices have different operating characteristics. The recloser curve configuration window shown here appears when the **Initialize From** setting in the EnerVista software is set to "Recloser Curve" and the **Initialize FlexCurve** button is clicked.

Figure 5-51: Recloser curve initialization



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

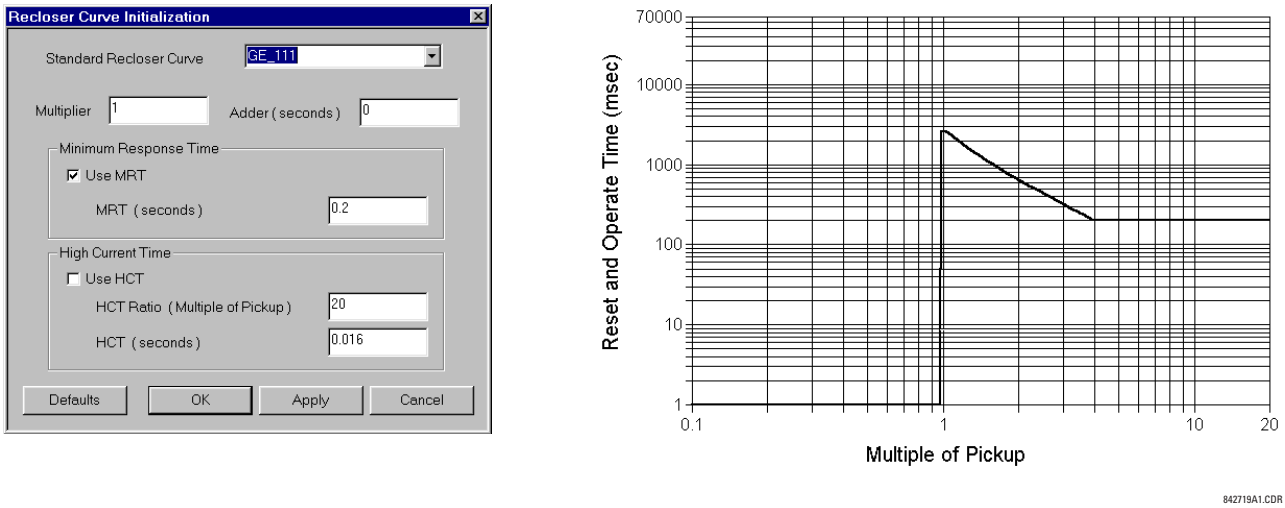
NOTE

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.

5.5.6.4 Example

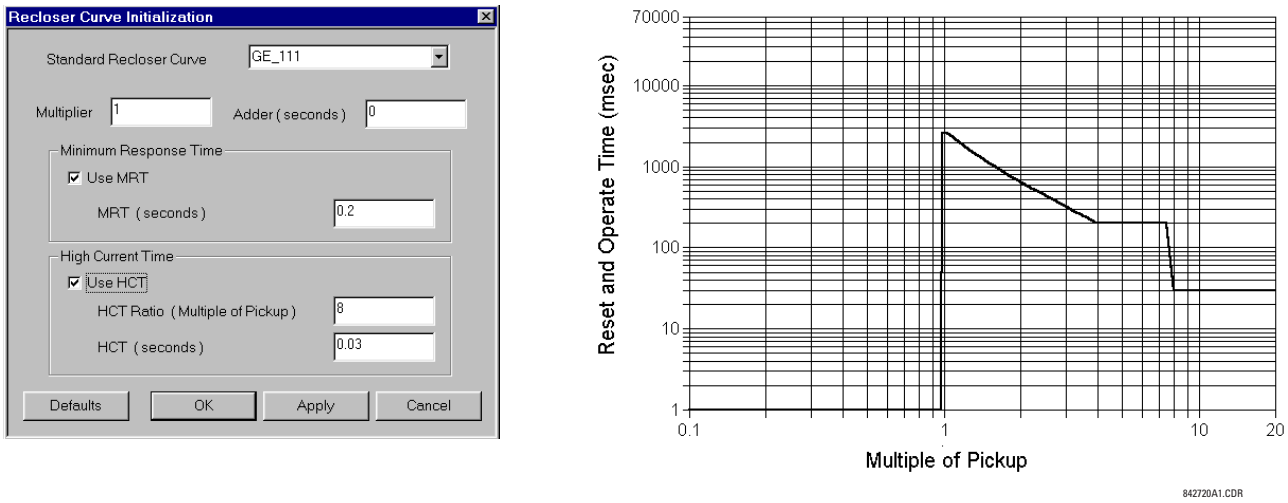
A composite curve can be created from the GE_111 standard with MRT = 200 ms and HCT initially disabled and then enabled at eight times pickup with an operating time of 30 ms. At approximately four times pickup, the curve operating time is equal to the MRT and from then onwards the operating time remains at 200 ms.

Figure 5-52: 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 5-53: 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 software generates an error message and discards the proposed changes.

5.5.6.5 Standard recloser curves

The following graphs display standard recloser curves available for the C70.

Figure 5-54: Recloser curves GE101 to GE106

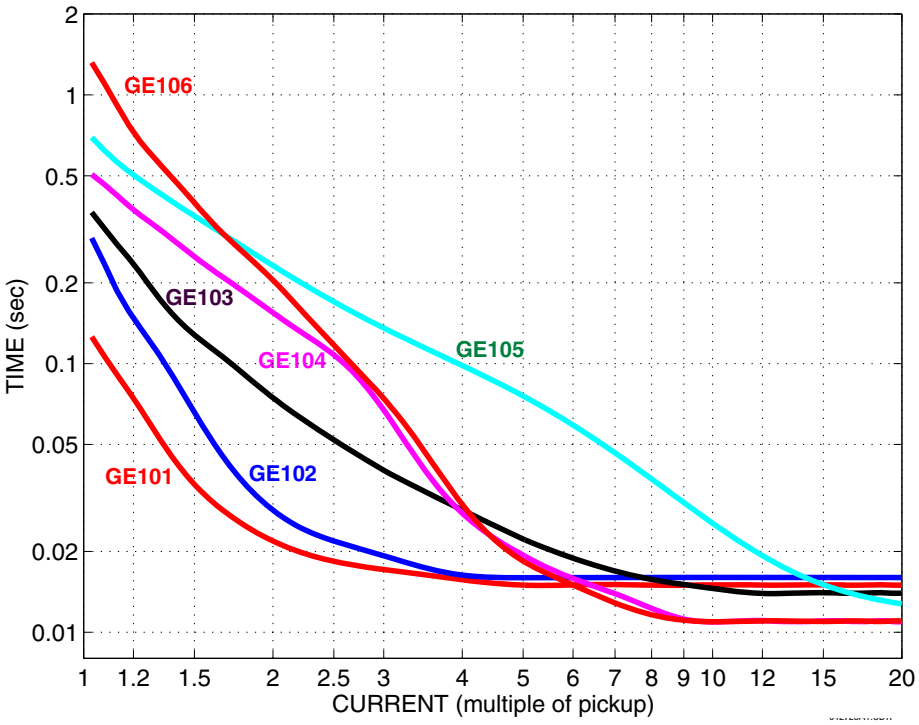
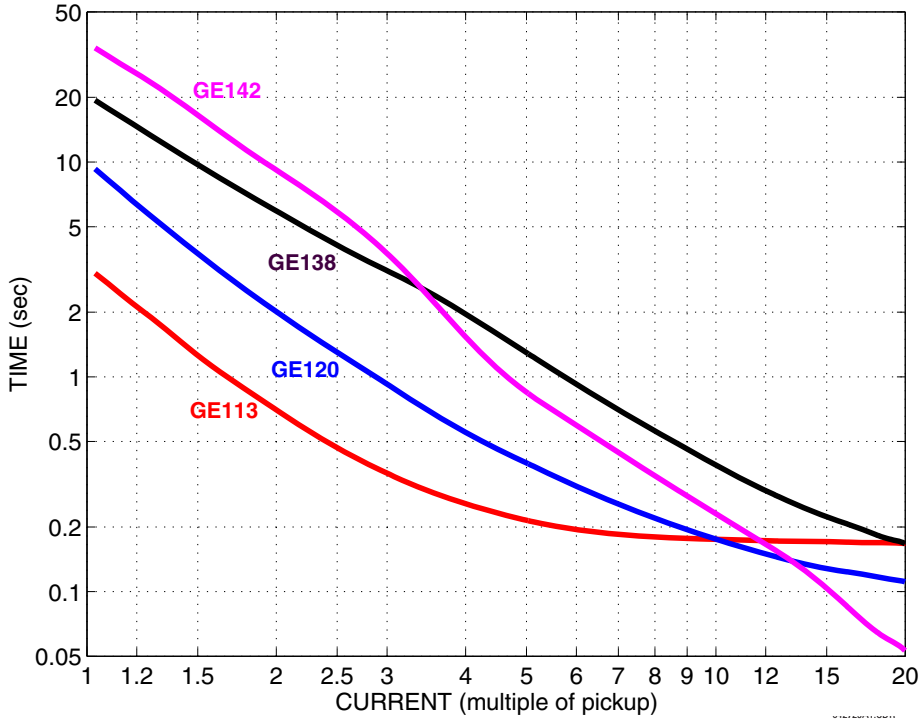


Figure 5-55: Recloser curves GE113, GE120, GE138, and GE142



5

Figure 5-56: Recloser curves GE134, GE137, GE140, GE151, and GE201

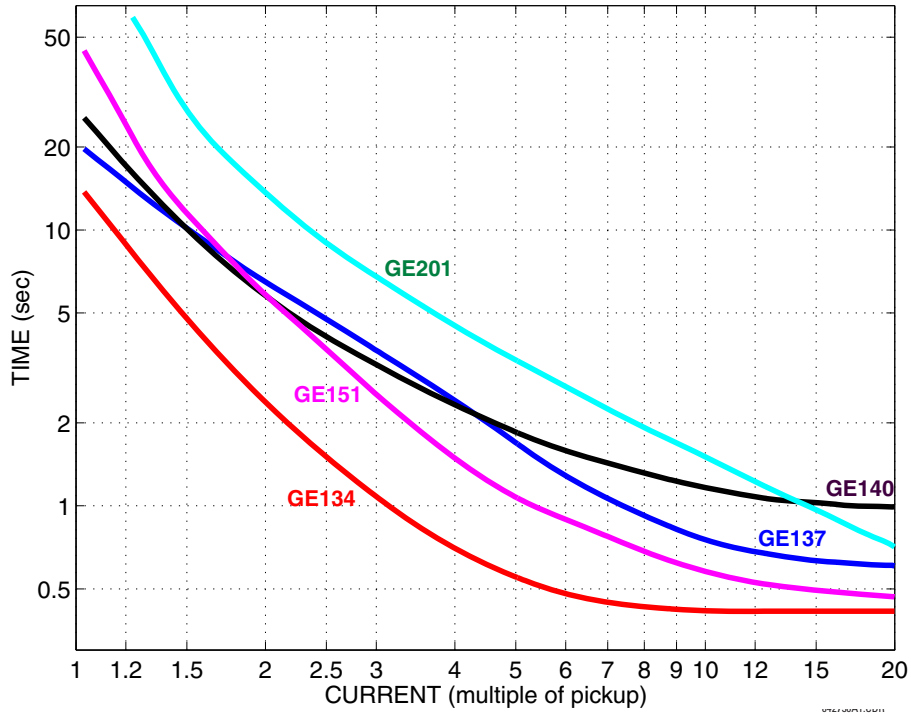


Figure 5-57: Recloser curves GE131, GE141, GE152, and GE200

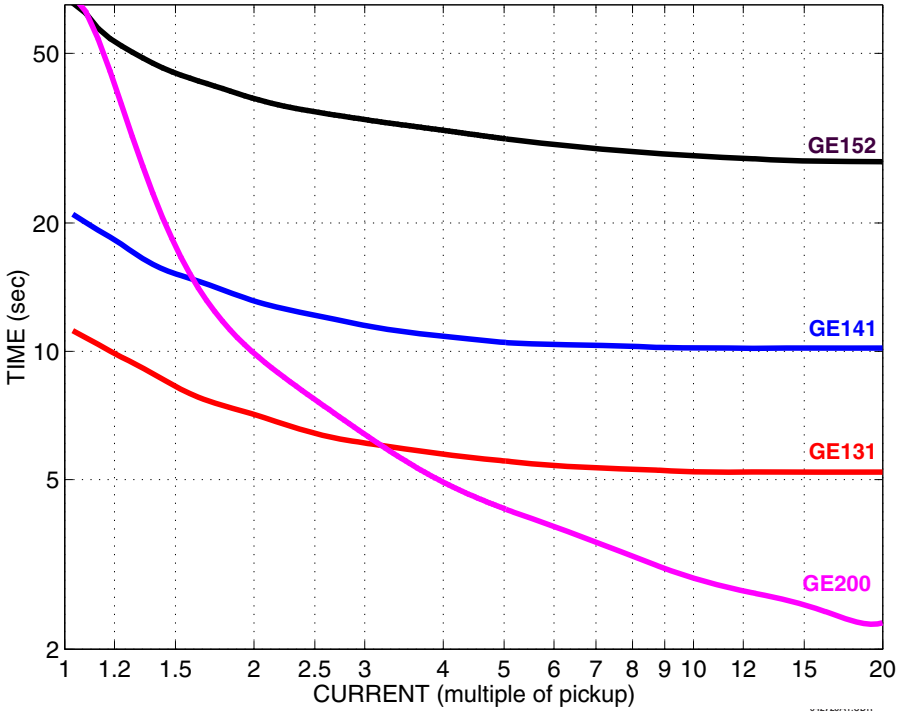


Figure 5-58: Recloser curves GE133, GE161, GE162, GE163, GE164, and GE165

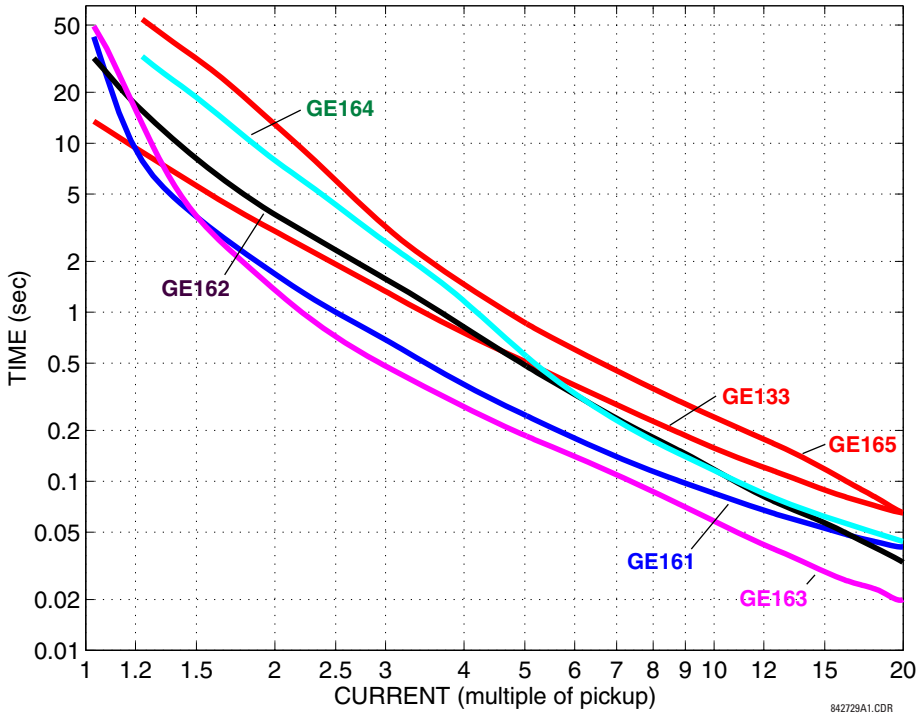


Figure 5-59: Recloser curves GE116, GE117, GE118, GE132, GE136, and GE139

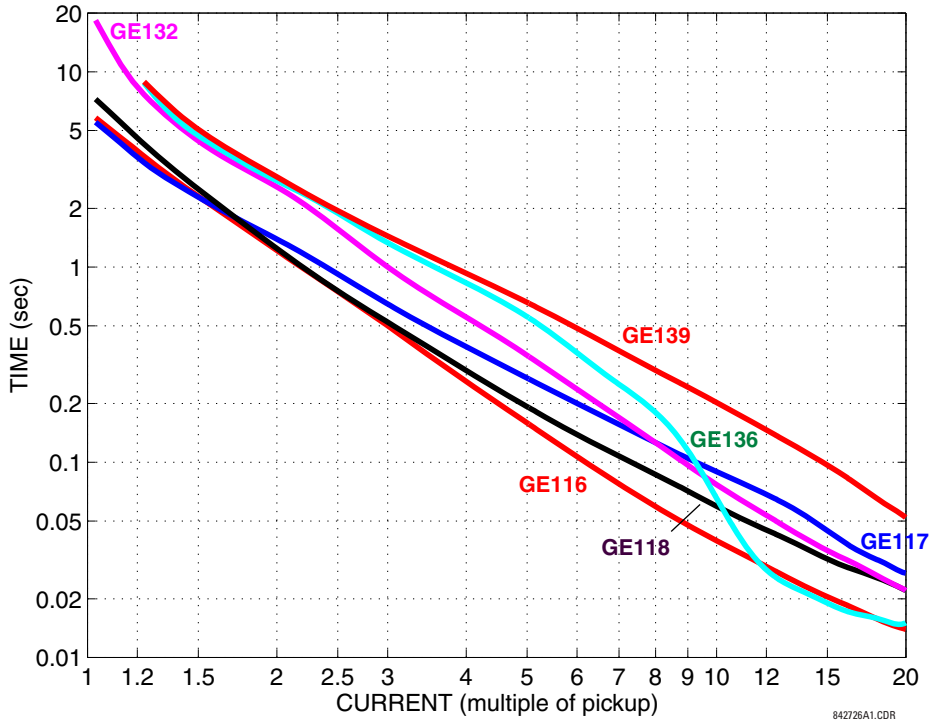


Figure 5-60: Recloser curves GE107, GE111, GE112, GE114, GE115, GE121, and GE122

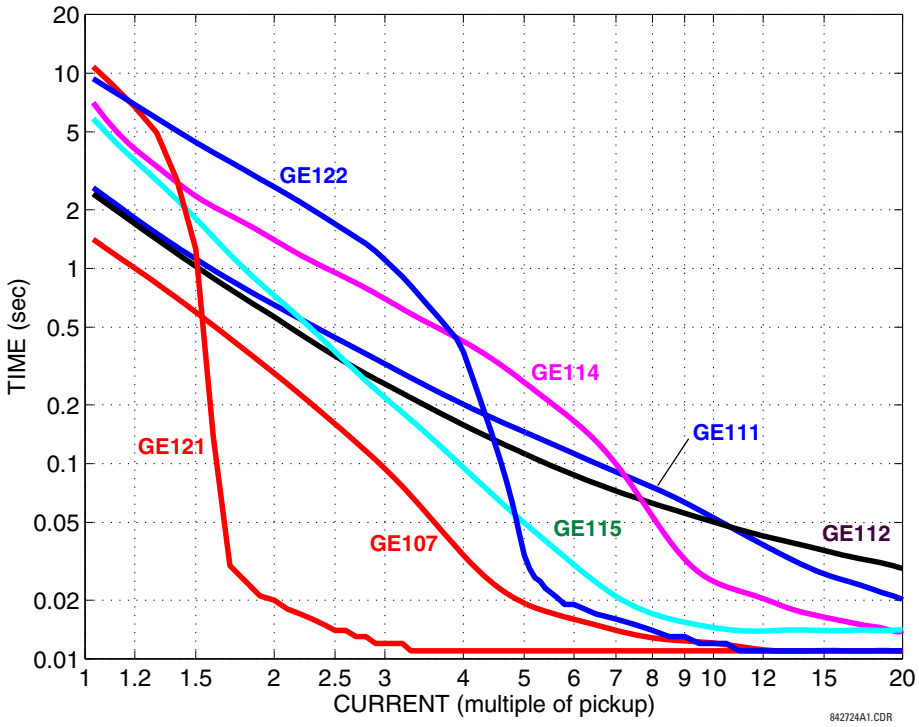
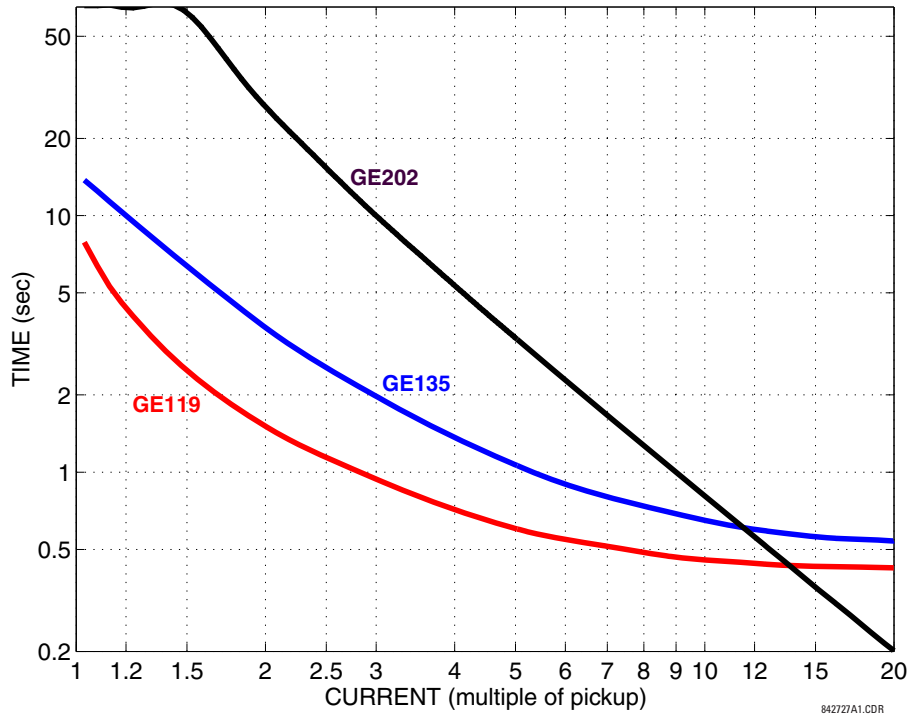


Figure 5-61: Recloser curves GE119, GE135, and GE202

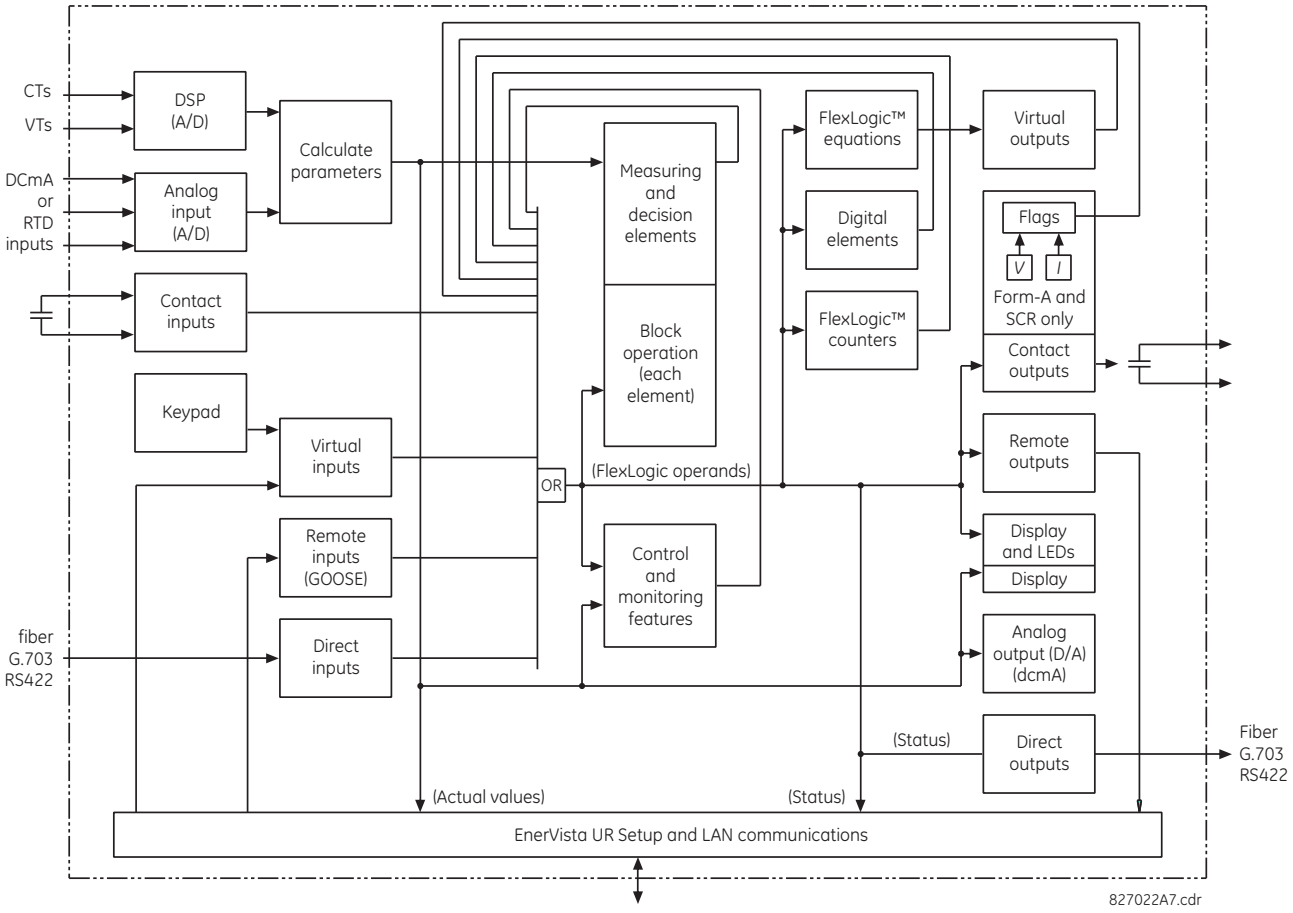


5.6 FlexLogic

5.6.1 FlexLogic operands

For flexibility, 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 contact input signals through elements or combinations of elements to contact outputs, is variable. The user has complete control of all variable logic through FlexLogic. In general, the system receives analog and digital inputs that it uses to produce analog and digital outputs. The figure shows major subsystems of a generic UR-series relay involved in this process.

Figure 5-62: UR architecture overview



The states of all digital signals used in the C70 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 wanted, 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 shown in the figure is required, it is implemented via FlexLogic. For example, 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 that 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 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, or flag set) or 0 (=OFF, or flag not set). Each equation is evaluated at least four times every power system cycle.

Some types of operands are present in the relay in multiple instances, for example contact and remote inputs. These types of operands are grouped together (for presentation purposes only) on the faceplate display. The table lists characteristics of the different types of operands.

Table 5-17: C70 FlexLogic operand types

Operand type	State	Example of format	Characteristics [Input Is '1' (= ON) if...]
Contact Input	On	Cont Ip On	Voltage is applied presently to the input (external contact closed)
	Off	Cont Ip Off	Voltage is not applied presently 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
	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 that responds to rising values or below the pickup setting of an element that 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

Operand type	State	Example of format	Characteristics [Input Is '1' (= ON) if...]
RxGOOSE Boolean	On	RxGOOSE Boolean 1 On	The RxGOOSE Boolean 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 (that is, evaluation of the equation that produces this virtual output results in a "1")

The following table lists alphabetically the operands available for the relay. The operands can be viewed online by entering the IP address of the relay in a web browser and accessing the Device Information Menu.

Table 5-18: C70 FlexLogic operands

Operand type	Operand syntax	Operand description
CONTROL PUSHBUTTONS	CONTROL PUSHBTN 1 ON CONTROL PUSHBTN 2 ON CONTROL PUSHBTN 3 ON CONTROL PUSHBTN 4 ON CONTROL PUSHBTN 5 ON CONTROL PUSHBTN 6 ON CONTROL PUSHBTN 7 ON	Control pushbutton 1 is being pressed Control pushbutton 2 is being pressed Control pushbutton 3 is being pressed Control pushbutton 4 is being pressed Control pushbutton 5 is being pressed Control pushbutton 6 is being pressed Control pushbutton 7 is being pressed
CYBERSENTRY	ROLE ADMIN ACT ROLE SUPERVISOR ACT ROLE ENGINEER ACT ROLE OPERATOR ACT ROLE OBSERVER ACT AUTHENTICATION FAIL UNAUTH FW ATTEMPT UNAUTH SETTING WRITE	Administrator role is active and is set to true when that is the case Supervisor role is active and is set to true when that is the case Engineer role is active and is set to true when that is the case Operator role is active and is set to true when that is the case Observer role is active and is set to true when that is the case Operand set for Failed Authentication self-test and alarm Operand set for firmware lock self-test and alarm Operand set for settings lock self-test and alarm
DIRECT DEVICES	DIRECT DEVICE 1On ↓ DIRECT DEVICE 16On DIRECT DEVICE 1Off ↓ DIRECT DEVICE 16Off	Flag is set, logic=1 ↓ Flag is set, logic=1 Flag is set, logic=1 ↓ Flag is set, logic=1
DIRECT INPUT/ OUTPUT CHANNEL MONITORING	DIR IO CH1 CRC ALARM DIR IO CH2 CRC ALARM DIR IO CH1 UNRET ALM DIR IO CH2 UNRET ALM	The rate of direct input messages received on channel 1 and failing the CRC exceeded the user-specified level The rate of direct input messages received on channel 2 and failing the CRC exceeded the user-specified level The rate of returned direct input/output messages on channel 1 exceeded the user-specified level (ring configurations only) The rate of returned direct input/output messages on channel 2 exceeded the user-specified level (ring configurations only)
ELEMENT: Auxiliary overvoltage	AUX OV1 PKP AUX OV1 DPO AUX OV1 OP	Auxiliary overvoltage element has picked up Auxiliary overvoltage element has dropped out Auxiliary overvoltage element has operated
	AUX OV2 to 3	Same set of operands as shown for AUX OV1
ELEMENT: Automatic voltage regulator	AVR 1 CLOSE PKP AVR 1 CLOSE OP AVR 1 CLOSE DPO AVR 1 OPEN PKP AVR 1 OPEN OP AVR 1 OPEN DPO	Automatic voltage regulator 1 picked up; close command pending Automatic voltage regulator 1 issued a close command Close command of automatic voltage regulator 1 dropped out Automatic voltage regulator 1 picked up; open command pending Automatic voltage regulator 1 issued an open command Open command of automatic voltage regulator 1 dropped out
	AVR 2 to 3	Same set of operands as shown for AVR 1

Operand type	Operand syntax	Operand description
ELEMENT: Bank phase overvoltage	BANK OV 1 STG 1A PKP	Bank overvoltage element 1 picked up in phase A of stage 1
	BANK OV 1 STG 1B PKP	Bank overvoltage element 1 picked up in phase B of stage 1
	BANK OV 1 STG 1C PKP	Bank overvoltage element 1 picked up in phase C of stage 1
	BANK OV 1 STG 2A PKP	Bank overvoltage element 1 picked up in phase A of stage 2
	BANK OV 1 STG 2B PKP	Bank overvoltage element 1 picked up in phase B of stage 2
	BANK OV 1 STG 2C PKP	Bank overvoltage element 1 picked up in phase C of stage 2
	BANK OV 1 STG 3A PKP	Bank overvoltage element 1 picked up in phase A of stage 3
	BANK OV 1 STG 3B PKP	Bank overvoltage element 1 picked up in phase B of stage 3
	BANK OV 1 STG 3C PKP	Bank overvoltage element 1 picked up in phase C of stage 3
	BANK OV 1 STG 4A PKP	Bank overvoltage element 1 picked up in phase A of stage 4
	BANK OV 1 STG 4B PKP	Bank overvoltage element 1 picked up in phase B of stage 4
	BANK OV 1 STG 4C PKP	Bank overvoltage element 1 picked up in phase C of stage 4
	BANK OV 1 PKP A	Bank overvoltage element 1 picked up in phase A
	BANK OV 1 PKP B	Bank overvoltage element 1 picked up in phase B
	BANK OV 1 PKP C	Bank overvoltage element 1 picked up in phase C
	BANK OV 1 PKP	Bank overvoltage element 1 picked up
	BANK OV 1 DPO	Bank overvoltage element 1 dropped out
	BANK OV 1 STG 1A OP	Bank overvoltage element 1 operated in phase A of stage 1
	BANK OV 1 STG 1B OP	Bank overvoltage element 1 operated in phase B of stage 1
	BANK OV 1 STG 1C OP	Bank overvoltage element 1 operated in phase C of stage 1
	BANK OV 1 STG 2A OP	Bank overvoltage element 1 operated in phase A of stage 2
	BANK OV 1 STG 2B OP	Bank overvoltage element 1 operated in phase B of stage 2
	BANK OV 1 STG 2C OP	Bank overvoltage element 1 operated in phase C of stage 2
	BANK OV 1 STG 3A OP	Bank overvoltage element 1 operated in phase A of stage 3
	BANK OV 1 STG 3B OP	Bank overvoltage element 1 operated in phase B of stage 3
	BANK OV 1 STG 3C OP	Bank overvoltage element 1 operated in phase C of stage 3
	BANK OV 1 STG 4A OP	Bank overvoltage element 1 operated in phase A of stage 4
	BANK OV 1 STG 4B OP	Bank overvoltage element 1 operated in phase B of stage 4
	BANK OV 1 STG 4C OP	Bank overvoltage element 1 operated in phase C of stage 4
	BANK OV 1 OP A	Bank overvoltage element 1 operated in phase A
	BANK OV 1 OP B	Bank overvoltage element 1 operated in phase B
	BANK OV 1 OP C	Bank overvoltage element 1 operated in phase C
	BANK OV 1 OP	Bank overvoltage element 1 operated
	BANK OV 2 to 3	Same set of operands as shown for BANK OV 1
ELEMENT: Breaker flashover	BKR 1 FLSHOVR PKP A	Breaker 1 flashover element phase A has picked up
	BKR 1 FLSHOVR PKP B	Breaker 1 flashover element phase B has picked up
	BKR 1 FLSHOVR PKP C	Breaker 1 flashover element phase C has picked up
	BKR 1 FLSHOVR PKP	Breaker 1 flashover element has picked up
	BKR 1 FLSHOVR OP A	Breaker 1 flashover element phase A has operated
	BKR 1 FLSHOVR OP B	Breaker 1 flashover element phase B has operated
	BKR 1 FLSHOVR OP C	Breaker 1 flashover element phase C has operated
	BKR 1 FLSHOVR OP	Breaker 1 flashover element has operated
	BKR 1 FLSHOVR DPO A	Breaker 1 flashover element phase A has dropped out
	BKR 1 FLSHOVR DPO B	Breaker 1 flashover element phase B has dropped out
	BKR 1 FLSHOVR DPO C	Breaker 1 flashover element phase C has dropped out
	BKR 1 FLSHOVR DPO	Breaker 1 flashover element has dropped out
ELEMENT: Breaker failure	BKR FAIL 1 RETRIPA	Breaker failure 1 re-trip phase A (only for 1-pole schemes)
	BKR FAIL 1 RETRIPB	Breaker failure 1 re-trip phase B (only for 1-pole schemes)
	BKR FAIL 1 RETRIPC	Breaker failure 1 re-trip phase C (only for 1-pole schemes)
	BKR FAIL 1 RETRIP	Breaker failure 1 re-trip 3-phase
	BKR FAIL 1 T1 OP	Breaker failure 1 timer 1 is operated
	BKR FAIL 1 T2 OP	Breaker failure 1 timer 2 is operated
	BKR FAIL 1 T3 OP	Breaker failure 1 timer 3 is operated
	BKR FAIL 1 TRIP OP	Breaker failure 1 trip is operated
ELEMENT: Breaker restrike	BRK RESTRIKE 1 OP	Breaker restrike detected in any phase of the breaker control 1 element
	BRK RESTRIKE 1 OP A	Breaker restrike detected in phase A of the breaker control 1 element
	BRK RESTRIKE 1 OP B	Breaker restrike detected in phase B of the breaker control 1 element
	BRK RESTRIKE 1 OP C	Breaker restrike detected in phase C of the breaker control 1 element
	BKR RESTRIKE 2 to 3	Same set of operands as shown for BKR RESTRIKE 1

Operand type	Operand syntax	Operand description
ELEMENT: Breaker control	BREAKER 1 OFF CMD BREAKER 1 ON CMD BREAKER 1 ΦA BAD ST BREAKER 1 ΦA INTERM BREAKER 1 ΦA CLSD BREAKER 1 ΦA OPEN BREAKER 1 ΦB BAD ST BREAKER 1 ΦB INTERM BREAKER 1 ΦB CLSD BREAKER 1 ΦB OPEN BREAKER 1 ΦC BAD ST BREAKER 1 ΦC INTERM BREAKER 1 ΦC CLSD BREAKER 1 ΦC OPEN BREAKER 1 BAD STATUS BREAKER 1 CLOSED BREAKER 1 OPEN BREAKER 1 DISCREP BREAKER 1 TROUBLE BREAKER 1 MNL CLS BREAKER 1 TRIP A BREAKER 1 TRIP B BREAKER 1 TRIP C BREAKER 1 ANY P OPEN BREAKER 1 ONE P OPEN BREAKER 1 OOS	Breaker 1 open command initiated Breaker 1 close command initiated Breaker 1 phase A bad status is detected (discrepancy between the 52/a and 52/b contacts) Breaker 1 phase A intermediate status is detected (transition from one position to another) Breaker 1 phase A is closed Breaker 1 phase A is open Breaker 1 phase B bad status is detected (discrepancy between the 52/a and 52/b contacts) Breaker 1 phase B intermediate status is detected (transition from one position to another) Breaker 1 phase B is closed Breaker 1 phase B is open Breaker 1 phase C bad status is detected (discrepancy between the 52/a and 52/b contacts) Breaker 1 phase C intermediate status is detected (transition from one position to another) Breaker 1 phase C is closed Breaker 1 phase C is open Breaker 1 bad status is detected on any pole Breaker 1 is closed Breaker 1 is open Breaker 1 has discrepancy Breaker 1 trouble alarm Breaker 1 manual close Breaker 1 trip phase A command Breaker 1 trip phase B command Breaker 1 trip phase C command At least one pole of breaker 1 is open Only one pole of breaker 1 is open Breaker 1 is out of service
	BREAKER 2 to 6	Same set of operands as shown for BREAKER 1
ELEMENT: Capacitor control	CAP 1 IN REMOTE CAP 1 IN LOCAL CAP 1 IN AUTO CAP 1 IN MAN CAP 1 DISCHARGING CAP 1 BKR TRIP CAP 1 BKR CLOSE	Capacitor control element 1 in remote control mode Capacitor control element 1 in local control mode Capacitor control element 1 in automatic mode Capacitor control element 1 in manual mode Capacitor 1 is discharging; asserted till discharge delay expires Capacitor 1 breaker trip command Capacitor 1 breaker close command
	CAP 2 to 4	Same set of operands as shown for CAP 1
ELEMENT: Digital counters	Counter 1 HI Counter 1 EQL Counter 1 LO	Digital counter 1 output is 'more than' comparison value Digital counter 1 output is 'equal to' comparison value Digital counter 1 output is 'less than' comparison value
	Counter 2 to 8	Same set of operands as shown for Counter 1

Operand type	Operand syntax	Operand description
ELEMENT: Phase current unbalance	CUR BAL 1 STG1A PKP	Phase current unbalance element 1 picked up in phase A of stage 1
	CUR BAL 1 STG1B PKP	Phase current unbalance element 1 picked up in phase B of stage 1
	CUR BAL 1 STG1C PKP	Phase current unbalance element 1 picked up in phase C of stage 1
	CUR BAL 1 STG2A PKP	Phase current unbalance element 1 picked up in phase A of stage 2
	CUR BAL 1 STG2B PKP	Phase current unbalance element 1 picked up in phase B of stage 2
	CUR BAL 1 STG2C PKP	Phase current unbalance element 1 picked up in phase C of stage 2
	CUR BAL 1 STG3A PKP	Phase current unbalance element 1 picked up in phase A of stage 3
	CUR BAL 1 STG3B PKP	Phase current unbalance element 1 picked up in phase B of stage 3
	CUR BAL 1 STG3C PKP	Phase current unbalance element 1 picked up in phase C of stage 3
	CUR BAL 1 STG4A PKP	Phase current unbalance element 1 picked up in phase A of stage 4
	CUR BAL 1 STG4B PKP	Phase current unbalance element 1 picked up in phase B of stage 4
	CUR BAL 1 STG4C PKP	Phase current unbalance element 1 picked up in phase C of stage 4
	CUR BAL 1 PKP A	Phase current unbalance element 1 picked up in phase A
	CUR BAL 1 PKP B	Phase current unbalance element 1 picked up in phase B
	CUR BAL 1 PKP C	Phase current unbalance element 1 picked up in phase C
	CUR BAL 1 PKP	Phase current unbalance element 1 picked up
	CUR BAL 1 DPO	Phase current unbalance element 1 dropped out
	CUR BAL 1 STG1A OP	Phase current unbalance element 1 operated in phase A of stage 1
	CUR BAL 1 STG1B OP	Phase current unbalance element 1 operated in phase B of stage 1
	CUR BAL 1 STG1C OP	Phase current unbalance element 1 operated in phase C of stage 1
	CUR BAL 1 STG2A OP	Phase current unbalance element 1 operated in phase A of stage 2
	CUR BAL 1 STG2B OP	Phase current unbalance element 1 operated in phase B of stage 2
	CUR BAL 1 STG2C OP	Phase current unbalance element 1 operated in phase C of stage 2
	CUR BAL 1 STG3A OP	Phase current unbalance element 1 operated in phase A of stage 3
	CUR BAL 1 STG3B OP	Phase current unbalance element 1 operated in phase B of stage 3
	CUR BAL 1 STG3C OP	Phase current unbalance element 1 operated in phase C of stage 3
	CUR BAL 1 STG4A OP	Phase current unbalance element 1 operated in phase A of stage 4
	CUR BAL 1 STG4B OP	Phase current unbalance element 1 operated in phase B of stage 4
	CUR BAL 1 STG4C OP	Phase current unbalance element 1 operated in phase C of stage 4
	CUR BAL 1 OP A	Phase current unbalance element 1 operated in phase A
	CUR BAL 1 OP B	Phase current unbalance element 1 operated in phase B
	CUR BAL 1 OP C	Phase current unbalance element 1 operated in phase C
	CUR BAL 1 OP	Phase current unbalance element 1 operated
	CUR BAL 2 to 3	Same set of operands as shown for CUR BAL 1
ELEMENT: Time of day timer day	DAY SUNDAY	Current day is Sunday
	DAY MONDAY	Current day is Monday
	DAY TUESDAY	Current day is Tuesday
	DAY WEDNESDAY	Current day is Wednesday
	DAY THURSDAY	Current day is Thursday
	DAY FRIDAY	Current day is Friday
	DAY SATURDAY	Current day is Saturday
ELEMENT: Digital elements	Dig Element 1 PKP	Digital Element 1 is picked up
	Dig Element 1 OP	Digital Element 1 is operated
	Dig Element 1 DPO	Digital Element 1 is dropped out
	Dig Element 2 to 48	Same set of operands as shown for Dig Element 1
ELEMENT: FlexElements	FxE 1 PKP	FlexElement 1 has picked up
	FxE 1 OP	FlexElement 1 has operated
	FxE 1 DPO	FlexElement 1 has dropped out
	FxE 2 to 16	Same set of operands as shown for FxE 1
ELEMENT: Ground instantaneous overcurrent	GROUND IOC1 PKP	Ground instantaneous overcurrent 1 has picked up
	GROUND IOC1 OP	Ground instantaneous overcurrent 1 has operated
	GROUND IOC1 DPO	Ground instantaneous overcurrent 1 has dropped out
	GROUND IOC2 to 12	Same set of operands as shown for GROUND IOC 1
ELEMENT: Ground time overcurrent	GROUND TOC1 PKP	Ground time overcurrent 1 has picked up
	GROUND TOC1 OP	Ground time overcurrent 1 has operated
	GROUND TOC1 DPO	Ground time overcurrent 1 has dropped out
	GROUND TOC2 to 6	Same set of operands as shown for GROUND TOC1
ELEMENT: Non-volatile latches	LATCH 1 ON	Non-volatile latch 1 is ON (Logic = 1)
	LATCH 1 OFF	Non-volatile latch 1 is OFF (Logic = 0)
	LATCH 2 to 16	Same set of operands as shown for LATCH 1

Operand type	Operand syntax	Operand description
ELEMENT: Time of day timer month	MONTH JANUARY MONTH FEBRUARY MONTH MARCH MONTH APRIL MONTH MAY MONTH JUNE MONTH JULY MONTH AUGUST MONTH SEPTEMBER MONTH OCTOBER MONTH NOVEMBER MONTH DECEMBER	Current month is January Current month is February Current month is March Current month is April Current month is May Current month is June Current month is July Current month is August Current month is September Current month is October Current month is November Current month is December
ELEMENT: Negative-sequence directional overcurrent	NEG SEQ DIR OC1 FWD NEG SEQ DIR OC1 REV NEG SEQ DIR OC2 FWD NEG SEQ DIR OC2 REV	Negative-sequence directional overcurrent 1 forward has operated Negative-sequence directional overcurrent 1 reverse has operated Negative-sequence directional overcurrent 2 forward has operated Negative-sequence directional overcurrent 2 reverse has operated
ELEMENT: Negative-sequence instantaneous overcurrent	NEG SEQ IOC1 PKP NEG SEQ IOC1 OP NEG SEQ IOC1 DPO	Negative-sequence instantaneous overcurrent 1 has picked up Negative-sequence instantaneous overcurrent 1 has operated 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 NEG SEQ OV1 DPO NEG SEQ OV1 OP	Negative-sequence overvoltage element has picked up Negative-sequence overvoltage element has dropped out 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 NEG SEQ TOC1 OP NEG SEQ TOC1 DPO	Negative-sequence time overcurrent 1 has picked up Negative-sequence time overcurrent 1 has operated 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 NEUTRAL IOC1 OP NEUTRAL IOC1 DPO	Neutral instantaneous overcurrent 1 has picked up Neutral instantaneous overcurrent 1 has operated Neutral instantaneous overcurrent 1 has dropped out
	NEUTRAL IOC2 to 12	Same set of operands as shown for NEUTRAL IOC1
ELEMENT: Neutral overvoltage	NEUTRAL OV1 PKP NEUTRAL OV1 DPO NEUTRAL OV1 OP	Neutral overvoltage element 1 has picked up Neutral overvoltage element 1 has dropped out Neutral overvoltage element 1 has operated
	NEUTRAL OV2 to 3	Same set of operands as shown for NEUTRAL OV1
ELEMENT: Neutral time overcurrent	NEUTRAL TOC1 PKP NEUTRAL TOC1 OP NEUTRAL TOC1 DPO	Neutral time overcurrent 1 has picked up Neutral time overcurrent 1 has operated Neutral time overcurrent 1 has dropped out
	NEUTRAL TOC2 to 6	Same set of operands as shown for NEUTRAL TOC1
ELEMENT: Neutral current unbalance	NTRL CUR 1 STG1 PKP NTRL CUR 1 STG2 PKP NTRL CUR 1 STG3 PKP NTRL CUR 1 STG4 PKP NTRL CUR 1 PKP NTRL CUR 1 DPO NTRL CUR 1 STG1 OP NTRL CUR 1 STG2 OP NTRL CUR 1 STG3 OP NTRL CUR 1 STG4 OP NTRL CUR 1 OP	Neutral current unbalance element 1 picked up in stage 1 Neutral current unbalance element 1 picked up in stage 2 Neutral current unbalance element 1 picked up in stage 3 Neutral current unbalance element 1 picked up in stage 4 Neutral current unbalance element 1 picked up Neutral current unbalance element 1 dropped out Neutral current unbalance element 1 operated in stage 1 Neutral current unbalance element 1 operated in stage 2 Neutral current unbalance element 1 operated in stage 3 Neutral current unbalance element 1 operated in stage 4 Neutral current unbalance element 1 operated
	NTRL CUR 2 to 3	Same set of operands as shown for NTRL CUR 1
ELEMENT: Neutral directional overcurrent	NTRL DIR OC1 FWD NTRL DIR OC1 REV	Neutral directional overcurrent 1 forward has operated Neutral directional overcurrent 1 reverse has operated

Operand type	Operand syntax	Operand description
ELEMENT: Neutral voltage unbalance	NTRL VOLT 1 STG1 PKP	Neutral voltage unbalance element 1 picked up in stage 1
	NTRL VOLT 1 STG2 PKP	Neutral voltage unbalance element 1 picked up in stage 2
	NTRL VOLT 1 STG3 PKP	Neutral voltage unbalance element 1 picked up in stage 3
	NTRL VOLT 1 STG4 PKP	Neutral voltage unbalance element 1 picked up in stage 4
	NTRL VOLT 1 PKP	Neutral voltage unbalance element 1 picked up
	NTRL VOLT 1 DPO	Neutral voltage unbalance element 1 dropped out
	NTRL VOLT 1 STG1 OP	Neutral voltage unbalance element 1 operated in stage 1
	NTRL VOLT 1 STG2 OP	Neutral voltage unbalance element 1 operated in stage 2
	NTRL VOLT 1 STG3 OP	Neutral voltage unbalance element 1 operated in stage 3
	NTRL VOLT 1 STG4 OP	Neutral voltage unbalance element 1 operated in stage 4
	NTRL VOLT 1 OP	Neutral voltage unbalance element 1 operated
	NTRL VOLT 2 to 3	Same set of operands as shown for NTRL VOLT 1
ELEMENT: Phase directional overcurrent	PH DIR1 BLK A	Phase A directional 1 block
	PH DIR1 BLK B	Phase B directional 1 block
	PH DIR1 BLK C	Phase C directional 1 block
	PH DIR1 BLK	Phase directional 1 block
	PH DIR2	Same set of operands as shown for PH DIR1
ELEMENT: Phase instantaneous overcurrent	PHASE IOC1 PKP	At least one phase of phase instantaneous overcurrent 1 has picked up
	PHASE IOC1 OP	At least one phase of phase instantaneous overcurrent 1 has operated
	PHASE IOC1 DPO	All phases of phase instantaneous overcurrent 1 have dropped out
	PHASE IOC1 PKP A	Phase A of phase instantaneous overcurrent 1 has picked up
	PHASE IOC1 PKP B	Phase B of phase instantaneous overcurrent 1 has picked up
	PHASE IOC1 PKP C	Phase C of phase instantaneous overcurrent 1 has picked up
	PHASE IOC1 OP A	Phase A of phase instantaneous overcurrent 1 has operated
	PHASE IOC1 OP B	Phase B of phase instantaneous overcurrent 1 has operated
	PHASE IOC1 OP C	Phase C of phase instantaneous overcurrent 1 has operated
	PHASE IOC1 DPO A	Phase A of phase instantaneous overcurrent 1 has dropped out
	PHASE IOC1 DPO B	Phase B of phase instantaneous overcurrent 1 has dropped out
	PHASE IOC1 DPO C	Phase C of phase instantaneous overcurrent 1 has dropped out
	PHASE IOC2 to 12	Same set of operands as shown for PHASE IOC1
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 to 6	Same set of operands as shown for PHASE TOC1
	PHASE TOC1 I2t RST	All phases I^2t accumulated energy dropped below level per reset curve
	PHASE TOC2 I2t RST	All phases I^2t accumulated energy dropped below level per reset curve

Operand type	Operand syntax	Operand description
ELEMENT: Phase undervoltage	PHASE UV1 PKP PHASE UV1 OP PHASE UV1 DPO PHASE UV1 PKP A PHASE UV1 PKP B PHASE UV1 PKP C PHASE UV1 OP A PHASE UV1 OP B PHASE UV1 OP C PHASE UV1 DPO A PHASE UV1 DPO B PHASE UV1 DPO C	At least one phase of phase undervoltage 1 has picked up At least one phase of phase undervoltage 1 has operated All phases of phase undervoltage 1 have dropped out Phase A of phase undervoltage 1 has picked up Phase B of phase undervoltage 1 has picked up Phase C of phase undervoltage 1 has picked up Phase A of phase undervoltage 1 has operated Phase B of phase undervoltage 1 has operated Phase C of phase undervoltage 1 has operated Phase A of phase undervoltage 1 has dropped out Phase B of phase undervoltage 1 has dropped out Phase C of phase undervoltage 1 has dropped out
	PHASE UV2 to 3	Same set of operands as shown for PHASE UV1
ELEMENT: Selector switch	SELECTOR 1 POS Y SELECTOR 1 BIT 0 SELECTOR 1 BIT 1 SELECTOR 1 BIT 2 SELECTOR 1 STP ALARM SELECTOR 1 BIT ALARM SELECTOR 1 ALARM SELECTOR 1 PWR ALARM	Selector switch 1 is in Position Y (mutually exclusive operands) First bit of the 3-bit word encoding position of selector 1 Second bit of the 3-bit word encoding position of selector 1 Third bit of the 3-bit word encoding position of selector 1 Position of selector 1 has been pre-selected with the stepping up control input but not acknowledged Position of selector 1 has been pre-selected with the 3-bit control input but not acknowledged Position of selector 1 has been pre-selected but not acknowledged 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 for SELECTOR 1
ELEMENT: Setting group	SETTING GROUP ACT 1 SETTING GROUP ACT 2 SETTING GROUP ACT 3 SETTING GROUP ACT 4 SETTING GROUP ACT 5 SETTING GROUP ACT 6	Setting group 1 is active Setting group 2 is active Setting group 3 is active Setting group 4 is active Setting group 5 is active Setting group 6 is active
ELEMENT: Disturbance detector	SRC1 50DD OP SRC2 50DD OP SRC3 50DD OP SRC4 50DD OP SRC5 50DD OP SRC6 50DD OP	Source 1 disturbance detector has operated Source 2 disturbance detector has operated Source 3 disturbance detector has operated Source 4 disturbance detector has operated Source 5 disturbance detector has operated Source 6 disturbance detector has operated
ELEMENT: VTFF (Voltage transformer fuse failure)	SRC1 VT FF OP SRC1 VT FF DPO SRC1 VT FF VOL LOSS SRC1 VT FF ALARM	Source 1 VT fuse failure detector has operated Source 1 VT fuse failure detector has dropped out Source 1 has lost voltage signals (V2 below 10% and V1 below 5% of nominal) Source 1 has triggered a VT fuse failure alarm
	SRC1 VT NEU WIRE OPEN	Source 1 VT neutral wire open detected. When the VT is connected in Delta, do not enable this function because there is no neutral wire for Delta connected VT.
	SRC2 VT FUSE FAIL to SRC6	Same set of operands as shown for SRC1 VT FF

Operand type	Operand syntax	Operand description
ELEMENT: Disconnect switch	SWITCH 1 OFF CMD	Disconnect switch 1 open command initiated
	SWITCH 1 ON CMD	Disconnect switch 1 close command initiated
	SWITCH 1 CLOSED	Disconnect switch 1 is closed
	SWITCH 1 OPEN	Disconnect switch 1 is open
	SWITCH 1 DISCREP	Disconnect switch 1 has discrepancy
	SWITCH 1 TROUBLE	Disconnect switch 1 trouble alarm
	SWITCH 1 ΦA CLSD	Disconnect switch 1 phase A is closed
	SWITCH 1 ΦA OPEN	Disconnect switch 1 phase A is open
	SWITCH 1 ΦA BAD ST	Disconnect switch 1 phase A bad status is detected (discrepancy between the 89/a and 89/b contacts)
	SWITCH 1 ΦA INTERM	Disconnect switch 1 phase A intermediate status is detected (transition from one position to another)
	SWITCH 1 ΦB CLSD	Disconnect switch 1 phase B is closed
	SWITCH 1 ΦB OPEN	Disconnect switch 1 phase B is open
	SWITCH 1 ΦB BAD ST	Disconnect switch 1 phase B bad status is detected (discrepancy between the 89/a and 89/b contacts)
	SWITCH 1 ΦB INTERM	Disconnect switch 1 phase B intermediate status is detected (transition from one position to another)
	SWITCH 1 ΦC CLSD	Disconnect switch 1 phase C is closed
	SWITCH 1 ΦC OPEN	Disconnect switch 1 phase C is open
	SWITCH 1 ΦC BAD ST	Disconnect switch 1 phase C bad status is detected (discrepancy between the 89/a and 89/b contacts)
	SWITCH 1 ΦC INTERM	Disconnect switch 1 phase C intermediate status is detected (transition from one position to another)
	SWITCH 1 BAD STATUS	Disconnect switch 1 bad status is detected on any pole
	SWITCH 2 to 24	Same set of operands as shown for SWITCH 1
ELEMENT: Thermal overload protection	THERMAL PROT 1 PKP	Thermal overload protection 1 picked up
	THERMAL PROT 1 OP	Thermal overload protection 1 operated
	THERMAL PROT 2	Same set of operands as shown for THERMAL PROT 1
ELEMENT: Time of day timer	TIME OF DAY 1 OFF	Time of day timer 1 is off
	TIME OF DAY 1 ON	Time of day timer 1 is on
	TIME OF DAY 1 START	One-second pulse at set time of day timer 1 start time
	TIME OF DAY 1 STOP	One-second pulse at set time of day timer 1 stop time
	TIME OF DAY 2 to 5	Same set of operands as shown for TIME OF DAY 1
ELEMENT: Trip bus	TRIP BUS 1 PKP	Asserted when the trip bus 1 element picks up
	TRIP BUS 1 OP	Asserted when the trip bus 1 element operates
	TRIP BUS 2 to 6	Same set of operands as shown for TRIP BUS 1

Operand type	Operand syntax	Operand description
ELEMENT: Voltage differential	VOLT DIF 1 STG1A PKP	Voltage differential element 1 picked up in phase A of stage 1
	VOLT DIF 1 STG1B PKP	Voltage differential element 1 picked up in phase B of stage 1
	VOLT DIF 1 STG1C PKP	Voltage differential element 1 picked up in phase C of stage 1
	VOLT DIF 1 STG2A PKP	Voltage differential element 1 picked up in phase A of stage 2
	VOLT DIF 1 STG2B PKP	Voltage differential element 1 picked up in phase B of stage 2
	VOLT DIF 1 STG2C PKP	Voltage differential element 1 picked up in phase C of stage 2
	VOLT DIF 1 STG3A PKP	Voltage differential element 1 picked up in phase A of stage 3
	VOLT DIF 1 STG3B PKP	Voltage differential element 1 picked up in phase B of stage 3
	VOLT DIF 1 STG3C PKP	Voltage differential element 1 picked up in phase C of stage 3
	VOLT DIF 1 STG4A PKP	Voltage differential element 1 picked up in phase A of stage 4
	VOLT DIF 1 STG4B PKP	Voltage differential element 1 picked up in phase B of stage 4
	VOLT DIF 1 STG4C PKP	Voltage differential element 1 picked up in phase C of stage 4
	VOLT DIF 1 PKP A	Voltage differential element 1 picked up in phase A
	VOLT DIF 1 PKP B	Voltage differential element 1 picked up in phase B
	VOLT DIF 1 PKP C	Voltage differential element 1 picked up in phase C
	VOLT DIF 1 PKP	Voltage differential element 1 picked up
	VOLT DIF 1 DPO	Voltage differential element 1 dropped out
	VOLT DIF 1 STG1A OP	Voltage differential element 1 operated in phase A of stage 1
	VOLT DIF 1 STG1B OP	Voltage differential element 1 operated in phase B of stage 1
	VOLT DIF 1 STG1C OP	Voltage differential element 1 operated in phase C of stage 1
	VOLT DIF 1 STG2A OP	Voltage differential element 1 operated in phase A of stage 2
	VOLT DIF 1 STG2B OP	Voltage differential element 1 operated in phase B of stage 2
	VOLT DIF 1 STG2C OP	Voltage differential element 1 operated in phase C of stage 2
	VOLT DIF 1 STG3A OP	Voltage differential element 1 operated in phase A of stage 3
	VOLT DIF 1 STG3B OP	Voltage differential element 1 operated in phase B of stage 3
	VOLT DIF 1 STG3C OP	Voltage differential element 1 operated in phase C of stage 3
	VOLT DIF 1 STG4A OP	Voltage differential element 1 operated in phase A of stage 4
	VOLT DIF 1 STG4B OP	Voltage differential element 1 operated in phase B of stage 4
	VOLT DIF 1 STG4C OP	Voltage differential element 1 operated in phase C of stage 4
	VOLT DIF 1 OP A	Voltage differential element 1 operated in phase A
	VOLT DIF 1 OP B	Voltage differential element 1 operated in phase B
	VOLT DIF 1 OP C	Voltage differential element 1 operated in phase C
	VOLT DIF 1 OP	Voltage differential element 1 operated
	VOLT DIF 2 to 3	Same set of operands as shown for VOLT DIF 1
FIXED OPERANDS	Off	Logic = 0. Does nothing and can 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	(does not appear unless ordered)
	Cont Ip 2 On	(does not appear unless ordered)
	↓	↓
	Cont Ip 1 Off	(does not appear unless ordered)
	Cont Ip 2 Off	(does not appear unless ordered)
	↓	↓
	Cont Ip 96 On	(does not appear unless ordered)
	Cont Ip 96 Off	(does not appear unless ordered)
INPUTS/OUTPUTS: Contact outputs,	Cont Op 1 Closed	Contact output is closed
	Cont Op 1 IOn	Current is flowing through the contact
	Cont Op 1 VOn	Voltage exists across the contact (present for contact outputs equipped with monitoring)
	Cont Op 1 VOff	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 inputs	DIRECT INPUT 1 On	Flag is set, logic=1
	↓	↓
	DIRECT INPUT 32 On	Flag is set, logic=1
INPUTS/OUTPUTS: RxGOOSE DPS	RxG DPS 1 BAD	Asserted while the RxGOOSE double-point status input is in the bad state
	RxG DPS 1 INTERM	Asserted while the RxGOOSE double-point status input is in the intermediate state
	RxG DPS 1 OFF	Asserted while the RxGOOSE double-point status input is off
	RxG DPS 1 ON	Asserted while the RxGOOSE double-point status input is on
	RxG DPS 2 to 5	Same set of operands as per RxG DPS 1

Operand type	Operand syntax	Operand description
INPUTS/OUTPUTS: RxGOOSE Booleans	RxG Bool 1 On RxG Bool 2 On RxG Bool 3 On ↓ RxG Bool 128 On	Flag is set, logic=1 Flag is set, logic=1 Flag is set, logic=1 ↓ Flag is set, logic=1
INPUTS/OUTPUTS: Virtual inputs	Virt Ip 1 On Virt Ip 2 On Virt Ip 3 On ↓ Virt Ip 64 On	Flag is set, logic=1 Flag is set, logic=1 Flag is set, logic=1 ↓ Flag is set, logic=1
INPUTS/OUTPUTS: Virtual outputs	Virt Op 1 On Virt Op 2 On Virt Op 3 On ↓ Virt Op 96 On	Flag is set, logic=1 Flag is set, logic=1 Flag is set, logic=1 ↓ Flag is set, logic=1
LED INDICATORS: Fixed front panel LEDs	LED IN SERVICE LED TROUBLE LED TEST MODE LED TRIP LED ALARM LED PICKUP LED VOLTAGE LED CURRENT LED FREQUENCY LED OTHER LED PHASE A LED PHASE B LED PHASE C LED NEUTRAL/GROUND	Asserted when the front panel IN SERVICE LED is on Asserted when the front panel TROUBLE LED is on Asserted when the front panel TEST MODE LED is on Asserted when the front panel TRIP LED is on Asserted when the front panel ALARM LED is on Asserted when the front panel PICKUP LED is on Asserted when the front panel VOLTAGE LED is on Asserted when the front panel CURRENT LED is on Asserted when the front panel FREQUENCY LED is on Asserted when the front panel OTHER LED is on Asserted when the front panel PHASE A LED is on Asserted when the front panel PHASE B LED is on Asserted when the front panel PHASE C LED is on 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
PASSWORD SECURITY	ACCESS LOC SETG OFF ACCESS LOC SETG ON ACCESS LOC CMND OFF ACCESS LOC CMND ON ACCESS REM SETG OFF ACCESS REM SETG ON ACCESS REM CMND OFF ACCESS REM CMND ON UNAUTHORIZED ACCESS	Asserted when local setting access is disabled Asserted when local setting access is enabled Asserted when local command access is disabled Asserted when local command access is enabled Asserted when remote setting access is disabled Asserted when remote setting access is enabled Asserted when remote command access is disabled Asserted when remote command access is enabled Asserted when a password entry fails while accessing a password protected level of the C70
RxGOOSE	RxGOOSE 1 On RxGOOSE 2 On RxGOOSE 3 On ↓ RxGOOSE 16 On	Flag is set, logic=1 Flag is set, logic=1 Flag is set, logic=1 ↓ Flag is set, logic=1
	RxGOOSE 1 Off RxGOOSE 2 Off RxGOOSE 3 Off ↓ RxGOOSE 16 Off	Flag is set, logic=1 Flag is set, logic=1 Flag is set, logic=1 ↓ Flag is set, logic=1
RESETTING	RESET OP RESET OP (COMMS) RESET OP (OPERAND) RESET OP (PUSHBUTTON)	Reset command is operated (set by all three operands below) Communications source of the reset command Operand (assigned in the **INPUTS/OUTPUTS ⇨⇩ RESETTING** menu) source of the reset command Reset key (pushbutton) source of the reset command

Operand type	Operand syntax	Operand description
SELF-DIAGNOSTICS (See Relay Self-tests descriptions in Chapter 7: Commands and Targets)	ANY MAJOR ERROR ANY MINOR ERROR ANY SELF-TESTS BATTERY FAIL CLOCK UNSYNCHRONIZED DIRECT DEVICE OFF DIRECT RING BREAK EQUIPMENT MISMATCH FLEXLOGIC ERR TOKEN IRIG-B FAILURE LATCHING OUT ERROR MAINTENANCE ALERT FIRST ETHERNET FAIL PROCESS BUS FAILURE PTP FAILURE RxGOOSE OFF RRTD COMM FAIL SECOND ETHERNET FAIL THIRD ETHERNET FAIL SNTP FAILURE SYSTEM EXCEPTION TEMP MONITOR UNIT NOT PROGRAMMED	Any of the major self-test errors generated (major error) Any of the minor self-test errors generated (minor error) Any self-test errors generated (generic, any error) The battery is not functioning. Replace as outlined in the Maintenance chapter. Relay is not synchronized to the international time standard A direct device is configured but not connected The Direct I/O settings is for a connection that is not in a ring The configuration of modules does not match the stored order code A FlexLogic equation is incorrect "Bad IRIG-B Signal" self-test. See Chapter 7: Commands and Targets. A difference is detected between the desired and actual latch contact state A subset of the minor self-test errors generated, see Chapter 7 Link failure detected. See description in Chapter 7: Commands and Targets. See description in Chapter 7: Commands and Targets "Bad PTP Signal" self-test as described in Chapter 7 One or more GOOSE messages are not being received See description in Chapter 7: Commands and Targets See description in Chapter 7: Commands and Targets See description in Chapter 7: Commands and Targets SNTP server is not responding See description in Chapter 7: Commands and Targets Monitors ambient temperature and maximum operating temperature The product **SETUP > INSTALLATION > RELAYS 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 PUSHBUTTON 1 OFF ANY PB ON	Pushbutton number 1 is in the "On" position Pushbutton number 1 is in the "Off" position Any of 12 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. 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 appears in the relay list of operands. The default names are shown in the FlexLogic operands table.

The characteristics of the logic gates are tabulated in the following table, and the operators available in FlexLogic are listed in the FlexLogic 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) ↓ OR(16)	2 input OR gate ↓ 16 input OR gate	Operates on the 2 previous parameters ↓ Operates on the 16 previous parameters
	AND(2) ↓ AND(16)	2 input AND gate ↓ 16 input AND gate	Operates on the 2 previous parameters ↓ Operates on the 16 previous parameters
	NOR(2) ↓ NOR(16)	2 input NOR gate ↓ 16 input NOR gate	Operates on the 2 previous parameters ↓ Operates on the 16 previous parameters
	NAND(2) ↓ NAND(16)	2 input NAND gate ↓ 16 input NAND gate	Operates on the 2 previous parameters ↓ 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 ↓ TIMER 32	Timer set with FlexLogic timer 1 settings ↓ 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 ↓ = Virt Op 96	Assigns previous FlexLogic operand to virtual output 1 ↓ Assigns previous FlexLogic operand to virtual output 96	The virtual output is set by the preceding parameter

5.6.2 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 that 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") can be used once only. If this rule is broken, a syntax error is declared.

5.6.3 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.

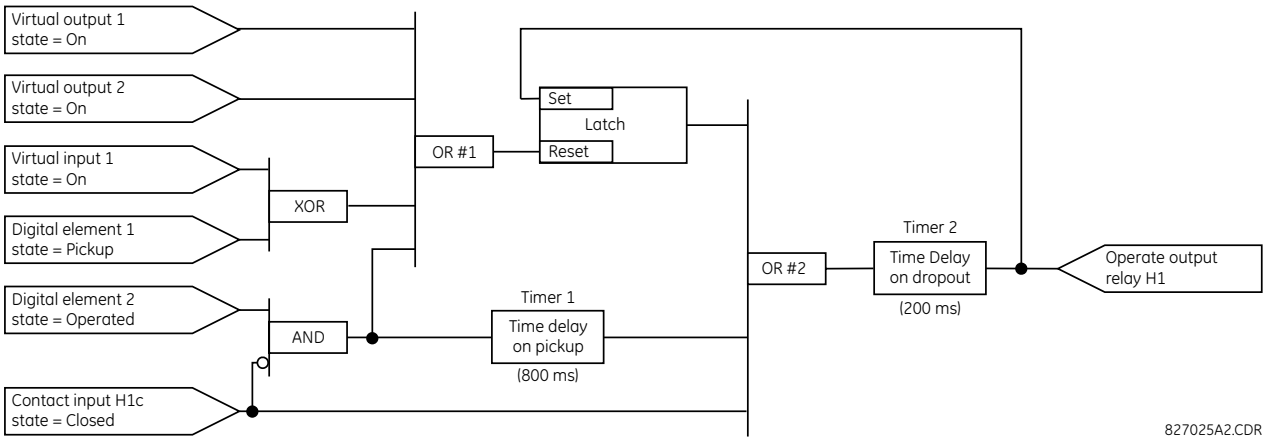
When making changes to FlexLogic entries in the settings, all FlexLogic equations are re-compiled whenever any new FlexLogic entry value is entered, and as a result of the re-compile all latches are reset automatically.

5.6.4 FlexLogic example

This section provides an example of logic implementation for a typical application. The sequence of steps is important to minimize the work to develop the relay settings. Note that the example in the following figure demonstrates the procedure, not to solve a specific application situation.

In the example, 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 be assigned only once.

Figure 5-63: Logic example



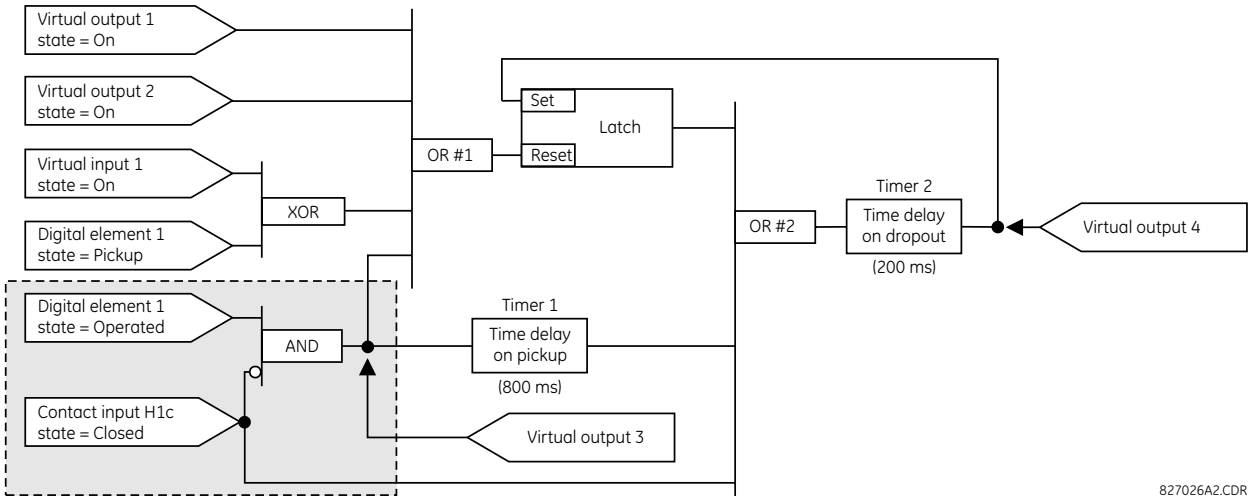
1. Inspect the example logic diagram to determine if the required logic can be implemented with the FlexLogic operators. If this is not possible, the logic must be altered until this condition is satisfied. Once done, count the inputs to each gate to verify that the number of inputs does not exceed the 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, 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 (that is, Virtual Output 3). The final output must also be assigned to a virtual output as virtual output 4, which is programmed in the contact output section to operate relay H1 (that is, contact output H1).

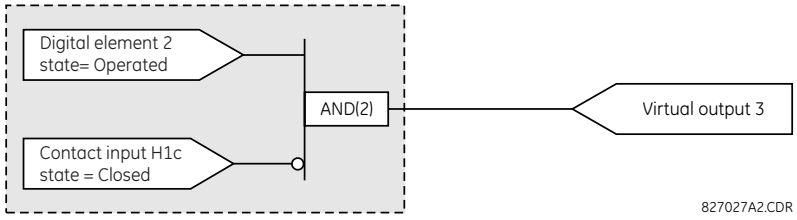
   Therefore, the required logic can be implemented with two FlexLogic equations with outputs of virtual output 3 and virtual output 4, shown as follows.

Figure 5-64: Logic example with virtual outputs



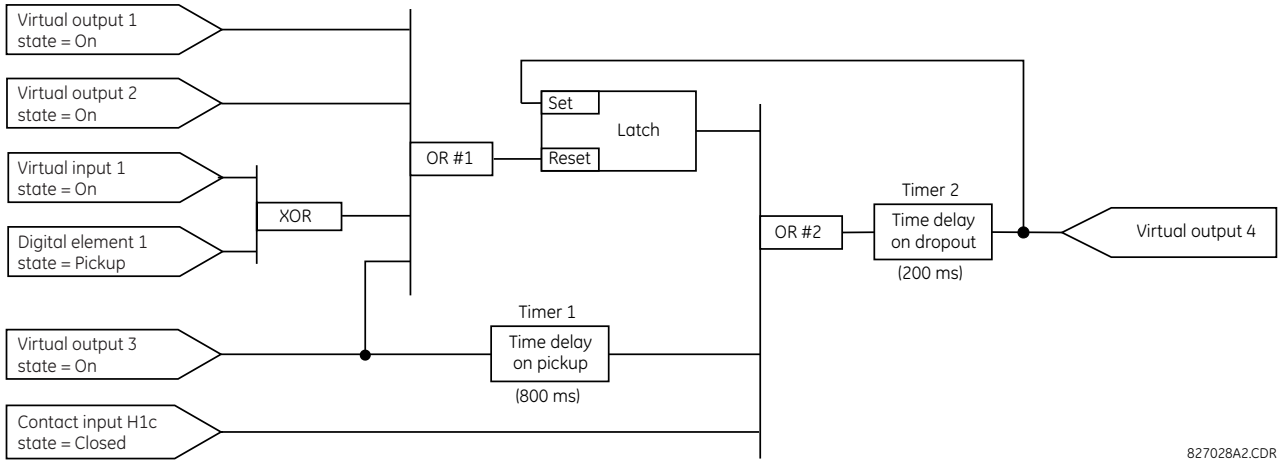
2. Prepare a logic diagram for the equation to produce virtual output 3, as this output is used as an operand in the virtual output 4 equation (create the equation for every output that is used as an operand first, so that when these operands are required they already have been evaluated and assigned to a specific virtual output). The logic for virtual output 3 is shown as follows with the final output assigned.

Figure 5-65: 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, shown as follows.

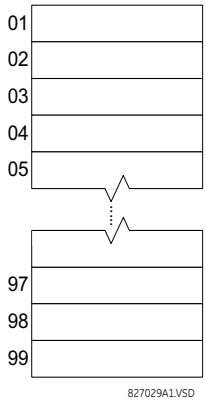
Figure 5-66: Logic for virtual output 4



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 output 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 outputs are 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 shown as follows.

Figure 5-67: FlexLogic worksheet



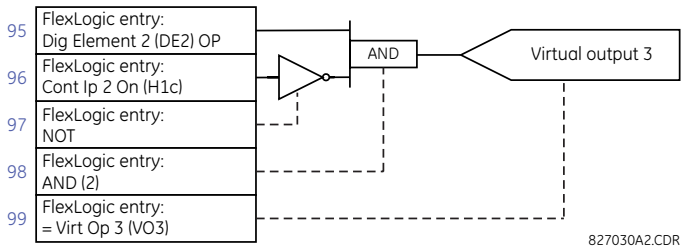
5. Following the procedure outlined, start with parameter 99, as follows:
   - 99: The final output of the equation is virtual output 3, which is created by the operator "= Virt Op n". This parameter is therefore "= Virt Op 3".
   - 98: The gate preceding the output is an AND, which in this case requires 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 operates 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 that 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 forms 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 produces the required logic by converting the set of parameters into a logic diagram. The result of this process is shown in the figure, which is compared to the logic for virtual output 3 diagram as a check.

Figure 5-68: FlexLogic equation for virtual output 3



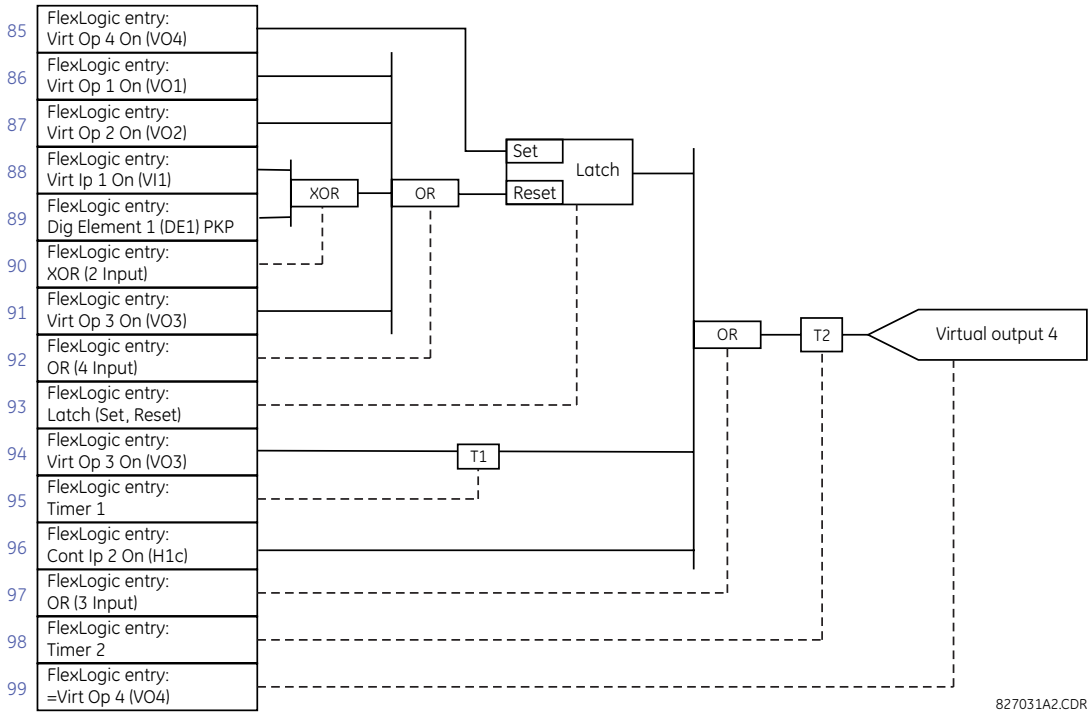
6. Repeating the process described for virtual output 3, select the FlexLogic parameters for Virtual Output 4.
   - 99: The final output of the equation is virtual output 4, which is parameter "= Virt Op 4".
   - 98: The operator preceding the output is timer 2, which is operand "TIMER 2". Note that 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
```

   Now check that the selection of parameters produce the required logic by converting the set of parameters into a logic diagram. The result is shown in the figure, which is compared to the logic for virtual output 4 diagram as a check.

Figure 5-69: 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 are used as inputs to operators are created before needed. In cases where a lot of processing is required to perform logic, this can be difficult to achieve, but in most cases does 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 following order:

```
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 this expression, 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.

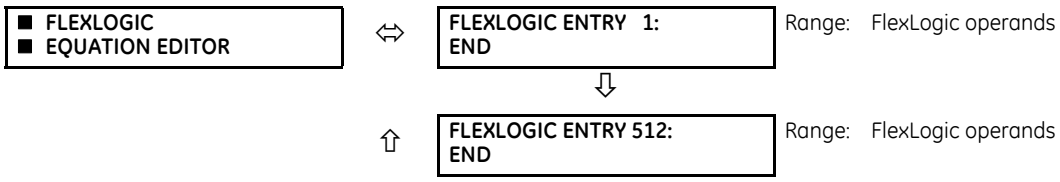
8. Always test the logic after it is loaded into the relay, in the same way as has been used in the past. Testing can be

simplified by placing an "END" operator within the overall set of FlexLogic equations. The equations are 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.

5.6.5 FlexLogic equation editor

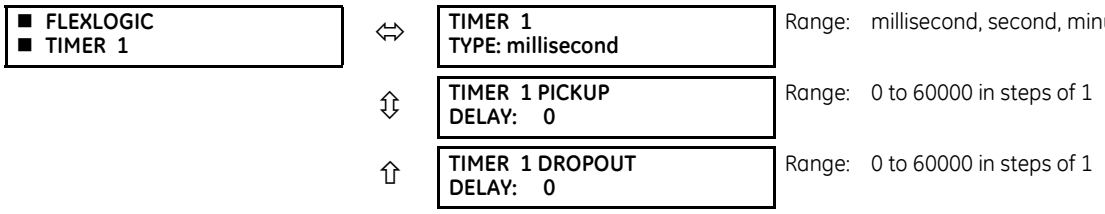
SETTINGS ⇨⇩ FLEXLOGIC ⇨ FLEXLOGIC EQUATION EDITOR



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 is never set to '1'. Press the **+/–** key when editing FlexLogic equations to quickly scan through the major parameter types.

5.6.6 FlexLogic timers

SETTINGS ⇨⇩ FLEXLOGIC ⇨⇩ FLEXLOGIC TIMERS ⇨ FLEXLOGIC TIMER 1(32)



There are 32 identical FlexLogic timers available. These timers are used as operators for FlexLogic equations.

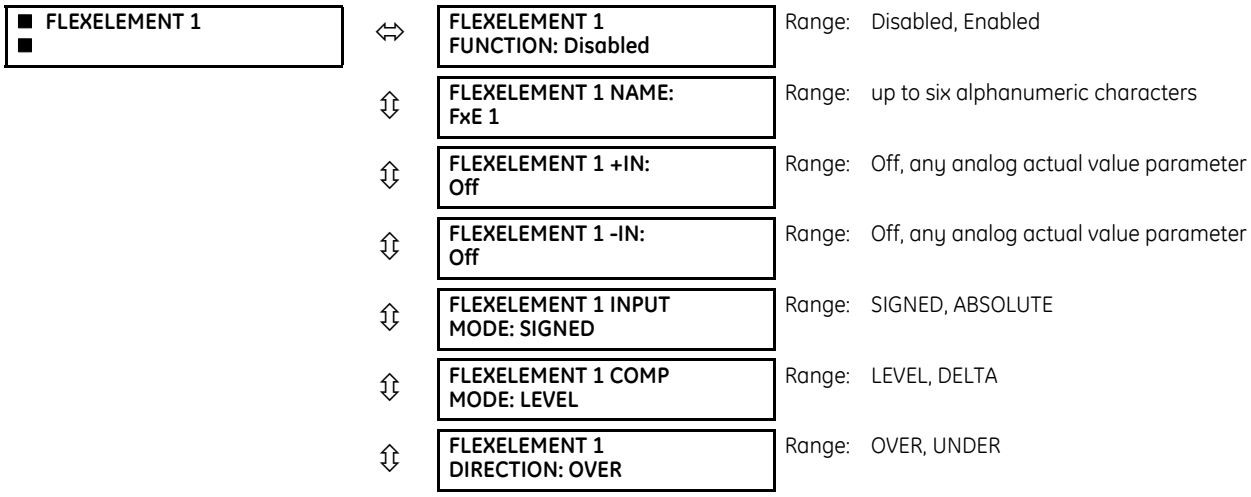
TIMER 1 TYPE — Selects the time measurement unit.

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."

5.6.7 FlexElements

SETTINGS ⇨⇩ FLEXLOGIC ⇨⇩ FLEXELEMENTS ⇨ FLEXELEMENT 1(16)



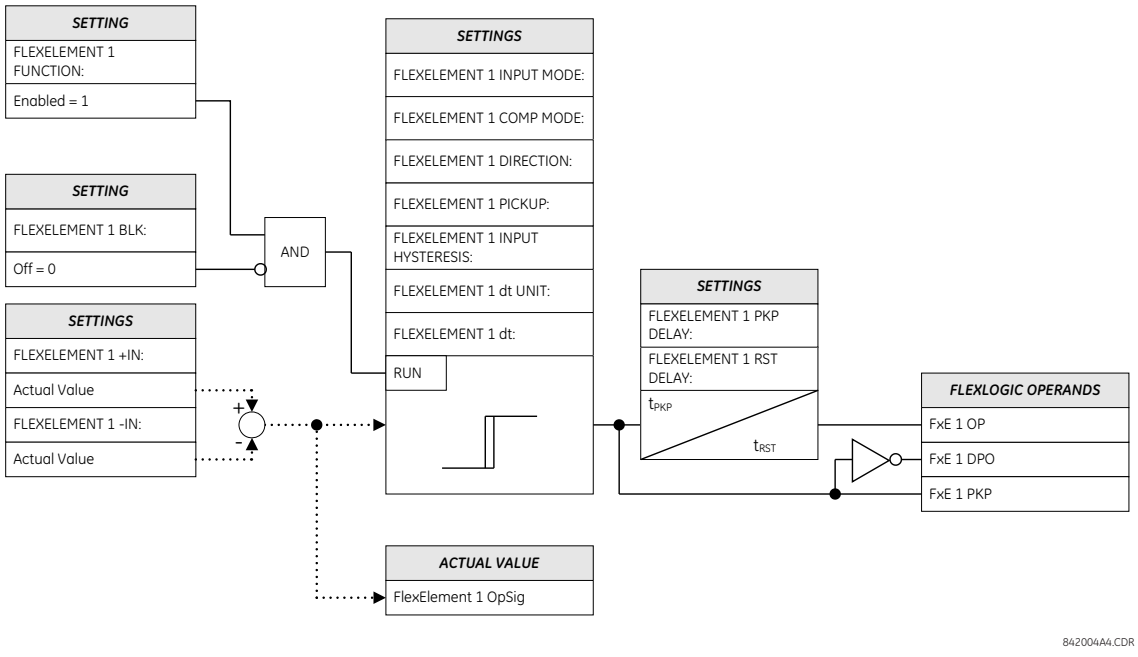
⇳	**FLEXELEMENT 1 PICKUP: 1.000 pu**	Range: –90.000 to 90.000 pu in steps of 0.001
⇳	**FLEXELEMENT 1 HYSTERESIS: 3.0%**	Range: 0.1 to 50.0% in steps of 0.1
⇳	**FLEXELEMENT 1 dt UNIT: Milliseconds**	Range: Milliseconds, Seconds, Minutes
⇳	**FLEXELEMENT 1 dt: 20**	Range: 20 to 86400 in steps of 1
⇳	**FLEXELEMENT 1 PKP DELAY: 0.000 s**	Range: 0.000 to 65.535 s in steps of 0.001
⇳	**FLEXELEMENT 1 RST DELAY: 0.000 s**	Range: 0.000 to 65.535 s in steps of 0.001
⇳	**FLEXELEMENT 1 BLK: Off**	Range: FlexLogic operand
⇳	**FLEXELEMENT 1 TARGET: Self-reset**	Range: Self-reset, Disabled, Latched
⇳	**FLEXELEMENT 1 EVENTS: Disabled**	Range: Disabled, Enabled

A FlexElement is a universal comparator 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 can be treated as a signed number or its absolute value can be used.

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 your choice.

Figure 5-70: FlexElement logic



FLEXELEMENT 1 +IN — This 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 does not assert its output operands.

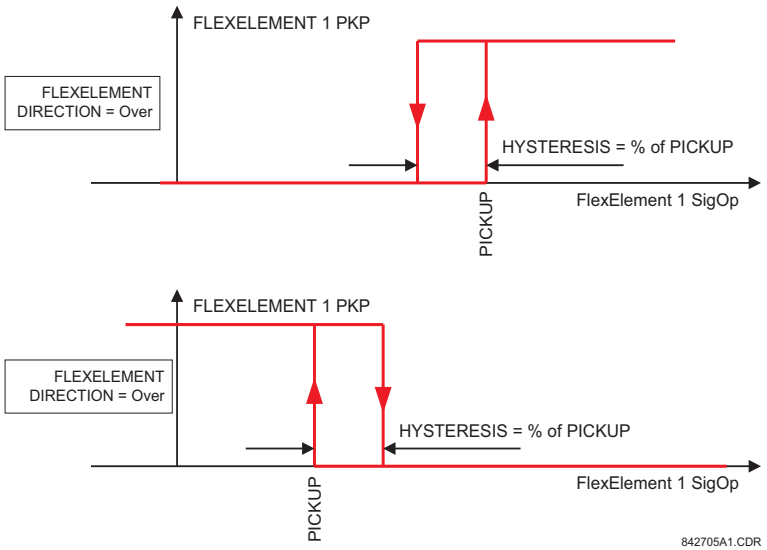
FLEXELEMENT 1 –IN — Specifies the second (inverted) input to the FlexElement. Zero is assumed as the input if this setting is set to "Off." For proper operation of the element, at least one input must be selected. Otherwise, the element does not assert its output operands. This input is used to invert 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 does 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.

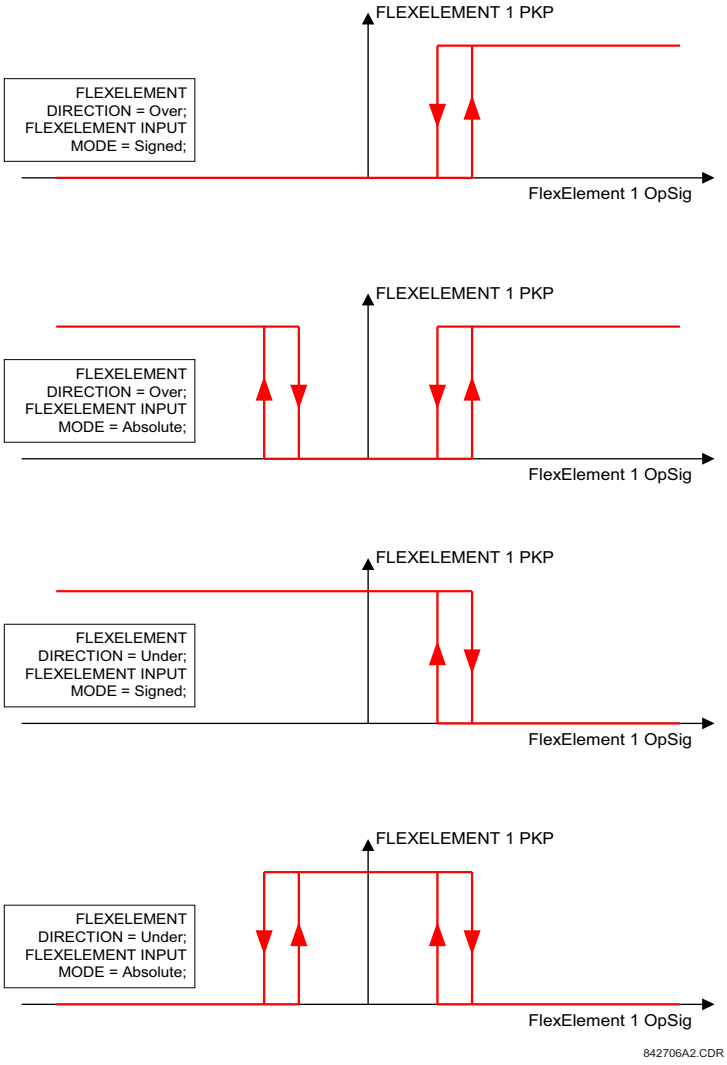
FLEXELEMENT 1 DIRECTION — Enables the relay to respond to either high or low values of the operating signal. The following figure explains the application of the **FLEXELEMENT 1 DIRECTION**, **FLEXELEMENT 1 PICKUP**, and **FLEXELEMENT 1 HYSTERESIS** settings.

Figure 5-71: FlexElement direction, pickup, and hysteresis



In conjunction with the **FLEXELEMENT 1 INPUT MODE** setting, the element can be programmed to provide two extra characteristics, as shown in the following figure.

Figure 5-72: FlexElement input mode setting



FLEXELEMENT 1 PICKUP — This 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.

FLEXELEMENT 1 HYSTERESIS — This setting controls the element dropout. Notice 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

Unit	Description
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
FREQUENCY	f_{BASE} = 1 Hz
PHASE ANGLE	φ_{BASE} = 360 degrees (see the UR angle referencing convention)

Unit	Description
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 THD & HARMONICS	BASE = 1%
SOURCE VOLTAGE	V_{BASE} = maximum nominal primary RMS value of the +IN and –IN inputs

FLEXELEMENT 1 HYSTERESIS — This 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.

FLEXELEMENT 1 dt UNIT — Specifies the time unit for the setting **FLEXELEMENT 1 dt**. This setting is applicable only if **FLEXELEMENT 1 COMP MODE** is set to "Delta."

FLEXELEMENT 1 dt — 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."

FLEXELEMENT 1 PKP DELAY — Specifies the pickup delay of the element.

FLEXELEMENT 1 RST DELAY — Specifies the reset delay of the element.

5.6.8 Non-volatile latches

SETTINGS ⇨⇩ FLEXLOGIC ⇨⇩ NON-VOLATILE LATCHES ⇨ LATCH 1(16)

■ LATCH 1
■

⇔ **LATCH 1 FUNCTION: Disabled** Range: Disabled, Enabled

⇕ **LATCH 1 TYPE: Reset Dominant** Range: Reset Dominant, Set Dominant

⇕ **LATCH 1 SET: Off** Range: FlexLogic operand

⇕ **LATCH 1 RESET: Off** Range: FlexLogic operand

⇕ **LATCH 1 TARGET: Self-reset** Range: Self-reset, Latched, Disabled

⇧ **LATCH 1 EVENTS: Disabled** Range: Disabled, Enabled

The non-volatile latches provide a permanent logical flag that is stored safely and do not reset upon restart after the relay is powered down. Typical applications include sustaining operator commands or permanently blocking relay functions, such as Autorecloser, until a deliberate interface action resets the latch.

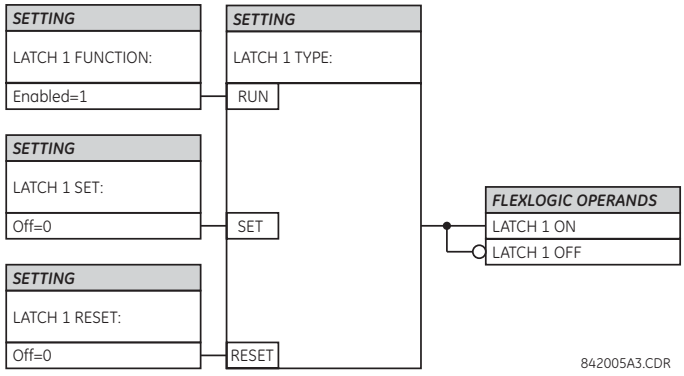
LATCH 1 TYPE — This setting characterizes Latch 1 to be Set- or Reset-dominant.

LATCH 1 SET — If asserted, the specified FlexLogic operands 'sets' Latch 1.

LATCH 1 RESET — If asserted, the specified FlexLogic operand 'resets' Latch 1.

Figure 5-73: Non-volatile latch operation table (N = 1 to 16) and logic

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



5.7 Grouped elements

5.7.1 Overview

Each protection element can be assigned up to six sets of settings with 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 or season of the year). The active setting group can be preset or selected in 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.

5.7.2 Setting group 1

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6)

■ SETTING GROUP 1 ■	⇔	■ PHASE CURRENT ■	See below
	⇳	■ NEUTRAL CURRENT ■	See page 5-171
	⇳	■ GROUND CURRENT ■	See page 5-183
	⇳	■ NEGATIVE SEQUENCE ■ CURRENT	See page 5-185
	⇳	■ BREAKER FAILURE ■	See page 5-191
	⇧	■ VOLTAGE ELEMENTS ■	See page 5-200

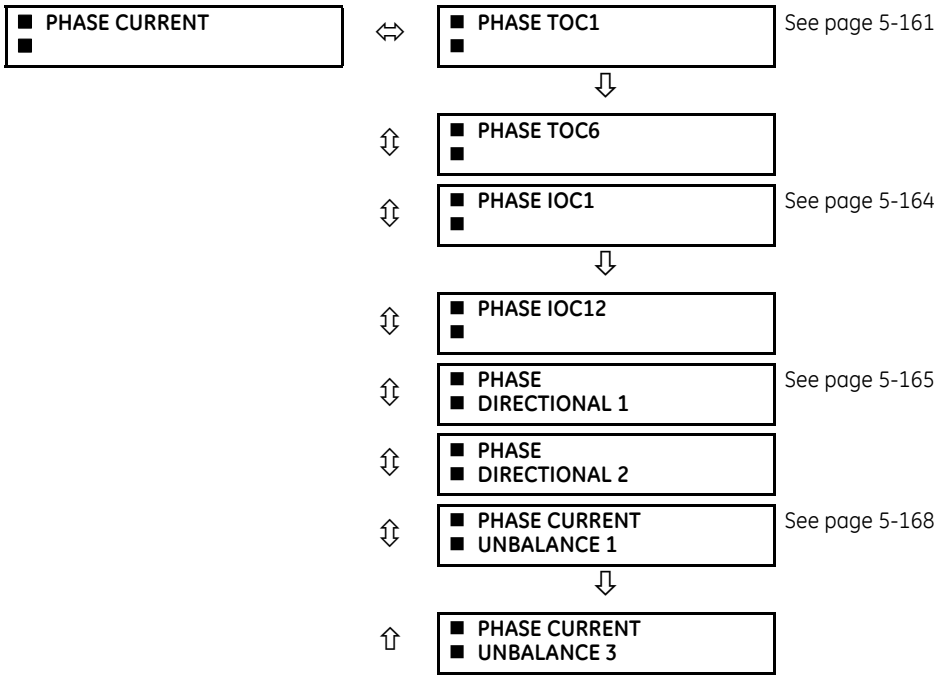
Each of the six setting group menus is identical. Setting group 1 (the default active group) is active automatically when no other group is active.

If the device incorrectly switches to group 1 after power cycling, upgrade the firmware to version 7.31 or later to correct this issue.

5.7.3 Phase current

5.7.3.1 Menu

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ PHASE CURRENT



5.7.3.2 Inverse TOC curve 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 can be used to customize the inverse time curve characteristics. The definite time curve is also an option that can 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 operates. 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 curves. The IEEE curves are derived from the operate and reset time equations.

$$T = TDM \times \left[\frac{A}{\left(\frac{I}{I_{pickup}} \right)^{p} - 1} + B \right], \quad T_{RESET} = TDM \times \left[\frac{t_r}{1 - \left(\frac{I}{I_{pickup}} \right)^{2}} \right] \qquad \text{Eq. 5-8}$$

where

T = operate time (in seconds)
TDM = Multiplier setting
I = input current
I_{pickup} = Pickup Current setting
A, B, p = constants defined in the table
T_{RESET} = reset time in seconds (assuming energy capacity is 100% and RESET is "Timed")
t_r = characteristic constant defined in the table

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
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

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	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

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 IEC curves are derived by the operate and reset time equations.

$$T = TDM \times \left[\frac{K}{(I/I_{pickup})^{E} - 1}\right], \quad T_{RESET} = TDM \times \left[\frac{t_r}{1 - (I/I_{pickup})^{2}}\right] \qquad \textbf{Eq. 5-9}$$

where

T = operate time (in seconds)
TDM = Multiplier setting
I = input current
I_{pickup} = Pickup Current setting
K, E = constants defined in the table
t_r = characteristic constant defined in the table
T_{RESET} = reset time in seconds (assuming energy capacity is 100% and **RESET** is "Timed")

5

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
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

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 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 Inverse										
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

IAC curves

The curves for the General Electric type IAC relay family are derived from the formulae:

$$T = TDM \times \left(A + \frac{B}{(I/I_{pkp}) - C} + \frac{D}{((I/I_{pkp}) - C)^2} + \frac{E}{((I/I_{pkp}) - C)^3} \right) \quad , \quad T_{RESET} = TDM \times \left[\frac{t_r}{1 - (I/I_{pkp})^2} \right] \qquad \text{Eq. 5-10}$$

where

T = operate time (in seconds)
TDM = Multiplier setting
I = Input current
I_{pkp} = Pickup Current setting
A to E = constants defined in the table
t_r = characteristic constant defined in the table
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: GE type 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
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

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
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

I^2t curves

The I^2t curves are derived as follows:

$$T = TDM \times \left[\frac{100}{\left(\frac{I}{I_{pickup}} \right)^2} \right], \quad T_{RESET} = TDM \times \left[\frac{100}{\left(\frac{I}{I_{pickup}} \right)^{-2}} \right] \qquad \text{Eq. 5-11}$$

where

T = Operate time (in seconds)
TDM = Multiplier setting
I = Input current
I_{pickup} = Pickup Current setting
T_{RESET} = reset time in seconds (assuming energy capacity is 100% and RESET is "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

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	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
600.00	26666.7	15000.0	6666.7	3750.0	2400.0	1666.7	1224.5	937.50	740.74	600.00

FlexCurves

FlexCurves are described in the FlexCurves section later in this chapter. The curve shapes for the FlexCurves are derived from the formulae:

$$T = TDM \times \left[\text{FlexCurve Time at } \left(\frac{I}{I_{pickup}}\right)\right] \text{ when } \left(\frac{I}{I_{pickup}}\right) \geq 1.00 \quad \textbf{Eq. 5-12}$$

$$T_{RESET} = TDM \times \left[\text{FlexCurve Time at } \left(\frac{I}{I_{pickup}}\right)\right] \text{ when } \left(\frac{I}{I_{pickup}}\right) \leq 0.98 \quad \textbf{Eq. 5-13}$$

where

T = operate time (in seconds)
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. The definite time curve shapes are defined as follows:

$$T = TDM \text{ in seconds, when } I > I_{pickup} \quad \textbf{Eq. 5-14}$$

$$T_{RESET} = TDM \text{ in seconds} \quad \textbf{Eq. 5-15}$$

where

T = Operate Time (in seconds)
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 C70 uses the FlexCurve feature to facilitate programming of 41 recloser curves. See the FlexCurves settings section earlier in this chapter for details.

5.7.3.3 Phase time overcurrent (ANSI 51P, IEC PTOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨⇩ SETTING GROUP 1(6) ⇨ PHASE CURRENT ⇨ PHASE TOC1(6)

■ PHASE TOC 1
■

⇔ **PHASE TOC1 FUNCTION: Disabled** — Range: Disabled, Enabled

⇳ **PHASE TOC1 SIGNAL SOURCE: SRC 1** — Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6

⇳ **PHASE TOC1 INPUT: Phasor** — Range: Phasor, RMS

⇳	**PHASE TOC1 PICKUP: 1.000 pu**	Range: 0.000 to 30.000 pu in steps of 0.001
⇳	**PHASE TOC1 CURVE: IEEE Mod Inv**	Range: see Overcurrent Curve Types table
⇳	**PHASE TOC1 TD MULTIPLIER: 1.00**	Range: 0.00 to 600.00 in steps of 0.01
⇳	**PHASE TOC1 RESET: Instantaneous**	Range: Instantaneous, Timed
⇳	**PHASE TOC1 VOLTAGE RESTRAINT: Disabled**	Range: Disabled, Enabled
⇳	**PHASE TOC1 BLOCK A: Off**	Range: FlexLogic operand
⇳	**PHASE TOC1 BLOCK B: Off**	Range: FlexLogic operand
⇳	**PHASE TOC1 BLOCK C: Off**	Range: FlexLogic operand
⇳	**PHASE TOC1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**PHASE TOC1 EVENTS: Disabled**	Range: Disabled, Enabled

The phase time overcurrent element can provide a specified time-delay operating characteristic versus the applied current or be used as a simple definite time element. The phase current input quantities can 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 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 clears 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); 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.

The Phase TOC element can be used as a basic thermal overload protection element, using I^2t curves. The thermal time characteristic with I^2t is based on the current squared, integrated over time during fault. The PHASE TOC 1 I2t RST operand is asserted indicating that protected apparatus is cooled down and can be safely put back into service.

Time to assert this operand after PHASE TOC 1 operated with I^2t curves is estimated using following formula.

$$t = \tau \times \ln\left(\left(\frac{I_{PKP}}{I_F}\right)^2\right) \qquad \textbf{Eq. 5-16}$$

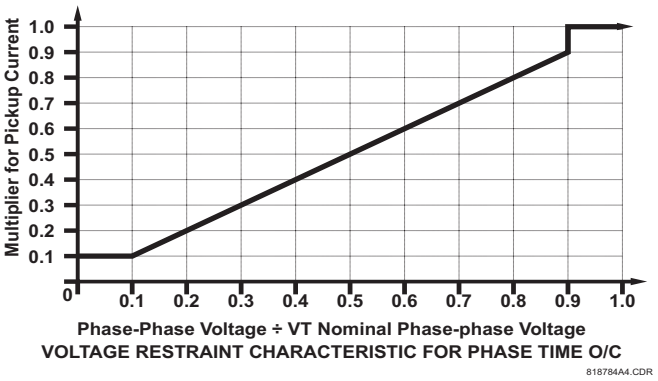
where

τ is a time constant fixed to a 10 minute value

I_{PKP} is a pickup setting of TOC

I_F is a maximum phase fault current

Figure 5-74: Phase time overcurrent voltage restraint characteristic



FUNCTION — This setting enables and disables the phase time overcurrent protection element.

SIGNAL SOURCE — Selects the signal source for the phase time overcurrent protection element.

INPUT — Selects how phase current input quantities are interpreted by the C70. Inputs can be selected as fundamental phasor magnitudes or total waveform RMS magnitudes as required by the application.

PICKUP — Specifies the phase time overcurrent pickup level in per-unit values.

CURVE — Selects the time inverse overcurrent curve style.

TD MULTIPLIER — Specifies a multiple of the base curve shape specified by the **CURVE** setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

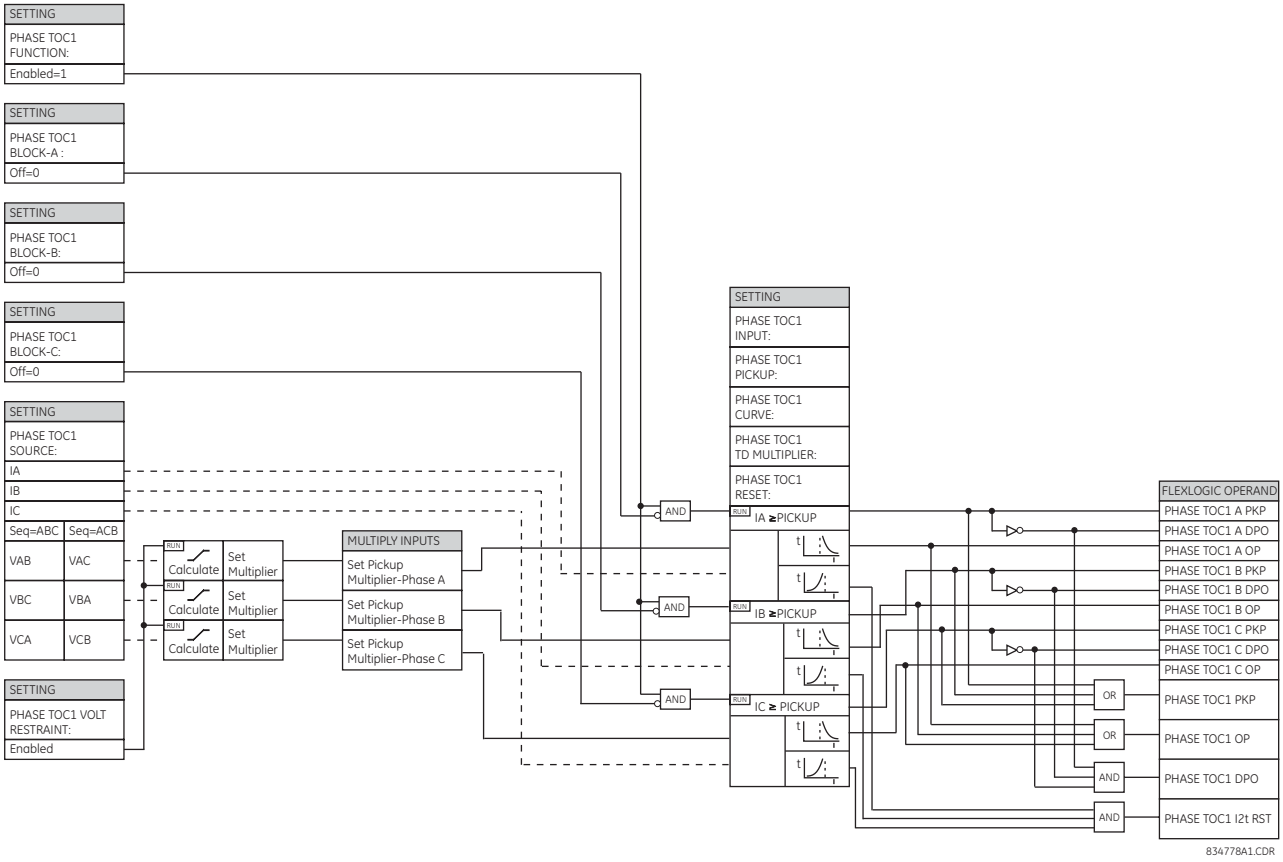
RESET — The "Instantaneous" reset method is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The "Timed" reset method can be used where the relay must coordinate with electromechanical relays.

VOLTAGE RESTRAINT — Enables and disables the phase time overcurrent voltage restraint feature.

BLOCK A — Assertion of the operand assigned to this setting blocks phase A of the phase time overcurrent element.

EVENTS — Enables and disables the logging of phase time overcurrent events in the sequence of events recorder.

Figure 5-75: Phase time overcurrent 1 logic



5.7.3.4 Phase instantaneous overcurrent (ANSI 50P, IEC PIOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ PHASE CURRENT ⇨ PHASE IOC 1(12)

■ PHASE IOC 1 ■	⇔	**PHASE IOC1 FUNCTION: Disabled** — Range: Disabled, Enabled
	⇕	**PHASE IOC1 SIGNAL SOURCE: SRC 1** — Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇕	**PHASE IOC1 PICKUP: 1.000 pu** — Range: 0.000 to 30.000 pu in steps of 0.001
	⇕	**PHASE IOC1 PICKUP DELAY: 0.00 s** — Range: 0.00 to 600.00 s in steps of 0.01
	⇕	**PHASE IOC1 RESET DELAY: 0.00 s** — Range: 0.00 to 600.00 s in steps of 0.01
	⇕	**PHASE IOC1 BLOCK A: Off** — Range: FlexLogic operand
	⇩	
	⇕	**PHASE IOC1 BLOCK C: Off** — Range: FlexLogic operand
	⇕	**PHASE IOC1 TARGET: Self-reset** — Range: Self-reset, Latched, Disabled
	⇧	**PHASE IOC1 EVENTS: Disabled** — Range: Disabled, Enabled

The phase instantaneous overcurrent element can be used as an instantaneous element with no intentional delay or as a definite time element. The input current is the fundamental phasor magnitude.

FUNCTION — This setting enables and disables the phase instantaneous overcurrent protection element.

SOURCE — Selects the signal source for the phase instantaneous overcurrent protection element.

PICKUP — Specifies the phase instantaneous overcurrent pickup level in per-unit values.

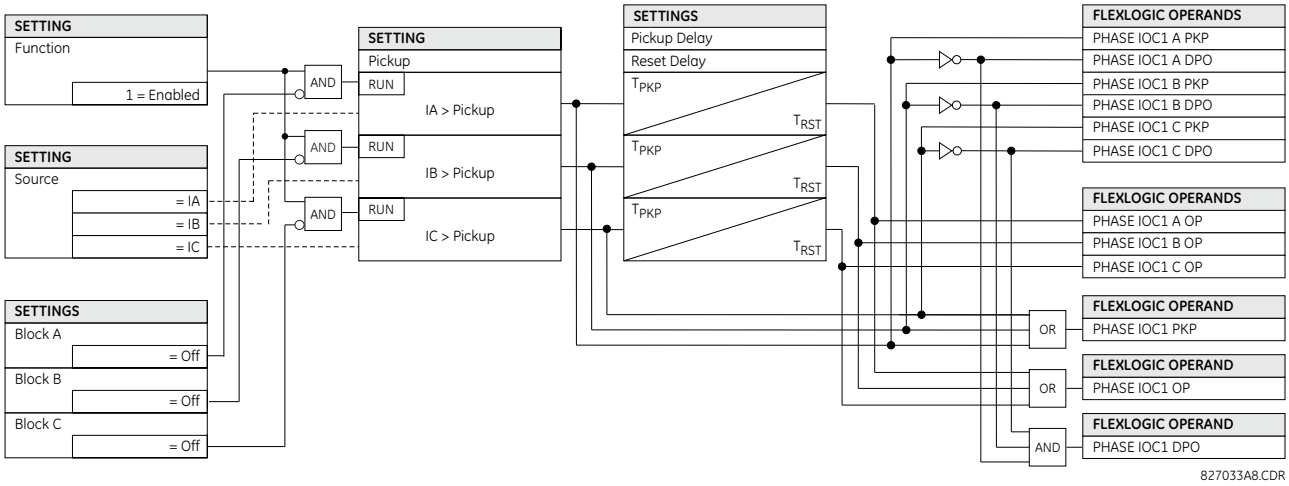
DELAY —Delays the assertion of the PHASE IOC OP operands. It is used to achieve timing coordination with other elements and relays.

RESET DELAY — Specifies a delay for the reset of the phase instantaneous overcurrent element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. This setting is used to ensure that the relay output contacts are closed long enough to ensure reception by downstream equipment.

BLOCK A — Assertion of the operand assigned to this setting block's phase A of the phase instantaneous overcurrent element.

EVENTS — Enables and disables the logging of phase instantaneous overcurrent events in the sequence of events recorder.

Figure 5-76: Phase instantaneous overcurrent 1 logic



5.7.3.5 Phase directional overcurrent (ANSI 67P, IEC PDOC/PTOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ PHASE CURRENT ⇨ PHASE DIRECTIONAL 1(2)

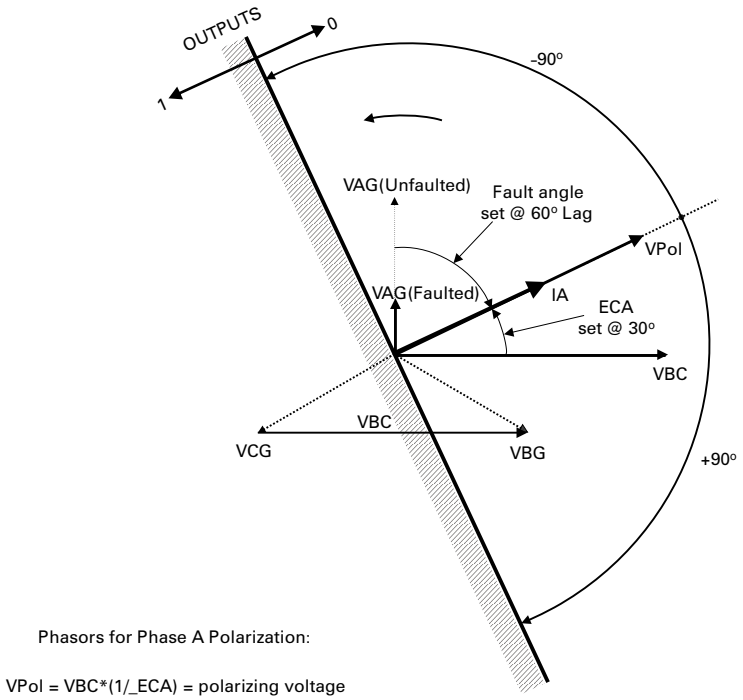
■ PHASE ■ DIRECTIONAL 1	⇔	**PHASE DIR 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇩	**PHASE DIR 1 SIGNAL SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇩	**PHASE DIR 1 BLOCK: Off**	Range: FlexLogic operand
	⇩	**PHASE DIR 1 ECA: 30°**	Range: 0 to 359° in steps of 1
	⇩	**PHASE DIR POL V1 THRESHOLD: 0.700 pu**	Range: 0.000 to 3.000 pu in steps of 0.001
	⇩	**PHASE DIR 1 BLOCK WHEN V MEM EXP: No**	Range: No, Yes
	⇩	**PHASE DIR 1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
	⇩	**PHASE DIR 1 EVENTS: Disabled**	Range: Disabled, Enabled

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 5-77: 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 table shows the operating and polarizing signals used for phase directional control.

Table 5-30: Operating and polarizing signals

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)

Phase	Operating signal	Polarizing signal V_{pol}	
		ABC phase sequence	ACB phase sequence
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 logic "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 blocks 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 is permitted to resume when the polarizing voltage becomes greater than the polarizing voltage threshold.

Settings

PHASE DIR 1 FUNCTION — This setting enables and disables the phase directional overcurrent protection element.

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 BLOCK — Assertion of the operand assigned to this setting blocks operation of the phase directional overcurrent element.

PHASE DIR 1 ECA — This setting specifies the element characteristic angle, that is, 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. Program the phase directional overcurrent element using this 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.

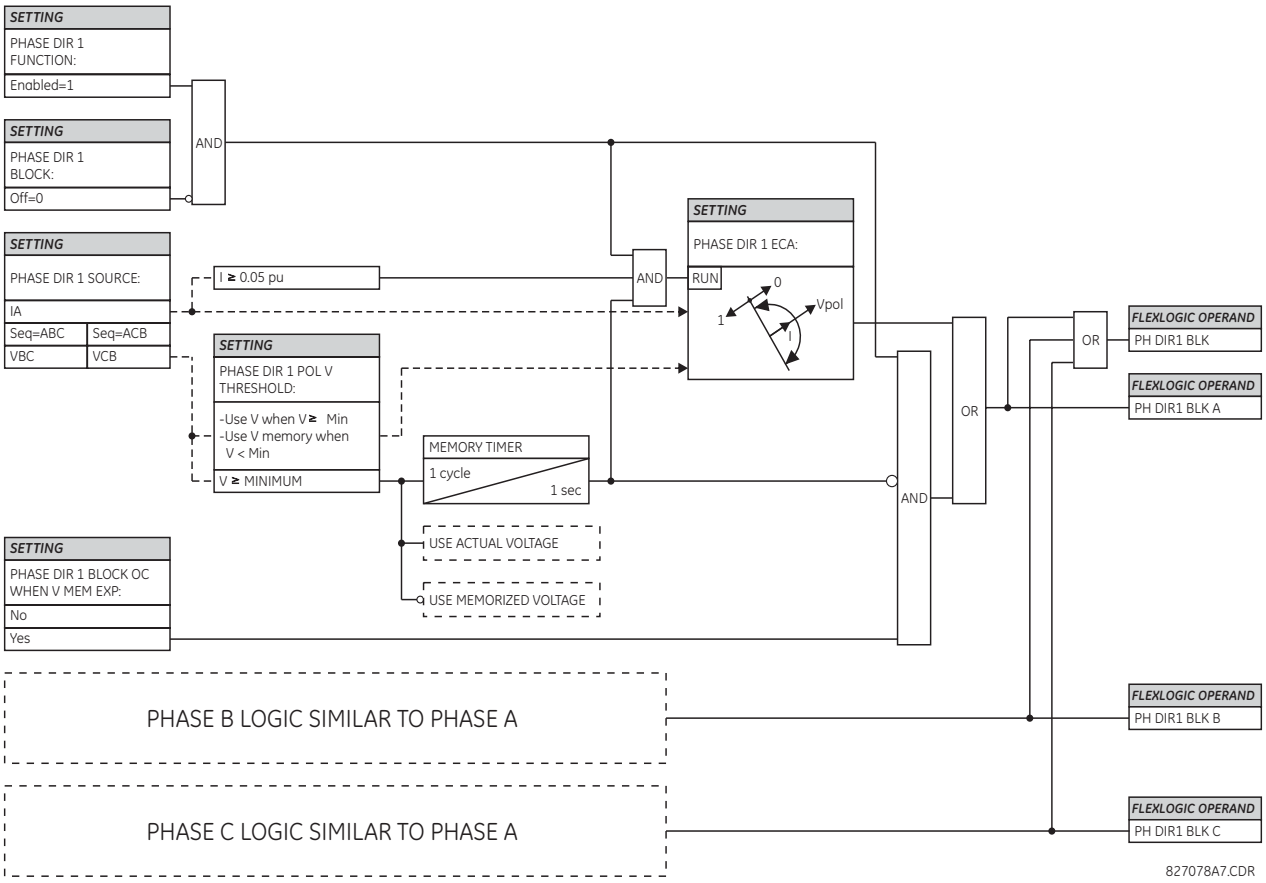
PHASE DIR 1 BLOCK WHEN V MEM EXP — This setting is used to select the required operation upon expiration of voltage memory. When set to "Yes," the directional element blocks the operation of any phase overcurrent element under directional control, when voltage memory expires. When set to "No," the directional element allows tripping of phase overcurrent elements under directional control.

PHASE DIR 1 EVENTS — This setting enables and disables the logging of phase directional overcurrent events in the sequence of events recorder.

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, 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 concern, a longer delay—in the order of 20 ms—is needed.

Figure 5-78: Phase directional logic



5.7.3.6 Phase current unbalance (ANSI 60P, IEC PVCB/PTOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ PHASE CURRENT ⇨⇩ PHASE CURRENT UNBALANCE 1(3)

■ PHASE CURRENT ■ UNBALANCE 1	⇔	**CUR UNBALCE 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇕	**CUR UNBALCE 1 DIF SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇕	**CUR UNBALCE 1 BANK SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇕	**CUR UNBALCE 1 INHNT FACTOR A: 0.0000**	Range: –0.1000 to 0.1000 in steps of 0.0001
		⇩	

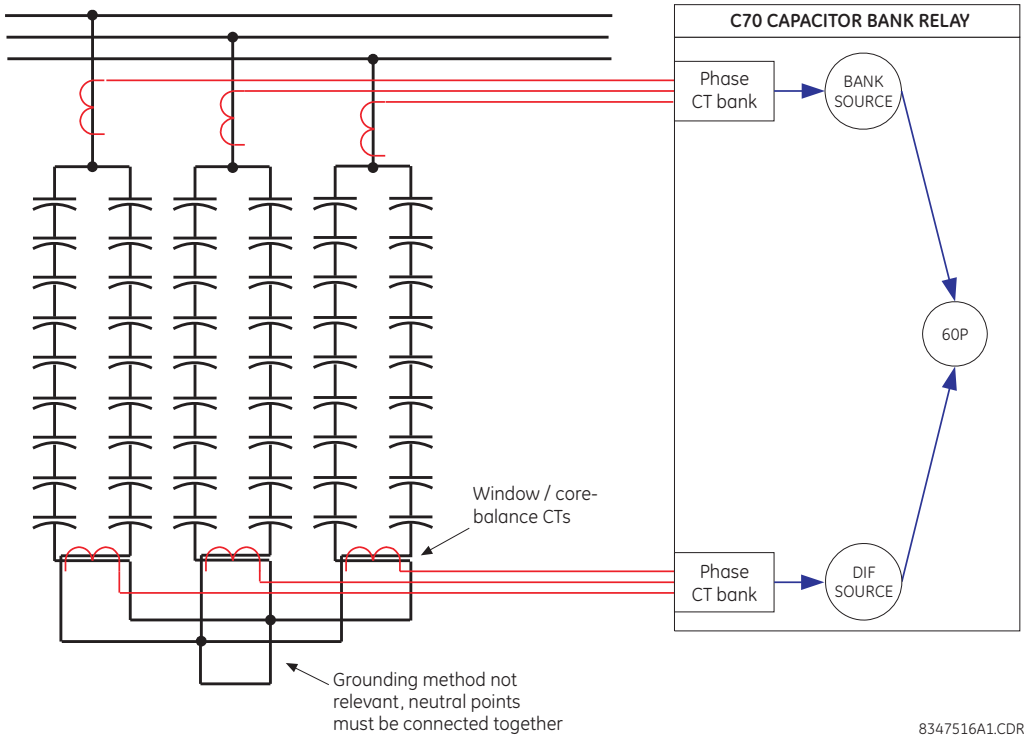
⇳	**CUR UNBALCE 1 INHNT FACTOR C: 0.0000**	Range: –0.1000 to 0.1000 in steps of 0.0001
⇳	**CUR UNBALCE 1 STG 1A PICKUP: 0.020 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 2A PICKUP: 0.030 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 3A PICKUP: 0.040 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 4A PICKUP: 0.050 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 1B PICKUP: 0.020 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 2B PICKUP: 0.030 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 3B PICKUP: 0.040 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 4B PICKUP: 0.050 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 1C PICKUP: 0.020 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 2C PICKUP: 0.030 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 3C PICKUP: 0.040 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 4C PICKUP: 0.050 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**CUR UNBALCE 1 STG 1 PKP DELAY: 30.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**CUR UNBALCE 1 STG 2 PKP DELAY: 10.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**CUR UNBALCE 1 STG 3 PKP DELAY: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**CUR UNBALCE 1 STG 4 PKP DELAY: 0.20 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**CUR UNBALCE 1 DPO DELAY: 0.25 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**CUR UNBL 1 BLK STG1: Off**	Range: FlexLogic operand
	⇩	
⇳	**CUR UNBL 1 BLK STG4: Off**	Range: FlexLogic operand
⇳	**CUR UNBALCE 1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**CUR UNBALCE 1 EVENTS: Disabled**	Range: Disabled, Enabled

Up to three identical phase current unbalance elements, one per each CT/VT module configured in hardware, are provided.

The element responds to a differential current signal measured via window-type CTs as a vectorial current difference between two parallel banks. With the two capacitors in the same phase identical, the said differential current is zero. Small differences between the capacitors of a given phase result in a small circulating current. Subtracting an adequate portion of the total bank current in a given phase compensates for this inherent unbalance current.

The relay allows manual setting of the inherent unbalance factors, or automatically via the **COMMANDS** menu. For more information, see the Application of Settings chapter.

Figure 5-79: Phase current unbalance basic connections



The following settings are available for all three elements.

CUR UNBALCE 1 DIF SOURCE — Indicate signal source that signifies the differential currents between the two parallel banks. In order to improve accuracy, a relatively low-ratio window CT can be used for instrumentation. CT primary and secondary ratings are entered under a separate menu. Directionality of wiring these current signals is not important for proper functioning of the feature as long as the sign of the factor compensating for the inherent unbalance is appropriate. For ease of analysis and consistency of relay records, wire all three currents with the same polarity.

CUR UNBALCE 1 BANK SOURCE — Indicate signal source that signifies the total current of the two parallel banks. Either the main CTs are placed in a way ensuring measurement of the total current, or the currents of individual banks are summed externally to the relay by paralleling the main CTs, or summed up internally to the relay using the configuration mechanism of sources. The total bank current is used for compensation for the inherent bank unbalance. CT primary and secondary ratings are entered under a separate menu. Directionality of wiring these current signals is not important for proper functioning of the feature as long as the sign of the factor compensating for the inherent unbalance is appropriate. For ease of analysis and consistency of relay records, wire all three currents with the same polarity. If any of the compensating factors is non-zero, the BANK SOURCE must have phase CT current configured for this function to run.

CUR UNBALCE 1 INHNT FACTOR A(B,C) — This setting specifies the compensating factor for the inherent unbalance between the two banks. Normally, the compensating factors are small numbers being a ratio of the difference between the two impedances, and the sum of the two impedances. For example, with 1% difference between the impedances, the factor is (1-0.99)/(1+0.99) = 0.005. The sign of the compensating factor depends on the polarity of wiring the differential signals, and on which of the two banks has the lower impedance. Quality of balancing the bank with a given value of this setting can be viewed under the **ACTUAL VALUES** menu. An auto-setting procedure is available under the **COMMANDS** menu to calculate the compensating factors automatically. Setting the compensating factors to zero effectively disables the compensation and turns this feature into a plain overcurrent element responding to the differential (split phase) currents.

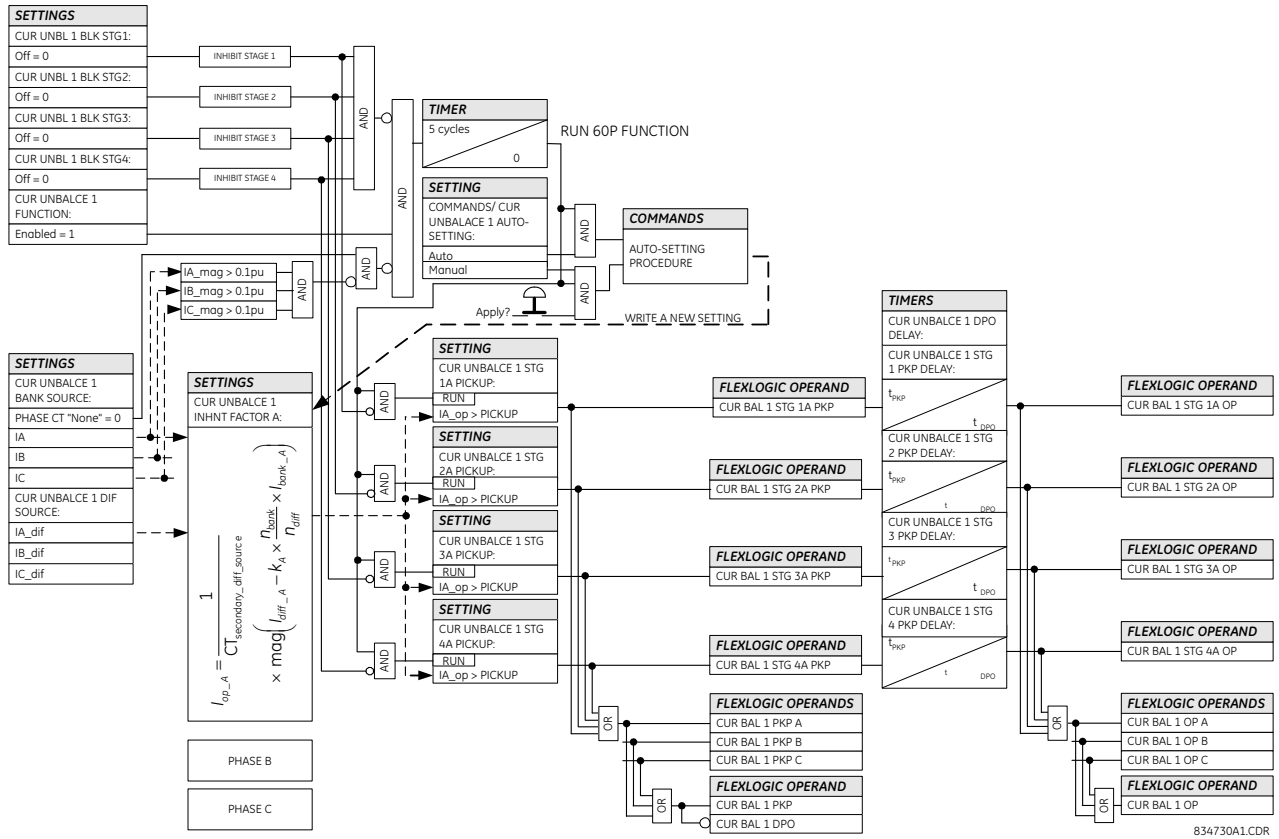
CUR UNBALCE 1 STG 1A PICKUP to **CUR UNBALCE 1 STG 4C PICKUP** — These settings specify pickup thresholds for stages 1 through 4 in phases A through C in per-units (pu) of the nominal current of the differential source. A value of 1 pu is the nominal secondary current, or the nominal primary current, respectively, as configured under the differential source of this function.

CUR UNBALCE 1 STG 1 PKP DELAY to **CUR UNBALCE 1 STG 4 PKP DELAY** — This setting specifies the pickup time delay, individually per each stage of alarming/tripping. Each of the 12 comparators (four stages in three phases) uses an individual timer, but settings for these timers are controlled individually per each stage, not per phase. The timers use a common drop out time delay specified by the next setting.

CUR UNBALCE 1 DPO DELAY — This setting controls a drop-out delay for the operate FlexLogic operands. Individual stages apply individually configurable pickup delays, but use this common drop-out delay.

CUR UNBL 1 BLK STG1 to **CUR UNBL 1 BLK STG4** — These settings are used to block the function on a per-stage basis when required. At minimum this function is blocked when the two banks are not paralleled. When unblocked, the function becomes operational after five cycles of intentional delay. High-set instantaneous protection on energization can be provided by a separate instantaneous overcurrent function.

Figure 5-80: Phase current unbalance logic



5.7.4 Neutral current

5.7.4.1 Menu

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEUTRAL CURRENT

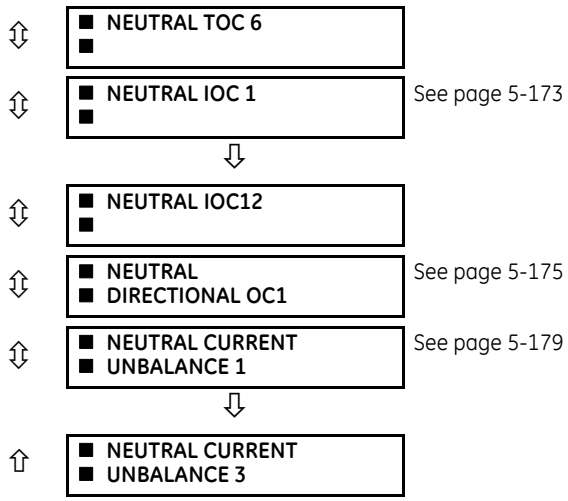
■ **NEUTRAL CURRENT**
■

⇔

■ **NEUTRAL TOC 1**
■

See below

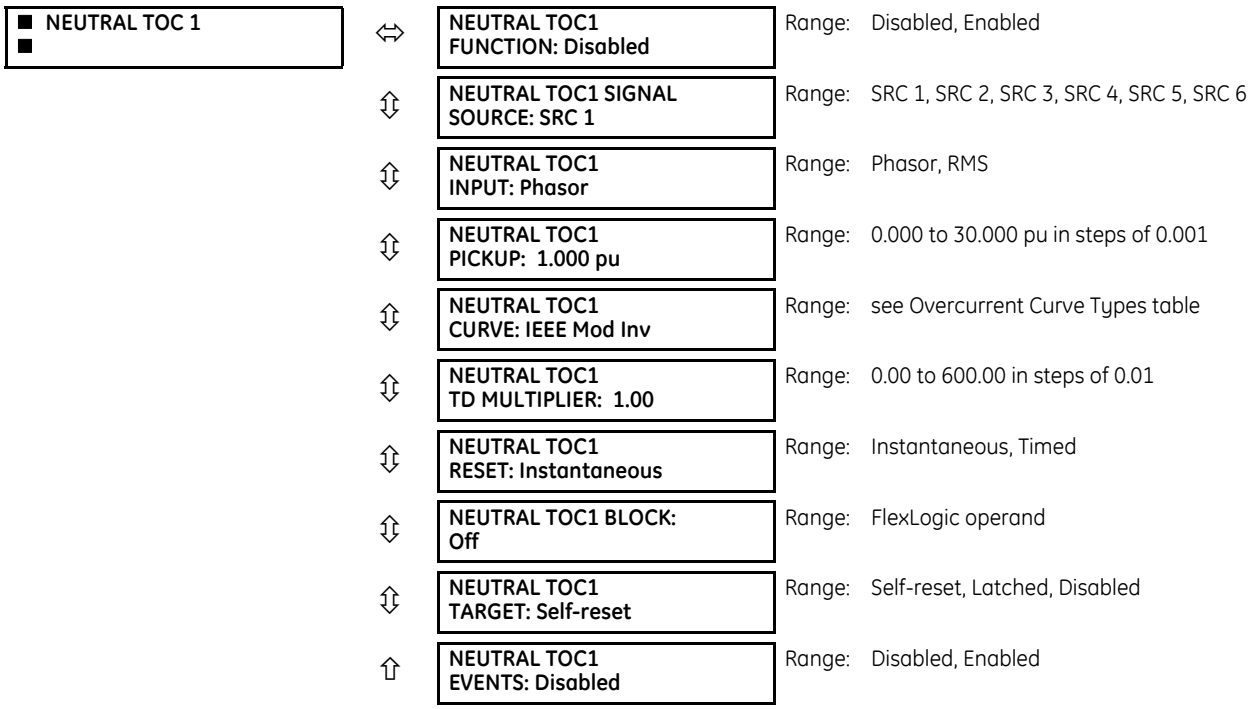
⇩



The C70 contains protection elements for neutral time overcurrent (ANSI device 51G), neutral instantaneous overcurrent (ANSI device 50G), and neutral current unbalance (ANSI device 60N). A maximum of six ground time overcurrent and 12 ground instantaneous overcurrent elements are available, dependent on the CT/VT modules ordered with the relay. Three neutral current unbalance elements are available.

5.7.4.2 Neutral time overcurrent (ANSI 51N, IEC PTOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEUTRAL CURRENT ⇨ NEUTRAL TOC1(6)



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 can 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 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 clears immediately.

NEUTRAL TOC1 FUNCTION — This setting enables and disables the neutral time overcurrent protection element.

NEUTRAL TOC1 SIGNAL SOURCE — This setting selects the signal source for the neutral time overcurrent protection element.

NEUTRAL TOC1 INPUT — This setting selects how neutral current input quantities are interpreted by the C70. Inputs can be selected as fundamental phasor magnitudes or total waveform RMS magnitudes as required by the application.

NEUTRAL TOC1 PICKUP — This setting specifies the neutral time overcurrent pickup level in per-unit values.

NEUTRAL TOC1 CURVE — This setting selects the inverse time overcurrent curve style.

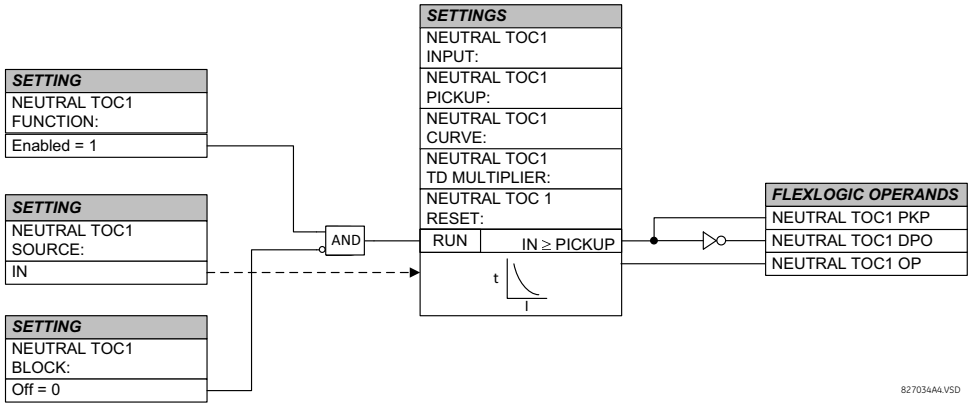
NEUTRAL TOC1 TD MULTIPLIER — This setting specifies a multiple of the base curve shape specified by the **CURVE** setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

NEUTRAL TOC1 RESET — The "Instantaneous" reset method 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" reset method can be used where the relay must coordinate with electromechanical relays.

NEUTRAL TOC1 BLOCK — Assertion of the operand assigned to this setting blocks operation of the neutral time overcurrent element.

NEUTRAL TOC1 EVENTS — This setting enables and disables the logging of neutral time overcurrent events in the sequence of events recorder.

Figure 5-81: Neutral time overcurrent 1 logic



5.7.4.3 Neutral instantaneous overcurrent (ANSI 50N, IEC PIOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL IOC1(12)

■ NEUTRAL IOC 1 ■	⇔	**NEUTRAL IOC1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇩	**NEUTRAL IOC1 SIGNAL SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇩	**NEUTRAL IOC1 PICKUP: 1.000 pu**	Range: 0.000 to 30.000 pu in steps of 0.001
	⇩	**NEUTRAL IOC1 PICKUP DELAY: 0.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
	⇩	**NEUTRAL IOC1 RESET DELAY: 0.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
	⇩	**NEUTRAL IOC1 BLOCK: Off**	Range: FlexLogic operand

⇳	**NEUTRAL IOC1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**NEUTRAL IOC1 EVENTS: Disabled**	Range: Disabled, Enabled

The neutral instantaneous overcurrent element can 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:

$$I_{op} = 3 \times (|I\_0| - K \times |I\_1|) \quad \text{where } K = 1/16 \qquad \textbf{Eq. 5-17}$$

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 $I_{op} = 3 \times I_{injected}$

NEUTRAL IOC1 FUNCTION — This setting enables and disables the neutral instantaneous overcurrent protection element.

NEUTRAL IOC1 SIGNAL SOURCE — This setting selects the signal source for the neutral instantaneous overcurrent protection element.

NEUTRAL IOC1 PICKUP — This setting specifies the neutral instantaneous overcurrent pickup level in per-unit values.

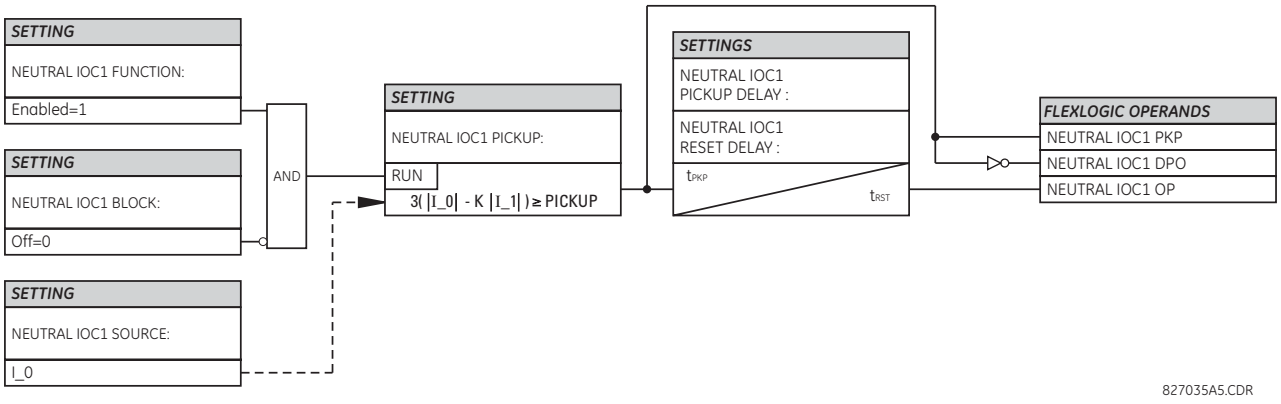
NEUTRAL IOC1 PICKUP DELAY — This setting delays the assertion of the NEUTRAL IOC OP operands. It is used to achieve timing coordination with other elements and relays.

NEUTRAL IOC1 RESET DELAY — This setting specifies a delay for the reset of the neutral instantaneous overcurrent element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. This setting is used to ensure that the relay output contacts are closed long enough to ensure reception by downstream equipment.

NEUTRAL IOC1 BLOCK — Assertion of the operand assigned to this setting blocks operation of the neutral instantaneous overcurrent element.

NEUTRAL IOC1 EVENTS — This setting enables and disables the logging of neutral instantaneous overcurrent events in the sequence of events recorder.

Figure 5-82: Neutral IOC1 logic



5.7.4.4 Neutral directional overcurrent (ANSI 67N, IEC PDEF/PTOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL DIRECTIONAL OC1

■ NEUTRAL ■ DIRECTIONAL OC1	⇔	**NEUTRAL DIR OC1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇩	**NEUTRAL DIR OC 1 SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇩	**NEUTRAL DIR OC1 POLARIZING: Voltage**	Range: Voltage, Current, Dual, Dual-V, Dual-I
	⇩	**NEUTRAL DIR OC1 POL VOLT: Calculated V0**	Range: Calculated V0, Aux. Voltage (VX)
	⇩	**NEUTRAL DIR OC1 OP CURR: Calculated 3I0**	Range: Calculated 3I0, Measured IG
	⇩	**NEUTRAL DIR OC1 POS-SEQ RESTRAINT: 0.063**	Range: 0.000 to 0.500 in steps of 0.001
	⇩	**NEUTRAL DIR OC1 OFFSET: 0.00 Ω**	Range: 0.00 to 250.00 Ω in steps of 0.01
	⇩	**NEUTRAL DIR OC1 FWD ECA: 75° Lag**	Range: –90 to 90° in steps of 1
	⇩	**NEUTRAL DIR OC1 FWD LIMIT ANGLE: 90°**	Range: 40 to 90° in steps of 1
	⇩	**NEUTRAL DIR OC1 FWD PICKUP: 0.050 pu**	Range: 0.006 to 30.000 pu in steps of 0.001
	⇩	**NEUTRAL DIR OC1 REV LIMIT ANGLE: 90°**	Range: 40 to 90° in steps of 1
	⇩	**NEUTRAL DIR OC1 REV PICKUP: 0.050 pu**	Range: 0.006 to 30.000 pu in steps of 0.001
	⇩	**NEUTRAL DIR OC1 BLK: Off**	Range: FlexLogic operand
	⇩	**NEUTRAL DIR OC1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
	⇩	**NEUTRAL DIR OC1 EVENTS: Disabled**	Range: Disabled, Enabled

The neutral directional overcurrent element provides both forward and reverse fault direction indications for 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 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.

$$I_{op} = 3 \times (|I\_0| - K \times |I\_1|) \qquad \textbf{Eq. 5-18}$$

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 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 can 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. V_0 is the zero-sequence voltage, I_0 is the zero-sequence current, ECA is the element characteristic angle, and IG is the ground current.

Table 5-31: 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	$I_{op} = 3 \times (\|I\_0\| - K \times \|I\_1\|)$ if $\|I_1\| > 0.8$ pu $I_{op} = 3 \times \|I\_0\|$ if $\|I_1\| \le 0.8$ 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 5-32: 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	$I_{op} = \|IG\|$
	Reverse	–V_0 + Z_offset × IG/3	–IG × 1∠ECA	

where:

$$V\_0 = \frac{1}{3}(VAG + VBG + VCG) = \text{zero sequence voltage}$$

$$I\_0 = \frac{1}{3}IN = \frac{1}{3}(IA + IB + IC) = \text{zero sequence current}$$

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

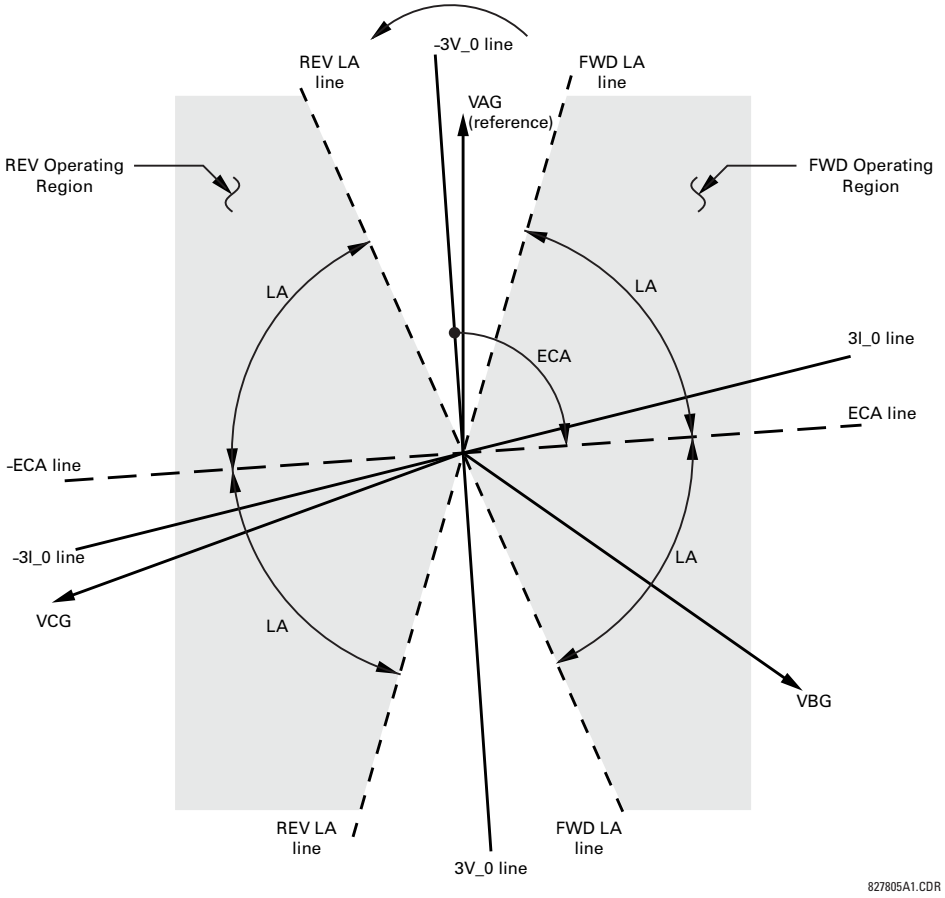
When **NEUTRAL DIR OC1 POL VOLT** is set to "Measured VX," one-third of this voltage is used in place of V_0. The following figure explains the usage of the voltage polarized directional unit of the element.

The figure 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)

Take the bias into account when using the neutral directional overcurrent element to directionalize other protection elements.

Figure 5-83: 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, ensure that a reversal of the ground current does not occur for a high-side fault. Assume that the

low-side system impedance is minimal when checking for this condition. A similar situation arises for a wye/delta/wye transformer, where current in one transformer winding neutral can 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 is used by this protection. This setting acts as a switch between the neutral and ground modes of operation (ANSI devices 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 ps to be used as operate quantity.

NEUTRAL DIR OC1 POS-SEQ RESTRAINT — This setting controls the amount of the positive-sequence restraint. Set it to 0.063 for backward compatibility with firmware revision 3.40 and older. Set it to zero to remove the restraint. Set it 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 is not to be larger than the zero-sequence impedance of the protected circuit. Practically, it shall be several times smaller. Enter the offset impedance 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°.

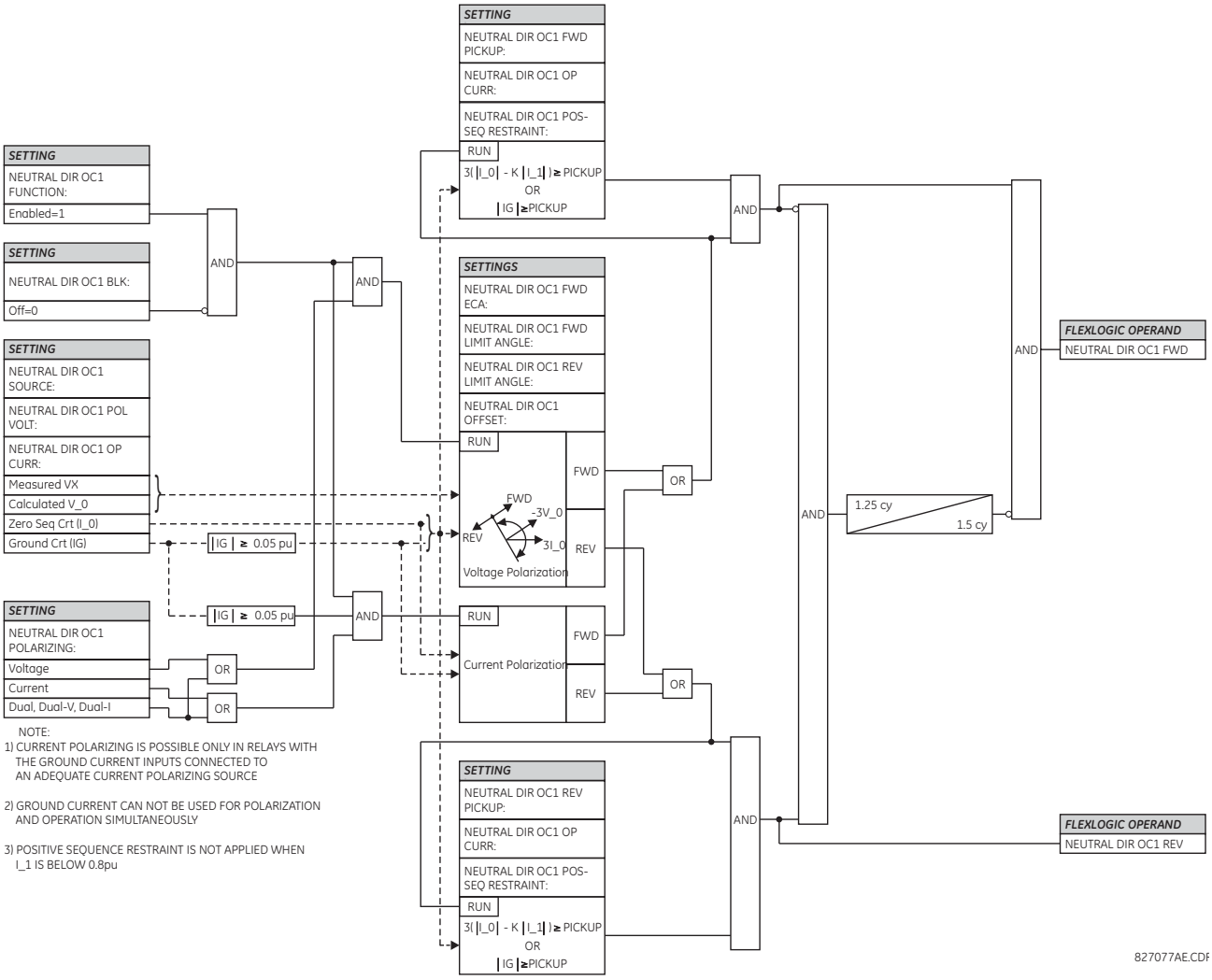
NEUTRAL DIR OC1 FWD LIMIT ANGLE — This setting defines a symmetrical (in both directions from the ECA) limit angle for the forward direction.

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, keep 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, keep in mind that the design uses a positive-sequence restraint technique for the “Calculated 3I0” mode of operation.

Figure 5-84: Neutral directional overcurrent logic



5.7.4.5 Neutral current unbalance (ANSI 60N, IEC PVCB/PTOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL CURRENT UNBALANCE 1(3)

■ NEUTRAL CURRENT ■ UNBALANCE 1	⇔	**NTRL CUR UNBALCE 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇳	**NTRL CUR UNBALCE 1 BANK SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇳	**NTRL CUR UNBALCE 1 K MAG: 0.0000**	Range: 0.0000 to 0.1500 in steps of 0.0001
	⇳	**NTRL CUR UNBALCE 1 K ANG: 0°**	Range: 0 to 359° in steps of 1
	⇳	**NTRL CUR UNBALCE 1 STG1 PKP: 0.020 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
	⇳	**NTRL CUR UNBALCE 1 STG1 SLOPE: 2.0%**	Range: 0.0 to 10.% in steps of 0.1

⇳	**NTRL CUR UNBALCE 1 STG2 PKP: 0.030 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**NTRL CUR UNBALCE 1 STG2 SLOPE: 2.0%**	Range: 0.0 to 10.% in steps of 0.1
⇳	**NTRL CUR UNBALCE 1 STG3 PKP: 0.040 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**NTRL CUR UNBALCE 1 STG3 SLOPE: 2.0%**	Range: 0.0 to 10.% in steps of 0.1
⇳	**NTRL CUR UNBALCE 1 STG4 PKP: 0.050 pu**	Range: 0.001 to 5.000 pu in steps of 0.001
⇳	**NTRL CUR UNBALCE 1 STG4 SLOPE: 5.0%**	Range: 0.0 to 10.% in steps of 0.1
⇳	**NTRL CUR UNBALCE 1 STG1 DEL: 30.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NTRL CUR UNBALCE 1 STG2 DEL: 10.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NTRL CUR UNBALCE 1 STG3 DEL: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NTRL CUR UNBALCE 1 STG4 DEL: 0.20 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NTRL CUR UNBALCE 1 DPO DELAY: 0.25 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NTRL CUR 1 BLK STG1: Off**	Range: FlexLogic operand
⇳	**NTRL CUR 1 BLK STG2: Off**	Range: FlexLogic operand
⇳	**NTRL CUR 1 BLK STG3: Off**	Range: FlexLogic operand
⇳	**NTRL CUR 1 BLK STG4: Off**	Range: FlexLogic operand
⇳	**NTRL CUR UNBALCE 1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**NTRL CUR UNBALCE 1 EVENTS: Disabled**	Range: Disabled, Enabled

Up to three identical neutral current unbalance elements, one per each installed CT/VT module.

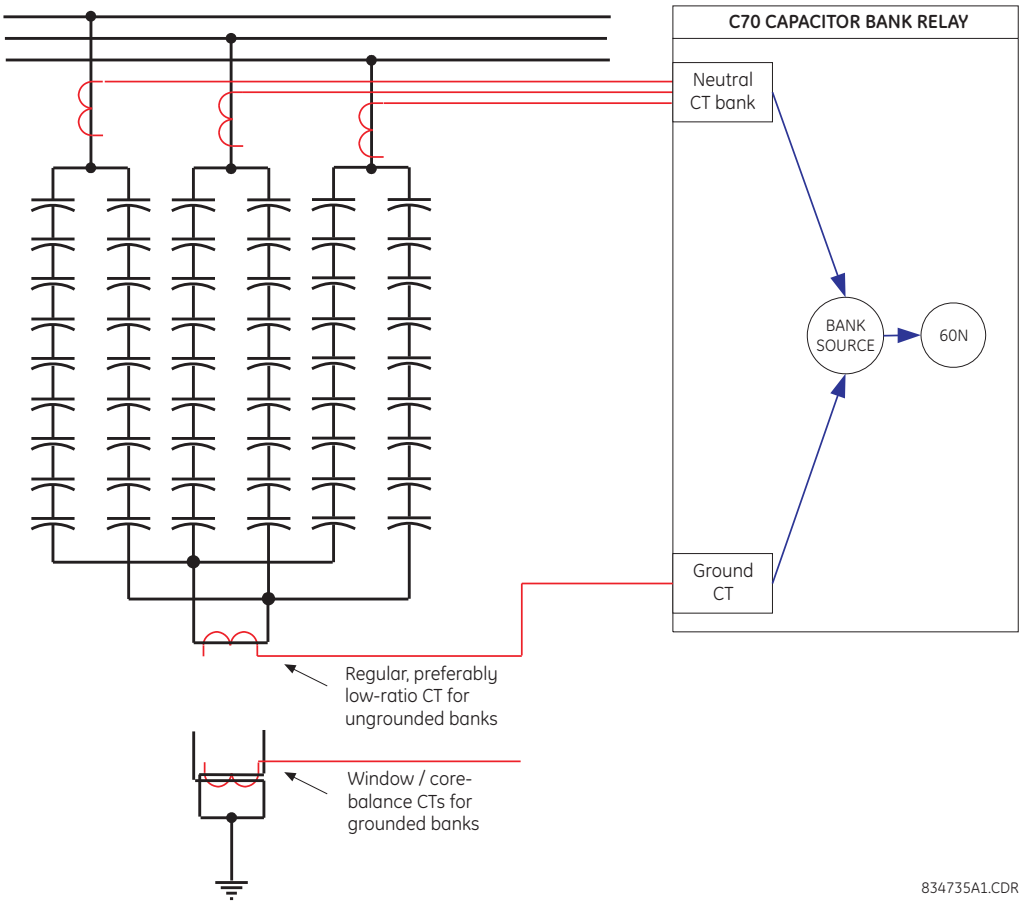
The neutral current unbalance element responds to a differential current signal measured as a vectorial current difference between neutral currents of parallel banks. In case of ungrounded banks, regular, preferably low-ratio CT can be used. In case of grounded banks, a window or core-balance CT shall be used for increased accuracy/sensitivity.

The function applies simplified compensation for the inherent bank unbalance. Accurate compensation requires three balancing factors that are difficult to measure in practical situations. Instead, a simple and practical compensation responding to both the positive-sequence current and negative-sequence current is applied. This method is easy to apply and remains accurate as long as the zero-sequence bank currents are relatively small. Under large zero-sequence bank currents, the applied method of compensation for the inherent bank unbalance is less accurate. The solution to this problem is to use a small portion of the zero-sequence current at the bank terminals to produce extra restraint and preserve high sensitivity of this protection method.

By setting both the slope and the inherent unbalance compensating factor to zero, one can apply the function as a plain overcurrent element responding to the split-phase neutral current.

The relay allows manual setting of the inherent unbalance factor or automatic setting via a dedicated command. For more information, see the Application of Settings chapter.

Figure 5-85: Neutral current unbalance connections



The following settings are available. They are for the neutral current unbalance 1 element. The same descriptions apply to the neutral current unbalance 2 and 3 elements.

NTRL CUR UNBALCE 1 BANK SOURCE — This setting indicates the signal source that signifies the split-phase neutral current in its ground current channel. At minimum the ground channel of this source must be set. If the factor compensating for inherent bank unbalance is set above zero signalling the intent of using the compensation, the phase currents of this source must be configured as well. Without the phase currents configured under this source, the function would run only if the magnitude of the inherent unbalance factor is set to zero.

To improve accuracy, a relatively low-ratio window CT can be used for instrumentation of the split-phase neutral current, and be wired to a 1 A or even sensitive ground relay input for extra sensitivity. CT primary and secondary ratings are entered under a separate menu. Directionality of wiring of the split-phase current is not important for proper functioning of the feature as long as the angle of the factor compensating for the inherent unbalance is set appropriately.

NTRL CUR UNBALCE 1 K MAG — This setting defines magnitude of the factor compensating for the inherent unbalance of the bank. Under balanced conditions, the amount of the spill current measured in the neutral connection between the banks is proportional to the positive-sequence component of the total current of the two banks. This setting defines the magnitude of the proportionality factor. Quality of balancing the bank with a given value of this setting can be viewed under **ACTUAL VALUES** menu. An automatic setting procedure is available via the **COMMANDS** menu to calculate the compensating factor automatically. Setting the compensating factor to zero effectively disables the compensation. If further the slope is set to zero as well, this feature becomes a plain overcurrent element responding to the neutral split-phase current.

NTRL CUR UNBALCE 1 K ANG — This setting defines angle of the factor compensating for the inherent unbalance of the bank. Under balanced conditions, the amount of the spill current measured in the neutral connection between the banks is proportional to the positive-sequence component of the total current of the two banks. This setting defines the angle of

the proportionality factor. Quality of balancing the bank with a given value of this setting can be viewed under **ACTUAL VALUES** menu. An automatic setting procedure is available under the **COMMANDS** menu to calculate the compensating factor automatically.

NTRL CUR UNBALCE 1 STG1 PKP to **NTRL CUR UNBALCE 1 STG4 PKP** — These settings specify pickup thresholds for stages 1 through 4 in per-units (pu) of the nominal current of the ground current channel of the bank source. A value of 1 pu is the nominal secondary current, or the nominal primary current, respectively, as configured under the bank source of this function.

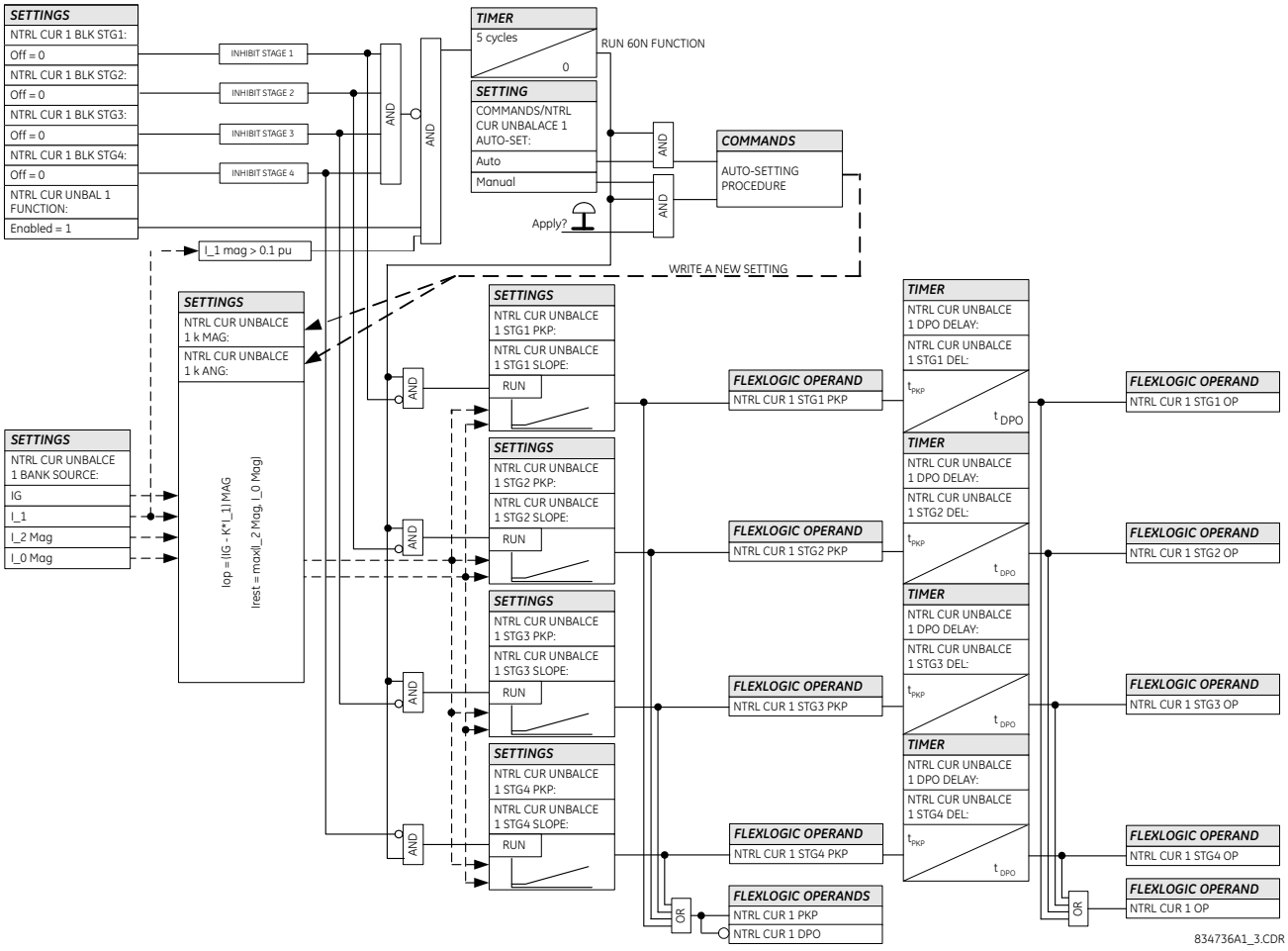
NTRL CUR UNBALCE 1 STG1 SLOPE to **NTRL CUR UNBALCE 1 STG4 SLOPE** — These settings specify the slopes for stages 1 through 4. The slope setting is applied if the phase CTs are configured under the bank source. The magnitude of the zero-sequence current is applied as a restraining signal. Typically few percent of slope is enough to ensure security of the function. The factor compensating for the inherent bank unbalance zeroes out the operating signal under relatively balanced bank currents. If the said currents contain a significant zero sequence component, the quality of compensation is lower, hence the need for the restraint, and this slope setting.

NTRL CUR UNBALCE 1 STG1 DEL to **NTRL CUR UNBALCE 1 STG4 DEL** — This setting specifies the pickup time delay, individually per each stage of alarming/tripping. The timers use a common drop out time delay specified by the next setting.

NTRL CUR UNBALCE 1 DPO DELAY — This setting controls a drop out delay for the operate FlexLogic operands. Individual stages apply individually configurable pickup delays, but use this common drop out delay.

NTRL CUR 1 BLK STG1 to **NTRL CUR 1 BLK STG4** — These settings are used to block the function on a per stage basis when required. At minimum this function shall be blocked when the two banks are not paralleled. Note that when unblocked, the function becomes operational after five cycles of intentional delay. High-set instantaneous protection on energization can be provided by a separate instantaneous overcurrent function.

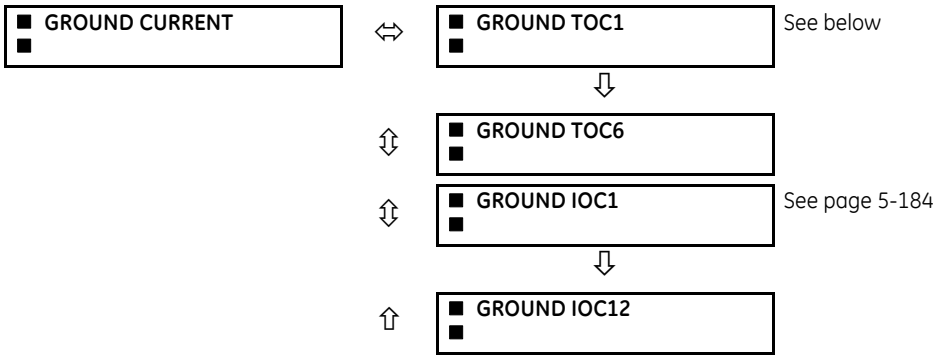
Figure 5-86: Neutral current unbalance logic



5.7.5 Ground current

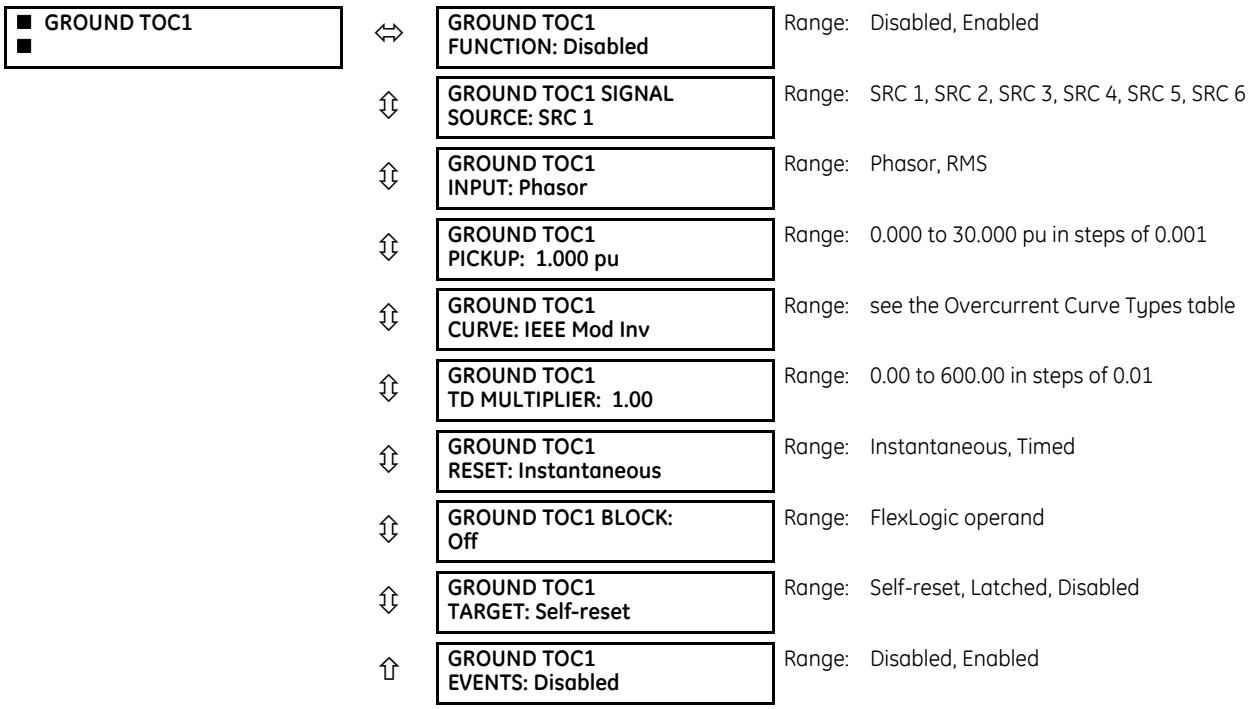
5.7.5.1 Menu

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ GROUND CURRENT



5.7.5.2 Ground time overcurrent (ANSI 51G, IEC PTOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ GROUND CURRENT ⇨ GROUND TOC1(6)



This element can provide a required 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 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 clears immediately.

GROUND TOC1 FUNCTION — This setting enables and disables the ground time overcurrent protection element.

GROUND TOC1 SIGNAL SOURCE — This setting selects the signal source for the ground time overcurrent protection element.

GROUND TOC1 INPUT — This setting selects how ground current input quantities are interpreted by the C70. Inputs can be selected as fundamental phasor magnitudes or total waveform RMS magnitudes as required by the application.

GROUND TOC1 PICKUP — This setting specifies the ground time overcurrent pickup level in per-unit values.

GROUND TOC1 CURVE — This setting selects the inverse time overcurrent curve style.

GROUND TOC1 TD MULTIPLIER — This setting specifies a multiple of the base curve shape specified by the **CURVE** setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

GROUND TOC1 RESET — The "Instantaneous" reset method 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" reset method can be used where the relay must coordinate with electromechanical relays.

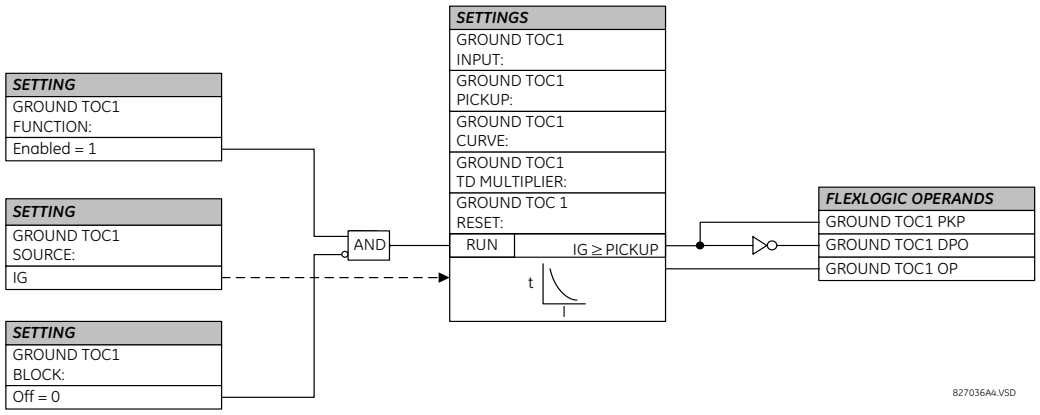
GROUND TOC1 BLOCK — Assertion of the operand assigned to this setting blocks operation of the ground time overcurrent element.

GROUND TOC1 EVENTS — This setting enables and disables the logging of ground time overcurrent events in the sequence of events recorder.

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 5-87: Ground TOC1 logic



5.7.5.3 Ground instantaneous overcurrent (ANSI 50G, IEC PIOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ GROUND CURRENT ⇨⇩ GROUND IOC1(12)

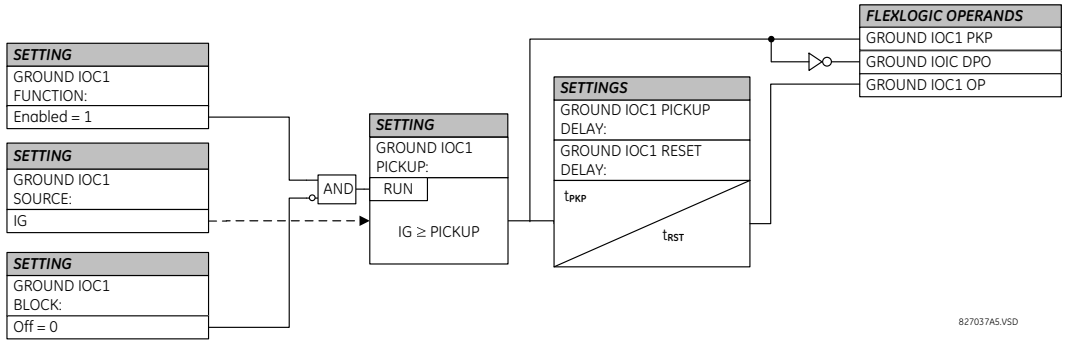
■ GROUND IOC1 ■	⇔	**GROUND IOC1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇩	**GROUND IOC1 SIGNAL SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇩	**GROUND IOC1 PICKUP: 1.000 pu**	Range: 0.000 to 30.000 pu in steps of 0.001
	⇩	**GROUND IOC1 PICKUP DELAY: 0.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
	⇩	**GROUND IOC1 RESET DELAY: 0.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
	⇩	**GROUND IOC1 BLOCK: Off**	Range: FlexLogic operand
	⇩	**GROUND IOC1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
	⇩	**GROUND IOC1 EVENTS: Disabled**	Range: Disabled, Enabled

The ground instantaneous overcurrent element can 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 5-88: Ground IOC1 logic



5.7.6 Negative sequence current

5.7.6.1 Menu

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEGATIVE SEQUENCE CURRENT

■ NEGATIVE SEQUENCE CURRENT	■ NEG SEQ TOC1 ■	See below
	■ NEG SEQ TOC2 ■	
	■ NEG SEQ IOC1 ■	See page 5-186
	■ NEG SEQ IOC2 ■	
	■ NEG SEQ DIR OC1 ■	See page 5-187
	■ NEG SEQ DIR OC2 ■	

5.7.6.2 Negative sequence time overcurrent (ANSI 51Q, IEC PTOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEGATIVE SEQUENCE CURRENT ⇨ NEG SEQ TOC1(2)

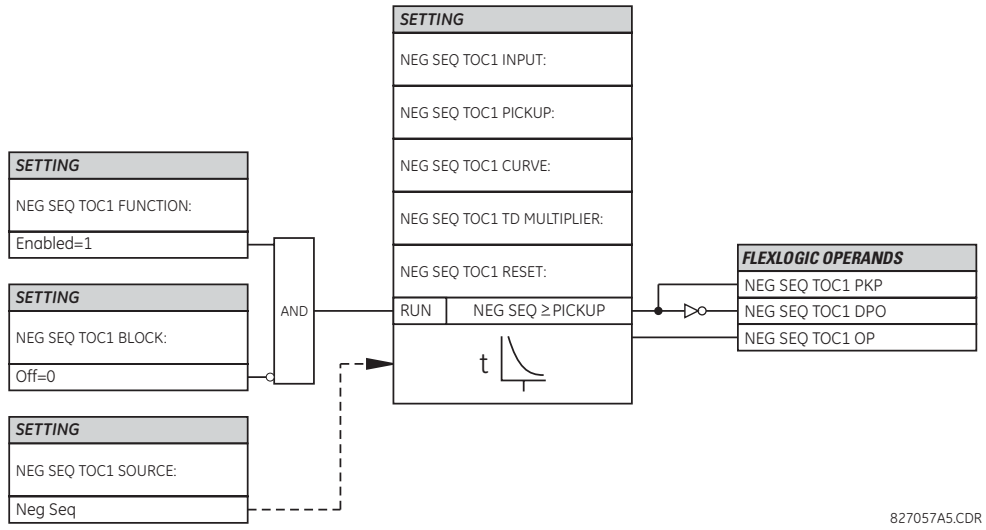
■ NEG SEQ TOC1 ■	NEG SEQ TOC1 FUNCTION: Disabled	Range: Disabled, Enabled
	NEG SEQ TOC1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	NEG SEQ TOC1 PICKUP: 1.000 pu	Range: 0.000 to 30.000 pu in steps of 0.001
	NEG SEQ TOC1 CURVE: IEEE Mod Inv	Range: see Overcurrent Curve Types table

⇳	**NEG SEQ TOC1 TD MULTIPLIER: 1.00**	Range: 0.00 to 600.00 in steps of 0.01
⇳	**NEG SEQ TOC1 RESET: Instantaneous**	Range: Instantaneous, Timed
⇳	**NEG SEQ TOC1 BLOCK: Off**	Range: FlexLogic operand
⇳	**NEG SEQ TOC1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**NEG SEQ TOC1 EVENTS: Disabled**	Range: Disabled, Enabled

The negative-sequence time overcurrent element can 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" (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 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 clears immediately.

Figure 5-89: Negative sequence TOC1 logic



5.7.6.3 Negative sequence instantaneous overcurrent (ANSI 50Q, IEC PIOC)

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
	⇳	**NEG SEQ IOC1 SIGNAL SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇳	**NEG SEQ IOC1 PICKUP: 1.000 pu**	Range: 0.000 to 30.000 pu in steps of 0.001
	⇳	**NEG SEQ IOC1 PICKUP DELAY: 0.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
	⇳	**NEG SEQ IOC1 RESET DELAY: 0.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
	⇧	**NEG SEQ IOC1 BLOCK: Off**	Range: FlexLogic operand

⇳	**NEG SEQ IOC1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇳	**NEG SEQ IOC1 EVENTS: Disabled**	Range: Disabled, Enabled

The negative-sequence instantaneous overcurrent element can 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.

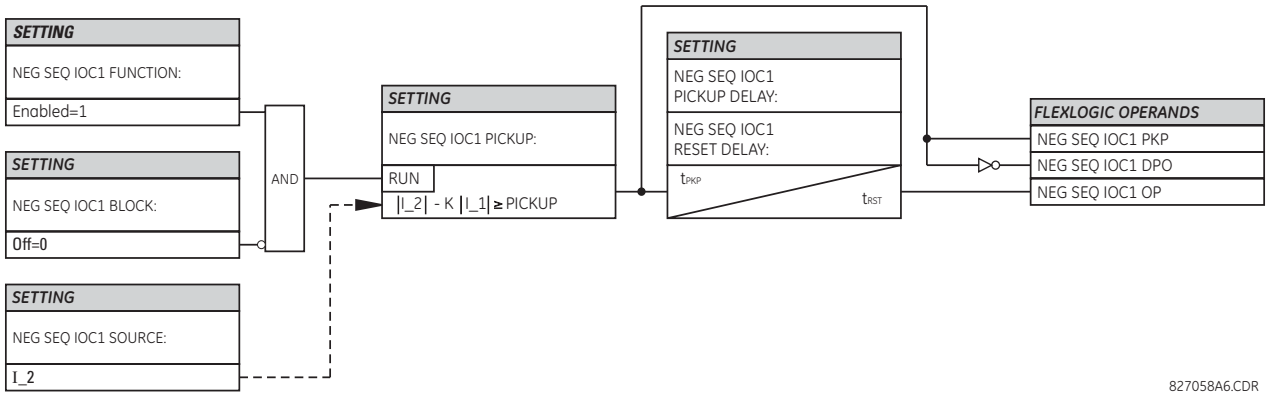
$$I_{op} = |I\_2| - K \cdot |I\_1| \quad \text{where } K = 1/8 \qquad \textbf{Eq. 5-19}$$

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 how 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 5-90: Negative sequence IOC1 logic



5.7.6.4 Negative sequence directional overcurrent (ANSI 67Q, IEC PDEF/PTOC)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ NEGATIVE SEQUENCE CURRENT ⇨⇩ NEG SEQ DIR OC1(2)

■ **NEG SEQ DIR OC1** ■		
⇔	**NEG SEQ DIR OC1 FUNCTION: Disabled**	Range: Disabled, Enabled
⇳	**NEG SEQ DIR OC1 SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
⇳	**NEG SEQ DIR OC1 OFFSET: 0.00 Ω**	Range: 0.00 to 250.00 ohms in steps of 0.01
⇳	**NEG SEQ DIR OC1 TYPE: Neg Sequence**	Range: Neg Sequence, Zero Sequence
⇳	**NEG SEQ DIR OC1 POS-SEQ RESTRAINT: 0.063**	Range: 0.000 to 0.500 in steps of 0.001
⇳	**NEG SEQ DIR OC1 FWD ECA: 75° Lag**	Range: 0 to 90° Lag in steps of 1

⇳	**NEG SEQ DIR OC1 FWD LIMIT ANGLE: 90°**	Range: 40 to 90° in steps of 1
⇳	**NEG SEQ DIR OC1 FWD PICKUP: 0.050 pu**	Range: 0.015 to 30.000 pu in steps of 0.005
⇳	**NEG SEQ DIR OC1 REV LIMIT ANGLE: 90°**	Range: 40 to 90° in steps of 1
⇳	**NEG SEQ DIR OC1 REV PICKUP: 0.050 pu**	Range: 0.015 to 30.000 pu in steps of 0.005
⇳	**NEG SEQ DIR OC1 BLK: Off**	Range: FlexLogic operand
⇳	**NEG SEQ DIR OC1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**NEG SEQ DIR OC1 EVENTS: Disabled**	Range: Disabled, Enabled

There are two negative-sequence directional overcurrent protection elements available. The element provides both forward and reverse fault direction indications through its output operands NEG SEQ DIR OC1 FWD and NEG SEQ DIR OC1 REV, 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 of the element essentially responds to the magnitude of a fundamental frequency phasor of either the negative-sequence or neutral current as per user selection.

A positive-sequence restraint is applied for better performance: a small user-programmable portion of the positive-sequence current magnitude is subtracted from the negative or zero-sequence current magnitude, respectively, when forming the element operating quantity.

$$I_{op} = |I\_2| - K \times |I\_1| \quad \text{or} \quad I_{op} = 3 \times (|I\_0| - K \times |I\_1|) \qquad \textbf{Eq. 5-20}$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious negative-sequence and zero-sequence currents resulting from

- System unbalances under heavy load conditions
- Transformation errors of current transformers (CTs)
- Fault inception and switch-off transients

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The positive-sequence restraint is removed for low currents. If the positive-sequence current is less than 0.8 pu, then the restraint is removed by changing the constant K to zero. This results in better response to high-resistance faults when the unbalance is very small and there is no danger of excessive CT errors, since the current is low.

The operating quantity depends on the way the test currents are injected into the C70. For single phase injection

- $I_{op} = ⅓ \times (1 - K) \times I_{injected}$ for I_2 mode
- $I_{op} = (1 - K) \times I_{injected}$ for I_0 mode if $|I\_1| > 0.8$ pu

The directional unit uses the negative-sequence current (I_2) and negative-sequence voltage (V_2).

The following tables define the negative-sequence directional overcurrent element.

Table 5-33: Negative-sequence directional overcurrent unit

Mode	Operating current
Negative-sequence	$I_{op} = \|I\_2\| - K \times \|I\_1\|$
Zero-sequence	$I_{op} = 3 \times (\|I\_0\| - K \times \|I\_1\|)$ if $\|I\_1\| > 0.8$ pu $I_{op} = 3 \times \|I\_0\|$ if $\|I\_1\| \le 0.8$ pu

Table 5-34: Negative-sequence directional unit

Direction	Compared phasors	
Forward	$-V\_2 + Z\_offset \times I\_2$	$I\_2 \times 1\angle ECA$

Direction	Compared phasors	
Reverse	–V_2 + Z_offset × I_2	–(I_2 × 1∠ECA)

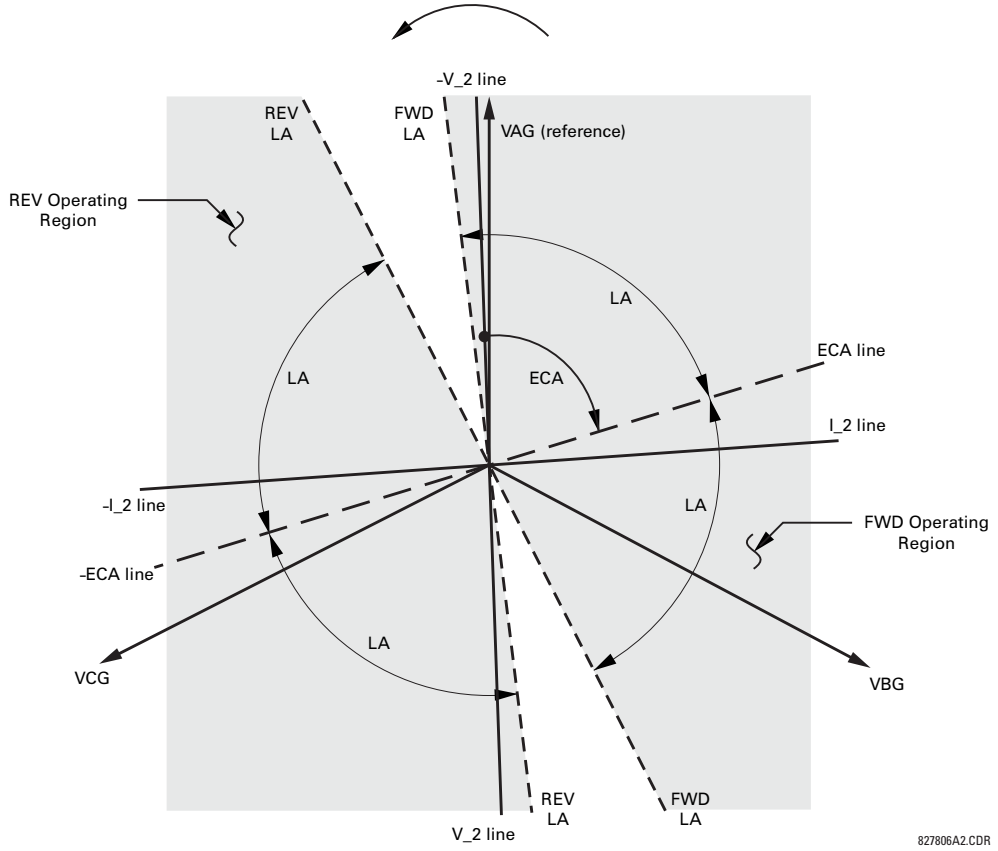
Z_offset is the offset impedance, for which magnitude is the OFFSET setting and angle is the FWD ECA.

The negative-sequence voltage 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 negative-sequence current is above 0.2 pu, compensated negative-sequence voltage -V_2 + Z_offset x I_2 has to be above 0.02 pu in order to discriminate fault direction; otherwise when negative-sequence current is less than 0.2 pu, -V_2 is then used as the polarizing signal. If the polarizing signal is not validated, neither forward nor reverse indication is given. The following figure explains the usage of the voltage polarized directional unit of the element. It shows the phase angle comparator characteristics for a phase A to ground fault, with settings of

ECA = 75° (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 element incorporates a current reversal logic: if the reverse direction is indicated for at least 1.25 of a power system cycle, the prospective forward indication is delayed by 1.5 of a power system cycle. The element emulates an electromechanical directional device. Larger operating and polarizing signals result in faster directional discrimination, bringing more security to the element operation.

Figure 5-91: Negative-sequence directional characteristic



The forward-looking function is designed to be more secure compared to the reverse-looking function, so use the forward-looking function for the tripping direction. The reverse-looking function is faster compared to the forward-looking function, so use the reverse-looking function for the blocking direction. This allows for better protection coordination. Take this bias into account when using the negative-sequence directional overcurrent element to directionalize other protection elements. The negative-sequence current must be greater than the **PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES ⇨⇩ CURRENT CUT-OFF LEVEL** setting value.

Settings

NEG SEQ DIR OC1 OFFSET — 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 (see the Application of Settings chapter for information on how to calculate this setting). In regular applications, the offset impedance ensures proper operation even if the negative-sequence voltage at the relaying point is very small. If this is the intent, the offset impedance shall not be larger than the negative-sequence impedance of the protected circuit. Practically, it is several times smaller. Enter the offset impedance in secondary ohms.

NEG SEQ DIR OC1 TYPE — Selects the operating mode for the overcurrent unit of the element. The choices are "Neg Sequence" and "Zero Sequence." In some applications it is advantageous to use a directional negative-sequence overcurrent function instead of a directional zero-sequence overcurrent function as inter-circuit mutual effects are minimized.

NEG SEQ DIR OC1 POS-SEQ RESTRAINT — Controls the positive-sequence restraint. Set it to 0.063 (in "Zero Sequence" mode) or 0.125 (in "Neg Sequence" mode) for backward compatibility with revisions 3.40 and earlier. Set it to zero to remove the restraint. Set it higher if large system unbalances or poor CT performance are expected.

NEG SEQ DIR OC1 FWD ECA — Select the element characteristic angle (ECA) for the forward direction. The element characteristic angle in the reverse direction is the angle set for the forward direction shifted by 180°.

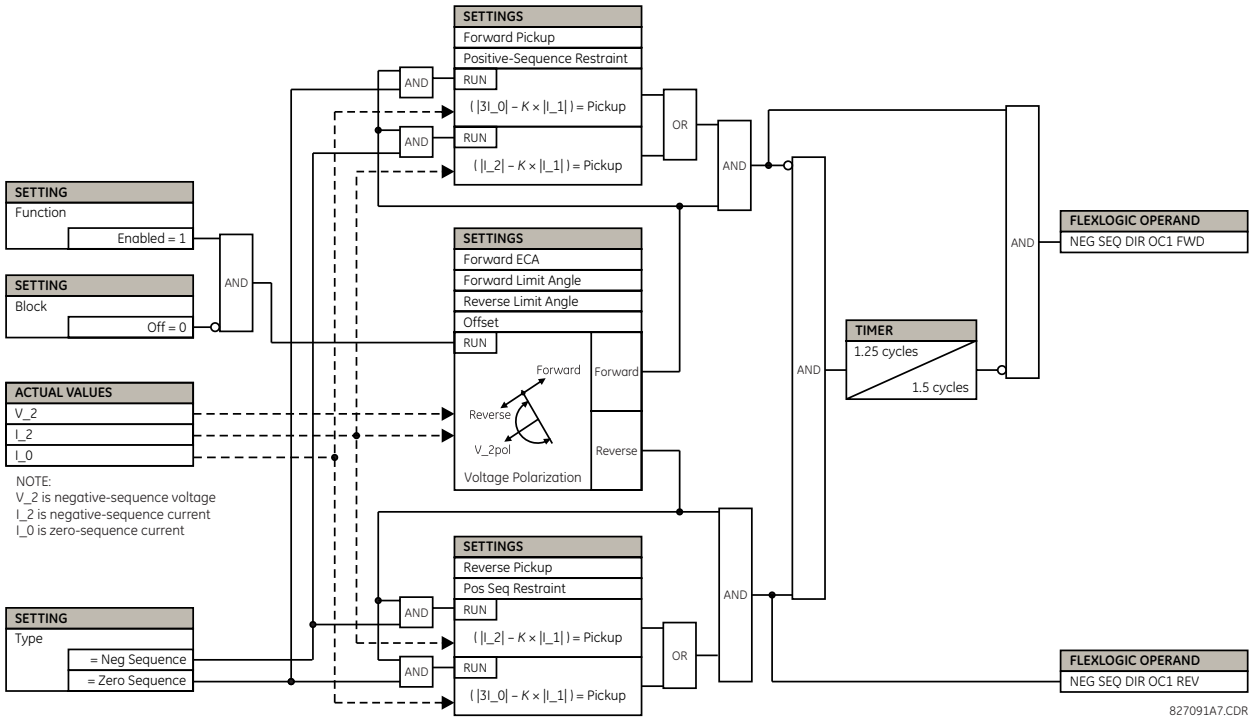
NEG SEQ DIR OC1 FWD LIMIT ANGLE — Defines a symmetrical limit angle (in both directions from the ECA) for the forward direction.

NEG SEQ DIR OC1 FWD PICKUP — Defines the pickup level for the overcurrent unit in the forward direction. This pickup threshold applies to zero-sequence or negative-sequence current based on the **NEG SEQ DIR OC1 TYPE** setting. When specifying this setting, keep in mind that the design uses a positive-sequence restraint technique.

NEG SEQ DIR OC1 REV LIMIT ANGLE — Defines a symmetrical limit angle (in both directions from the ECA) for the reverse direction.

NEG SEQ DIR OC1 REV PICKUP — Defines the pickup level for the overcurrent unit in the reverse direction. This pickup threshold applies to zero-sequence or negative-sequence current based on the **NEG SEQ DIR OC1 TYPE** setting. When selecting this setting, keep in mind that the design uses a positive-sequence restraint technique.

Figure 5-92: Negative-sequence directional OC1 logic



5.7.7 Breaker failure (ANSI 50BF)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ BREAKER FAILURE ⇨ BREAKER FAILURE 1

■ BREAKER FAILURE 1 ■	⇔	**BF1 FUNCTION:** **Disabled**	Range: Disabled, Enabled
	⇳	**BF1 MODE:** **3-Pole**	Range: 3-Pole, 1-Pole
	⇳	**BF1 SOURCE:** **SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇳	**BF1 USE AMP SUPV:** **Yes**	Range: Yes, No
	⇳	**BF1 USE SEAL-IN:** **Yes**	Range: Yes, No
	⇳	**BF1 3-POLE INITIATE:** **Off**	Range: FlexLogic operand
	⇳	**BF1 BLOCK:** **Off**	Range: FlexLogic operand
	⇳	**BF1 PH AMP SUPV** **PICKUP: 1.050 pu**	Range: 0.001 to 30.000 pu in steps of 0.001
	⇳	**BF1 N AMP SUPV** **PICKUP: 1.050 pu**	Range: 0.001 to 30.000 pu in steps of 0.001
	⇳	**BF1 USE TIMER 1:** **Yes**	Range: Yes, No
	⇳	**BF1 TIMER 1 PICKUP** **DELAY: 0.000 s**	Range: 0.000 to 65.535 s in steps of 0.001
	⇳	**BF1 USE TIMER 2:** **Yes**	Range: Yes, No
	⇳	**BF1 TIMER 2 PICKUP** **DELAY: 0.000 s**	Range: 0.000 to 65.535 s in steps of 0.001
	⇳	**BF1 USE TIMER 3:** **Yes**	Range: Yes, No
	⇳	**BF1 TIMER 3 PICKUP** **DELAY: 0.000 s**	Range: 0.000 to 65.535 s in steps of 0.001
	⇳	**BF1 BKR POS1 ϕA/3P:** **Off**	Range: FlexLogic operand
	⇳	**BF1 BKR POS2 ϕA/3P:** **Off**	Range: FlexLogic operand
	⇳	**BF1 BREAKER TEST ON:** **Off**	Range: FlexLogic operand
	⇳	**BF1 PH AMP HISET** **PICKUP: 1.050 pu**	Range: 0.001 to 30.000 pu in steps of 0.001
	⇳	**BF1 N AMP HISET** **PICKUP: 1.050 pu**	Range: 0.001 to 30.000 pu in steps of 0.001
	⇳	**BF1 PH AMP LOSET** **PICKUP: 1.050 pu**	Range: 0.001 to 30.000 pu in steps of 0.001
	⇳	**BF1 N AMP LOSET** **PICKUP: 1.050 pu**	Range: 0.001 to 30.000 pu in steps of 0.001
	⇳	**BF1 LOSET TIME** **DELAY: 0.000 s**	Range: 0.000 to 65.535 s in steps of 0.001

BF1 TRIP DROPOUT DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
BF1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
BF1 EVENTS: Disabled	Range: Disabled, Enabled
BF1 PH A INITIATE: Off	Range: FlexLogic operand Valid only for 1-Pole breaker failure schemes
BF1 PH B INITIATE: Off	Range: FlexLogic operand Valid only for 1-Pole breaker failure schemes
BF1 PH C INITIATE: Off	Range: FlexLogic operand Valid only for 1-Pole breaker failure schemes
BF1 BKR POS1 ϕB: Off	Range: FlexLogic operand Valid only for 1-Pole breaker failure schemes
BF1 BKR POS1 ϕC: Off	Range: FlexLogic operand Valid only for 1-Pole breaker failure schemes
BF1 BKR POS2 ϕB: Off	Range: FlexLogic operand Valid only for 1-Pole breaker failure schemes
BF1 BKR POS2 ϕC: Off	Range: FlexLogic operand Valid only for 1-Pole breaker failure schemes

5

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 causes 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 is 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 can 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, do not use a current supervised initiate. Utilize this feature for those situations where coordinating margins can 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.

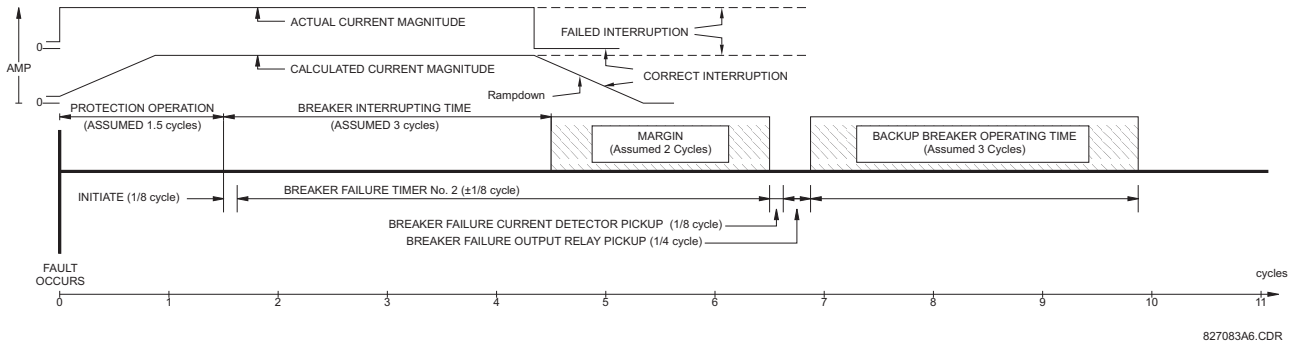
Output

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)

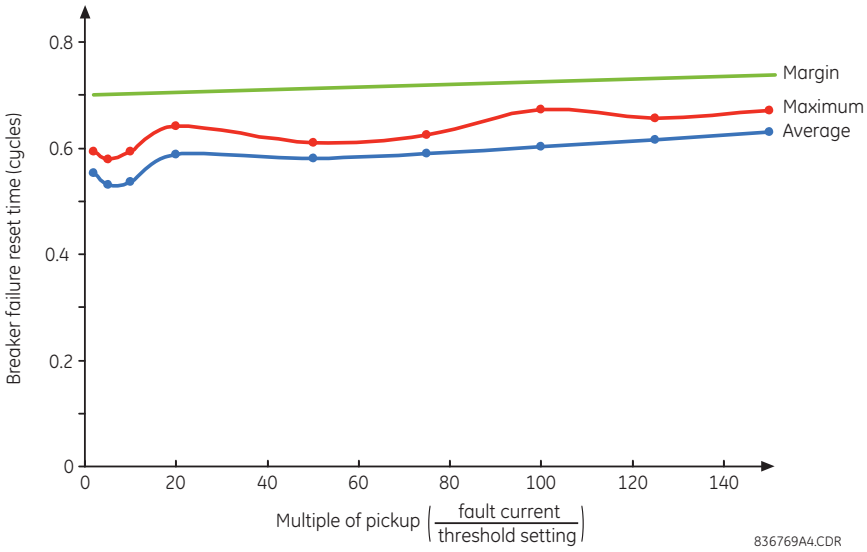
Main path sequence

Figure 5-93: 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 in the following figure.

Figure 5-94: 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 is initiated if current flowing through the breaker is above the supervision pickup level.

BF1 USE SEAL-IN — If set to "Yes," the element is 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 initiates 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 detects 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 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 detects 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 C70 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 can 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 can 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 is to 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 is to 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 is to 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 is to 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 can 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 can 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 can 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 needs to be given via output operand BKR FAIL 1 TRIP OP.

Figure 5-95: Single-pole breaker failure initiate logic

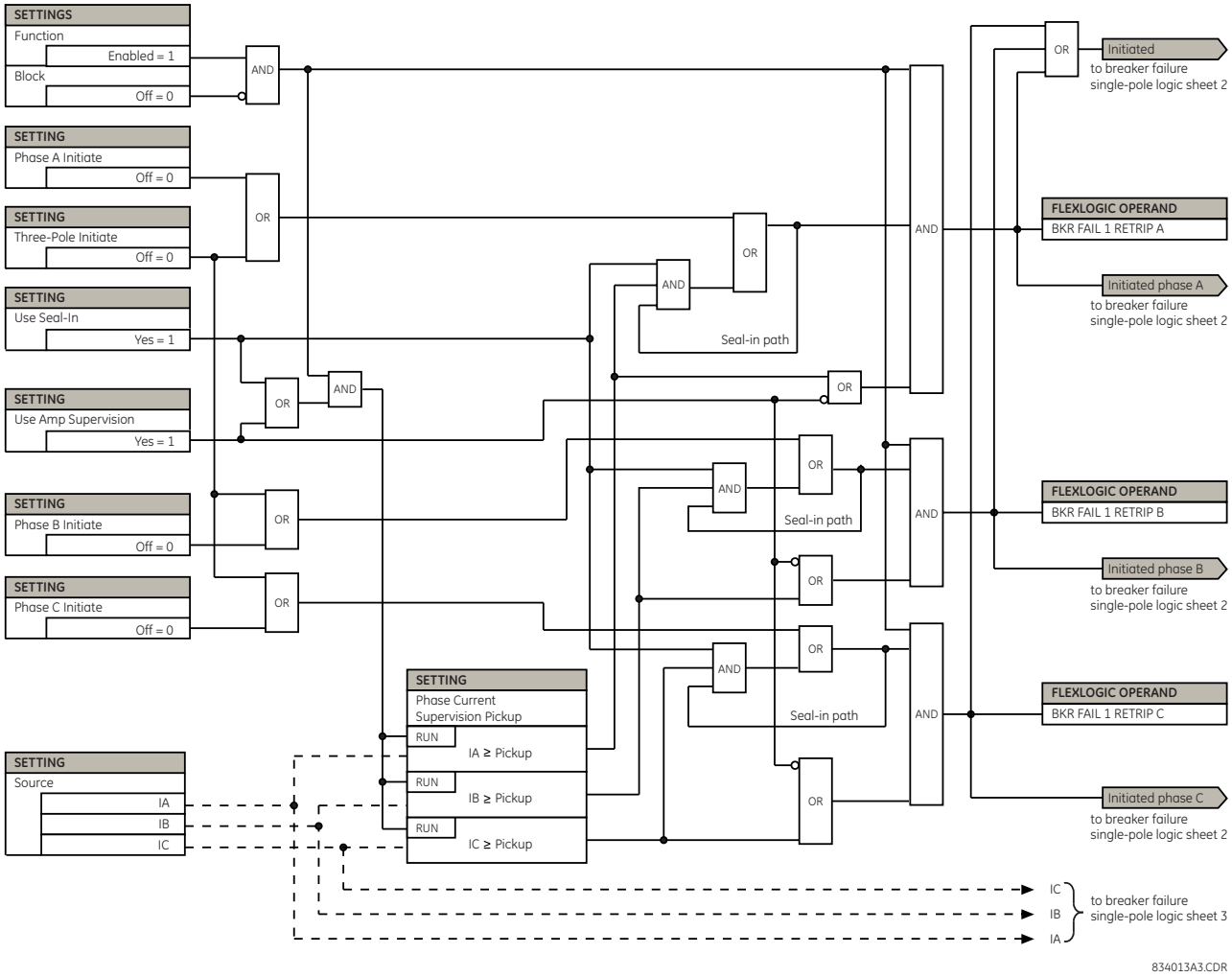


Figure 5-96: Single-pole breaker failure, timers logic

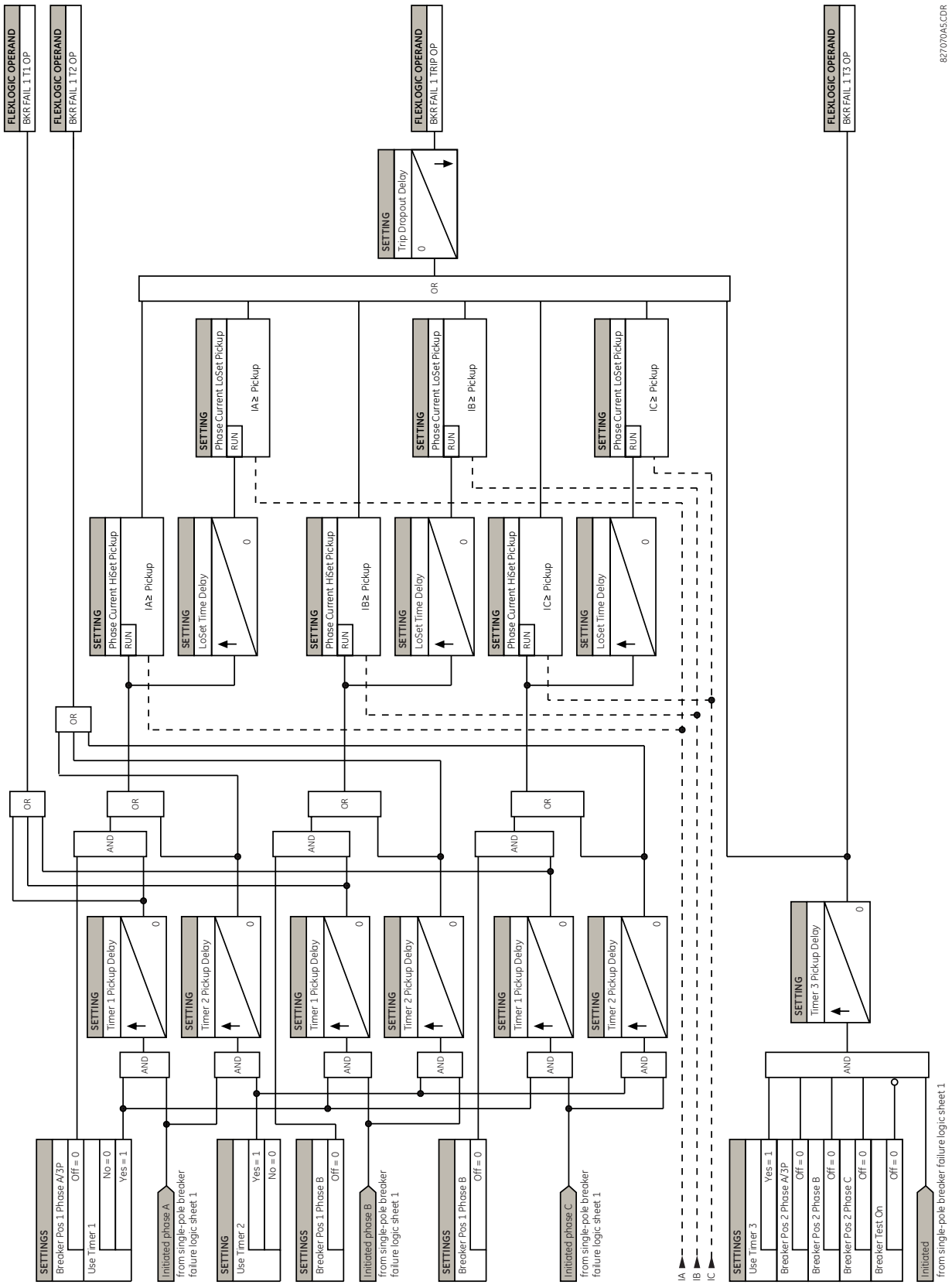


Figure 5-97: Three-pole breaker failure, initiate logic

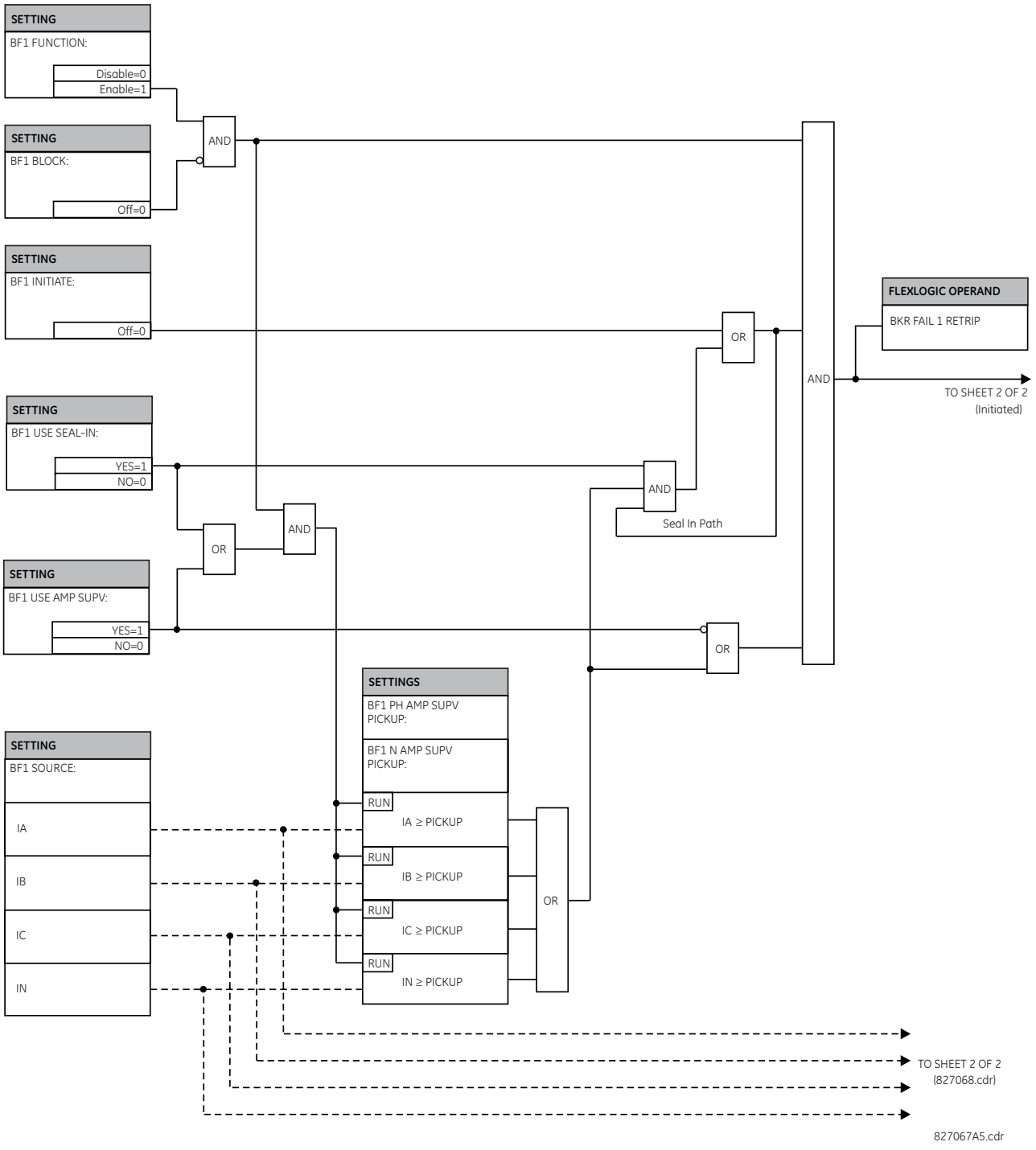
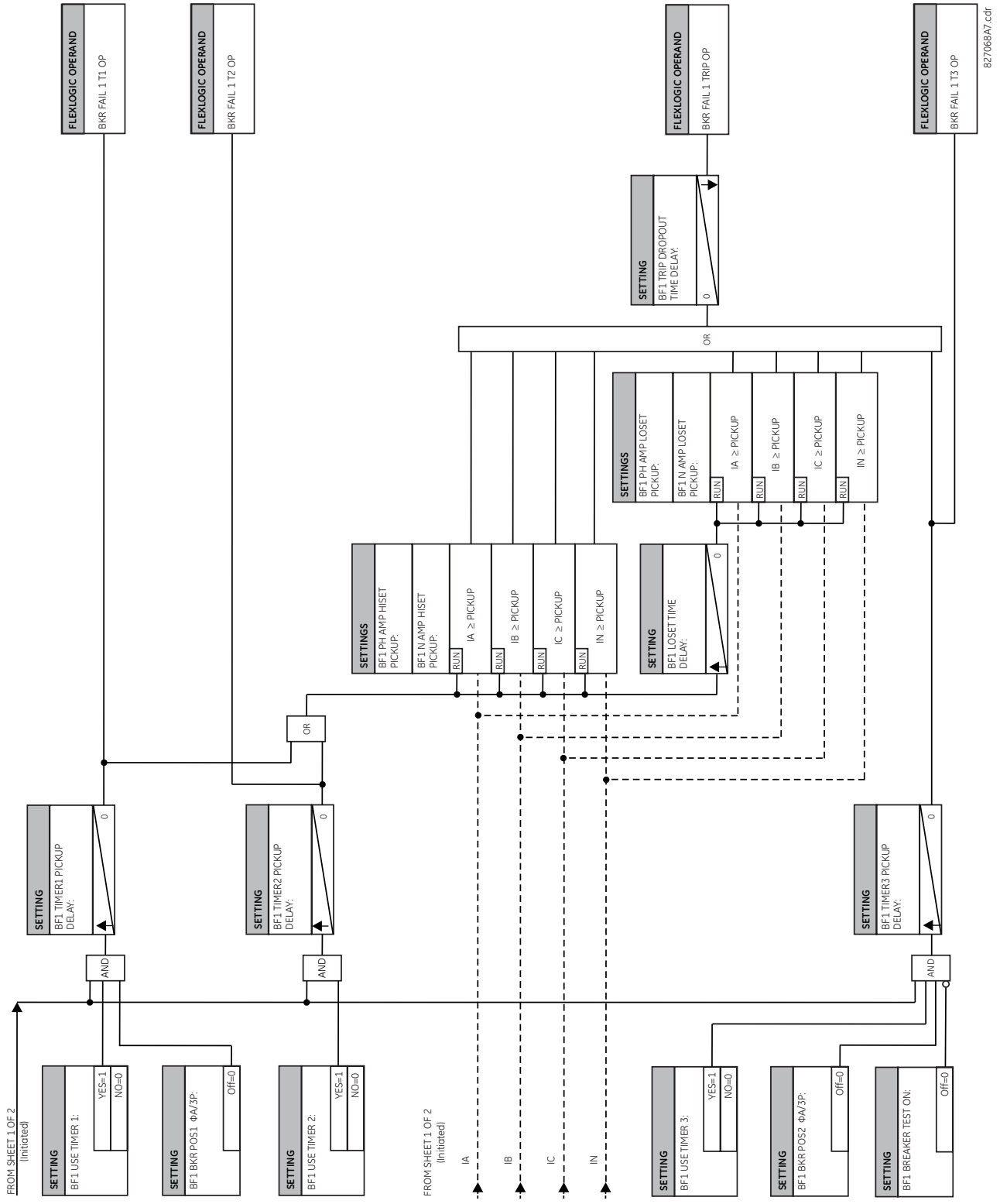


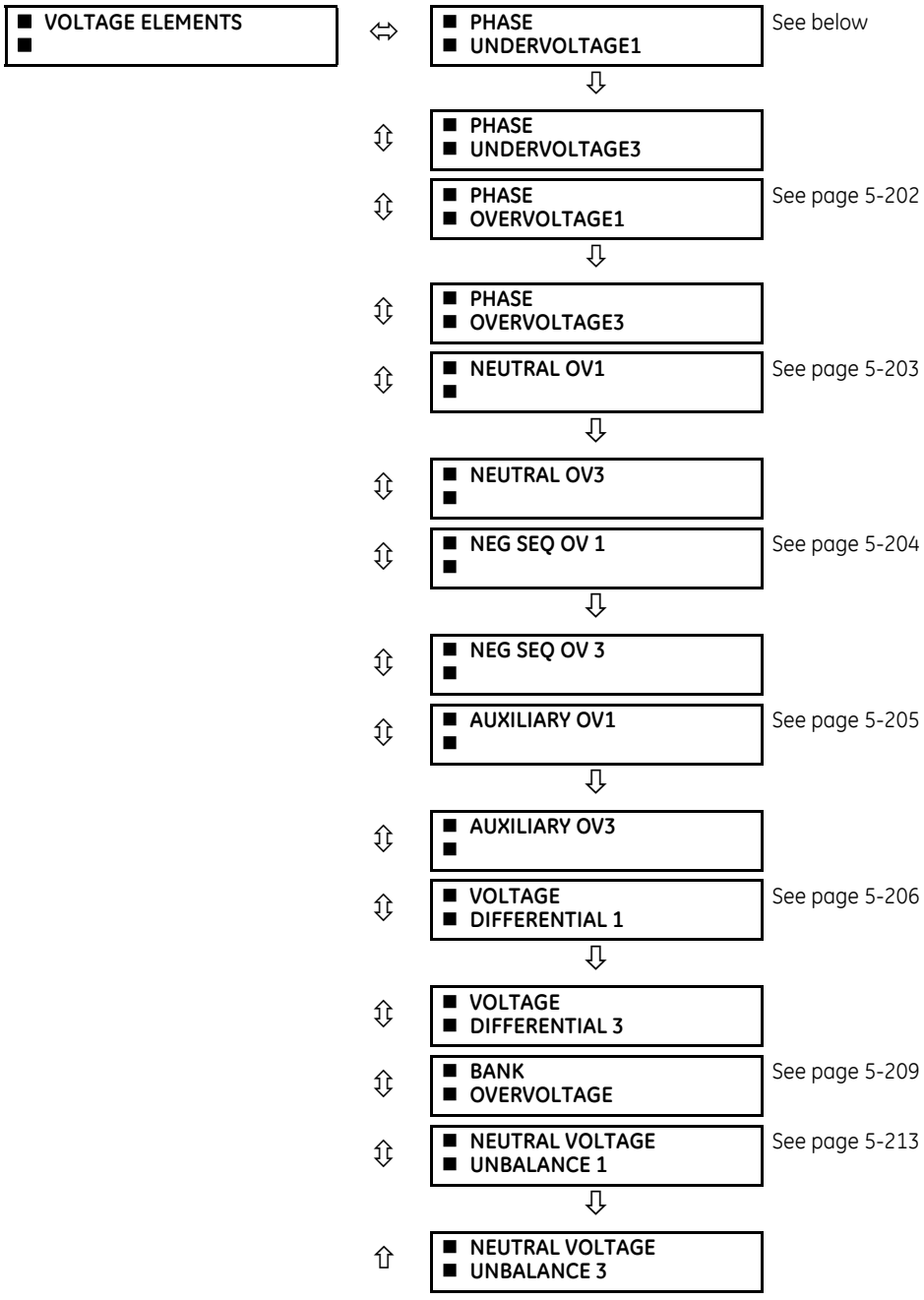
Figure 5-98: Three-pole breaker failure, timers logic



5.7.8 Voltage elements

5.7.8.1 Menu

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 can 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 can 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 can 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 can 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.

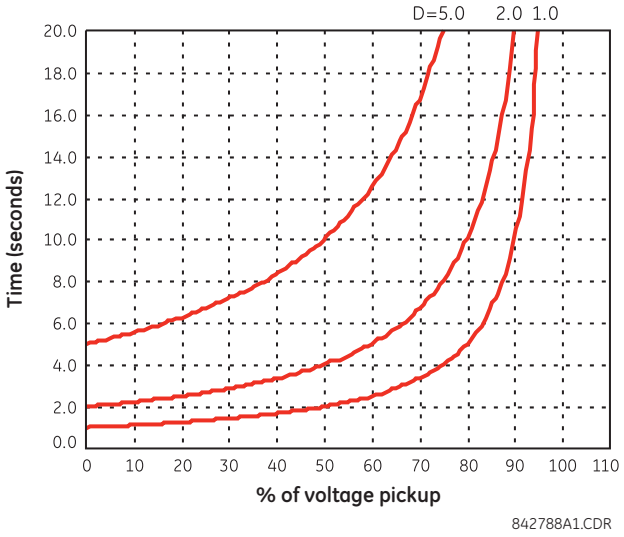
The undervoltage delay setting defines the family of curves shown as follows.

$$T = \frac{D}{\left(1 - \frac{V}{V_{pickup}}\right)} \qquad \textbf{Eq. 5-21}$$

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 5-99: Inverse time undervoltage curves



At 0% of pickup, the operating time equals the **PHASE UNDERVOLTAGE DELAY** setting.

5.7.8.2 Phase undervoltage (ANSI 27P, IEC PTUV)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨ PHASE UNDERVOLTAGE1(3)

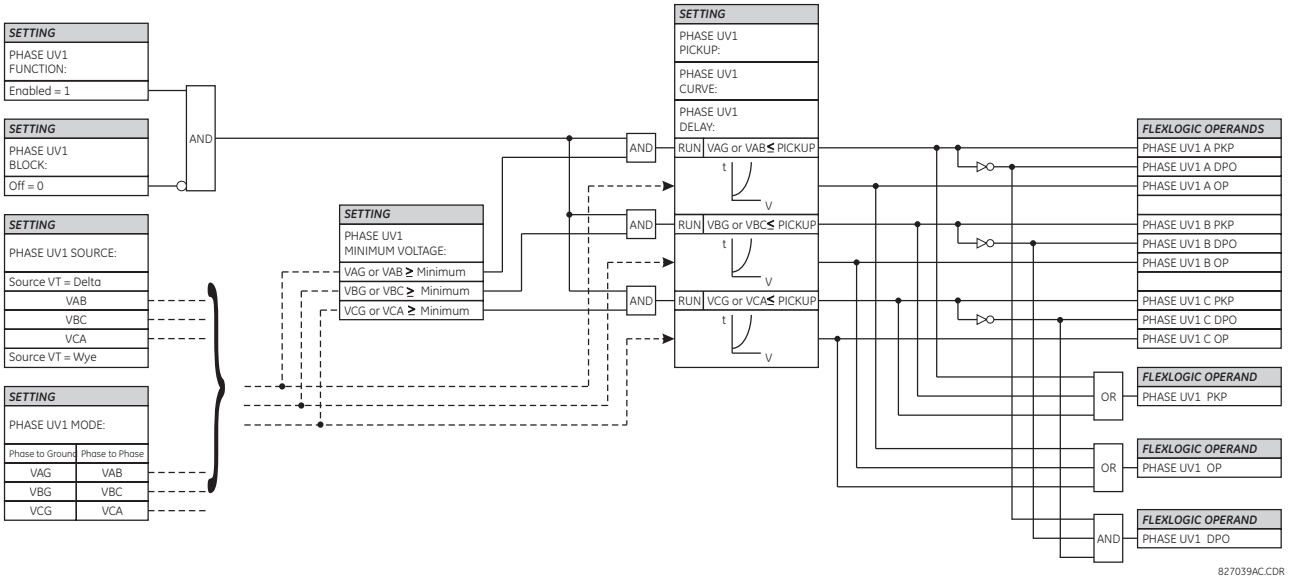
■ PHASE ■ UNDERVOLTAGE1	⇔	**PHASE UV1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇳	**PHASE UV1 SIGNAL SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇳	**PHASE UV1 MODE: Phase to Ground**	Range: Phase to Ground, Phase to Phase
	⇳	**PHASE UV1 PICKUP: 1.000 pu**	Range: 0.000 to 3.000 pu in steps of 0.001

⇳	**PHASE UV1 CURVE: Definite Time**	Range: Definite Time, Inverse Time
⇳	**PHASE UV1 DELAY: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**PHASE UV1 MINIMUM VOLTAGE: 0.100 pu**	Range: 0.000 to 3.000 pu in steps of 0.001
⇳	**PHASE UV1 BLOCK: Off**	Range: FlexLogic operand
⇳	**PHASE UV1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**PHASE UV1 EVENTS: Disabled**	Range: Disabled, Enabled

One element is provided per each VT bank to a maximum of three.

This element is used to give a 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" allows a dead source to be considered a fault condition).

Figure 5-100: Phase undervoltage1 logic



5.7.8.3 Phase overvoltage (ANSI 59P, IEC PTOV)

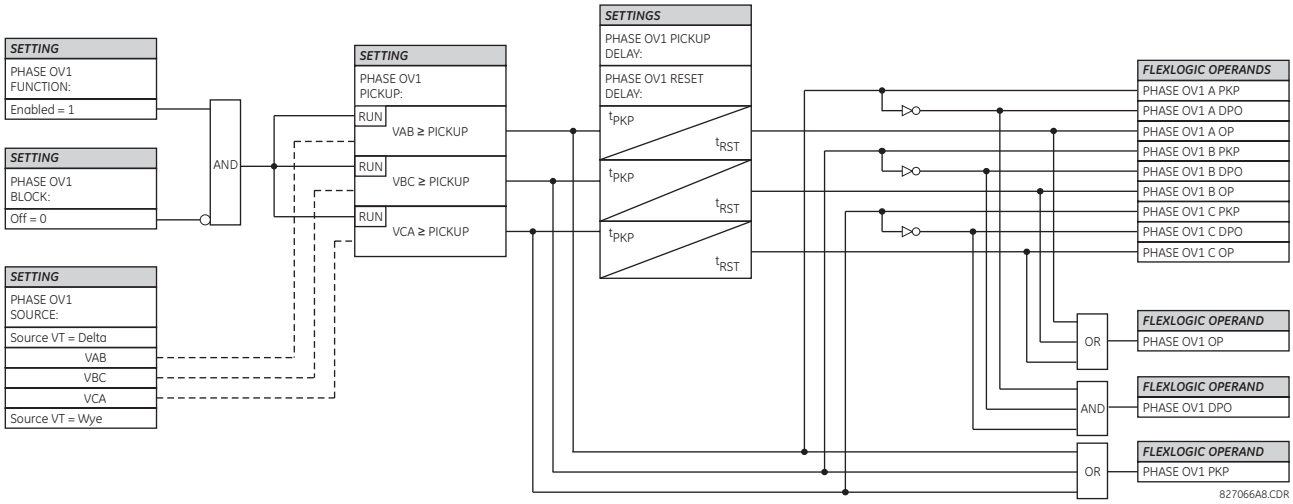
SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ PHASE OVERVOLTAGE1(3)

■ **PHASE** ■ **OVERVOLTAGE1**		
⇔	**PHASE OV1 FUNCTION: Disabled**	Range: Disabled, Enabled
⇳	**PHASE OV1 SIGNAL SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
⇳	**PHASE OV1 PICKUP: 1.000 pu**	Range: 0.000 to 3.000 pu in steps of 0.001
⇳	**PHASE OV1 PICKUP DELAY: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01

⇳	**PHASE OV1 RESET DELAY: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**PHASE OV1 BLOCK: Off**	Range: FlexLogic Operand
⇳	**PHASE OV1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇳	**PHASE OV1 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 figure shows specific voltages to be used for each phase.

Figure 5-101: Phase overvoltage 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}.

5.7.8.4 Neutral overvoltage (ANSI 59N, IEC PTOV)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ NEUTRAL OV1(3)

■ **NEUTRAL OV1** ■		
⇔	**NEUTRAL OV1 FUNCTION: Disabled**	Range: Disabled, Enabled
⇳	**NEUTRAL OV1 SIGNAL SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
⇳	**NEUTRAL OV1 PICKUP: 0.300 pu**	Range: 0.000 to 3.000 pu in steps of 0.001
⇳	**NEUTRAL OV1 CURVE: Definite time**	Range: Definite time, FlexCurve A, FlexCurve B, FlexCurve C
⇳	**NEUTRAL OV1 PICKUP: DELAY: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NEUTRAL OV1 RESET: DELAY: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01

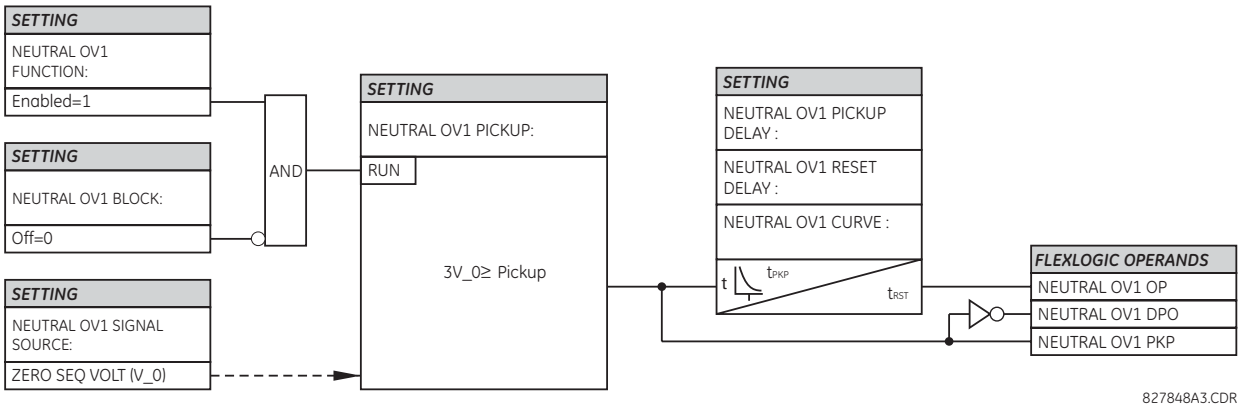
⇳	**NEUTRAL OV1 BLOCK: Off**	Range: FlexLogic operand
⇳	**NEUTRAL OV1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**NEUTRAL OV1 EVENTS: Disabled**	Range: Disabled, Enabled

There are three neutral overvoltage elements available. The neutral overvoltage element can be used to detect asymmetrical system voltage condition due to a ground fault or to the loss of one or two phases of the source. The element responds to the system neutral voltage (3V_0), calculated from the phase voltages. The nominal secondary voltage of the phase voltage channels entered under **SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK ⇨ PHASE VT SECONDARY** is the p.u. base used when setting the pickup level.

The neutral overvoltage element can provide a time-delayed operating characteristic versus the applied voltage (initialized from FlexCurves A, B, or C) or be used as a definite time element. The **NEUTRAL OV1 PICKUP DELAY** setting applies only if the **NEUTRAL OV1 CURVE** setting is "Definite time." The source assigned to this element must be configured for a phase VT.

VT errors and normal voltage unbalance must be considered when setting this element. This function requires the VTs to be wye-connected.

Figure 5-102: Neutral overvoltage1 logic



5.7.8.5 Negative-sequence overvoltage (ANSI 59Q, IEC PTOV)

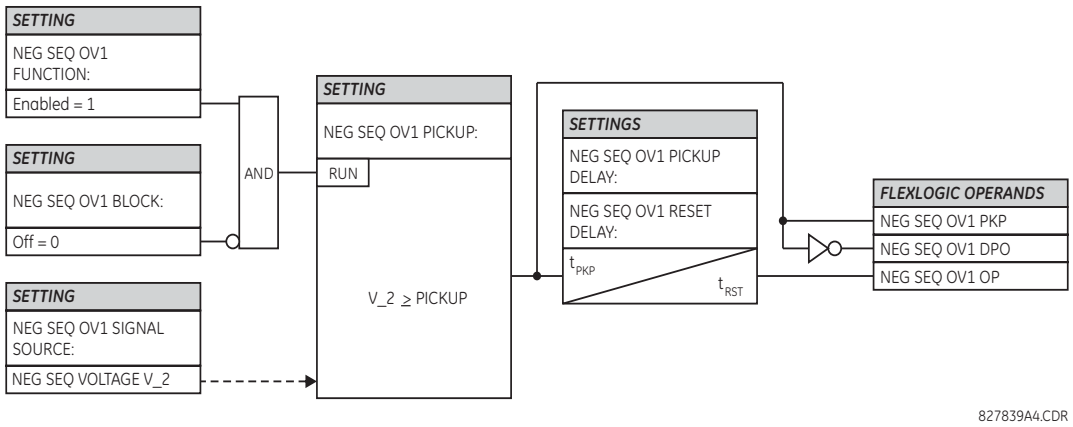
SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ NEG SEQ OV 1(3)

■ **NEG SEQ OV 1** ■	⇔	**NEG SEQ OV 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇳	**NEG SEQ OV 1 SIGNAL SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇳	**NEG SEQ OV 1 PICKUP: 0.300 pu**	Range: 0.000 to 1.250 pu in steps of 0.001
	⇳	**NEG SEQ OV 1 PICKUP DELAY: 0.50 s**	Range: 0.00 to 600.00 s in steps of 0.01
	⇳	**NEG SEQ OV 1 RESET DELAY: 0.50 s**	Range: 0.00 to 600.00 s in steps of 0.01
	⇳	**NEG SEQ OV 1 BLOCK: Off**	Range: FlexLogic operand
	⇳	**NEG SEQ OV 1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
	⇧	**NEG SEQ OV 1 EVENTS: Disabled**	Range: Disabled, Enabled

There is one negative-sequence overvoltage element available per CT bank, to a maximum of three.

Use the negative-sequence overvoltage element 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 5-103: Negative-sequence overvoltage logic



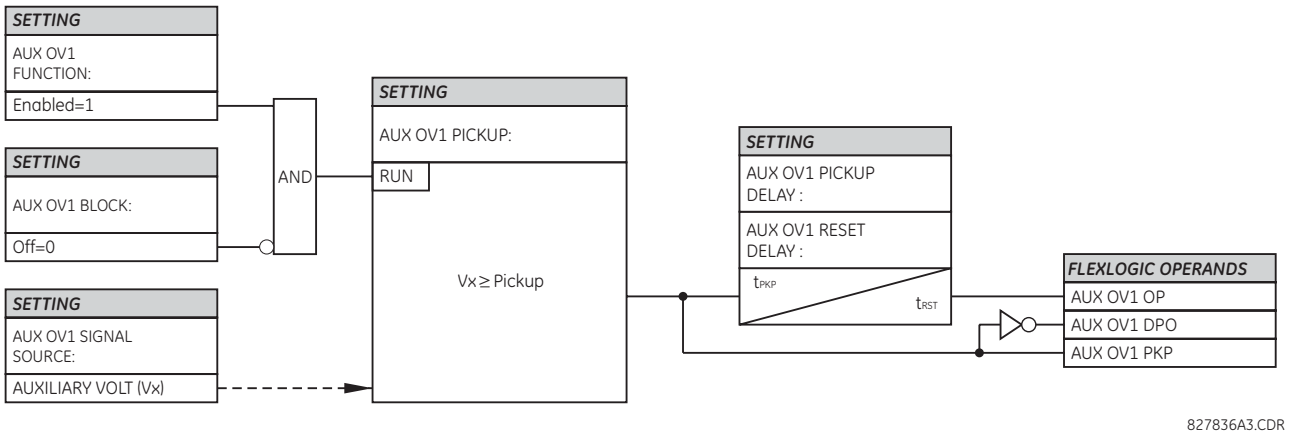
5.7.8.6 Auxiliary overvoltage (ANSI 59X, IEC PTOV)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ AUXILIARY OV1(3)

■ AUXILIARY OV1 ■	⇔	**AUX OV1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇩	**AUX OV1 SIGNAL SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇩	**AUX OV1 PICKUP: 0.300 pu**	Range: 0.000 to 3.000 pu in steps of 0.001
	⇩	**AUX OV1 PICKUP DELAY: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
	⇩	**AUX OV1 RESET DELAY: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
	⇩	**AUX OV1 BLOCK: Off**	Range: FlexLogic operand
	⇩	**AUX OV1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
	⇩	**AUX OV1 EVENTS: Disabled**	Range: Disabled, Enabled

The C70 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.

Figure 5-104: Auxiliary overvoltage logic



5.7.8.7 Bank voltage differential (ANSI 87V, IEC PDIF)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ VOLTAGE DIFFERENTIAL 1(3)

■ VOLTAGE DIFFERENTIAL 1

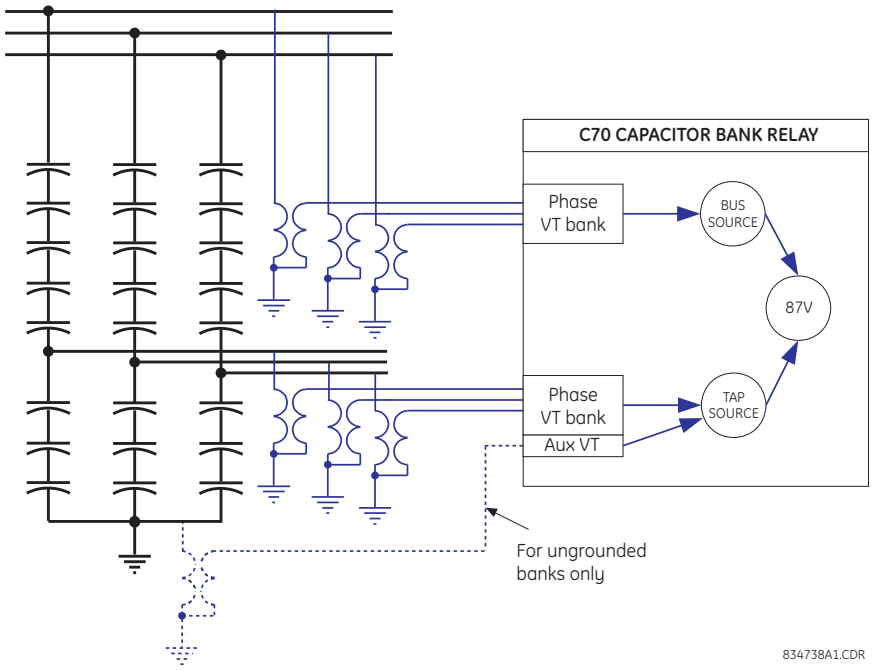
⇔	**VOLTAGE DIF 1 FUNCTION: Disabled**	Range: Disabled, Enabled
⇕	**VOLTAGE DIF 1 BUS SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
⇕	**VOLTAGE DIF 1 TAP SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
⇕	**VOLTAGE DIF 1 BANK GROUND: Grounded**	Range: Grounded, Ungrounded
⇕	**VOLTAGE DIF 1 MATCH FACTOR A: 2.0000**	Range: 0.5000 to 2000.0000 in steps of 0.0001
⇕	**VOLTAGE DIF 1 MATCH FACTOR B: 2.0000**	Range: 0.5000 to 2000.0000 in steps of 0.0001
⇕	**VOLTAGE DIF 1 MATCH FACTOR C: 2.0000**	Range: 0.5000 to 2000.0000 in steps of 0.0001
⇕	**VOLTAGE DIF 1 STG 1A PICKUP: 0.010 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇕	**VOLTAGE DIF 1 STG 2A PICKUP: 0.020 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇕	**VOLTAGE DIF 1 STG 3A PICKUP: 0.030 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇕	**VOLTAGE DIF 1 STG 4A PICKUP: 0.040 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇕	**VOLTAGE DIF 1 STG 1B PICKUP: 0.010 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇕	**VOLTAGE DIF 1 STG 2B PICKUP: 0.020 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇕	**VOLTAGE DIF 1 STG 3B PICKUP: 0.030 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇕	**VOLTAGE DIF 1 STG 4B PICKUP: 0.040 pu**	Range: 0.001 to 1.000 pu in steps of 0.001

⇳	**VOLTAGE DIF 1 STG 1C PICKUP: 0.010 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇳	**VOLTAGE DIF 1 STG 2C PICKUP: 0.020 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇳	**VOLTAGE DIF 1 STG 3C PICKUP: 0.030 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇳	**VOLTAGE DIF 1 STG 4C PICKUP: 0.040 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇳	**VOLTAGE DIF 1 STG 1 PKP DELAY: 30.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**VOLTAGE DIF 1 STG 2 PKP DELAY: 10.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**VOLTAGE DIF 1 STG 3 PKP DELAY: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**VOLTAGE DIF 1 STG 4 PKP DELAY: 0.20 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**VOLTAGE DIF 1 DPO DELAY: 0.25 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**VOLT DIF 1 BLK STG1: Off**	Range: FlexLogic operand
⇳	**VOLT DIF 1 BLK STG 2: Off**	Range: FlexLogic operand
⇳	**VOLT DIF 1 BLK STG 3: Off**	Range: FlexLogic operand
⇳	**VOLT DIF 1 BLK STG 4: Off**	Range: FlexLogic operand
⇳	**VOLT DIF 1 TARGET: Self-Reset**	Range: Self-reset, Latched, Disabled
⇧	**VOLT DIF 1 EVENTS: Disabled**	Range: Disabled, Enabled

Up to three identical voltage differential elements, one per each VT bank configured in hardware, are provided.

The element responds to a differential signal between magnitudes of the bus and tap voltages. The latter is scaled using a matching factor to account for the position of the tap. An automatic setting procedure is available under the **COMMAND** menu to calculate automatically the matching factor when installing the relay or after repairs of the bank.

Figure 5-105: Voltage differential basic connections



The function works with grounded and ungrounded banks. In the latter case, the neutral point voltage must be measured by the relay. For information, see the Application of Settings chapter.

The following settings are available for each voltage differential element.

VOLTAGE DIF 1 BUS SOURCE — Indicates signal source that signifies the bus voltage of the bank. The function uses this source as reference for pu settings of pickup thresholds, and scales the tap voltages to this signal level. The VT ratio and secondary nominal voltage are set under separate menu. Voltages of this source must be connected in wye for the function to operate.

VOLTAGE DIF 1 TAP SOURCE — Indicates signal source that signifies the tap voltage of the bank. The function scales this voltage to the bus level using the matching factor setting. The matching is performed on primary voltages, or per unit of the bus voltage. The VT ratio and secondary nominal voltage are set under separate menu. Voltages of this source must be connected in wye for the function to operate. If this function is used on ungrounded banks, the tap source must have the neutral point voltage of the bank configured under the auxiliary voltage channel. That auxiliary voltage must be labelled "Vn" under the VT setup menu.

VOLTAGE DIF 1 BANK GROUND — Indicates if the protected bank is grounded or ungrounded. In the latter case, the auxiliary voltage configured under the tap source is subtracted from the phase voltages of both the bus and tap. This results in the actual voltage drop along the capacitor string, and thus facilitates the voltage differential principle. The relay automatically compensates for different VT ratios and secondary voltages of the neutral point voltage and the bus and tap voltages.

VOLTAGE DIF 1 MATCH FACTOR A to **VOLTAGE DIF 1 MATCH FACTOR C** — Specifies the division ratio of the healthy bank, that is, the ratio between the bus and tap voltages (value greater than 1). The matching factor is applied as a multiplier for the primary tap voltage before comparing with the primary bus voltage. Quality of balancing the bank with a given value of this setting can be viewed under the **ACTUAL VALUES** menu. An automatic setting procedure is available under the **COMMANDS** menu to calculate the matching factors automatically.

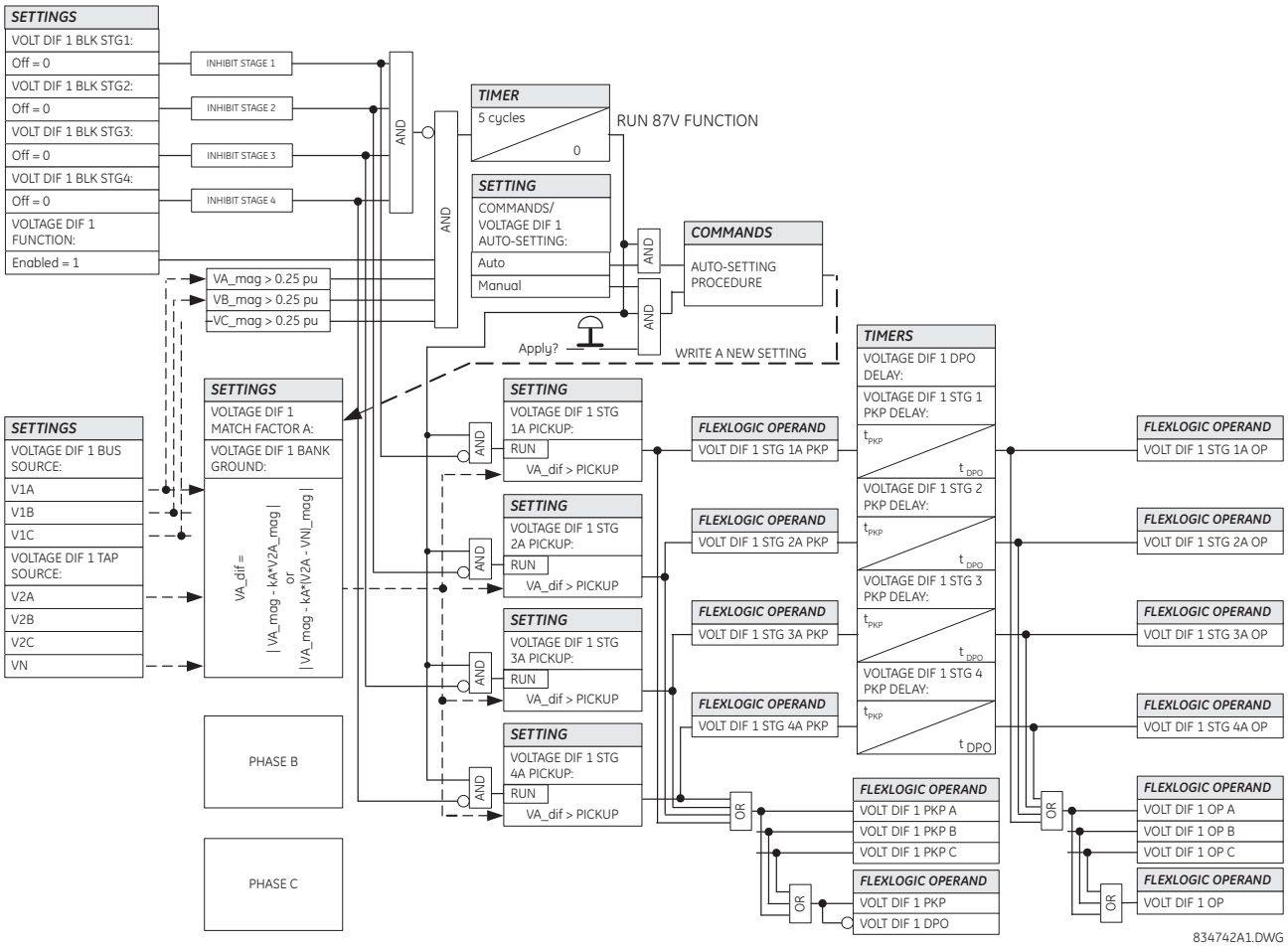
VOLTAGE DIF 1 STG 1A PICKUP to **VOLTAGE DIF 1 STG 4C PICKUP** — Specify pickup thresholds for stages 1 through 4 for phases A to C in per-units (pu) of the nominal bus voltage. A value of 1 pu is a product of the nominal secondary voltage and VT ratio of the voltage bank configured under the bus source of this function. Four independent stages are provided for each phase of protection.

VOLTAGE DIF 1 STG 1 PKP DELAY — Specifies the pickup time delay, individually per each stage of alarming/tripping. Note that each of the 12 comparators (four stages in three phases) uses an individual timer, but settings for these timers are controlled individually per each stage, not per phase. The timers use a common drop-out time delay specified by the next setting.

VOLTAGE DIF 1 DPO DELAY — Controls a drop out delay for the operate FlexLogic operands. Note that individual stages apply individually configurable pickup delays, but use this common drop out delay.

VOLT DIF 1 BLK STG 1 to **VOLT DIF 1 BLK STG 4** — These inputs are used to block the function on a per stage basis when required. At minimum this function shall be blocked when the bank is offline, or else it operates unnecessarily. Either breaker position or undercurrent indication via any available instantaneous function, or a combination, can be used for blocking. Also consider the VT fuse fail condition from both the bus and tap VT. When unblocked, the function becomes operational after five cycles of intentional delay.

Figure 5-106: Voltage differential logic



5.7.8.8 Bank phase overvoltage (ANSI 59B, IEC PTOV)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ BANK OVERVOLTAGE ⇨ BANK OVERVOLTAGE 1(3)

■ **BANK OVERVOLTAGE 1** ■	⇔	**BANK OV 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇩	**BANK OV 1 BUS SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6

⇳	**BANK OV 1 NTRL SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
⇳	**BANK OV 1 BANK GROUND: Grounded**	Range: Grounded, Ungrounded, Ungr w/o Vn
⇳	**BANK OV 1 CURVE: FlexCurve A**	Range: FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D
⇳	**BANK OV 1 CURVE TIME MULTIPLIER: 1.00**	Range: 1.00 to 10.00 in steps of 0.01
⇳	**BANK OV 1 STG 1A PICKUP: 1.050 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 2A PICKUP: 1.100 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 3A PICKUP: 1.200 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 4A PICKUP: 1.050 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 1B PICKUP: 1.050 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 2B PICKUP: 1.100 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 3B PICKUP: 1.200 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 4B PICKUP: 1.050 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 1C PICKUP: 1.050 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 2C PICKUP: 1.100 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 3C PICKUP: 1.200 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 4C PICKUP: 1.050 pu**	Range: 0.800 to 2.000 pu in steps of 0.001
⇳	**BANK OV 1 STG 1 PKP DELAY: 60.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**BANK OV 1 STG 2 PKP DELAY: 10.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**BANK OV 1 STG 3 PKP DELAY: 2.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**BANK OV 1 STG 4 PKP DELAY: 0.20 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**BANK OV 1 DPO DELAY: 0.25 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**BANK OV 1 BLK: Off**	Range: FlexLogic operand
⇳	**BANK OV 1 TARGET: Self-Reset**	Range: Self-reset, Latched, Disabled
⇧	**BANK OV 1 EVENTS: Disabled**	Range: Disabled, Enabled

Up to three identical bank overvoltage elements, one per each VT bank configured in hardware, are provided.

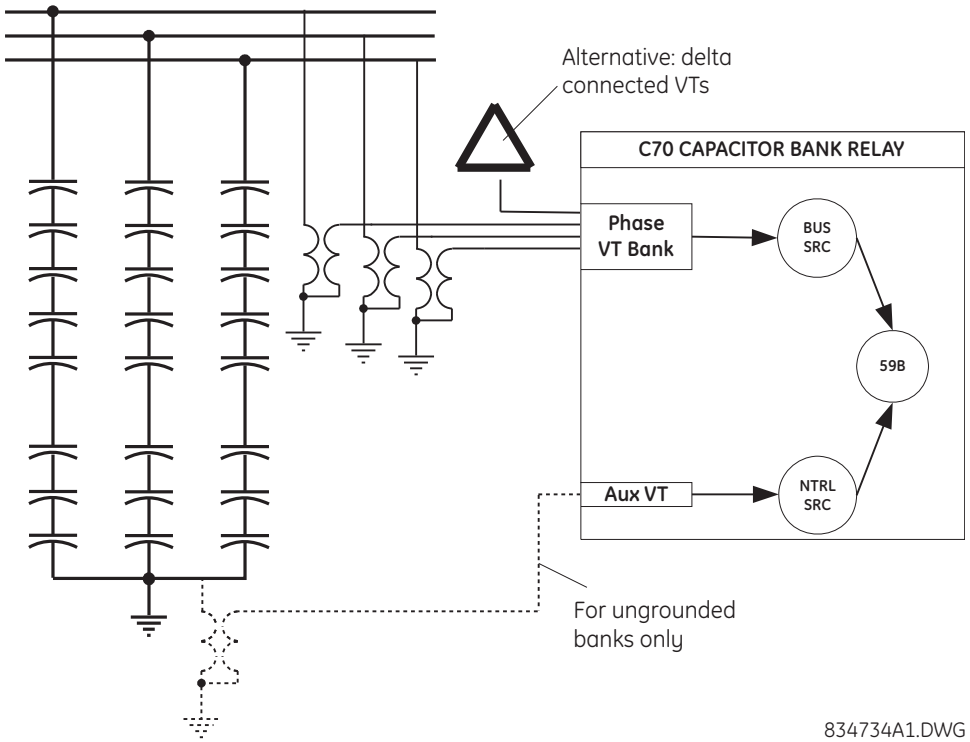
The bank phase overvoltage element responds to voltages across the capacitors of the bank. Three stages of definite time operation, and one stage of inverse time operation are provided. Pickup thresholds of this function are adjustable on a per-phase basis. The shape of the inverse time curve is user-programmable (via FlexCurves™) with individual pickup levels and a multiplier common for all three phases. The definite time delays are individually programmable per stage.

The function works with grounded and ungrounded banks. With ungrounded banks, either the neutral point voltage is measured by the relay and used to derive the true bank voltage based on the bus and neutral-point voltages, or a simplified method to provide proper voltage protection is used responding to vector differences between the phase-to-phase voltages.

When fed from wye-connected VTs, the function responds to phase-to-ground voltages. When fed from delta-connected VTs, it responds to the vector difference between the phase-to-phase voltages.

The function responds to true RMS voltages to account for effects of harmonics (harmonics impacting losses in the capacitor, harmonics increasing peak values in the voltages compared with the filtered fundamental frequency magnitudes).

Figure 5-107: Bank overvoltage basic connections



For more information, see the Application of Settings chapter.

The following settings are available for each bank phase overvoltage element.

BANK OV 1 BUS SOURCE — Indicates the signal source that signifies the bus voltage of the capacitor bank. The function uses this source as reference for per-unit (pu) settings of the pickup thresholds. The VT ratio and secondary nominal voltage are set under the **SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK** menu.

BANK OV 1 NTRL SOURCE — Indicates the signal source that signifies the neutral-point voltage of the bank. The auxiliary voltage channel of this source is used, and must be labelled "Vn" under the VT setup menu. The neutral point voltage is used only when the function is applied to an ungrounded bank, to derive the true voltage drop across the capacitors. The VT ratio and secondary nominal voltage are set under the **SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK** menu.

BANK OV 1 BANK GROUND — This setting indicates if the protected bank is grounded, ungrounded with the neutral point voltage measured, and ungrounded without the neutral point voltage. The relay automatically compensates for potentially different VT ratios and secondary voltages of the bus and neutral point voltages. The following table explains the operating signals of the function based on the input signals available to the relay.

Table 5-35: Operating signals based on input signals

VT connection	Bank configuration		
	Grounded	Ungrounded	Ungrounded w/o VN
Wye	Vop_A = VA Vop_B = VB Vop_C = VC	Vop_A = VA – VX Vop_B = VB – VX Vop_C = VC – VX	Vop_A = (VCA – VAB) / 3 Vop_B = (VAB – VBC) / 3 Vop_C = (VBC – VCA) / 3
Delta	Vop_A = (VCA – VAB) / 3 Vop_B = (VAB – VBC) / 3 Vop_C = (VBC – VCA) / 3		

BANK OV 1 CURVE — This setting specifies a FlexCurve used by the fourth inverse time stage of this function. FlexCurves are user-programmable on a point-by-point basis. This function applies a common curve shape in all three phases. However, the curve is specified as time versus multiple of pickup. With three individually programmable pickup values per phase one accommodates possible differences between individual phases of the bank even though a common curve shape is used.

Implementation of the inverse-time stage is based on the concept of a virtual disk emulating electromechanical relays. When above the pickup level, the function integrates towards the trip level at the rate dictated by the curve at a given multiple of pickup. When activated but with the operating signal below the pickup, the function integrates down toward a complete reset. This mode of operation assures dependability in situations when the voltage oscillates and causes stress to the protected capacitor in repetitive cycles each lasting too short to expire a straight timer. As a result of this implementation, the shape of the curve below multiple of pickup of 1 is important as it controls the speed of reset of a partially energized function.

BANK OV 1 STG 1A PICKUP to **BANK OV 1 STG 3C PICKUP** — Specify pickup thresholds for stages 1 through 3 in phases A through C in per-units (pu) of the nominal phase-to-ground bus voltage. A value of 1 pu is a product of the nominal secondary voltage and VT ratio of the voltage bank configured under the bus source of this function. With a delta VT configuration, a value of 1 pu is a product of the nominal secondary voltage and VT ratio divided by $\sqrt{3}$. Three independent stages of definite-time operation are provided for each phase of the bank.

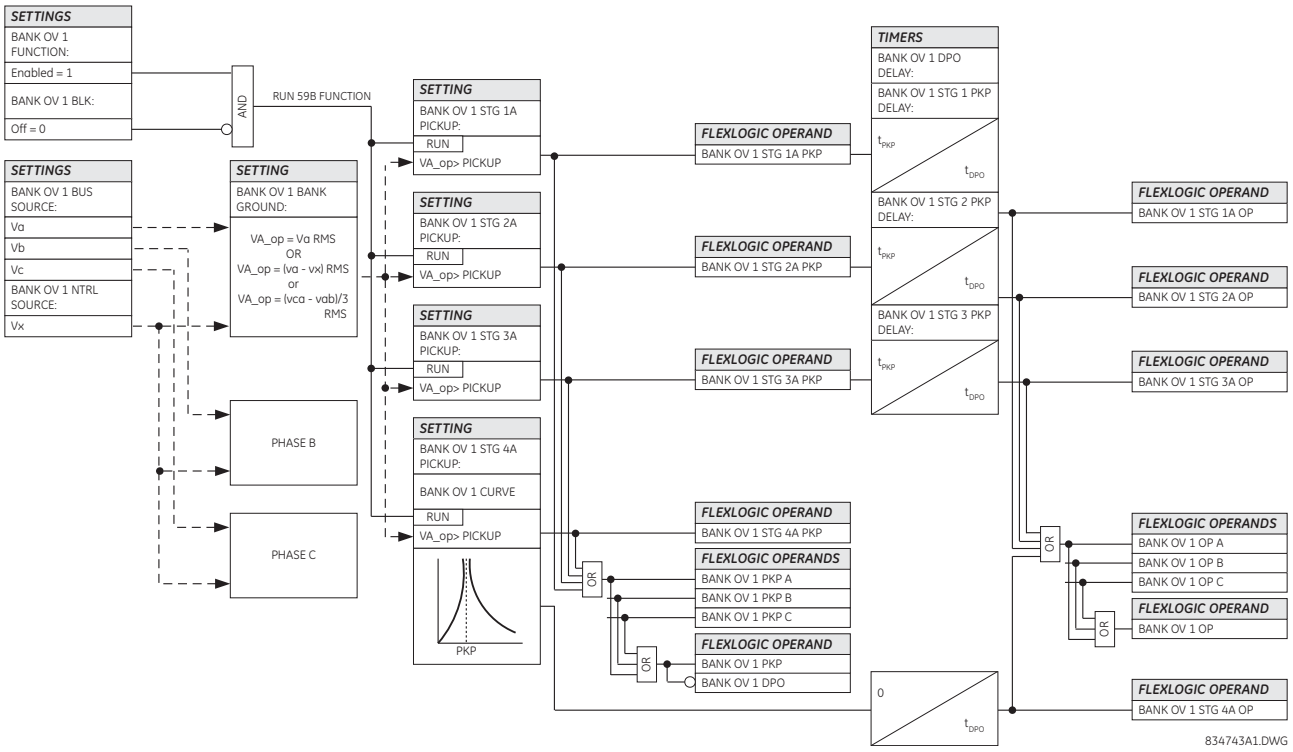
BANK OV 1 STG 4A PICKUP to **BANK OV 1 STG 4C PICKUP** — Specify pickup thresholds for the inverse time stage 4 in phase A through C in per-units (pu) of the nominal phase-to-ground bus voltage. With a wye VT configuration, a value of 1 pu is a product of the nominal secondary voltage and VT ratio of the voltage bank configured under the bus source of this function. With a delta VT configuration, a value of 1 pu is a product of the nominal secondary voltage and VT ratio divided by $\sqrt{3}$. The inverse time stage uses a user-programmable FlexCurve selected by the **BANK OV 1 CURVE** setting.

BANK OV 1 STG 1 PKP DELAY to **BANK OV 1 STG 3 PKP DELAY** — Specify the pickup time delays for each definite time stage of alarming/tripping. Note that each of the nine comparators (three definite-time stages in three phases) uses an individual timer, but settings for these timers are controlled individually per each stage, not per phase. The timers use a common dropout time delay specified by the **BANK OV 1 DPO DELAY** setting.

BANK OV 1 DPO DELAY — This setting controls a dropout delay for the operate FlexLogic operands. Note that individual stages apply individually configurable pickup delays, but use this common dropout delay.

BANK OV 1 BLK — This input is used to block the function when required; in particular, when the bank is offline.

Figure 5-108: Bank phase overvoltage logic



5.7.8.9 Neutral voltage unbalance (ANSI 59NU, IEC PVCB/PTOV)

SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ NEUTRAL VOLTAGE UNBALANCE 1(3)

■ NEUTRAL VOLTAGE ■ UNBALANCE 1	⇔	NTRL VOL UNBAL 1 FUNCTION: Disabled	Range: Disabled, Enabled
	⇕	NTRL VOL UNBAL 1 NTRL SOURCE: SRC 1	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇕	NTRL VOL UNBAL 1 BUS SOURCE: SRC 1	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇕	NTRL VOL UNBAL 1 BUS 3V0: Calculated	Range: Calculated, Measured
	⇕	NTRL VOL UNBAL 1 GROUND: VT (ungrnd)	Range: VT (ungrnd), CTxR (grnd)
	⇕	NTRL VOL UNBAL 1 AB RATIO: 1.0000	Range: 0.7500 to 1.2500 in steps of 0.0001
	⇕	NTRL VOL UNBAL 1 AC RATIO: 1.0000	Range: 0.7500 to 1.2500 in steps of 0.0001
	⇕	NTRL VOL UNBAL 1 STG 1 PKP: 0.010 pu	Range: 0.001 to 1.000 pu in steps of 0.001
	⇕	NTRL VOL UNBAL 1 STG 1 SLOPE: 0.0%	Range: 0.0 to 10.0% in steps of 0.1
	⇕	NTRL VOL UNBAL 1 STG 2 PKP: 0.020 pu	Range: 0.001 to 1.000 pu in steps of 0.001

⇳	**NTRL VOL UNBAL 1 STG 2 SLOPE: 0.0%**	Range: 0.0 to 10.0% in steps of 0.1
⇳	**NTRL VOL UNBAL 1 STG 3 PKP: 0.020 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇳	**NTRL VOL UNBAL 1 STG 3 SLOPE: 5.0%**	Range: 0.0 to 10.0% in steps of 0.1
⇳	**NTRL VOL UNBAL 1 STG 4 PKP: 0.030 pu**	Range: 0.001 to 1.000 pu in steps of 0.001
⇳	**NTRL VOL UNBAL 1 STG 4 SLOPE: 5.0%**	Range: 0.0 to 10.0% in steps of 0.1
⇳	**NTRL VOL UNBAL 1 STG 1 PKP DELAY: 30.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NTRL VOL UNBAL 1 STG 2 PKP DELAY: 10.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NTRL VOL UNBAL 1 STG 3 PKP DELAY: 1.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NTRL VOL UNBAL 1 STG 4 PKP DELAY: 0.20 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NTRL VOL UNBAL 1 DPO DELAY: 0.25 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**NTRL VOL 1 BLK STG1: Off**	Range: FlexLogic operand
⇳	**NTRL VOL 1 BLK STG2: Off**	Range: FlexLogic operand
⇳	**NTRL VOL 1 BLK STG3: Off**	Range: FlexLogic operand
⇳	**NTRL VOL 1 BLK STG4: Off**	Range: FlexLogic operand
⇳	**NTRL VOL UNBAL 1 TARGET: Self-Reset**	Range: Self-reset, Latched, Disabled
⇧	**NTRL VOL UNBAL 1 EVENTS: Disabled**	Range: Disabled, Enabled

Up to three identical neutral voltage unbalance elements, one per each VT bank configured in hardware, are provided.

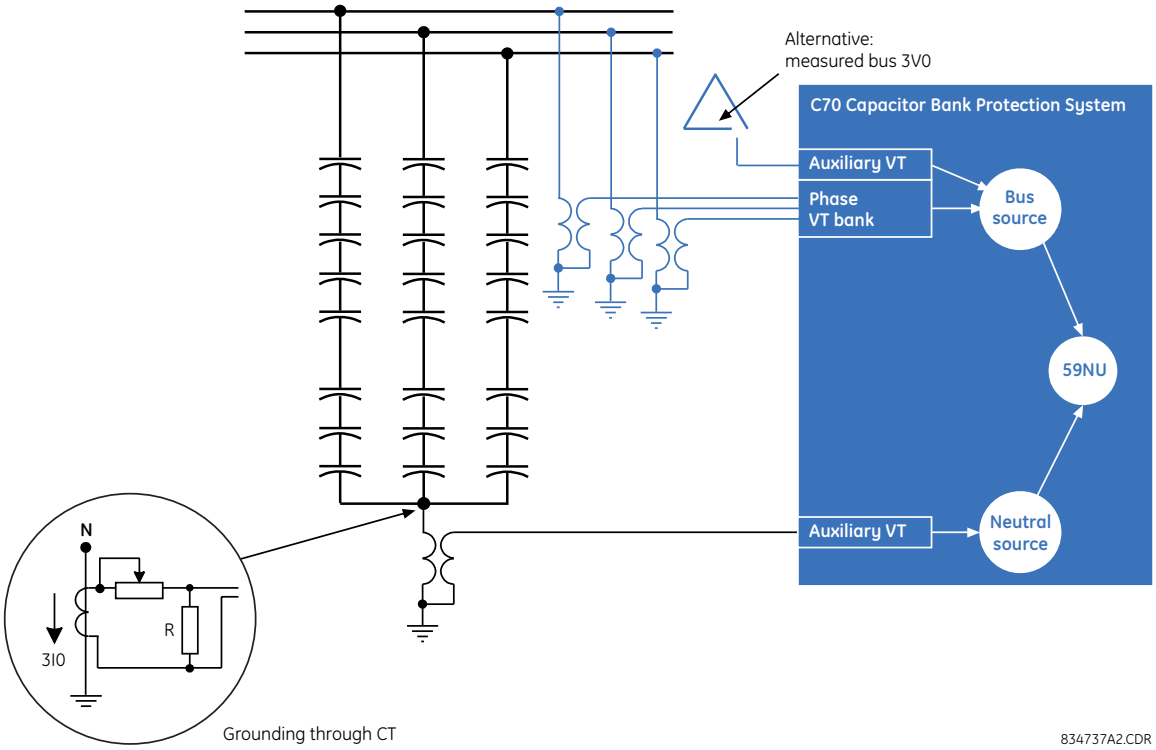
The element responds to the voltage signal at the neutral point of the capacitor bank. The operating equations are properly compensated for both the system unbalance such as during close-in external faults, and the inherent bank unbalance. The bus zero-sequence voltage required for compensation of the system unbalance can be measured internally to the relay from phase voltages, or delivered as a 3V0 signal from an open-corner-delta VT via an auxiliary voltage channel of the relay.

Compensation for the inherent unbalance of the protected bank uses the B and C phase voltages, and thus this function requires wye connected phase VTs. The inherent unbalance is zeroed out using ratios of the reactances between the reference phase A, and the two other phases. An automatic setting procedure is available under the **COMMAND** menu to calculate the compensating factors automatically when installing the relay, or after repairs of the bank.

To enhance performance under large system unbalances when the neutral-point and system zero-sequence voltages can become significant, a concept of a restraint is introduced. The slope of the operating characteristic is user adjustable, and if required, it can be effectively removed yielding a straight compensated overvoltage function.

For information, see the Application of Settings chapter.

Figure 5-109: Neutral voltage unbalance basic connection



The following settings are available for all three neutral voltage unbalance elements.

NTRL VOL UNBAL 1 NTRL SOURCE — Indicates signal source that signifies the neutral-point voltage of the protected bank. This single-phase voltage is to be configured under the auxiliary VT channel. The VT ratio and secondary nominal voltage are set under separate menu. Nominal voltage of this auxiliary channel becomes a unit (1 pu) for the pickup settings of this function.

NTRL VOL UNBAL 1 BUS SOURCE — Indicates signal source that signifies the bus voltages of the bank. This source must have the phase voltages configured in order to facilitate compensation for the inherent unbalance of the bank. The zero-sequence voltage required for system unbalance compensation can be derived from the phase voltages, or delivered to the relay from an external source, typically a broken-delta VT (the selection is controlled by the next setting of this function). In the latter case, the 3V0 signal is expected and must be wired and configured under the auxiliary voltage channel of this source. This 3V0 voltage must be labelled as "Vn" under the VT configuration. The VT ratio and secondary nominal voltage are set under separate menu. Phase voltages of this source must be connected in wye for the function to operate. The function uses several voltages potentially produced by VTs of different ratios and nominal secondary values. The relay scales all the signals automatically for meaningful calculations.

NTRL VOL UNBAL 1 BUS 3V0 — Specifies the source of the bus zero-sequence voltage required for system unbalance compensation. If set to "Calculated", the relay would derive the zero-sequence voltage as a vector sum of the three phase voltages and will run the function if voltage in all three phases is greater than 0.25 pu. If set to "Measured", the relay expects the 3V0 signal (not a V0) to be wired to the relay under the auxiliary channel of the bus source, and labelled as "Vn". In this case, the voltage check to run this function is not performed.

NTRL VOL UNBAL 1 GROUND — Selects the grounding arrangement of the bank. For ungrounded banks, set it to "VT (ungrnd)". When the bank neutral is solidly grounded through the CT with a resistor in the CT secondary, set it as "CTxR (grnd)".

When the "CTxR (grnd)" value is selected, the measured bank neutral point voltage is shifted by 90° lagging to compensate for the angular difference between the bus neutral voltage and the voltage derived from the bank neutral point current. Choose the value of resistor R so the voltage measured by the auxiliary input of the relay matches bus V0 during system faults (for example, an SLG fault at the bus). This is accomplished by the following condition:

$$\frac{3V0_{BUS}}{n_{BUS\_VT}} - \frac{3I0_{NTRL} \times R \times n_{NTRL\_VT}}{n_{NTRL\_CT} \times n_{BUS\_VT}} = 0 \qquad \textbf{Eq. 5-22}$$

where

$V0_{BUS}$ is the bus primary zero-sequence voltage during system fault

$3I0_{NTRL}$ is the primary current in the bank neutral during system fault

n_{BUS_VT} is the bus VT ratio set in the source selected by the **NTRL VOL UNBAL 1 BUS SOURCE** setting

n_{NTRL_VT} is a neutral point VT ratio set in the source selected by the **NTRL VOL UNBAL 1 NTRL SOURCE** setting. If R can be chosen precisely, then n_{NTRL_VT} can be set same as n_{BUS_VT}. If R cannot be chosen precisely, then n_{NTRL_VT} is used to match zero-sequence voltage as per the equation above.

n_{NTRL_CT} is the CT ratio in the bank neutral

NTRL VOL UNBAL 1 AB RATIO — This setting compensates for the bank inherent unbalance. Physically this value is a ratio of the reactance in phase A divided by the reactance in phase B. Auto-setting procedure is available under the Commands menu to calculate this value automatically. When tuning this setting manually, after bank repairs, this ratio shall be increased or decreased from the nominal value of 1.00 depending on whether the A or B phase got affected by failures or repairs and whether a given reactance increased or decreased as a result of the failure or repair. Use this setting only when the **NTRL VOL UNBAL 1 BUS 3V0** setting is set as "Calculated."

5

NTRL VOL UNBAL 1 AC RATIO — Compensates for the bank inherent unbalance. Physically this value is a ratio of the reactance in phase A divided by the reactance in phase C. Auto-setting procedure is available under the Commands menu to calculate this value automatically. When tuning this setting manually, after bank repairs, this ratio shall be increased or decreased from the nominal value of 1.00 depending on whether the A or C phase got affected by failures or repairs and whether a given reactance increased or decreased as a result of the failure or repair. Use this setting only when the **NTRL VOL UNBAL 1 BUS 3V0** setting is set as "Calculated".

NTRL VOL UNBAL 1 STG 1 PKP to **NTRL VOL UNBAL 1 STG 1 PKP** — Specify pickup thresholds for stages 1 through 4 of the function in per-units (pu) of the nominal value of the neutral-point VT (the auxiliary channel of the neutral source).

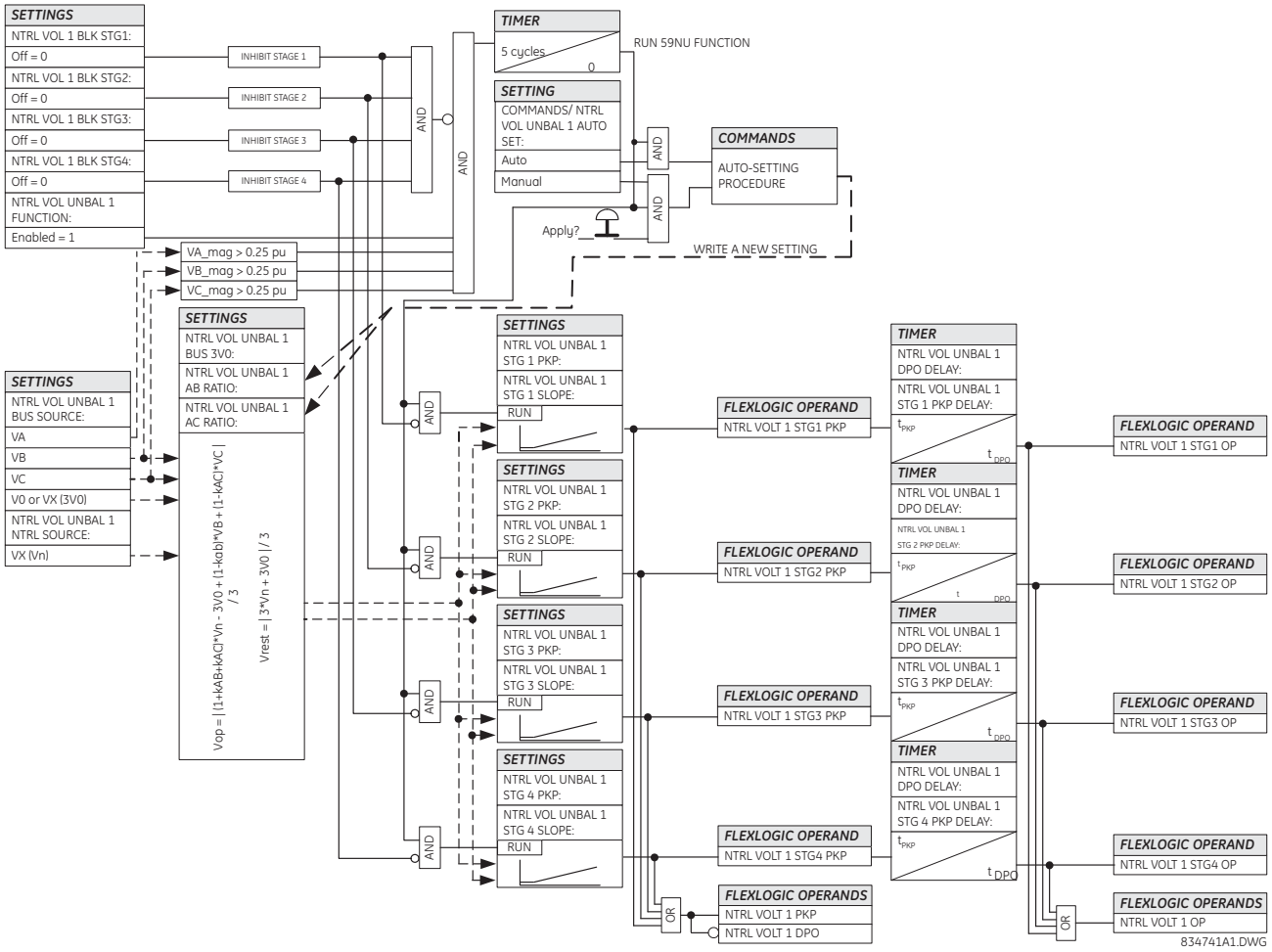
NTRL VOL UNBAL 1 STG 1 SLOPE to **NTRL VOL UNBAL 1 STG 4 SLOPE** — Specify the slopes of the operating characteristic. Neglecting compensation for the inherent bank unbalance, the operating signal is a vectorial difference between the neutral point voltage and the zero-sequence bus voltage. Therefore, the optimum restraining signal is a vectorial sum of the two signals. During external ground faults, the two voltages are approximately in phase generating a large restraining signal being twice the zero-sequence voltage at the bus. A slope of few percent is typically sufficient to provide good security under large system unbalances. If a given stage is used with a time delay longer than the expected external fault duration, the slope may be reduced or eliminated. In general, the slope can be understood as a adaptive threshold, and the user is provided with three ways to control sensitivity and security: pickup, time delay and slope. See the Application of Settings chapter for information.

NTRL VOL UNBAL 1 STG 1 PKP DELAY to **NTRL VOL UNBAL 1 STG 4 PKP DELAY** — Specify the pickup time delays for each stage of alarming or tripping. Each of the four comparators (four stages) uses an individual pickup timer, but a common drop out time delay as specified by the next setting.

NTRL VOL UNBAL 1 DPO DELAY — Controls a drop out delay for the operate FlexLogic operands. Note that individual stages apply individually configurable pickup delays, but use this common drop out delay.

NTRL VOL 1 BLK STG1 to **NTRL VOL 1 BLK STG4** — These settings are used to block the function when required on a per-stage basis. At minimum this function shall be blocked when the bank is off-line, or else it will operate unnecessarily during external ground faults and/or natural system unbalance if set sensitive. Either breaker position or undercurrent indication via any available instantaneous overcurrent function, or a combination, may be used for blocking. Note that when unblocked, the function becomes operational after five cycles of intentional delay. Optionally only the sensitive stages are blocked, and one stage set high enough to ride through possible problems is left operational. This stage can be used for abnormal conditions such as a failure of one pole of the breaker to close. The function becomes blocked if all four blocking inputs are asserted. The individual blocking inputs inhibit the associated stages of the function.

Figure 5-110: Neutral voltage unbalance logic



5.8 Control elements

5.8.1 Overview

Control elements are used for control rather than protection. See the Introduction to Elements section at the beginning of this chapter for information.

5.8.2 Trip bus

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨ TRIP BUS ⇨⇩ TRIP BUS 1(6)

■ TRIP BUS 1 ■	⇔	**TRIP BUS 1 FUNCTION: Disabled**	Range: Enabled, Disabled
	⇳	**TRIP BUS 1 BLOCK: Off**	Range: FlexLogic operand
	⇳	**TRIP BUS 1 PICKUP DELAY: 0.00 s**	Range: 0.00 to 600.00 s in steps of 0.01

⇳	**TRIP BUS 1 RESET DELAY: 0.00 s**	Range: 0.00 to 600.00 s in steps of 0.01
⇳	**TRIP BUS 1 INPUT 1 Off**	Range: FlexLogic operand
⇩		
⇳	**TRIP BUS 1 INPUT 16 Off**	Range: FlexLogic operand
⇳	**TRIP BUS 1 LATCHING: Disabled**	Range: Enabled, Disabled
⇳	**TRIP BUS 1 RESET: Off**	Range: FlexLogic operand
⇳	**TRIP BUS 1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**TRIP BUS 1 EVENTS: Disabled**	Range: Enabled, Disabled

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 software under **Settings > Protection Summary**. Navigate to a specific protection or control protection element and check the bus box by hovering over the blank check box and selecting an option that displays. 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 can be assigned directly from the trip bus menu.

5

Figure 5-111: Trip bus fields in the protection summary

Protection Summary // Quick Connect: Quick Connect Device: Settings

Save | Restore | Default | Reset | VIEW ALL mode

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

Quick Connect Device

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.

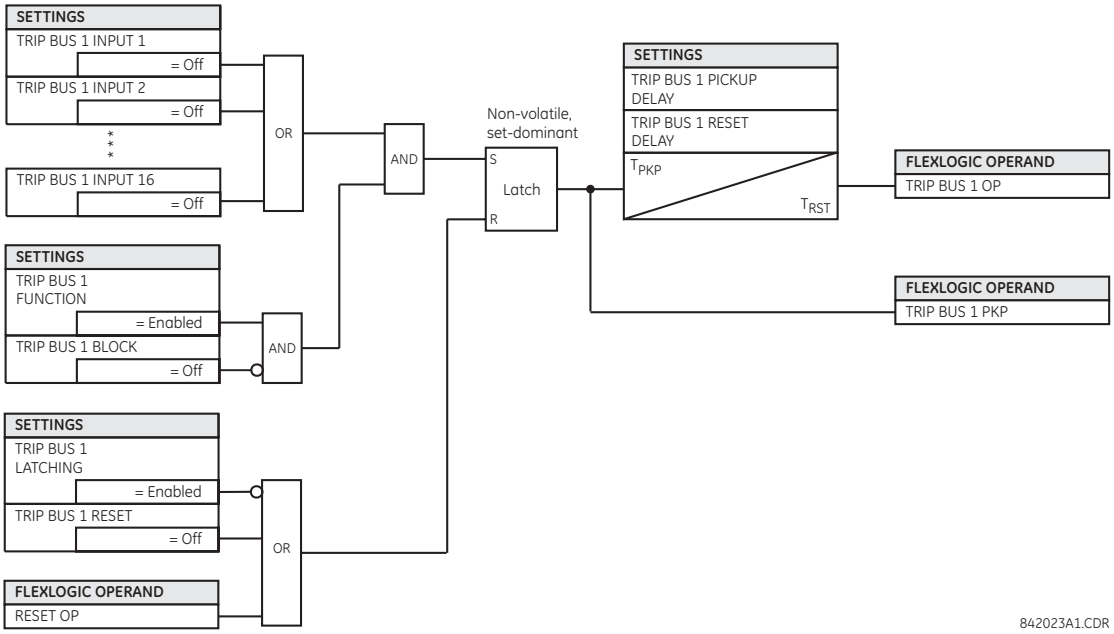
TRIP BUS 1 RESET DELAY — This setting specifies a time delay to reset an output command. Set the time delay long enough to allow the breaker or contactor to perform a required action.

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.

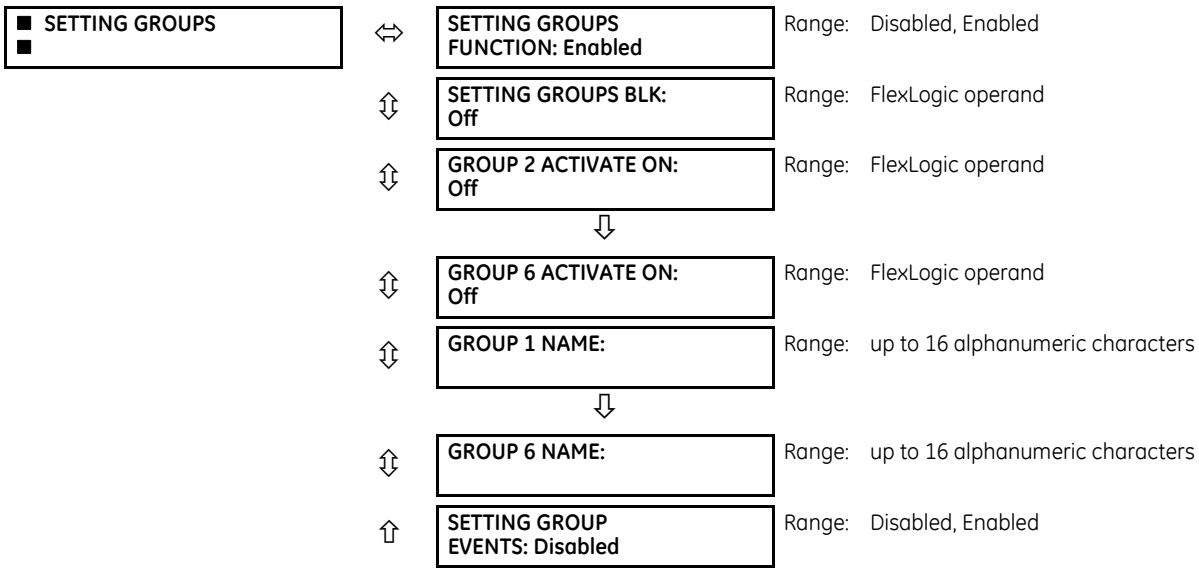
TRIP BUS 1 RESET — The trip bus output is reset when the operand assigned to this setting is asserted. Note that the RESET OP operand is pre-wired to the reset gate of the latch, As such, a reset command from the front panel interface or via communications resets the trip bus output.

Figure 5-112: Trip bus logic



5.8.3 Setting groups

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨ SETTING GROUPS



The setting groups menu controls the activation and deactivation of up to six possible groups of settings in the **GROUPED ELEMENTS** settings menu. The active setting group can be indicated on the front display of the UR by configuring User-Programmable LEDs to display the state of the SETTING GROUP ACT FlexLogic operands.

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.

SETTING GROUPS FUNCTION — When Enabled, allows setting groups other than group 1 (the default active group) to be activated. The default setting group is forced active while the **SETTING GROUPS FUNCTION** setting is Disabled.

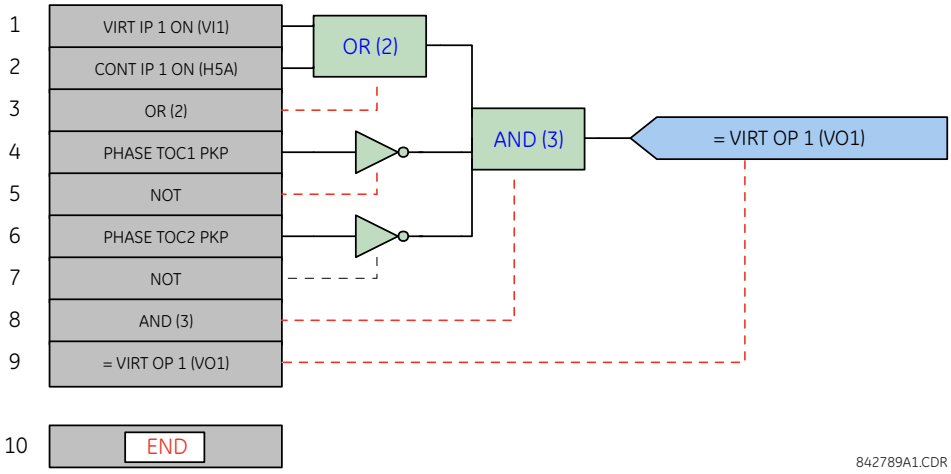
SETTING GROUPS BLK — Prevents the active setting group from changing when the selected FlexLogic operand is "On." This can be useful in applications where it is undesirable to change the settings under certain conditions, such as during a control sequence.

GROUP 2 ACTIVATE ON to **GROUP 6 ACTIVATE ON** — Selects 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.

SETTING GROUP 1 NAME to **SETTING GROUP 6 NAME** — 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 5-113: Example of FlexLogic control of a setting group



A setting group selection can also be made by the IEC 61850 MMS service SelectActiveSG to the control block @Master/LLN0.SGCB. The priority scheme mentioned makes active the highest numbered group selected by SelectActiveSG or the **GROUP ACTIVATE ON** settings. The SelectActiveSG selection has a default value of 1, so until a higher SelectActiveSG selection is received, the **GROUP ACTIVATE ON** settings control the active group.

The most recent SelectActiveSG selection is preserved while the UR is powered down or reset.

If it becomes necessary to cancel the SelectActiveSG selection without using a SelectActiveSG service request, change the **SETTING GROUPS FUNCTION** setting to Disabled. This resets the SelectActiveSG selection to 1.

5.8.4 Selector switch

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨ SELECTOR SWITCH ⇨ SELECTOR SWITCH 1(2)

■ **SELECTOR SWITCH 1** ■	⇔	**SELECTOR 1 FUNCTION: Disabled**	Range: Disabled, Enabled

⇳	**SELECTOR 1 FULL RANGE: 7**	Range: 1 to 7 in steps of 1
⇳	**SELECTOR 1 TIME-OUT: 5.0 s**	Range: 3.0 to 60.0 s in steps of 0.1
⇳	**SELECTOR 1 STEP-UP: Off**	Range: FlexLogic operand
⇳	**SELECTOR 1 STEP-UP MODE: Time-out**	Range: Time-out, Acknowledge
⇳	**SELECTOR 1 ACK: Off**	Range: FlexLogic operand
⇳	**SELECTOR 1 3BIT A0: Off**	Range: FlexLogic operand
⇳	**SELECTOR 1 3BIT A1: Off**	Range: FlexLogic operand
⇳	**SELECTOR 1 3BIT A2: Off**	Range: FlexLogic operand
⇳	**SELECTOR 1 3BIT MODE: Time-out**	Range: Time-out, Acknowledge
⇳	**SELECTOR 1 3BIT ACK: Off**	Range: FlexLogic operand
⇳	**SELECTOR 1 POWER-UP MODE: Restore**	Range: Restore, Synchronize, Sync/Restore
⇳	**SELECTOR 1 TARGETS: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**SELECTOR 1 EVENTS: Disabled**	Range: Disabled, Enabled

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 does not take place and an alarm is 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 changes 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 changes 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," the 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 attempts 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 5-114: Time-out mode

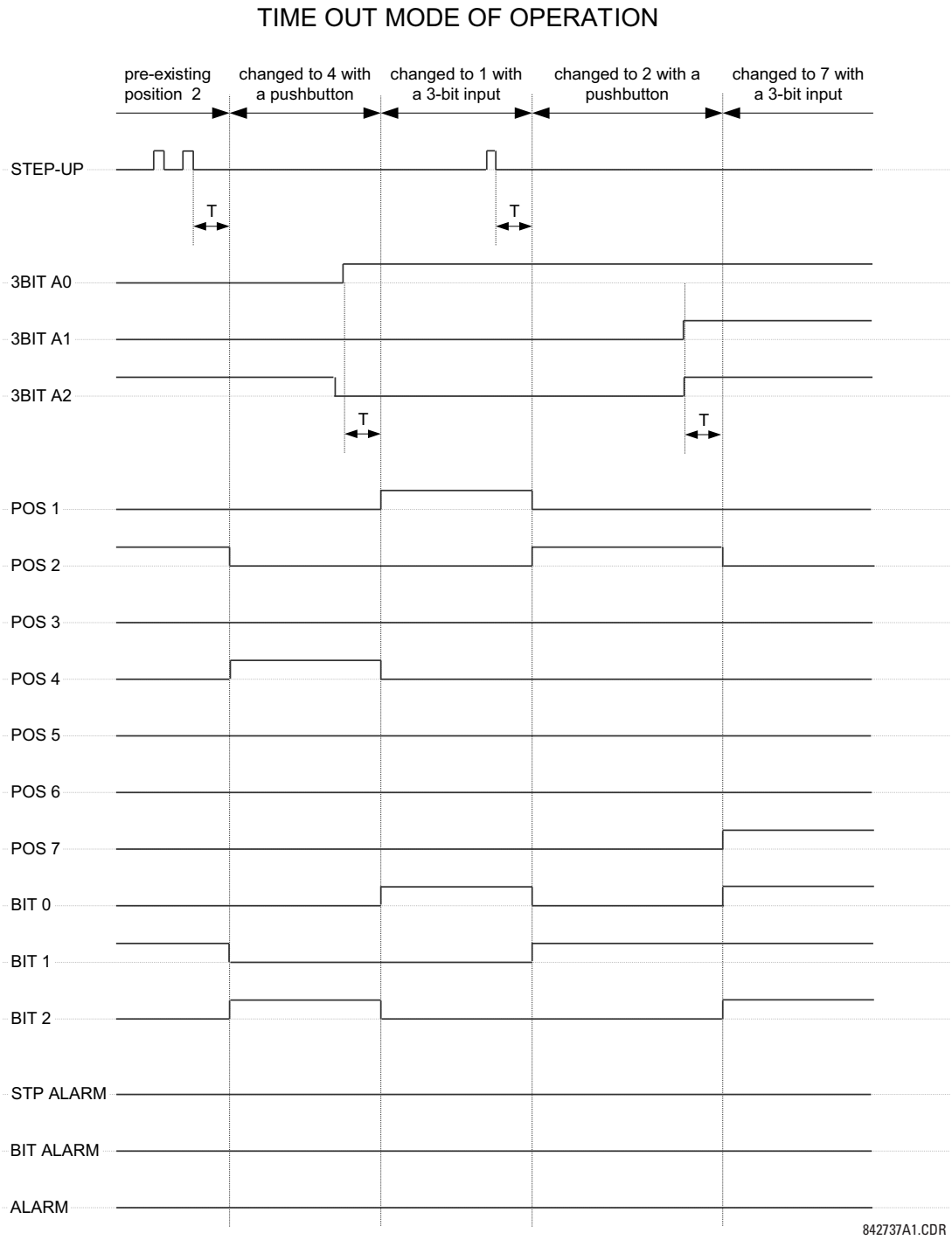
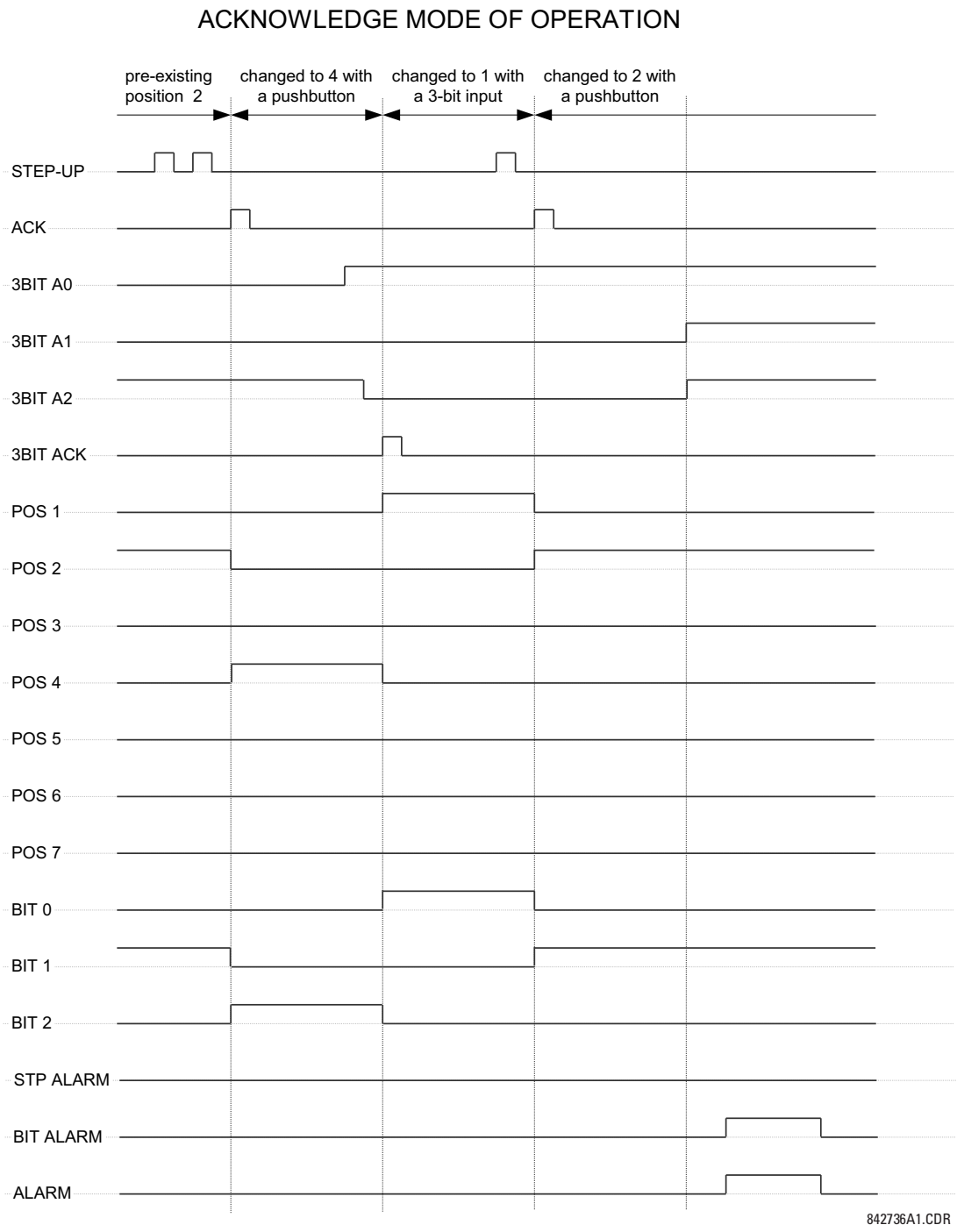


Figure 5-115: Acknowledge mode



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 is to 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 is to be applied automatically after five seconds of inactivity of the control inputs. When the relay powers up, it is to 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:

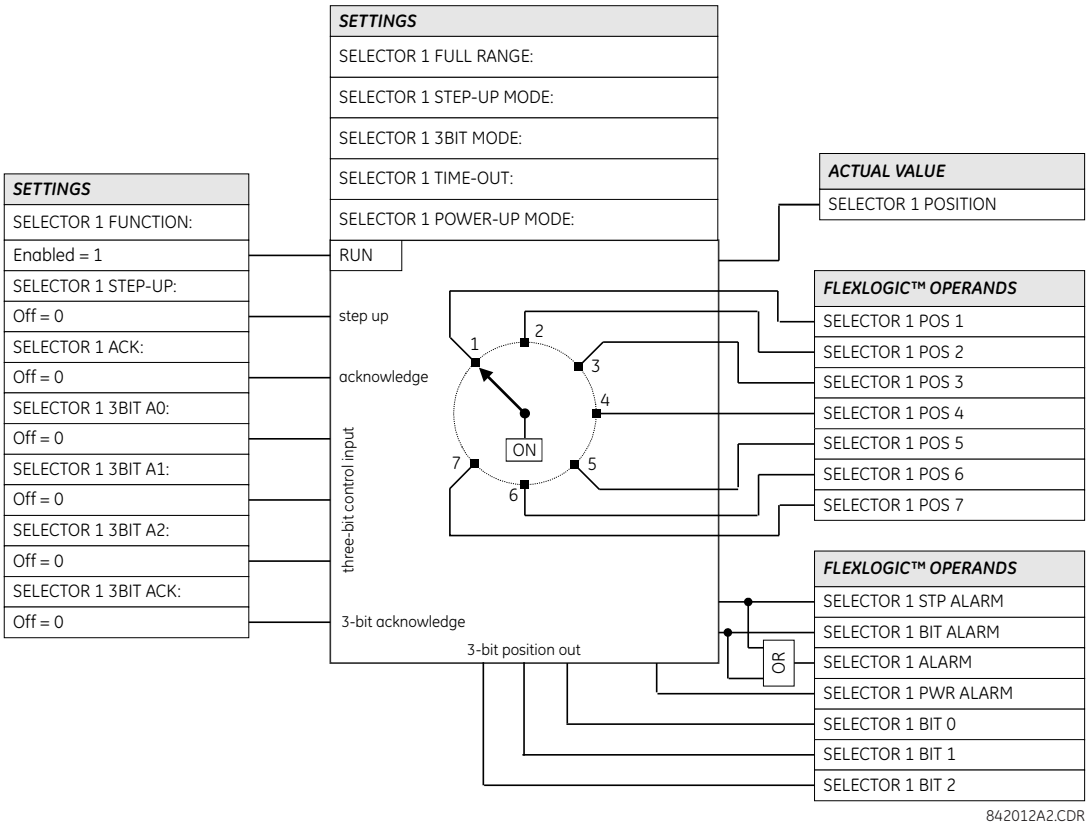
OUTPUT H1 OPERATE: "SELECTOR 1 BIT 0"
OUTPUT H2 OPERATE: "SELECTOR 1 BIT 1"
OUTPUT H3 OPERATE: "SELECTOR 1 BIT 2"

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 figure shows the logic for the selector switch.

Figure 5-116: Selector switch logic



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5.8.5 Capacitor control

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ CAPACITOR CONTROL ⇨ CAP 1(4) CONTROL

■ CAP 1 CONTROL ■	⇔	**CAP 1 CTRL FUNCTION: Disabled**	Range: Disabled, Enabled
	⇳	**CAP 1 SET REMOTE 1: Off**	Range: FlexLogic operand
	⇳	**CAP 1 SET REMOTE 2: Off**	Range: FlexLogic operand
	⇳	**CAP 1 SET LOCAL 1: Off**	Range: FlexLogic operand
	⇳	**CAP 1 SET LOCAL 2: Off**	Range: FlexLogic operand
	⇳	**CAP 1 RMT CTRL EN: Off**	Range: FlexLogic operand
	⇳	**CAP 1 LCL CTRL EN: Off**	Range: FlexLogic operand
	⇳	**CAP 1 RMT SET AUTO: Off**	Range: FlexLogic operand
	⇳	**CAP 1 LCL SET AUTO: Off**	Range: FlexLogic operand
	⇳	**CAP 1 RMT SET MAN: Off**	Range: FlexLogic operand

⇳	**CAP 1 LCL SET MAN: Off**	Range: FlexLogic operand
⇳	**CAP 1 TRIP 1: Off**	Range: FlexLogic operand
	⇩	
⇳	**CAP 1 TRIP 6: Off**	Range: FlexLogic operand
⇳	**CAP 1 SWITCH TO MANUAL ON TRIP: Yes**	Range: Yes, No
⇳	**CAP 1 AUTO CTRL EN: Off**	Range: FlexLogic operand
⇳	**CAP 1 LOCAL OPEN: Off**	Range: FlexLogic operand
⇳	**CAP 1 AUTO OPEN: Off**	Range: FlexLogic operand
⇳	**CAP 1 BKR OPEN 52b: Off**	Range: FlexLogic operand
⇳	**CAP 1 TRIP SEAL-IN DELAY: 0.400 s**	Range: 0.000 to 60.000 s in steps of 0.001
⇳	**CAP 1 REMOTE CLOSE: Off**	Range: FlexLogic operand
⇳	**CAP 1 LOCAL CLOSE: Off**	Range: FlexLogic operand
⇳	**CAP 1 AUTO CLOSE: Off**	Range: FlexLogic operand
⇳	**CAP 1 BKR CLSD 52a: Off**	Range: FlexLogic operand
⇳	**CAP 1 DISCHARGE DELAY: 300 s**	Range: 0 to 3600 s in steps of 1
⇳	**CAP 1 CLOSE SEAL-IN DELAY: 0.400 s**	Range: 0.000 to 60.000 s in steps of 0.001
⇳	**CAP 1 BKR CLOSE BLK: Off**	Range: FlexLogic operand
⇳	**CAP 1 CLS OVERRIDE: Off**	Range: FlexLogic operand
⇳	**CAP 1 TARGETS: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**CAP 1 EVENTS: Disabled**	Range: Disabled, Enabled



The C70 is provided with optional capacity bank control. This feature is specified as an option at the time of ordering. See the Order Codes section in chapter 2 for details.

The capacitor control element gathers on/off commands from various sources and executes them, while maintaining remote/local and auto/manual control rights. Local control refers to control from the front panel of the relay. Remote control refers to control via communications from outside of the relay, an on-site interface, and/or from an off-site control center. There is flexibility to support other configurations.

This element provides a user-programmable time delay that inhibits closing after the bank has been switched out of service until the bank has had time to discharge any trapped charge. If the capacitor were to be closed with trapped charge of opposite polarity from the system voltage at that instant, larger than normal transients would occur. A FlexAnalog value is available to inform the time remaining before the next permissible close operation.

Seal-in is provided to stretch short input commands to lengths suitable for breaker control. An interlock prevents simultaneous trip and close output, which can result in breaker pumping. To prevent a continuous close input from causing reclosing of the breaker following a trip command, the interlock is sealed-in for the duration of any close input.

A provision is provided to force the auto/manual mode to manual on protection operation. This prevents the capacitor automatic switching scheme from attempting to close a faulted capacitor. A setting controls the automatic switchover to manual upon the protection trip.

The following settings are available for each capacitor control element.

CAP 1 CTRL FUNCTION — This setting is used to enable the element. When disabled, the remote/local latch is forced to local, the auto/manual latch is forced to manual, the trip and close command outputs are forced off, and their seal-in latches and timers are reset.

CAP 1 SET REMOTE 1(2) — Sets one or two FlexLogic operands to select the remote mode. It is expected that one of these settings is programmed to a pushbutton "on" operand. This allows a local operator to hand over control to remote operators. Where appropriate, the other one of these settings can be set to a virtual input. This allows remote operators to grant themselves control rights.

CAP 1 SET LOCAL 1(2) — Similar to previous setting, but selects local mode.

CAP 1 RMT CTRL EN — Selects a FlexLogic operand to enable remote auto/manual and open/close control. It is expected to be set to CAP 1 IN REMOTE to obtain the baseline functionality, but variations via FlexLogic are possible. For example, if it is required that remote control is always available, this setting can be set to "On."

CAP 1 LCL CTRL EN — Similar to previous setting, but enables local controls. Expected to be set to CAP 1 IN LOCAL.

CAP 1 RMT SET AUTO — Selects a FlexLogic operand that selects auto mode when remote control is enabled. It is expected to be set to a virtual input to enables HMI/SCADA access via one of the supported protocols.

CAP 1 LCL SET AUTO — Similar to previous setting, but expected to be set to a pushbutton "on" operand.

CAP 1 RMT SET MAN — Similar to the **CAP RMT SET AUTO** setting, but selects manual mode.

CAP 1 LCL SET MAN — Similar to the **CAP LCL SET AUTO** setting, but selects manual mode.

CAP 1 TRIP 1(6) — Selects up to six FlexLogic operands to activate the CAP 1 BKR TRIP operand, no matter what control modes prevail. Expected to be set to the appropriate protection element operate operand.

CAP 1 SWITCH TO MANUAL ON TRIP — Allows control of the auto/manual mode when issuing a trip command. When set to "Yes," the element switches to manual mode upon tripping the bank from protection.

CAP 1 AUTO CTRL EN — Selects a FlexLogic operand to enable automatic open/close control. It is expected to be set to CAP 1 IN AUTO to obtain the baseline functionality, but variations are possible.

CAP 1 MAN CTRL EN — Similar to previous setting, but enables manual controls. Expected to be set to CAP 1 IN MAN.

CAP 1 REMOTE OPEN — Selects a FlexLogic operand to activate the CAP 1 BKR TRIP operand when both remote and manual control are enabled. It is expected to be set to a virtual input, and that the contact output wired to the capacitor breaker trip coil is set to CAP 1 BKR TRIP.

CAP 1 LOCAL OPEN — Similar to previous setting, but requires both local and manual control to be enabled. Expected to be set to a pushbutton "on" operand.

CAP 1 AUTO OPEN — Similar to previous setting, but requires automatic control to be enabled. Expected to be set to the open command of the voltage regulator either built-in or customer via FlexLogic.

CAP 1 BKR OPEN 52b — Selects a FlexLogic operand that cancels the trip seal-in. Expected to be set to the contact input to which a contact is wired that is closed when the capacitor breaker is open. When both 52a and 52b contacts are used for security, the appropriate filtering logic possibly including discrepancy alarming can be programmed in FlexLogic, and the resulting virtual output can be configured under this setting.

CAP 1 TRIP SEAL-IN DELAY — Sets a maximum trip seal-in duration for where the **CAP 1 BKR OPEN 52b** setting is not configured or fails to operate.

CAP 1 REMOTE CLOSE — Similar to the **CAP 1 REMOTE OPEN** setting, but closes the breaker.

CAP 1 LOCAL CLOSE — Similar to the **CAP 1 LOCAL OPEN** setting, but closes the breaker.

CAP 1 AUTO CLOSE — Similar to the **CAP 1 AUTO OPEN** setting, but closes the breaker.

CAP 1 BKR CLSD 52a — Similar to the **CAP 1 BKR OPEN 52b** setting, but cancels the close seal-in, and is expected to be set to a contact that is closed when the breaker is closed. The selected operand also triggers the **CAP 1 DISCHARGE TIME**. When both 52a and 52b contacts are used for security, the appropriate filtering logic possibly including discrepancy alarming can be programmed in FlexLogic, and the resulting virtual output can be configured under this setting.

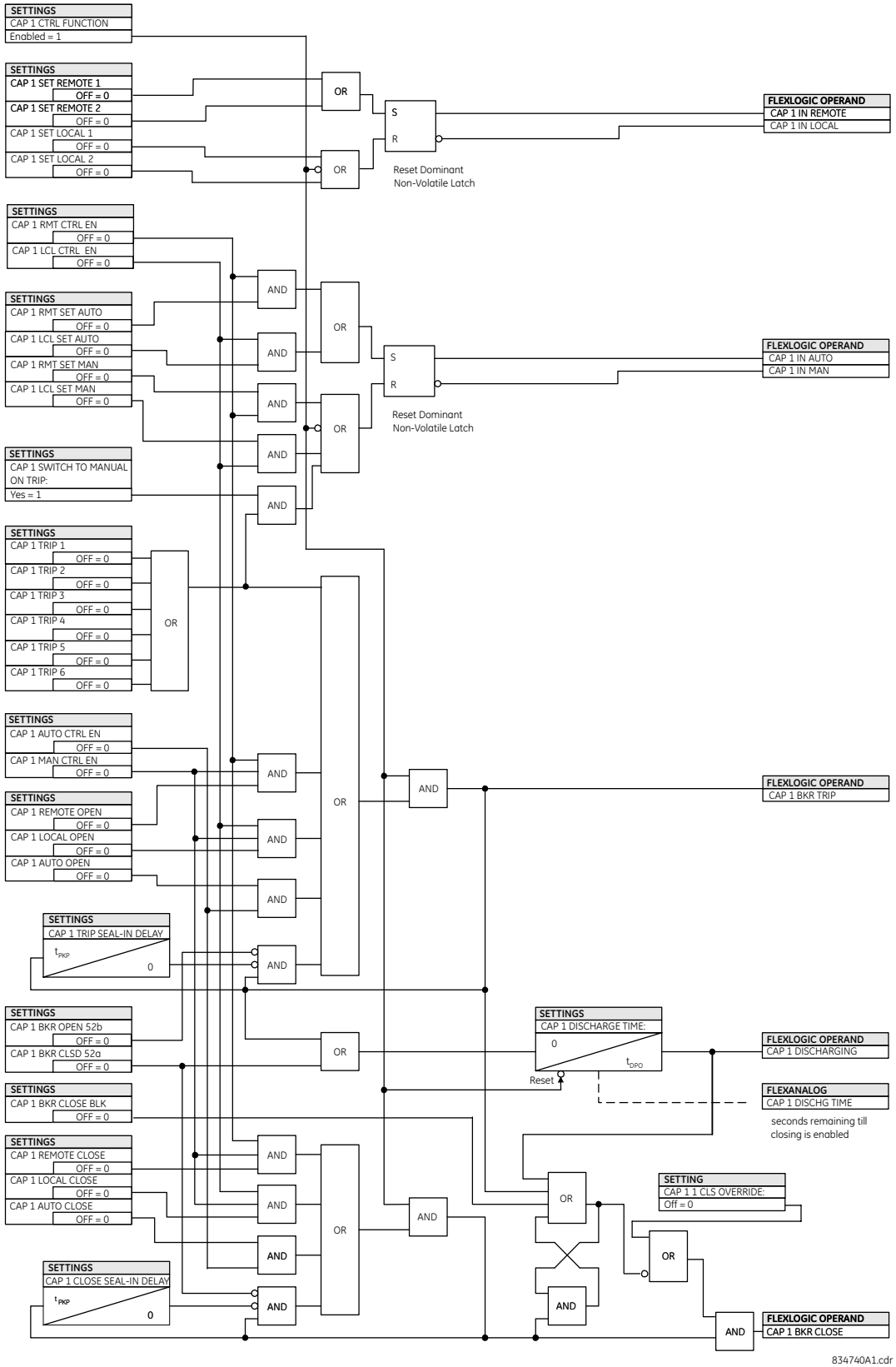
CAP 1 CLOSE SEAL-IN DELAY — Sets a maximum close seal-in duration for where the **CAP BKR CLSD 52a** setting is not configured or fails to operate.

CAP 1 DISCHARGE TIME — Sets a time delay that inhibits closing after the bank has been switched out-of-service (the **CAP BKR CLSD 52a** setting goes low or trip command terminates) until the bank has had time to discharge any trapped charge. The correct value for this setting depends on the specifics of the capacitor installation.

CAP 1 BKR CLOSE BLK — Selects a FlexLogic operand that triggers the CAP 1 BKR CLOSE interlock logic. Its signal is expected to originate from capacitor breaker trips external to the relay, and thus not otherwise able to block relay closing (for example, from the opposite group's capacitor protection).

CAP 1 CLS OVERRIDE — Selects a FlexLogic operand that overrides all inhibits for the breaker close command and allows the CLOSE command to be issued from any source as per the logic diagram.

Figure 5-117: Capacitor bank control logic



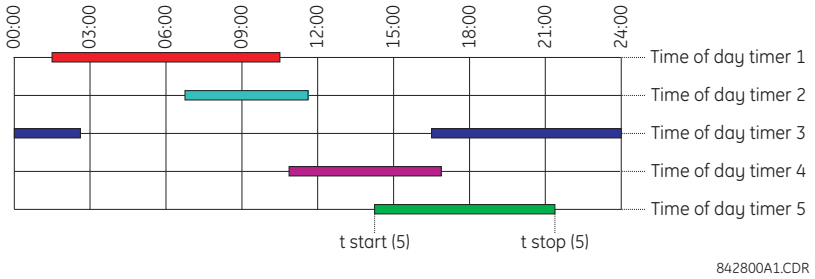
5.8.6 Time of day timers

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ TIME OF DAY TIMERS ⇨ TIME OF DAY TIMER1(5)

■ TIME OF DAY TIMER1 ■	⇔ TIME OF DAY TIMER1 FUNCTION: Disabled	Range: Disabled, Enabled
	⇳ TIME OF DAY TIMER1 START TIME: 00:00	Range: 00:00 to 23:59 in steps of 00:01
	⇳ TIME OF DAY TIMER1 STOP TIME: 23:59	Range: 00:00 to 23:59 in steps of 00:01
	⇳ TIME OF DAY TIMER1 TARGETS: Self-reset	Range: Self-reset, Latched, Disabled
	⇧ TIME OF DAY TIMER1 EVENTS: Disabled	Range: Disabled, Enabled

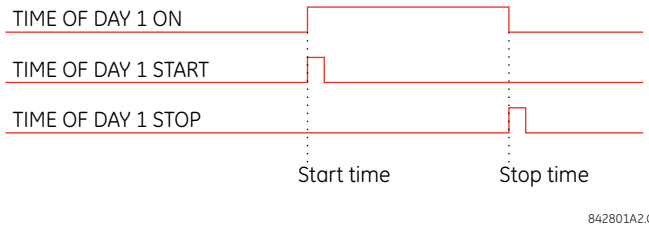
The time of day timer function provides the ability to program control actions based on real time. There are five identical timers, each with an independent start and stop time setting. Each timer is on when the C70 real-time clock/calendar value is later than its programmed start time, and earlier than its programmed stop time. The timers wrap around 24 hours, as the figure shows.

Figure 5-118: Time of day timer example



The TIME OF DAY 1 ON FlexLogic operand follows the state of the timers. In addition, one-second pulses are generated on the TIME OF DAY 1 START and TIME OF DAY 1 STOP FlexLogic operands when the timers turn on and off, respectively (see the following figure). These operands can be combined in FlexLogic with the day and month FlexLogic operands and/or with FlexElements operating on the DAYOFYEAR, DAYOFMONTH, and SECONDOFDAY FlexAnalog parameters to create virtually any time and date condition for custom time or season-based control actions. To activate these FlexAnalog parameters, enable at least one time of day timer.

Figure 5-119: Close/open/maintain control via FlexLogic operands



If the relay is connected to an external clock that follows daylight savings time changes, take care that the changes do not result in undesired operation.

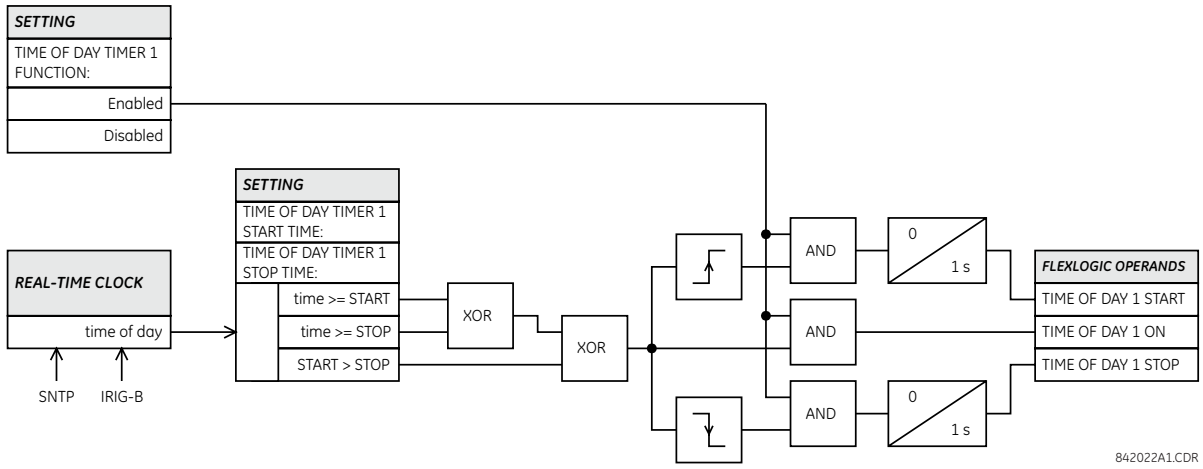
The following settings are available for each time of day timer element.

TIME OF DAY TIMER1 START TIME — Used to program the relay clock/calendar value for which the timer turns on.

TIME OF DAY TIMER1 STOP TIME — Used to program the relay clock/calendar value for which the timer turns off.

TIME OF DAY TIMER1 EVENTS — If enabled, the TIME OF DAY 1 ON and TIME OF DAY 1 OFF events are logged.

Figure 5-120: Time of day timer logic



5.8.7 Automatic voltage regulator

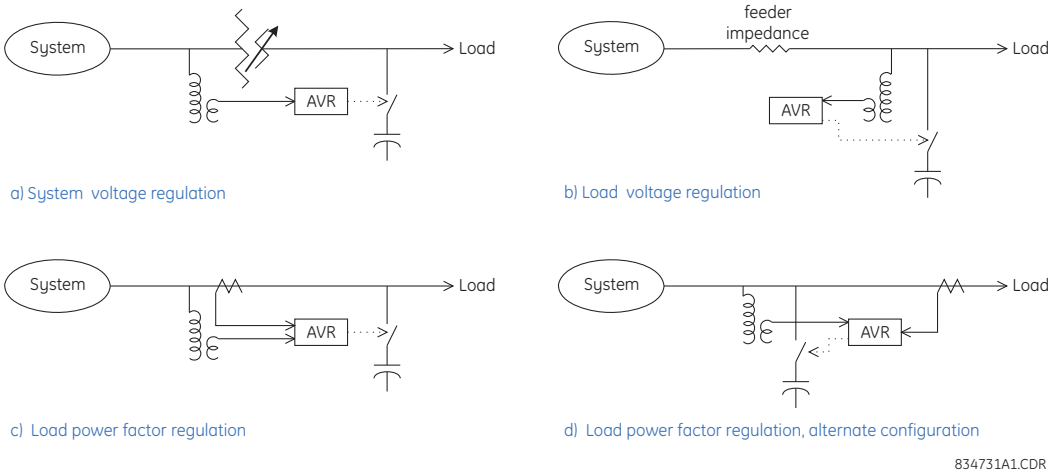
SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ AUTOMATIC VOLTAGE REGULATOR ⇨ AUTOMATIC VOLTAGE REGULATOR 1(3)

■ AUTOMATIC VOLTAGE REGULATOR 1	⇔	**AVR 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇕	**AVR 1 SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇕	**AVR 1 MINIMUM VOLTAGE: 0.500 pu**	Range: 0.500 to 1.500 pu in steps of 0.001
	⇕	**AVR 1 CONTROL MODE: Voltage**	Range: Voltage, VAR
	⇕	**AVR 1 VOLT OPERATING SIGNAL: V1**	Range: Vab, Vbc, Vca, Vaver, V1, Vaux, Vag, Vbg, Vcg
	⇕	**AVR 1 VOLT LEVEL TO CLOSE: 0.950 pu**	Range: 0.750 to 1.500 pu in steps of 0.001
	⇕	**AVR 1 VOLT LEVEL TO OPEN: 1.050 pu**	Range: 0.750 to 1.500 pu in steps of 0.001
	⇕	**AVR 1 VOLT DROP COMPENS Z: 0.00 Ω**	Range: 0 to 250.00 ohms in steps of 0.01
	⇕	**AVR 1 VOLT DROP COMPENS RCA: 75°**	Range: 30 to 90° in steps of 1
	⇕	**AVR 1 VAR LEVEL TO CLOSE: 0.500 pu**	Range: –1.500 to 1.500 pu in steps of 0.001
	⇕	**AVR 1 VAR LEVEL TO OPEN: -0.500 pu**	Range: –1.500 to 1.500 pu in steps of 0.001
	⇕	**AVR 1 POWER FACTOR LIMIT: 1.00**	Range: 0.50 to 1.00 pu in steps of 0.01
	⇕	**AVR 1 VAR OPEN MODE: Minimize No. of Ops.**	Range: Minimize Uptime, Minimize No. of Ops.
	⇕	**AVR 1 DELAY BEFORE CLOSE: 1.000 s**	Range: 0.000 to 65.353 s in steps of 0.001
	⇕	**AVR 1 DELAY BEFORE OPEN: 1.000 s**	Range: 0.000 to 65.353 s in steps of 0.001

⇳	**AVR 1 BLOCK: Off**	Range: FlexLogic operand
⇳	**AVR 1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**AVR 1 EVENTS: Disabled**	Range: Disabled, Enabled

The automatic voltage regulator element (AVR) is intended to switch a static capacitor bank breaker open and closed to regulate system voltage, load voltage, power factor, or reactive power. The figure shows some applications.

Figure 5-121: Applications of the capacitor automatic voltage regulator function



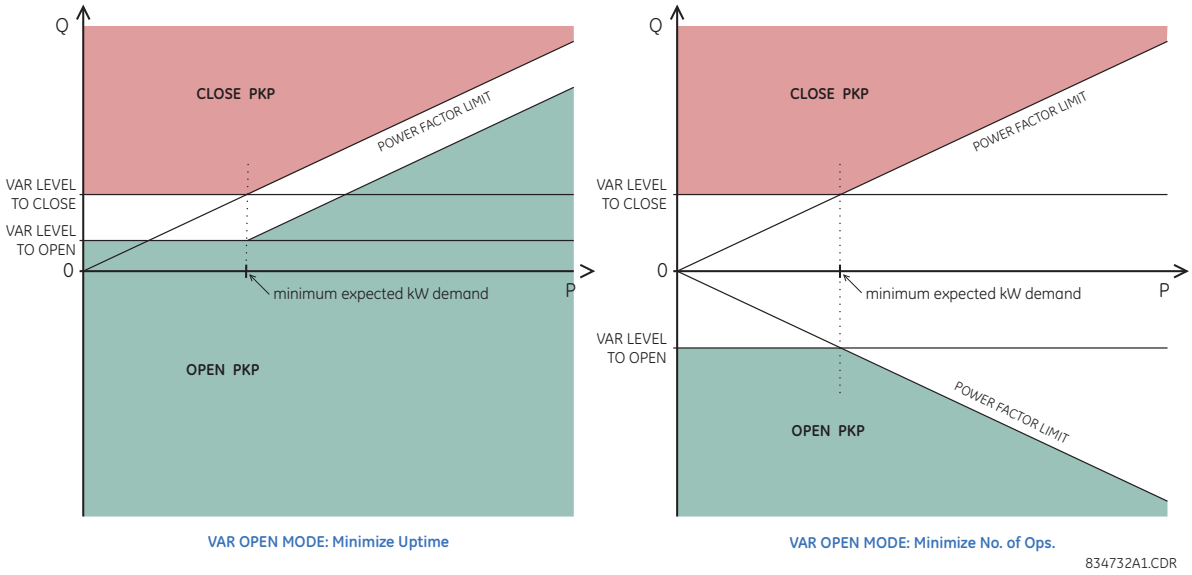
Up to three identical automatic voltage regulator elements are provided, allowing the relay to be used with capacitor banks divided into sections for finer compensation steps, to provide switching speed dependent on the extent of the voltage or power deviation, or to provide different settings depending on a user-programmable factor such as time of day.

Each element can be set to operate in either "Voltage" mode or "VAR" mode. The voltage mode can be used with relatively short time delay settings as a system stability aid, or with longer time delay settings to assist in the regulation of steady state voltage. When the voltage decreases to the volts level to close setting, after the set close delay the capacitor is closed, raising the voltage. When the voltage increases to the level to open setting, after the set open delay the capacitor is opened, lowering the voltage. The load drop compensation feature can be used to effectively sense the voltage at a location remote from the relay.

The "VAR" mode can be used to regulate the var and power factor of a load to reduce transmission and distribution costs. If the capacitor deployment objective is to minimize system power losses, set the power factor limit to 1.000 to disable it and set the var open and close levels symmetrically about zero reactive power, with a difference between levels equal to the reactive power produced by the capacitor plus margin. Larger margins result in less frequent switching.

If on the other hand the deployment objective is solely to minimize power factor rate charges, set the power factor limit to the value at which power factor penalties are incurred, typically 0.9. Set the var close level to the vars that would flow should the power factor be at the limit when at the minimum expected kW demand. The open command characteristics can be selected to suit whether the preference is to minimize the amount of time the capacitor is online or to minimize the number of capacitor close operations. For the former preference, set the var open mode to "Minimize Uptime" and set the var open level below the close level by an amount equal to the capacitor var rating plus margin. For the latter preference, set the var open mode to "Minimize No. of Ops" (minimize number of operations) and set the var open level to the negative of the close level.

Figure 5-122: Automatic voltage regulator pickup characteristics in "VAR" mode



Take care that the settings do not result in the capacitor being continuously cycled close and open. In the voltage mode, set the close voltage settings lower than the open voltage setting by more than the voltage change expected from capacitor switching, plus margin. Similarly in the "VAR" mode, set the close var setting higher than the open var setting by more than the expected var change due to capacitor switching, plus margin. For configurations where the capacitor current is not included in the measured current, there can still be a measured var change due to loads whose power factor increases with increasing voltage. In general, the larger the margin, the less the capacitor is switched.

Set delays long enough to avoid undesired operations on transient conditions. Depending on the application, this can include operations for noise hits, for transient voltage depressions accompanying successful fault clearance, and short-term voltage conditions pending automatic reclosure. Delays can also be used to time co-ordinate the switching of multiple capacitor banks, or sections of the same bank.

The following settings are available.

AVR 1 SOURCE — This setting selects signal source of the control variables of interest. In case of voltage control applications, the selected source needs to have the appropriate voltages configured for proper operation. For example, when using positive-sequence voltage as a control variable, phase voltages must be configured under the source; or when using single-phase auxiliary voltage, the auxiliary source voltage must be configured. In case of "VAR" mode and of voltage mode with voltage drop compensation, the indicated source must be configured with phase voltages and currents into the regulated load or bus, and should include the capacitor current. If the source indicated here does not support the control variable selected, the function will restrain itself from operating, and assert neither the close or open command.

AVR 1 MINIMUM VOLTAGE — This value sets the minimum voltage for capacitor switching, to discriminate against loss of voltage. For voltage mode, this setting applies to the voltage selected for control. For "VAR" mode, this setting applies to the positive sequence voltage.

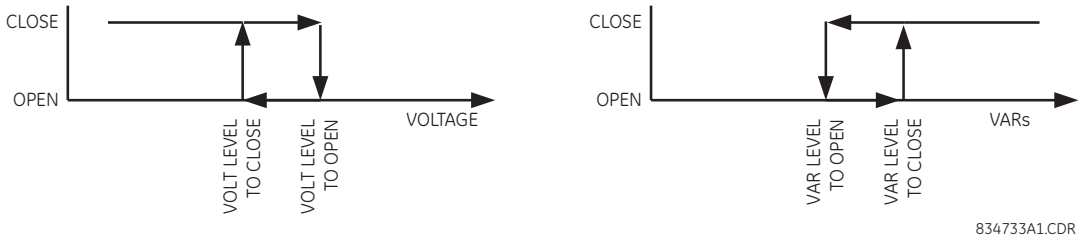
AVR 1 CONTROL MODE — This setting selects either voltage control for voltage regulation applications, or var control for power factor/reactive power regulation applications.

AVR 1 VOLT OPERATING SIGNAL — When the control mode is voltage, this setting is used to select whether the AVR responds to an individual phase-to-phase voltage or phase-to-ground voltage, the average of the three phase-to-phase voltages, the positive sequence voltage, or the auxiliary RMS voltage. The ability to select the same voltage quantity as is used by other AVRs facilitates coordination with those AVRs.

AVR 1 VOLT LEVEL TO CLOSE — In the voltage mode, this setting specifies the voltage level at or below which to issue the close command.

AVR 1 VOLT LEVEL TO OPEN — In the voltage mode, this setting specifies the voltage level at or above which to issue the open command. The following figure illustrates voltage control level settings.

Figure 5-123: Close and open levels when controlling voltage or VARs



AVR 1 VOLT DROP COMPENS Z — In the voltage mode, this setting allows compensating for voltage drop on the line when the relay measuring point is located upstream of the load. Positive-sequence line impedance is entered in secondary ohms. Compensation cannot exceed 20% of the nominal phase voltage.

AVR 1 VOLT DROP COMPENS RCA — In the voltage mode, this setting specifies the angle of the line impedance for voltage drop calculations.

AVR 1 VAR LEVEL TO CLOSE — In the "VAR" mode, this setting specifies level for the three-phase reactive power level at or above which to issue the close command. The 1 pu value is the product of the nominal primary phase-to-phase voltage, the CT primary, and $\sqrt{3}$. When the source current is an internal summation of two or more CT bank currents, the largest CT primary is used to define the 1 pu value for this setting.

AVR 1 VAR LEVEL TO OPEN — In the "VAR" mode, this setting specifies level for the three-phase reactive power level at or below which to issue the OPEN command. The 1 pu value is defined as for the **VAR LEVEL TO CLOSE** setting.

AVR 1 POWER FACTOR LIMIT — In the "VAR" mode, this setting specifies the power factor below which close commands are allowed. Also affects open commands as shown in the above figure. If set to "1.00", the power factor has no effect.

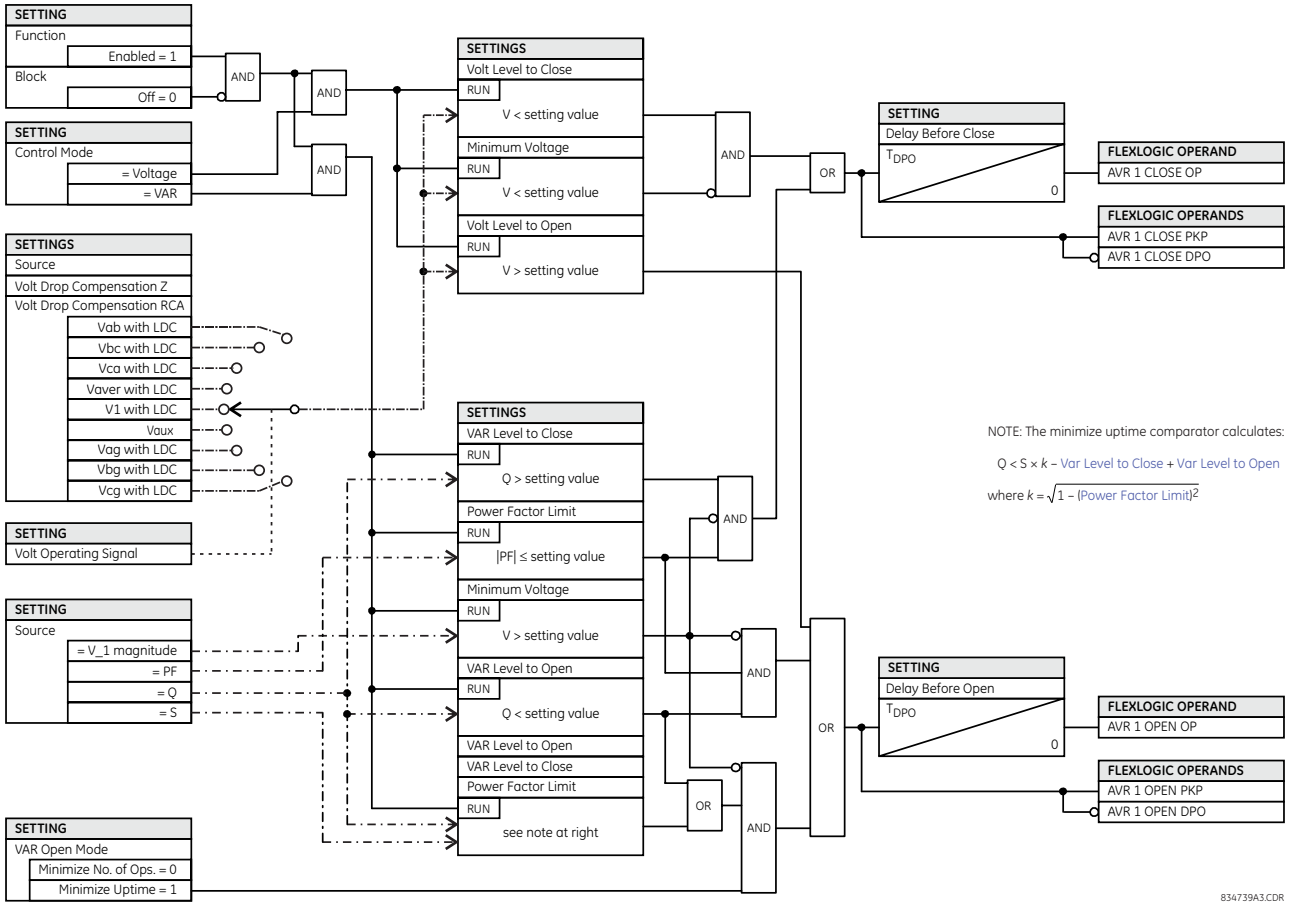
AVR 1 VAR OPEN MODE — Selects the close command characteristic, either "Minimize No. of Ops." (minimize number of operations) or "Minimize Uptime", as described earlier in the Automatic Voltage Regulator Pickup Characteristics in "VAR" Mode diagram.

AVR 1 DELAY BEFORE CLOSE — Specifies delay before issuing the close command, and is used to coordinate with other regulators, or to ride through abnormal system conditions such as faults or re-close sequences.

AVR 1 DELAY BEFORE OPEN — Specifies delay before issuing the open command, and is used to coordinate with other regulators, or to ride through abnormal system conditions such as faults or re-close sequences.

AVR 1 BLOCK — Specifies a dynamic blocking condition. When blocked the element resets its output flags and internal timers. VT fuse fail is a typical application.

Figure 5-124: Automatic voltage regulator logic



5.8.8 Digital elements

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ DIGITAL ELEMENTS ⇨ DIGITAL ELEMENT 1(48)

■ DIGITAL ELEMENT 1 ■	⇔	**DIGITAL ELEMENT 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇳	**DIG ELEM 1 NAME: Dig Element 1**	Range: 16 alphanumeric characters
	⇳	**DIG ELEM 1 INPUT: Off**	Range: FlexLogic operand
	⇳	**DIG ELEM 1 PICKUP DELAY: 0.000 s**	Range: 0.000 to 999999.999 s in steps of 0.001
	⇳	**DIG ELEM 1 RESET DELAY: 0.000 s**	Range: 0.000 to 999999.999 s in steps of 0.001
	⇳	**DIGITAL ELEMENT 1 PICKUP LED: Enabled**	Range: Disabled, Enabled
	⇳	**DIG ELEM 1 BLOCK: Off**	Range: FlexLogic operand
	⇳	**DIGITAL ELEMENT 1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
	⇳	**DIGITAL ELEMENT 1 EVENTS: Disabled**	Range: Disabled, Enabled

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 to 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.

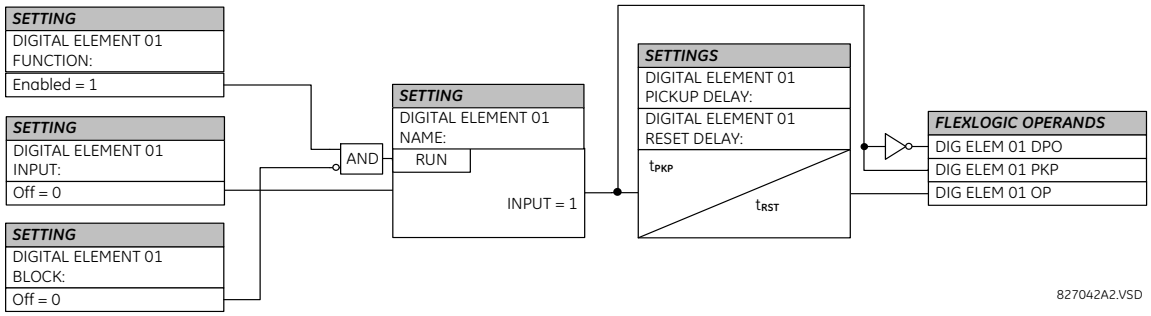
DIGITAL ELEMENT 1 INPUT — Selects a FlexLogic operand to be monitored by the digital element.

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 5-125: Digital element 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).

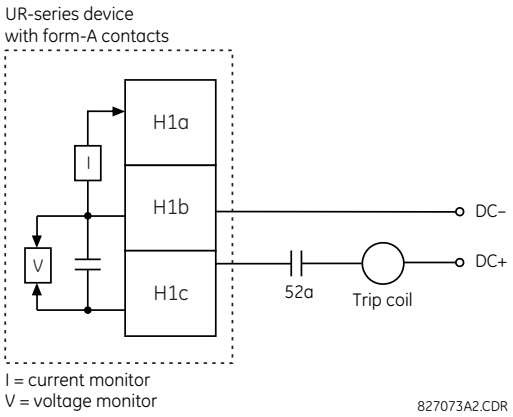
As long as the current through the voltage monitor is above a threshold (see technical specifications for form-A), the Cont Op 1 VOn FlexLogic operand is set (for contact input 1—corresponding operands exist for each contact output). If the output circuit has a high resistance or the DC current is interrupted, the trickle current drops below the threshold and the Cont Op 1 VOff FlexLogic operand is 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

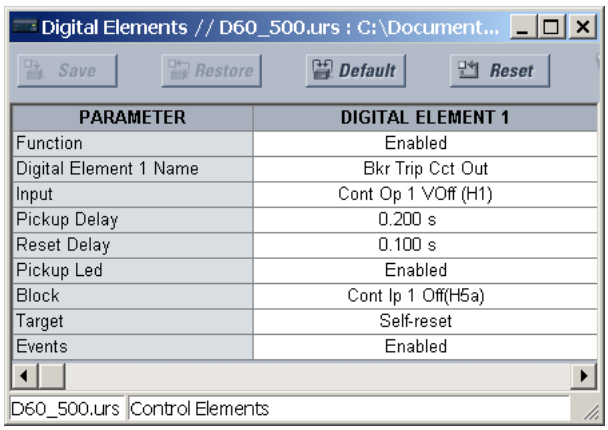
In many applications it is desired to monitor the breaker trip circuit integrity so that problems can be detected before a trip operation is required. The circuit is considered to be healthy when the voltage monitor connected across the trip output contact detects a low level of current, well below the operating current of the breaker trip coil. If the circuit presents a high resistance, the trickle current falls below the monitor threshold, and an alarm is declared.

In most breaker control circuits, the trip coil is connected in series with a breaker auxiliary contact that is open when the breaker is open (see figure). To prevent unwanted alarms in this situation, the trip circuit monitoring logic must include the breaker position.

Figure 5-126: Trip circuit example 1



Assume the output contact H1 is a trip contact. Using the contact output settings, this output is 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 is given an ID name, for example, "Cont Ip 1," and is set "On" when the breaker is closed. The settings to use digital element 1 to monitor the breaker trip circuit are indicated (EnerVista 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 following figure). This can be achieved by connecting a suitable resistor (see figure) 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 example shown).

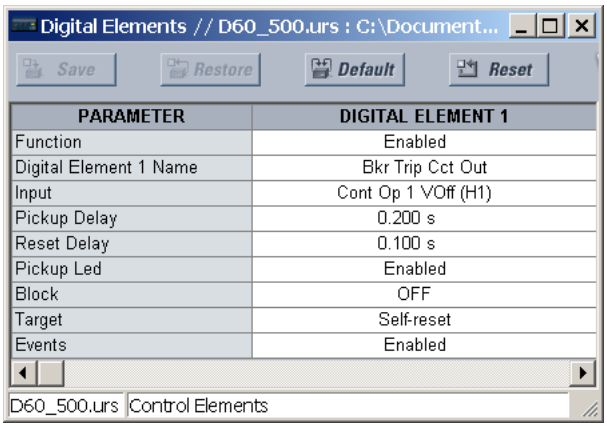
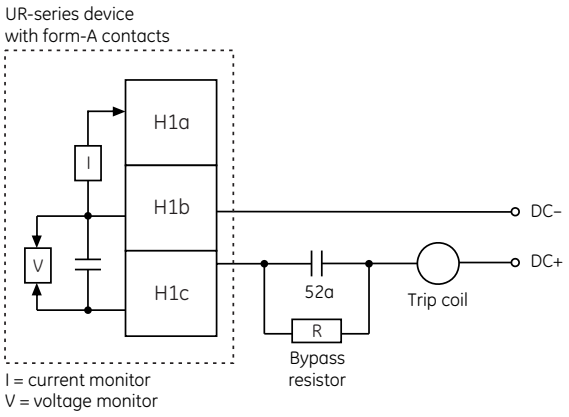


Figure 5-127: Trip circuit example 2



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

827074A3.CDR

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.

5.8.9 Digital counters

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ DIGITAL COUNTERS ⇨⇩ COUNTER 1(8)

■ COUNTER 1 ■	⇔	**COUNTER 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇕	**COUNTER 1 NAME: Counter 1**	Range: 12 alphanumeric characters
	⇕	**COUNTER 1 UNITS:**	Range: six alphanumeric characters
	⇕	**COUNTER 1 PRESET: 0**	Range: –2,147,483,648 to +2,147,483,647

⇳	**COUNTER 1 COMPARE:** **0**	Range: –2,147,483,648 to +2,147,483,647
⇳	**COUNTER 1 UP:** **Off**	Range: FlexLogic operand
⇳	**COUNTER 1 DOWN:** **Off**	Range: FlexLogic operand
⇳	**COUNTER 1 BLOCK:** **Off**	Range: FlexLogic operand
⇳	**CNT1 SET TO PRESET:** **Off**	Range: FlexLogic operand
⇳	**COUNTER 1 RESET:** **Off**	Range: FlexLogic operand
⇳	**COUNT1 FREEZE/RESET:** **Off**	Range: FlexLogic operand
⇧	**COUNT1 FREEZE/COUNT:** **Off**	Range: FlexLogic operand

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 (for example, 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 appears 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 rolls over 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 rolls over 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 sets to the preset value in the following situations:

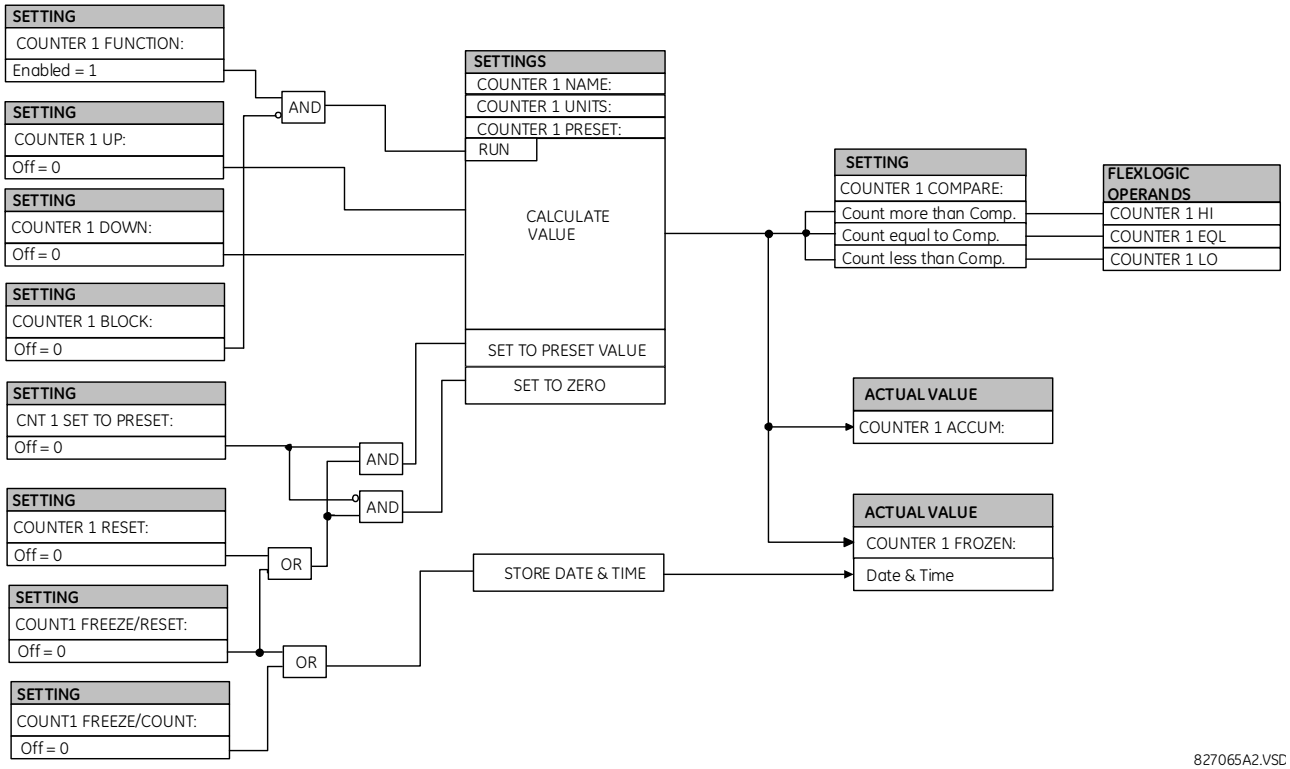
- When the counter is enabled and the **CNT1 SET TO PRESET** operand has the value 1 (when the counter is enabled and **CNT1 SET TO PRESET** operand is 0, the counter sets to 0)
- When the counter is running and the **CNT1 SET TO PRESET** operand changes the state from 0 to 1 (**CNT1 SET TO PRESET** changing from 1 to 0 while the counter is running has no effect on the count)
- 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 sets 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.

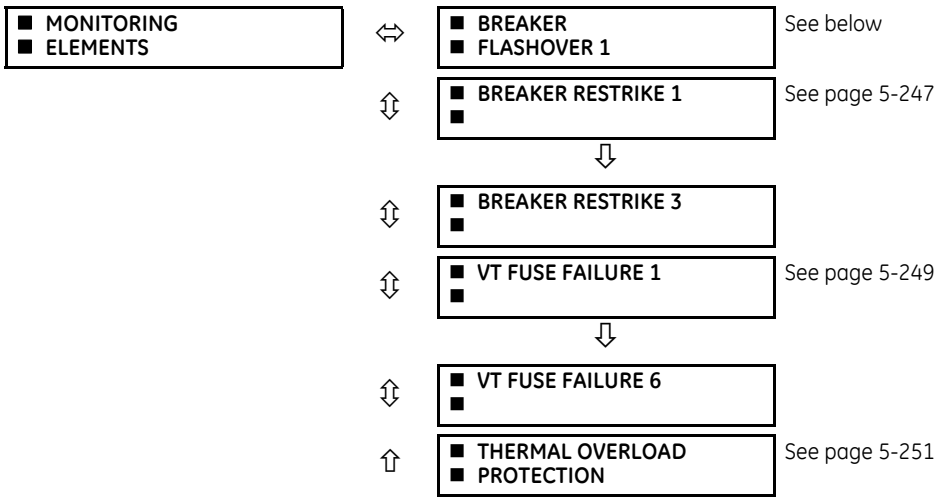
Figure 5-128: Digital counter logic



5.8.10 Monitoring elements

5.8.10.1 Menu

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS



5.8.10.2 Breaker flashover

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ BREAKER FLASHOVER 1



⇳	**BRK 1 FLSHOVR SIDE 1 SRC: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
⇳	**BRK 1 FLSHOVR SIDE 2 SRC: None**	Range: None, SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
⇳	**BRK 1 STATUS CLSD A: Off**	Range: FlexLogic operand
⇩		
⇳	**BRK 1 STATUS CLSD C: Off**	Range: FlexLogic operand
⇳	**BRK 1 FLSHOVR V PKP: 0.850 pu**	Range: 0.000 to 1.500 pu in steps of 0.001
⇳	**BRK 1 FLSHOVR DIFF V PKP: 1000 V**	Range: 0 to 100000 V in steps of 1
⇳	**BRK 1 FLSHOVR AMP PKP: 0.600 pu**	Range: 0.000 to 1.500 pu in steps of 0.001
⇳	**BRK 1 FLSHOVR PKP DELAY: 0.100 s**	Range: 0.000 to 65.535 s in steps of 0.001
⇳	**BRK 1 FLSHOVR SPV A: Off**	Range: FlexLogic operand
⇩		
⇳	**BRK 1 FLSHOVR SPV C: Off**	Range: FlexLogic operand
⇳	**BRK 1 FLSHOVR BLOCK: Off**	Range: FlexLogic operand
⇳	**BRK 1 FLSHOVR TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
⇧	**BRK 1 FLSHOVR EVENTS: Disabled**	Range: Disabled, Enabled

The detection of the breaker flashover is based on the following conditions:

- Breaker open,
- When phase voltage measured from either side of the breaker is greater than the setting,
- Measured current through the breaker is greater than the pickup setting, and
- Voltage difference across the breaker drops below the pickup setting (only applicable to six VTs application)

Furthermore, the scheme is applicable for cases where one or two sets of three-phase voltages are available across the breaker, as follows:

- One set of three-phase voltages is available across the breaker (three VTs application)
- Two sets of three-phase voltages are available across the breaker (six VTs application)

Three VT breaker flashover application

When only one set of VTs is available across the breaker, set the **BRK 1 FLSHOVR SIDE 2 SRC** setting to "None."

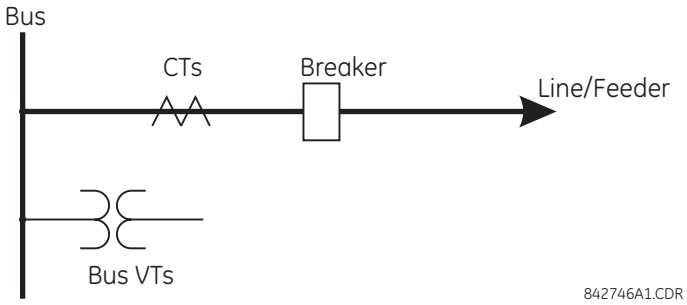
NOTE

Voltages must be present prior to flashover conditions. If the three VTs are placed after the breaker on the line (or feeder), and the downstream breaker is open, the measured voltage is zero and the flashover element is not initiated.

The flashover detection resets if the current drops below **BRK 1 FLSHOVR AMP PKP**, the breaker closes, or the FlexLogic operand selected by **BRK 1 FLSHOVR SPV A** changes to high. It is recommended to use the supervision **BRK 1 FLSHOVR SPV A** setting, and select a trip operand that does not allow the flashover element to pick up prior to the trip.

The flashover detection can be used for external alarm, re-tripping the breaker, or energizing the lockout relay.

Consider the following configuration:



The source 1 (SRC1) phase currents are feeder CTs and phase voltages are bus VTs, and Contact Input 1 is set as Breaker 52a contact. The conditions prior to flashover detection are:

- 52a status = 0
- VAg is greater than the **BRK 1 FLSHOVR V PKP** setting
- IA is below **BRK 1 FLSHOVR AMP PKP** (ideally, IA = 0)

The conditions at flashover detection are:

- 52a status = 0
- VAg is greater or lesser than the **BRK 1 FLSHOVR V PKP** setting
- IA is greater than the **BRK 1 FLSHOVR AMP PKP** setting

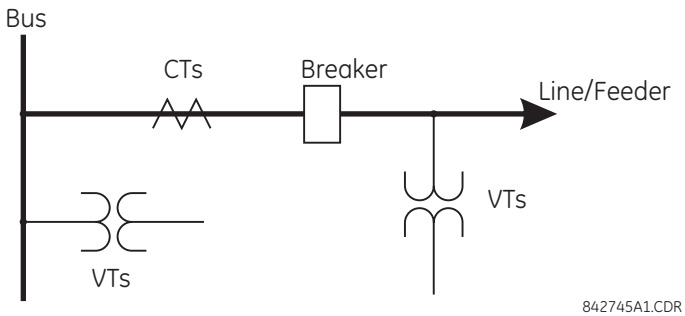
5

Six VT breaker flashover application

In a six-VT application, the VTs located on both sides of a breaker are available. When the breaker is open, the voltage difference across the breaker is the rated voltage if the line is not energized from the remote end, or it can be two times the rated voltage at the time of synchronization if the line is energized from the remote. At the occurrence of breaker flashover, the voltage difference across breaker drops and current greater than **BRK 1 FLSHOVR AMP PKP** starts flowing through the breaker. These conditions are also true for a normal closed operation of a breaker where the voltage difference across breaker is practically zero and load current flows through the breaker. To distinguish between breaker flashover and normal closed operation of breaker, the Breaker Status is utilized.

In a six-VT configuration, if the voltages from VTs located on one of the sides of breaker disappear due to VT fuse failure or other reason, a three-VT configuration can provide the breaker flashover detection. If however, the blocking of breaker flashover detection is wanted under voltage loss on one side condition, then it can be done by applying the appropriate FlexLogic operand to the **BRK FLSHOVR BLOCK** setting.

Consider the following configuration:



The source 1 (SRC1) phase currents are CTs and phase voltages are bus VTs. The source 2 (SRC2) phase voltages are line VTs. Contact input 1 is set as the breaker 52a contact (optional).

The conditions prior to flashover detection are:

- 52a status = 0
- VAg or Vag greater than the **BRK 1 FLSHOVR V PKP** setting
- IA is below **BRK 1 FLSHOVR AMP PKP** (ideally, IA = 0)
- ΔVA is greater than the **BRK 1 FLSHOVR DIFF V PKP** setting

The conditions at flashover detection are:

- 52a status = 0
- VAg or Vag greater or lesser than the **BRK 1 FLSHOVR V PKP** setting
- IA is greater than the **BRK 1 FLSHOVR AMP PKP** setting
- ΔVA is less than the **BRK 1 FLSHOVR DIFF V PKP** setting

NOTE

The element operates only when phase-to-ground voltages are connected to relay terminals. The flashover element does not operate if delta voltages are applied.

Settings

BRK 1 FLSHOVR SIDE 1 SRC — This setting specifies a signal source used to provide three-phase voltages and three-phase currents from one side of the current breaker. The source selected as a setting and must be configured with breaker phase voltages and currents, even if only three VTs are available across the breaker.

BRK 1 FLSHOVR SIDE 2 SRC — This setting specifies a signal source used to provide another set of three phase voltages whenever six VTs are available across the breaker. For a three-VT application, set this setting to "None."

BRK 1 STATUS CLSD A to **BRK 1 STATUS CLSD C** — These settings specify FlexLogic operands to indicate the closed status of the breaker. A separate FlexLogic operand can be selected to detect individual breaker pole status and provide flashover detection. The recommended setting is 52a breaker contact or another operand defining the breaker poles closed status.

NOTE

Leaving this setting off, meaning not configuring any FlexLogic to indicated Closed Breaker leads to maloperation of the element.

BRK 1 FLSHOVR V PKP — This setting specifies a pickup level for the phase voltages from one or both sides of the breaker. If six VTs are available, opening the breaker leads to two possible combinations – live voltages from only one side of the breaker, or live voltages from both sides of the breaker. The detection of voltage above the selected value on either side of the breaker sets the scheme ready for flashover detection. Set **BRK FLSHOVR V PKP** to 85 to 90% of the nominal voltage.

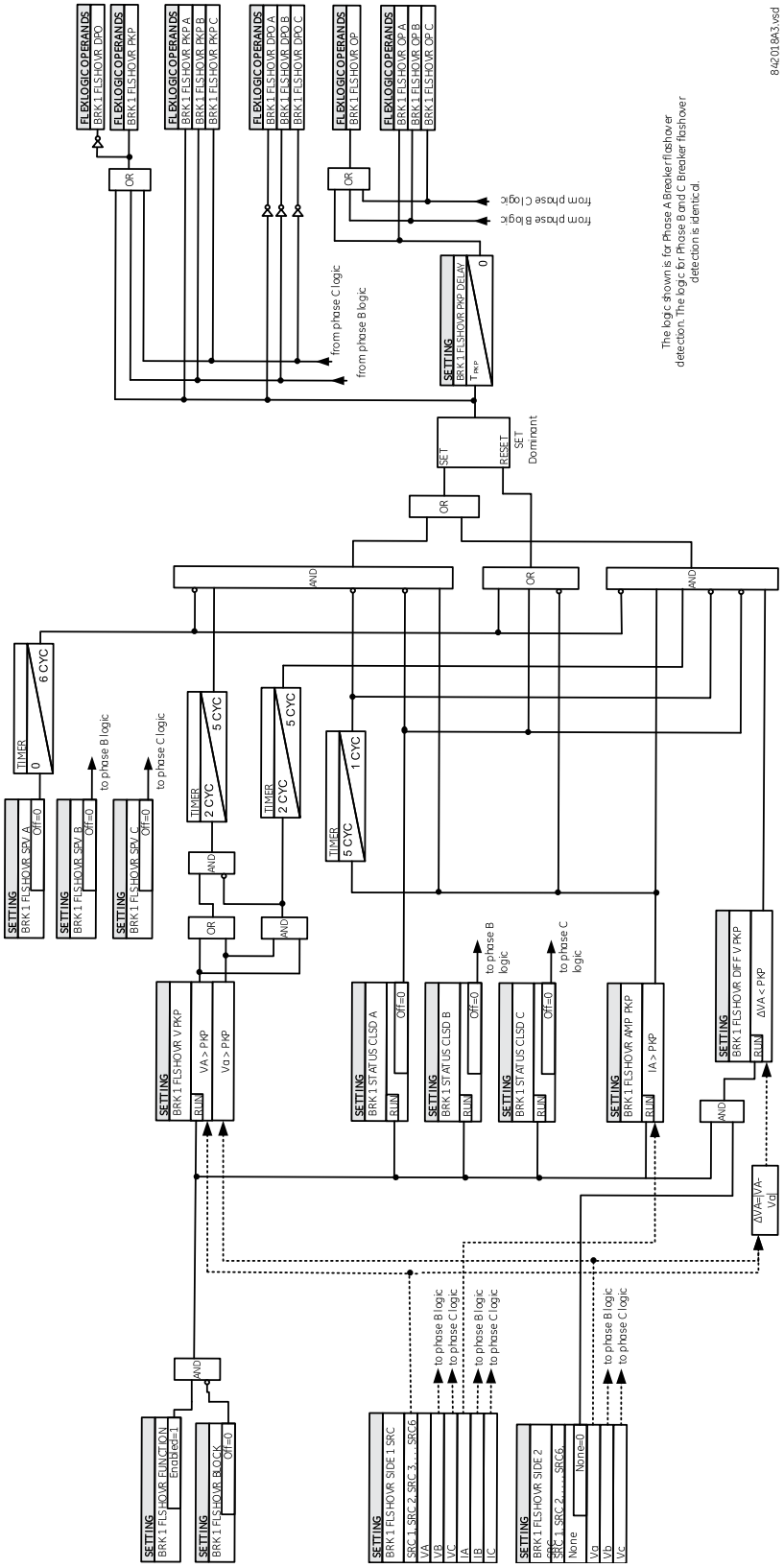
BRK 1 FLSHOVR DIFF V PKP — This setting specifies a pickup level for the phase voltage difference when two VTs per phase are available across the breaker. Set this setting to be lower than the monitored voltage difference that is observed when closed or opened breaker resistors are left in service. The setting is selected as primary volts difference between the sources.

BRK 1 FLSHOVR AMP PKP — This setting specifies the normal load current which can flow through the breaker. Depending on the flashover protection application, the flashover current can vary from levels of the charging current when the line is not loaded to well above the maximum line (feeder) load (line/feeder connected to load).

BRK 1 FLSHOVR SPV A to **BRK 1 FLSHOVR SPV C** — These settings specify FlexLogic operands (per breaker pole) that supervise the operation of the element per phase. Supervision can be provided by operation of other protection elements, breaker failure, and close and trip commands. A six-cycle time delay applies after the selected FlexLogic operand resets.

BRK FLSHOVR PKP DELAY — This setting specifies the time delay to operate after a pickup condition is detected. Do not set it too long else the flashover current can disappear before its detection.

Figure 5-129: Breaker flashover logic



5.8.10.3 Breaker restrike

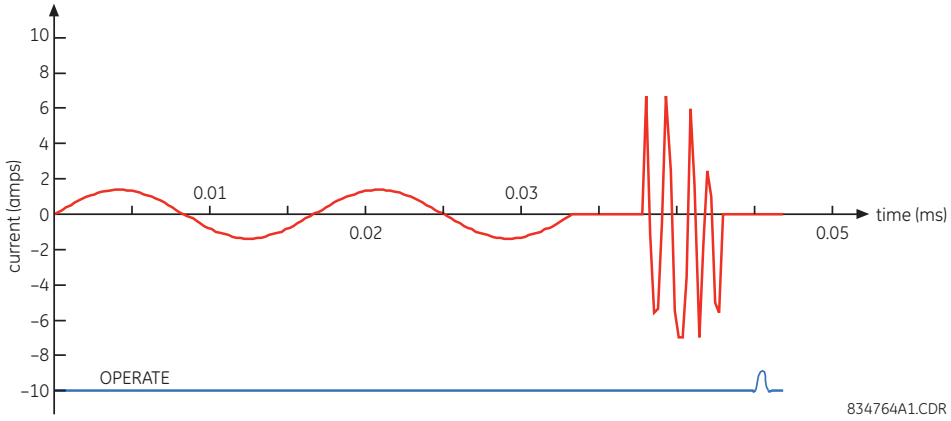
SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ BREAKER RESTRIKE 1(3)

■ BREAKER RESTRIKE 1 ■	⇔	**BREAKER RESTRIKE 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇩	**BRK RESTRIKE 1 BLOCK: Off**	Range: FlexLogic operand
	⇩	**BREAKER RESTRIKE 1 SOURCE: SRC 1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇩	**BREAKER RESTRIKE 1 PICKUP: 0.50 pu**	Range: 0.10 to 2.00 pu in steps of 0.01
	⇩	**BREAKER RESTRIKE 1 RST DELAY: 0.100 s**	Range: 0.000 to 65.535 s in steps of 0.001
	⇩	**BREAKER RESTRIKE 1 HF DETECT: Enabled**	Range: Disabled, Enabled
	⇩	**BRK RSTR 1 BRK OPEN: Off**	Range: FlexLogic operand
	⇩	**BRK RSTR 1 OPEN CMD: Off**	Range: FlexLogic operand
	⇩	**BRK RSTR 1 CLS CMD: Off**	Range: FlexLogic operand
	⇩	**BREAKER RESTRIKE 1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
	⇩	**BREAKER RESTRIKE 1 EVENTS: Disabled**	Range: Disabled, Enabled

One breaker restrike element is provided for each CT bank in the C70.

According to IEEE standard C37.100 entitled IEEE Standard Definitions for Power Switchgear, restrike is defined as "a resumption of current between the contacts of a switching device during an opening operation after an interval of zero current of ¼ cycle at normal frequency or longer."

Figure 5-130: Typical restrike waveform and detection flag



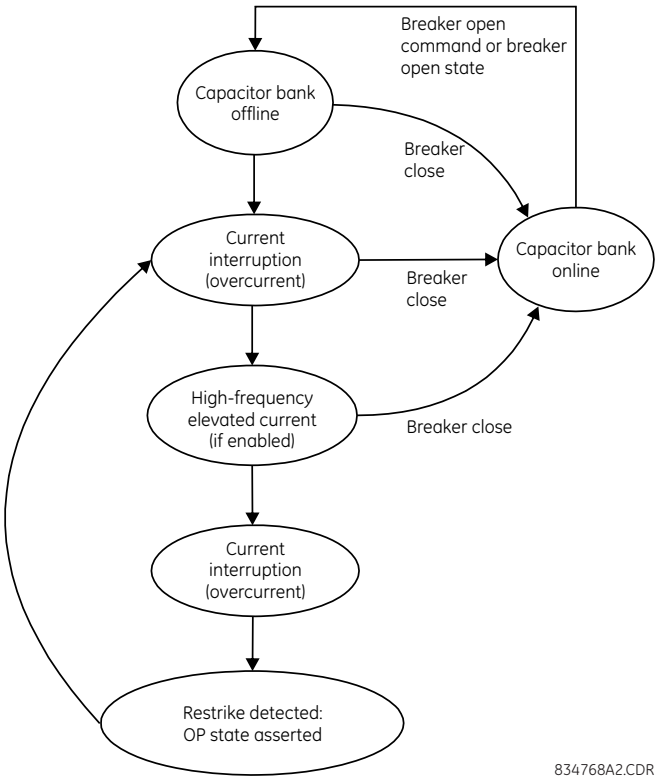
The breaker restrike algorithm responds to a successful interruption of the phase current following a declaration of capacitor bank offline as per the breaker pole indication. If a high-frequency or system frequency current with a magnitude greater than the threshold is resumed at least ¼ of a cycle later than the phase current interruption, then a breaker restrike condition is declared in the corresponding phase and the BRK RESTRIKE 1 OP operand asserts for a short period of time. The user can add counters and other logic to facilitate the decision making process as to the appropriate actions upon detecting a single restrike or a series of consecutive restrikes.

A restrike event (FlexLogic operand) is declared if all of the following hold:

- The current is initially interrupted
- The breaker status is open
- An elevated high frequency current condition occurs (if the **BREAKER RESTRIKE 1 HF DETECT** setting is Enabled, otherwise the condition is bypassed), and
- The current subsequently drops out again

The algorithm is illustrated in the following state machine diagram.

Figure 5-131: Algorithm illustration of state machine to detect restrike



In this way, a distinction is made between a self-extinguishing restrike and permanent breaker failure condition. The latter can be detected by the breaker failure function or a regular instantaneous overcurrent element. Also, a fast succession of restrikes is picked up by breaker failure or instantaneous overcurrent protection.

The following settings are available for each element.

BREAKER RESTRIKE 1 FUNCTION — Enables and disables operation of the breaker restrike detection element.

BRK RESTRIKE 1 BLOCK — Blocks operation of the breaker restrike detection element.

BREAKER RESTRIKE 1 SOURCE — Selects the source of the current for this element. This source must have a valid CT bank assigned.

BREAKER RESTRIKE 1 PICKUP — Specifies the pickup level of the overcurrent detector in per-unit values of CT nominal current.

BREAKER RESTRIKE 1 RST DELAY — Specifies the reset delay for this element. When set to "0 ms," then FlexLogic operand is picked up for only 1/8th of the power cycle.

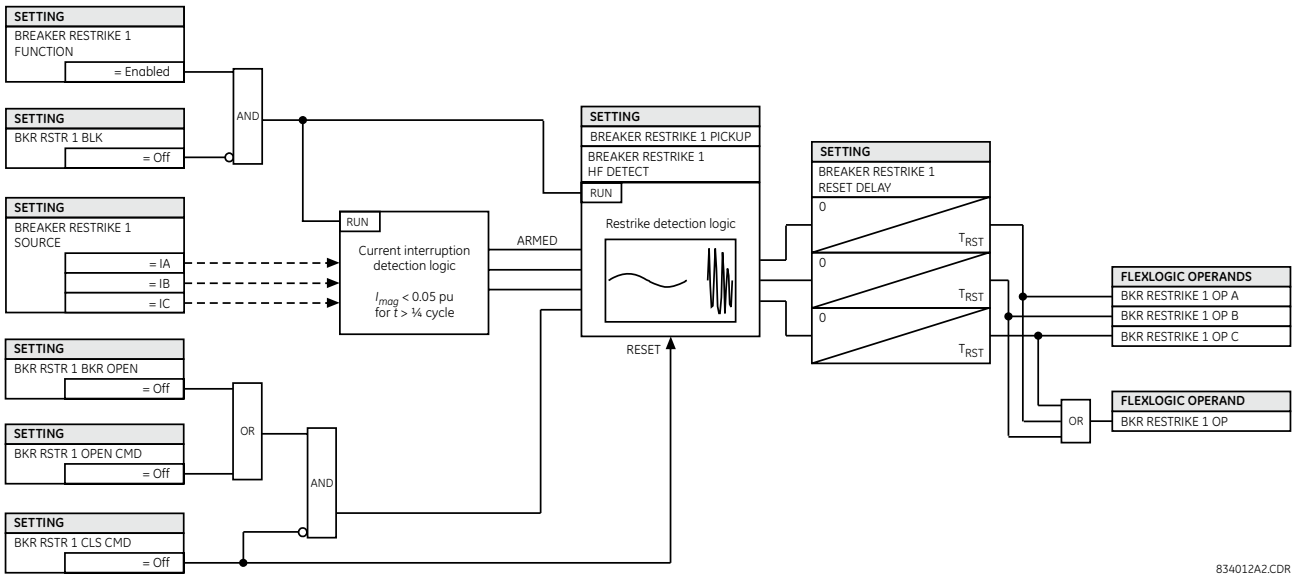
BREAKER RESTRIKE 1 HF DETECT — Enables/disables high-frequency (HF) pattern detection when breaker restrike occurs. High-frequency pattern is typical for capacitor bank, cables, and long transmission line applications.

BRK RSTR 1 BRK OPEN — Assigns a FlexLogic operand indicating the open position of the breaker. It must be logic "1" when the breaker is open. It is important to assign either 52 contact with this setting or breaker close command with **BRK RSTR 1 CLS CMD** setting to give clear indication to the relay about breaker status.

BRK RSTR 1 OPEN CMD — Assigns a FlexLogic operand indicating a breaker open command. It must be logic "1" when the breaker is opened, either manually or from protection logic.

BRK RSTR 1 CLS CMD — Assigns a FlexLogic operand indicating a breaker close command. It must be logic "1" when the breaker is closed.

Figure 5-132: Breaker restrike logic



5.8.10.4 VT fuse failure

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ VT FUSE FAILURE 1(6)

■ VT FUSE FAILURE 1 ■	⇔	VT FUSE FAILURE 1 FUNCTION: Disabled	Range: Disabled, Enabled
	⇳	VT FUSE FAILURE 1 ALARM DELAY: 1.000 s	Range: 0.000 to 65.535 s in steps of 0.001
	⇳	NEUTRAL WIRE OPEN 1 DETECTION: Disabled	Range: Disabled, Enabled
	⇧	NEUTRAL WIRE OPEN 1 3 HARM PKP: 0.100 pu	Range: 0.000 to 3.000 pu in steps of 0.001

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 is used to raise an alarm and/or block elements that operate incorrectly for a full or partial loss of AC potential caused by one or more blown fuses. Some elements that can 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, a rapid decrease in the phase voltages magnitude from a healthy

voltage level without disturbance in current can indicate 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.

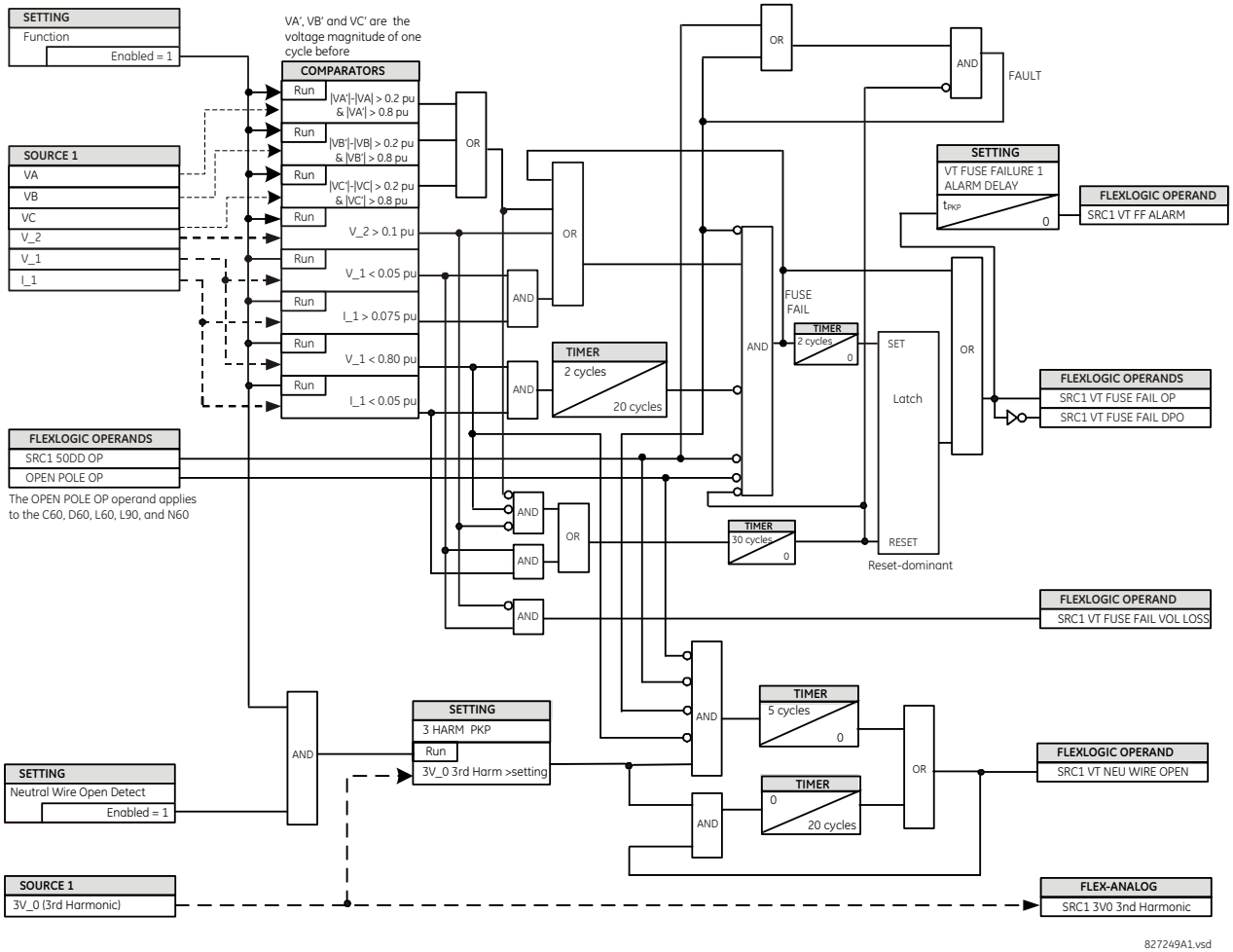
VT FUSE FAILURE 1 FUNCTION — Enables and disables the fuse failure feature for Source 1 VT Fuse Fail.

NEUTRAL WIRE OPEN 1 DETECTION — Enables and disables the VT neutral wire open detection function. When the VT is connected in Delta, do not enable this function because there is no neutral wire for Delta connected VT.

NEUTRAL WIRE OPEN 1 3 HRAM PKP — Specifies the pickup level of 3rd harmonic of 3V0 signal for the **NEUTRAL WIRE OPEN DETECTION** logic to pick up.

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. The setting is found under **SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK ⇨ PHASE VT SECONDARY**.

Figure 5-133: VT fuse fail logic



5.8.10.5 Thermal overload protection (ANSI 49)

SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ THERMAL OVERLOAD PROTECTION ⇨⇩ THERMAL PROTECTION 1(2)

■ THERMAL ■ PROTECTION 1	⇔	**THERMAL PROTECTION 1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇩	**THERMAL PROTECTION 1 SOURCE: SRC1**	Range: SRC 1, SRC 2, SRC 3, SRC 4, SRC 5, SRC 6
	⇩	**THERMAL PROTECTION 1 BASE CURR: 0.80 pu**	Range: 0.20 to 3.00 pu in steps of 0.01
	⇩	**THERMAL PROTECTION 1 k FACTOR: 1.10**	Range: 1.00 to 1.20 in steps of 0.05
	⇩	**THERM PROT 1 TRIP TIME CONST: 45 min.**	Range: 0 to 1000 min. in steps of 1
	⇩	**THERM PROT 1 RESET TIME CONST: 45 min.**	Range: 0 to 1000 min. in steps of 1
	⇩	**THERM PROT 1 MINIM RESET TIME: 20 min.**	Range: 0 to 1000 min. in steps of 1
	⇩	**THERM PROT 1 RESET: Off**	Range: FlexLogic operand
	⇩	**THERM PROT 1 BLOCK: Off**	Range: FlexLogic operand
	⇩	**THERMAL PROTECTION 1 TARGET: Self-reset**	Range: Self-reset, Latched, Disabled
	⇩	**THERMAL PROTECTION 1 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:

$$t_{op} = \tau_{op} \times \ln\left(\frac{I^2}{I^2 - (k \times I_B)^2}\right) \qquad \textbf{Eq. 5-23}$$

The IEC255-8 hot curve is defined as follows:

$$t_{op} = \tau_{op} \times \ln\left(\frac{I^2 - I_p^2}{I^2 - (k \times I_B)^2}\right) \qquad \textbf{Eq. 5-24}$$

where

t_{op} = time to operate
τ_{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 $I/(k \times I_B)$ is limited to 8, even when realistically it is exceeding this value.

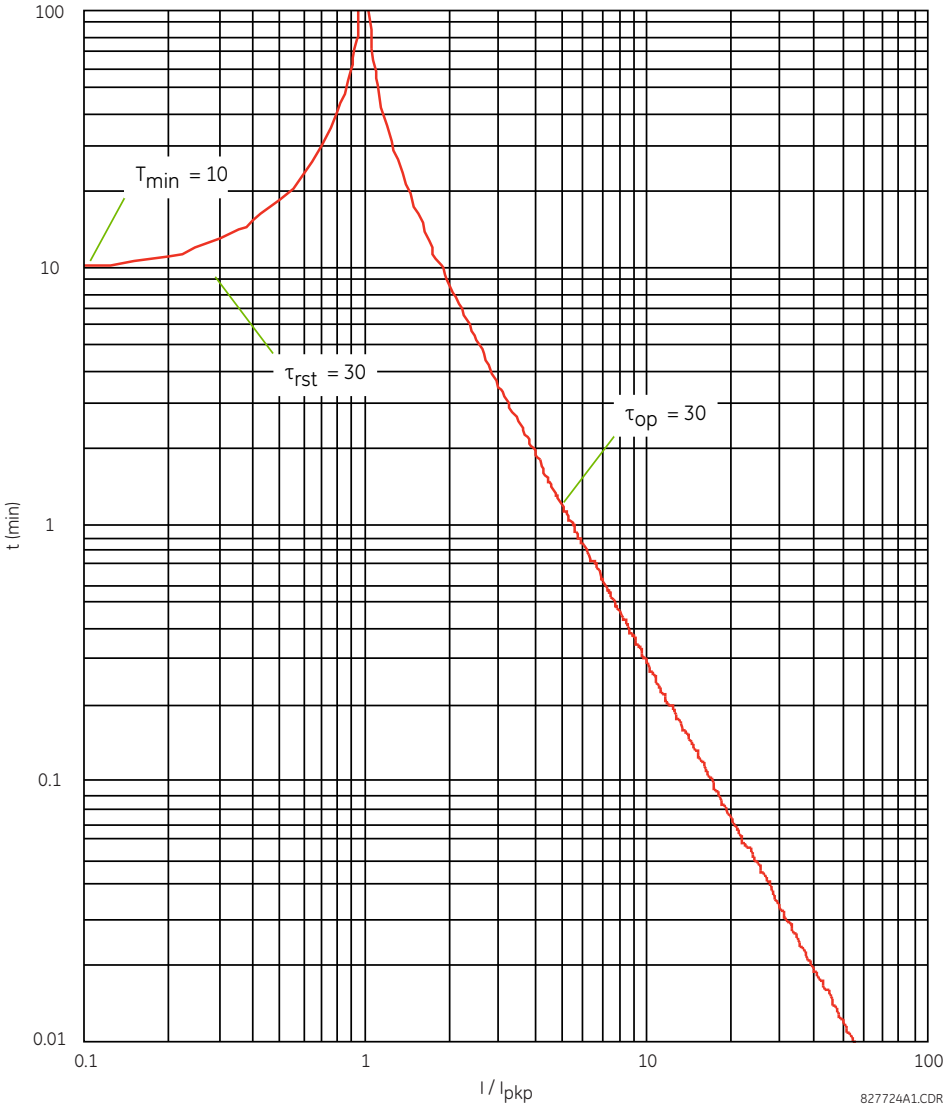
The reset time of the thermal overload protection element is also time delayed using following formula:

$$t_{rst} = \tau_{rst} \times \ln\left(\frac{(k \times I_B)^2}{\left|I^2 - (k \times I_B)^2\right|}\right) + T_{min} \quad \textbf{Eq. 5-25}$$

where

τ_{rst} = thermal protection trip time constant
T_{min} = a minimum reset time setting

Figure 5-134: 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:

$$E_n = E_{n-1} + \frac{\Delta t}{t_{op(In)}} \quad \textbf{Eq. 5-26}$$

When current is less than the dropout level, $I_n > 0.97 \times k \times I_B$, the element starts decreasing the thermal energy:

$$E_n = E_{n-1} - \frac{\Delta t}{t_{rst(In)}} \quad \text{Eq. 5-27}$$

where

Δt 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

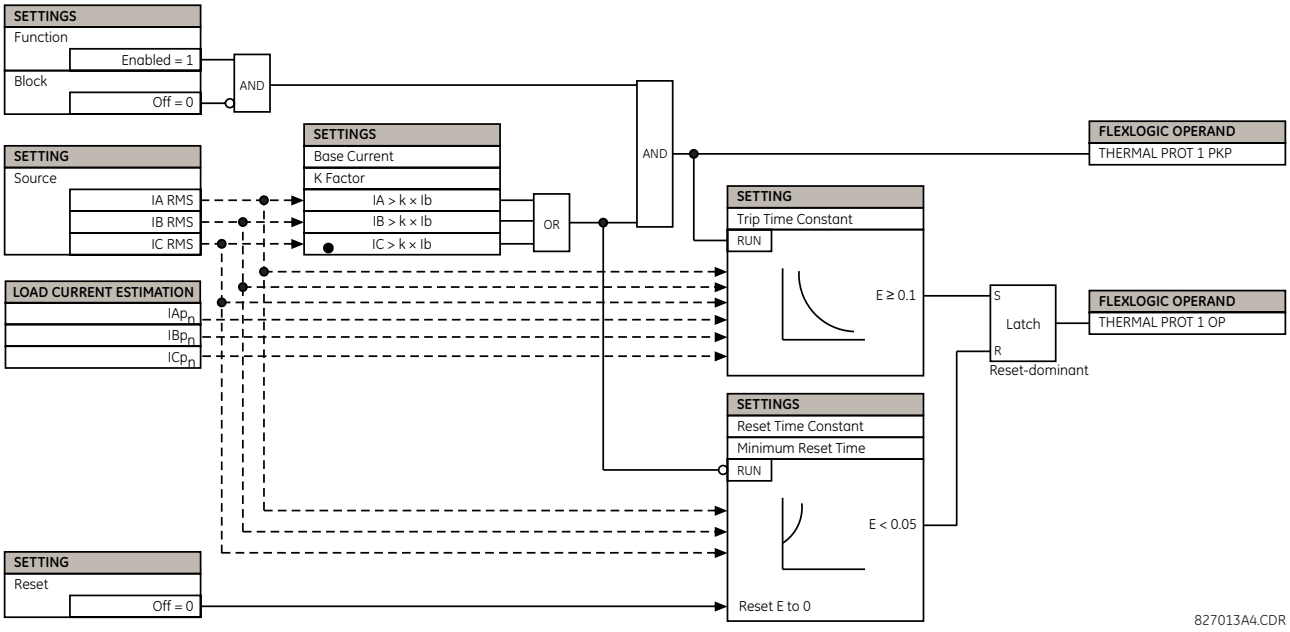
The thermal overload protection element removes the **THERMAL PROT 1 OP** output operand when E < 0.05. In case of emergency, the thermal memory and **THERMAL PROT 1 OP** output operand can be reset using **THERM PROT 1 RESET** setting. All calculations are performed per phase. If the accumulated energy 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.

Table 5-36: 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 figure shows the logic for the thermal overload protection element.

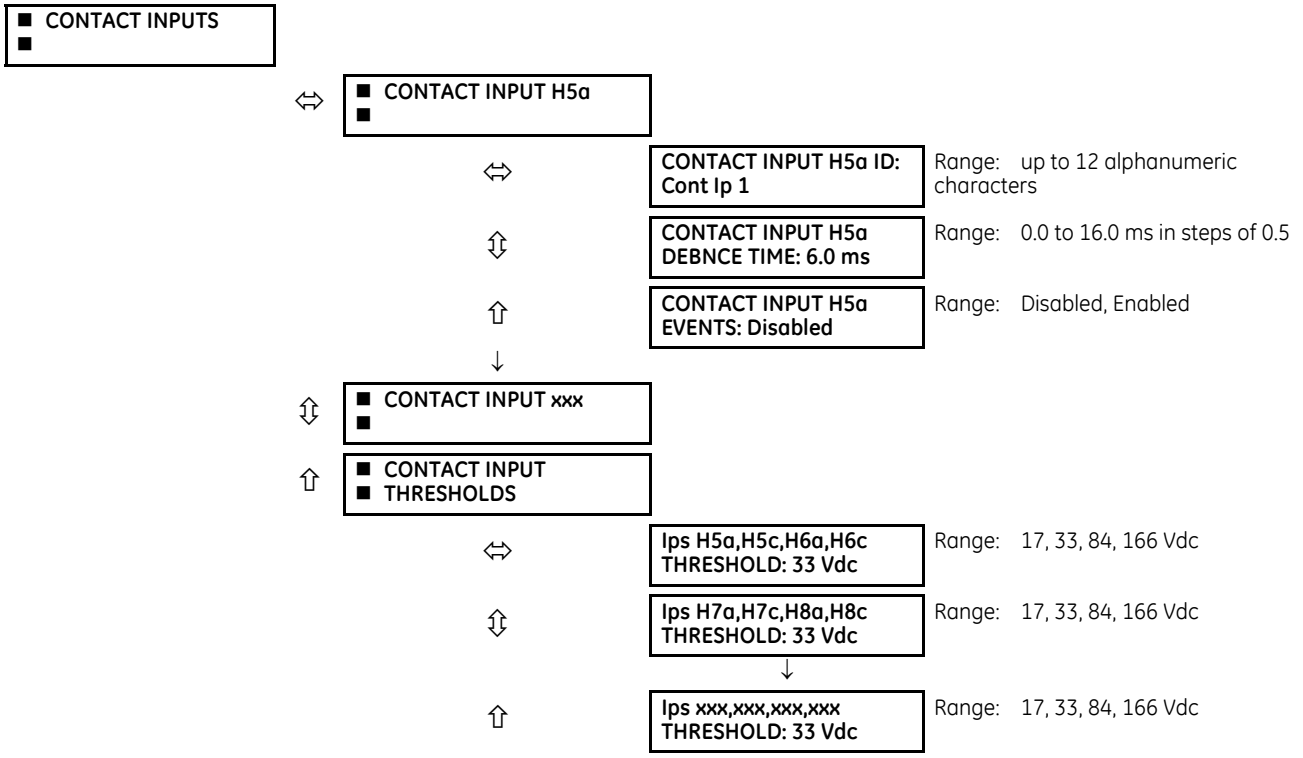
Figure 5-135: Thermal overload protection logic



5.9 Inputs/outputs

5.9.1 Contact inputs

SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨ CONTACT INPUTS



Contact inputs and outputs are digital signals associated with connections to hard-wired contacts. Wet and dry contacts are supported.

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 can 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 triggers an event.

A raw status is scanned for all Contact Inputs synchronously at the constant rate of 0.5 ms as shown in the following figure. 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 C70 to validate the new contact state. In the following figure, 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 (de-bounced), 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 figure).

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 that follows). 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.

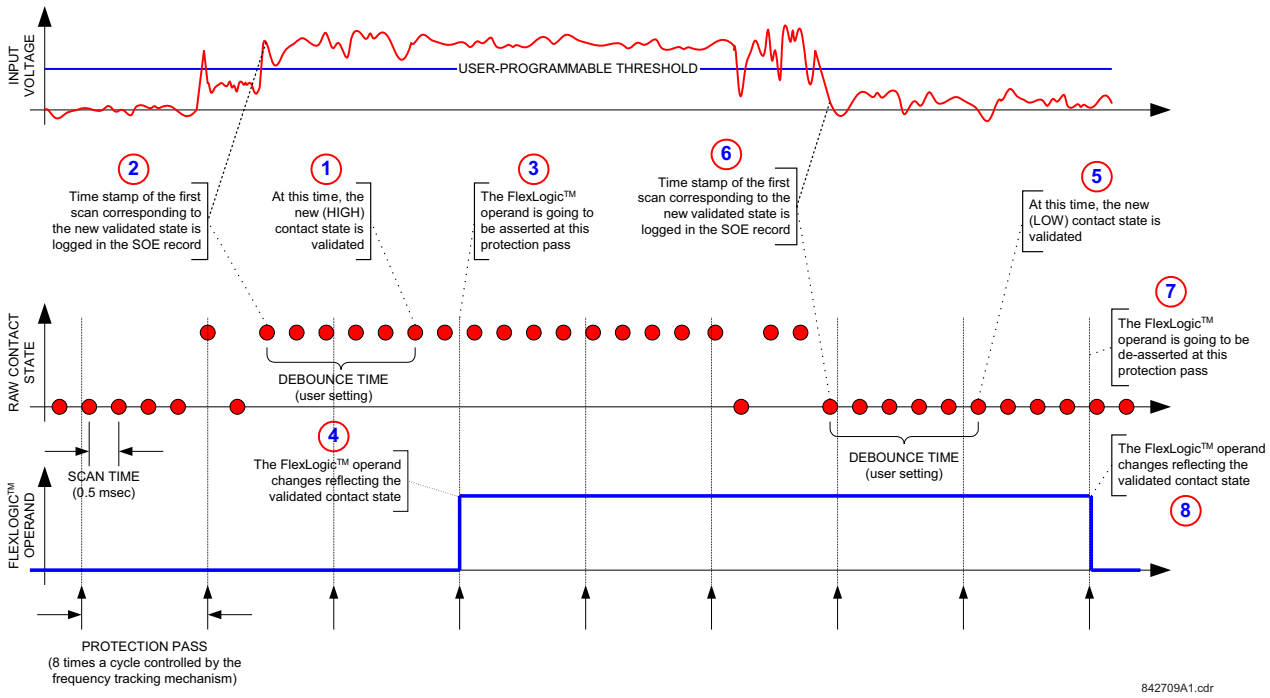
The FlexLogic operand response time to the contact input change is equal to the debounce time setting plus up to one protection pass (variable and depending on system frequency if frequency tracking enabled). If the change of state occurs just after a protection pass, the recognition is delayed until 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 1 ms.

For example, eight 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 shown). 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) and HIGH-LOW (marks no. 5, 6, 7, and 8) transitions.

Figure 5-136: 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 is 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.

5.9.2 Virtual inputs

SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ VIRTUAL INPUTS ⇨ VIRTUAL INPUT 1(64)

■ VIRTUAL INPUT 1 ■	⇔	VIRTUAL INPUT 1 FUNCTION: Disabled	Range: Disabled, Enabled
	⇩	VIRTUAL INPUT 1 ID: Virt Ip 1	Range: up to 12 alphanumeric characters
	⇩	VIRTUAL INPUT 1 TYPE: Latched	Range: Self-Reset, Latched
	⇩	VIRTUAL INPUT 1 EVENTS: Disabled	Range: Disabled, Enabled

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.

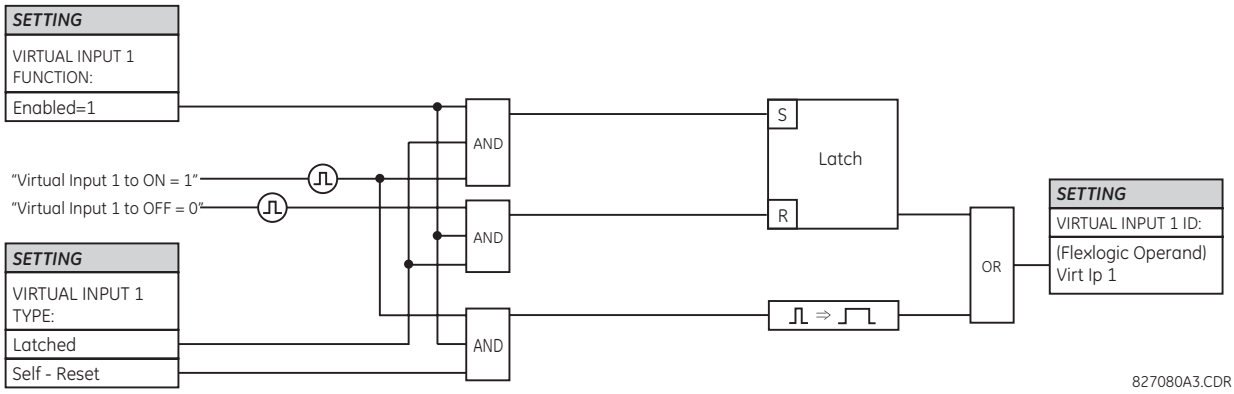
There are 64 virtual inputs that can be individually programmed to respond to input signals from the keypad (via the **COMMANDS** menu) and communications protocols. All virtual input operands are defaulted to "Off" (logic 0) unless the appropriate input signal is received.

If the **VIRTUAL INPUT x FUNCTION** is to "Disabled," the input is 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 is 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.

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 likely needs to be lengthened in time. A FlexLogic timer with a delayed reset can perform this function.

Figure 5-137: Virtual inputs logic



5.9.3 Contact outputs

5.9.3.1 Digital outputs

SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS ⇨⇩ CONTACT OUTPUT H1

■ CONTACT OUTPUT H1 ■	⇔	CONTACT OUTPUT H1 ID Cont Op 1	Range: up to 12 alphanumeric characters
	⇕	OUTPUT H1 OPERATE: Off	Range: FlexLogic operand
	⇕	OUTPUT H1 SEAL-IN: Off	Range: FlexLogic operand
	⇧	CONTACT OUTPUT H1 EVENTS: Enabled	Range: Disabled, Enabled

A contact inputs and outputs are digital signals associated with connections to hard-wired contacts. Wet and dry contacts are supported.

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 then presents the settings for only these outputs. Where the contact input is non-latching, the settings are as shown.

An ID can be assigned to each contact output. The signal that can **OPERATE** a contact output can be any FlexLogic operand (virtual output, element state, contact input, or virtual input). An additional FlexLogic operand can 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 5-138: Contact input/output module type 6A contact 1 logic



5.9.3.2 Latching outputs

SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS ⇨ CONTACT OUTPUT H1a

■ CONTACT OUTPUT H1a ■	⇔	**OUTPUT H1a ID** **L-Cont Op 1**	Range: up to 12 alphanumeric characters
	⇩	**OUTPUT H1a OPERATE:** **Off**	Range: FlexLogic operand
	⇩	**OUTPUT H1a RESET:** **Off**	Range: FlexLogic operand
	⇩	**OUTPUT H1a TYPE:** **Operate-dominant**	Range: Operate-dominant, Reset-dominant
	⇩	**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.

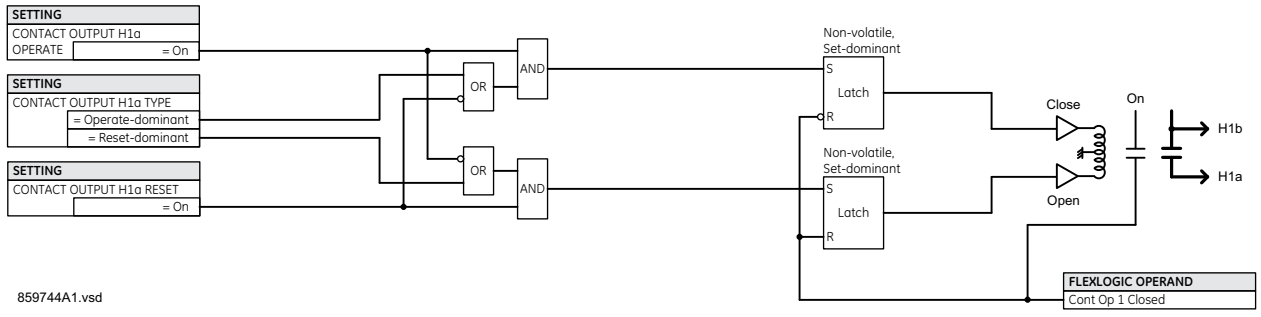
Since the relay asserts the output contact and reads back its position, it is possible to incorporate self-monitoring capabilities for the latching outputs. If any latching outputs exhibits a discrepancy, the LATCHING OUTPUT ERROR self-test error is declared. The error is signaled by the LATCHING OUT 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 seals-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, does 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 seals-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, does 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 closes if set to "Operate-dominant" and opens if set to "Reset-dominant."

Figure 5-139: 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 are 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):

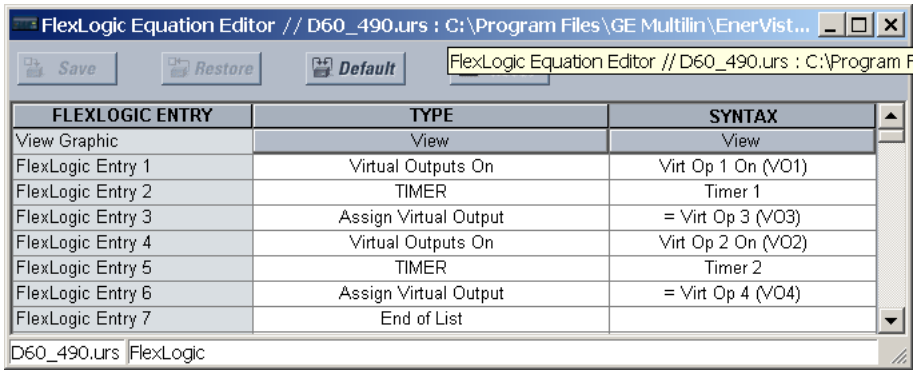
OUTPUT H1a OPERATE: "VO1"
OUTPUT H1a RESET: "VO2"
OUTPUT H1c OPERATE: "VO2"
OUTPUT H1c RESET: "VO1"

Since the two physical contacts in this example are mechanically separated and have individual control inputs, they do not operate at exactly the same time. A discrepancy in the range of a fraction of a maximum operating time can occur. Therefore, a pair of contacts programmed to be a multi-contact relay do 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.

Write the following FlexLogic equation (EnerVista example shown).



Set both timers (Timer 1 and Timer 2) to 20 ms pickup and 0 ms dropout.

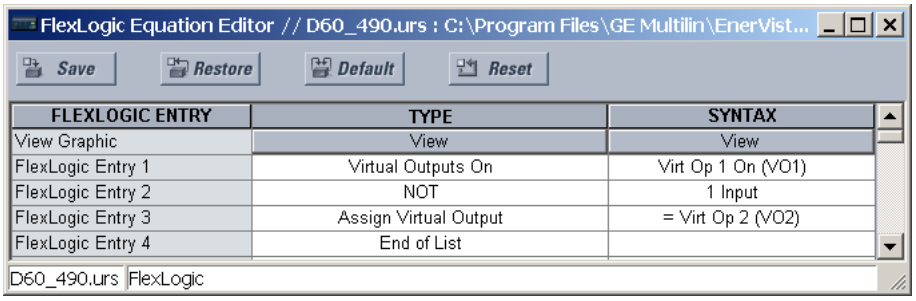
Program the Latching Outputs by making the following changes in the **SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS ⇨ CONTACT OUTPUT H1a** and **CONTACT OUTPUT H1c** menus (assuming an H4L module):

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 is to remain closed as long as VO1 is high, and is to remain opened when VO1 is low. Program the relay as follows.

Write the following FlexLogic equation (EnerVista 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"

5.9.4 Virtual outputs

SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ VIRTUAL OUTPUTS ⇨ VIRTUAL OUTPUT 1(96)

■ **VIRTUAL OUTPUT 1** ■	⇔	**VIRTUAL OUTPUT 1 ID** **Virt Op 1**	Range: up to 12 alphanumeric characters
	⇧	**VIRTUAL OUTPUT 1 EVENTS: Disabled**	Range: Disabled, Enabled

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.

There are 96 virtual outputs that can be assigned using FlexLogic. If not assigned, the output is forced to 'OFF' (Logic 0). An ID also can 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 is programmed as follows:

VIRTUAL OUTPUT 1 ID: "Trip"
VIRTUAL OUTPUT 1 EVENTS: "Disabled"

5.9.5 Resetting

SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ RESETTING

■ **RESETTING** ■	⇔	**RESET OPERAND:** **Off**	Range: FlexLogic operand

Some events can be programmed to latch the faceplate LED event indicators, target messages, 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 **RESET OPERAND** setting here selects the operand that activates the RESET OP (OPERAND) operand.

5.9.6 Direct inputs and outputs

5.9.6.1 Direct inputs

SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ DIRECT INPUTS ⇨ DIRECT INPUT 1(32)

■ DIRECT INPUT 1 ■	⇔	DIRECT INPUT 1 NAME: Dir Ip 1	Range: up to 12 alphanumeric characters
	⇩	DIRECT INPUT 1 DEVICE ID: 0	Range: 0 to 16
	⇩	DIRECT INPUT 1 BIT NUMBER: 0	Range: 0 to 32
	⇩	DIRECT INPUT 1 DEFAULT: Off	Range: On, Off, Latest/On, Latest/Off
	⇧	DIRECT INPUT 1 EVENTS: Disabled	Range: Enabled, Disabled

These settings specify how the direct input information is processed.

DIRECT INPUT 1 NAME — This setting allows the user to assign a descriptive name to the direct input.

DIRECT INPUT 1 DEVICE ID — Represents the source of direct input 1. The specified direct input is driven by the device identified here.

DIRECT INPUT 1 BIT NUMBER — The bit number to extract the state for direct input 1. Direct Input 1 is driven by the bit identified as **DIRECT INPUT 1 BIT NUMBER**. This corresponds to the direct output number of the sending device.

DIRECT INPUT 1 DEFAULT — Represents the state of the direct input when the associated direct device is offline. The following choices are available:

- On — Defaults the input to Logic 1
- Off — Defaults the input to Logic 0
- Latest/On — Freezes the input in case of lost communications. When the latest state is not known, such as after relay power-up but before the first communication exchange, the input defaults to Logic 1. When communication resumes, the input becomes fully operational.
- Latest/Off — Freezes the input in case of lost communications. When the latest state is not known, such as after relay power-up but before the first communication exchange, the input defaults to Logic 0. When communication resumes, the input becomes fully operational.

5.9.6.2 Direct outputs

SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ DIRECT OUTPUTS ⇨ DIRECT OUTPUT 1(32)

■ DIRECT OUTPUT 1 ■	⇔	DIRECT OUT 1 NAME: Dir Out 1	Range: up to 12 alphanumeric characters
	⇩	DIRECT OUT 1 OPERAND: Off	Range: FlexLogic operand
	⇧	DIRECT OUTPUT 1 EVENTS: Disabled	Range: Enabled, Disabled

DIRECT OUT 1 NAME — This setting allows the user to assign a descriptive name to the direct output.

DIR OUT 1 OPERAND — This sets the FlexLogic operand that determines the state of this direct output.

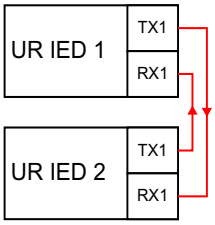
5.9.6.3 Application examples

The examples introduced in the earlier Direct Inputs and Outputs section (part of the Product Setup section) are continued here to illustrate usage of the direct inputs and outputs.

Example 1: Extending input/output capabilities of a UR relay

Consider an application that requires additional quantities of contact inputs or output contacts or lines of programmable logic that exceed the capabilities of a single UR-series chassis. The problem is solved by adding an extra UR-series IED, such as the C30, to satisfy the additional inputs/outputs and programmable logic requirements. The figure shows that two IEDs are connected via single-channel digital communication cards.

Figure 5-140: Input and output extension via direct inputs and outputs



Assume that contact input 1 from UR IED 2 is to be used by UR IED 1. The following settings are applied (Direct Input 5 and bit number 12 are used, as an example).

UR IED 1:

DIRECT INPUT 5 DEVICE ID = "2"
DIRECT INPUT 5 BIT NUMBER = "12"

UR IED 2:

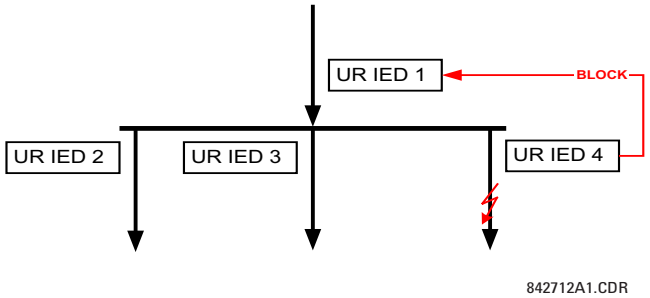
DIRECT OUT 12 OPERAND = "Cont Ip 1 On"

The Cont Ip 1 On operand of UR IED 2 is now available in UR IED 1 as DIRECT INPUT 5 ON.

Example 2: Interlocking busbar protection

A simple interlocking busbar protection scheme can be accomplished by sending a blocking signal from downstream devices, say 2, 3 and 4, to the upstream device that monitors a single incomer of the busbar, as shown in the figure.

Figure 5-141: Sample interlocking busbar protection scheme



Assume that Phase Instantaneous Overcurrent 1 is used by Devices 2, 3, and 4 to block Device 1. If not blocked, Device 1 trips the bus upon detecting a fault and applying a short coordination time delay.

The following settings are applied (assume Bit 3 is used by all 3 devices to send the blocking signal and Direct Inputs 7, 8, and 9 are used by the receiving device to monitor the three blocking signals).

UR IED 2:

DIRECT OUT 3 OPERAND: "PHASE IOC1 OP"

UR IED 3:

DIRECT OUT 3 OPERAND: "PHASE IOC1 OP"

UR IED 4:

DIRECT OUT 3 OPERAND: "PHASE IOC1 OP"

UR IED 1:

DIRECT INPUT 7 DEVICE ID: "2"
DIRECT INPUT 7 BIT NUMBER: "3"
DIRECT INPUT 7 DEFAULT STATE: select "On" for security, select "Off" for dependability

DIRECT INPUT 8 DEVICE ID: "3"
DIRECT INPUT 8 BIT NUMBER: "3"
DIRECT INPUT 8 DEFAULT STATE: select "On" for security, select "Off" for dependability

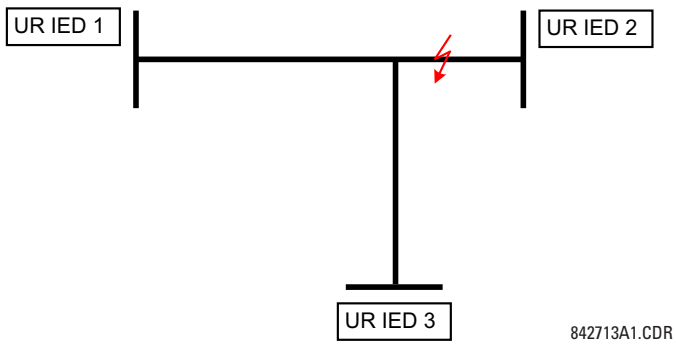
DIRECT INPUT 9 DEVICE ID: "4"
DIRECT INPUT 9 BIT NUMBER: "3"
DIRECT INPUT 9 DEFAULT STATE: select "On" for security, select "Off" for dependability

Now the three blocking signals are available in UR IED 1 as DIRECT INPUT 7 ON, DIRECT INPUT 8 ON, and DIRECT INPUT 9 ON. Upon losing communications or a device, the scheme is inclined to block (if any default state is set to "On"), or to trip the bus on any overcurrent condition (all default states set to "Off").

Example 3: Pilot-aided schemes

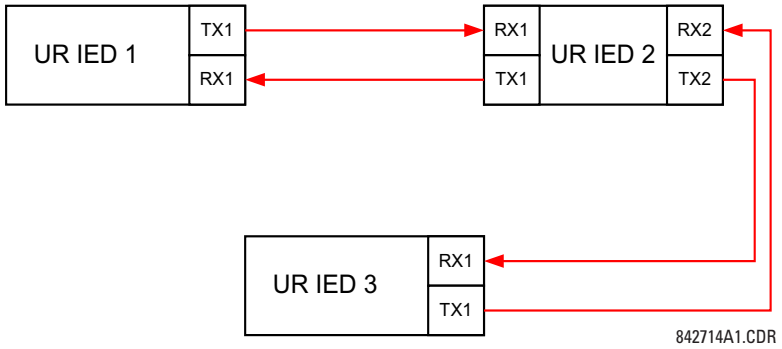
Consider a three-terminal line protection application shown in the following figure.

Figure 5-142: Three-terminal line application



Assume the Hybrid Permissive Overreaching Transfer Trip (Hybrid POTT) scheme is applied using the architecture shown as follows. The scheme output operand HYB POTT TX1 is used to key the permission.

Figure 5-143: Single-channel open-loop configuration



In this architecture, Devices 1 and 3 do not communicate directly. Therefore, Device 2 must act as a 'bridge'. The following settings are applied:

UR IEC 1:

DIRECT OUT 2 OPERAND: "HYB POTT TX1"
DIRECT INPUT 5 DEVICE ID: "2"
DIRECT INPUT 5 BIT NUMBER: "2" (this is a message from IED 2)
DIRECT INPUT 6 DEVICE ID: "2"
DIRECT INPUT 6 BIT NUMBER: "4" (effectively, this is a message from IED 3)

UR IED 3:

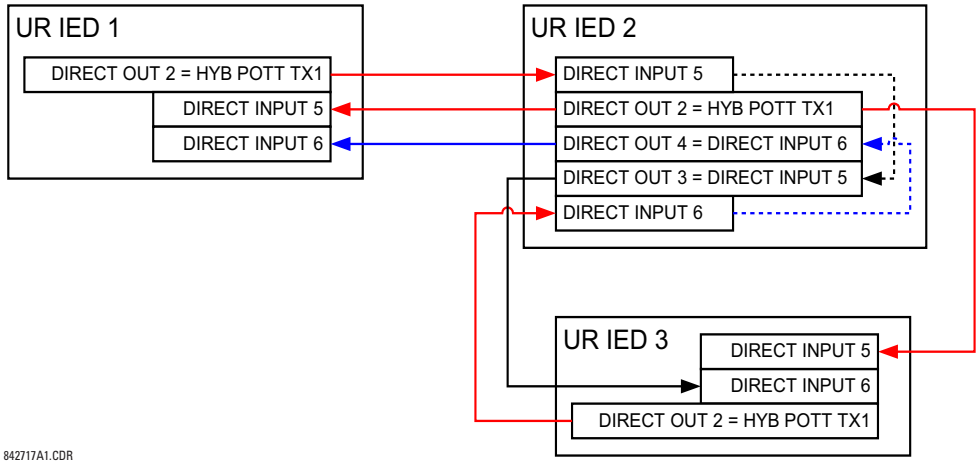
DIRECT OUT 2 OPERAND: "HYB POTT TX1"
DIRECT INPUT 5 DEVICE ID: "2"
DIRECT INPUT 5 BIT NUMBER: "2" (this is a message from IED 2)
DIRECT INPUT 6 DEVICE ID: "2"
DIRECT INPUT 6 BIT NUMBER: "3" (effectively, this is a message from IED 1)

UR IED 2:

DIRECT INPUT 5 DEVICE ID: "1"
DIRECT INPUT 5 BIT NUMBER: "2"
DIRECT INPUT 6 DEVICE ID: "3"
DIRECT INPUT 6 BIT NUMBER: "2"
DIRECT OUT 2 OPERAND: "HYB POTT TX1"
DIRECT OUT 3 OPERAND: "DIRECT INPUT 5" (forward a message from 1 to 3)
DIRECT OUT 4 OPERAND: "DIRECT INPUT 6" (forward a message from 3 to 1)

The figure shows the signal flow among the three IEDs.

Figure 5-144: Signal flow for direct input and output



In three-terminal applications, both the remote terminals must grant permission to trip. Therefore, at each terminal, direct inputs 5 and 6 are ANDed in FlexLogic and the resulting operand configured as the permission to trip (**HYB POTT RX1** setting).

5.10 Transducer inputs/outputs

5.10.1 DCmA inputs

SETTINGS ⇨⇩ TRANSDUCER I/O ⇨⇩ DCMA INPUTS ⇨ DCMA INPUT F1(U8)

■ DCMA INPUT F1 ■	⇔	DCMA INPUT F1 FUNCTION: Disabled	Range: Disabled, Enabled
	⇩	DCMA INPUT F1 ID: DCMA Ip 1	Range: up to 20 alphanumeric characters
	⇩	DCMA INPUT F1 UNITS: μA	Range: six alphanumeric characters
	⇩	DCMA INPUT F1 RANGE: 0 to -1 mA	Range: 0 to –1 mA, 0 to +1 mA, –1 to +1 mA, 0 to 5 mA, 0 to 10mA, 0 to 20 mA, 4 to 20 m
	⇩	DCMA INPUT F1 MIN VALUE: 0.000	Range: –9999.999 to +9999.999 in steps of 0.001
	⇧	DCMA INPUT F1 MAX VALUE: 0.000	Range: –9999.999 to +9999.999 in steps of 0.001



The C70 is provided with optional DCmA capability. This feature is specified as an option at the time of ordering. See the Order Codes section in chapter 2 for details.

Hardware and software are provided to receive signals from external transducers and to convert these signals into a digital format for use as required. The relay accepts 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. 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. Configure the 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 automatically generates 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 generated automatically for every channel available in the specific relay as shown above for the first channel of a type 5F transducer module installed in slot F.

The function of the channel can be "Enabled" or "Disabled." If "Disabled," no actual values are created for the channel. An alphanumeric "ID" is assigned to each channel; this ID is included in the channel actual value, along with the programmed units associated with the parameter measured by the transducer, such as volts, °C, megawatts, and so on. 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 F1 RANGE** setting specifies the mA DC range of the transducer connected to the input channel.

The **DCMA INPUT F1 MIN VALUE** and **DCMA INPUT F1 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 F1 MIN VALUE** value is "0" and the **DCMA INPUT F1 MAX VALUE** value is "250." Another example is a watts transducer with a span from –20 to +180 MW; in this case the **DCMA INPUT F1 MIN VALUE** value is "–20" and the **DCMA INPUT F1 MAX VALUE** value is "180." Intermediate values between the minimum and maximum values are scaled linearly.

5.10.2 RTD inputs

SETTINGS ⇨⇩ TRANSDUCER I/O ⇨⇩ RTD INPUTS ⇨ RTD INPUT F1(U8)

■ RTD INPUT F1 ■	⇔	**RTD INPUT F1 FUNCTION: Disabled**	Range: Disabled, Enabled
	⇳	**RTD INPUT F1 ID: RTD Ip 1**	Range: up to 20 alphanumeric characters
	⇧	**RTD INPUT F1 TYPE: 100Ω Platinum**	Range: 100Ω Nickel, 10Ω Copper, 100Ω Platinum, 120Ω Nickel

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 automatically generates 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 can be either "Enabled" or "Disabled." If "Disabled," there is not an actual value created for the channel. An alphanumeric ID is assigned to the channel; this ID is 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.

See the following table for reference temperature values for each RTD type.

Table 5-37: 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

5.10.3 DCmA outputs

SETTINGS ⇨⇩ TRANSDUCER I/O ⇨⇩ DCMA OUTPUTS ⇨ DCMA OUTPUT F1(U8)

■ DCMA OUTPUT F1 ■	⇔	DCMA OUTPUT F1 SOURCE: Off	Range: Off, any analog actual value parameter
	⇳	DCMA OUTPUT F1 RANGE: –1 to 1 mA	Range: –1 to 1 mA, 0 to 1 mA, 4 to 20 mA
	⇳	DCMA OUTPUT F1 MIN VAL: 0.000 pu	Range: –90.000 to 90.000 pu in steps of 0.001
	⇧	DCMA OUTPUT F1 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. 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 as follows.

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).

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:

$$I_{out} = \begin{cases} I_{min} & \text{if } x < \textbf{MIN VAL} \\ I_{max} & \text{if } x > \textbf{MAX VAL} \\ k(x - \textbf{MIN VAL}) + I_{min} & \text{otherwise} \end{cases} \quad \textbf{Eq. 5-28}$$

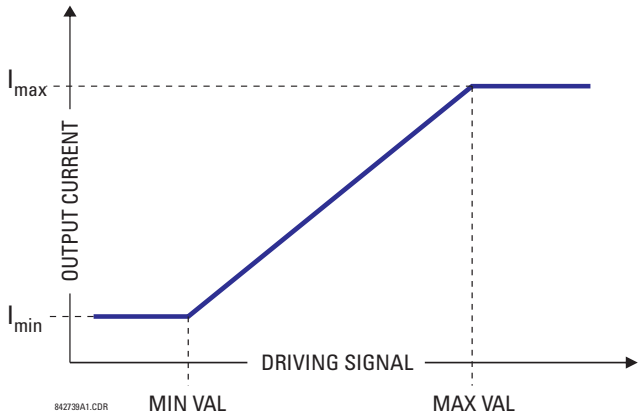
where

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, for example when **MAX VAL** – **MIN VAL** < 0.1 pu. The resulting characteristic is illustrated in the following figure.

Figure 5-145: DCmA output characteristic



Settings

DCMA OUTPUT F1 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. See Appendix A for a list of FlexAnalog parameters.

DCMA OUTPUT F1 RANGE — This setting allows selection of the output range. Each DCmA channel can be set independently to work with different ranges. The three most commonly used output ranges are available.

DCMA OUTPUT F1 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 F1 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 F1 MIN VAL** and **DCMA OUTPUT F1 MAX VAL** settings are ignored for power factor base units (i.e. if the **DCMA OUTPUT F1 SOURCE** is set to FlexAnalog value based on power factor measurement).

Three application examples follow.

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 are 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 is to 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 (see 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 are 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 can be calculated by superimposing the following two sources of error:

- ±0.5% of the full scale for the analog output module, or $\pm 0.005 \times (20 - 4) \times 6.3 \text{ kA} = \pm 0.504 \text{ kA}$
- ±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 is to be monitored in the range from 70% to 110% of nominal.

The minimum and maximum positive-sequence voltages to be monitored are:

$$V_{min} = 0.7 \times \frac{400 \text{ kV}}{\sqrt{3}} = 161.66 \text{ kV}, \quad V_{max} = 1.1 \times \frac{400 \text{ kV}}{\sqrt{3}} = 254.03 \text{ kV} \qquad \textbf{Eq. 5-37}$$

The base unit for voltage (see the FlexElements section in this chapter for additional details) is:

$$V_{BASE} = 0.0664 \text{ kV} \times 6024 = 400 \text{ kV} \qquad \textbf{Eq. 5-38}$$

The minimum and maximum voltage values to be monitored (in pu) are:

$$\text{minimum voltage} = \frac{161.66 \text{ kV}}{400 \text{ kV}} = 0.404 \text{ pu}, \quad \text{maximum voltage} = \frac{254.03 \text{ kV}}{400 \text{ kV}} = 0.635 \text{ pu} \qquad \textbf{Eq. 5-39}$$

The following settings are 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 × 230.94 kV + 1.27 kV = 2.42 kV.

5.11 Testing

5.11.1 Test mode function

SETTINGS ⇨⇩ TESTING ⇨ TEST MODE FUNCTION

■ TESTING ■	⇔	TEST MODE FUNCTION: Disabled	Range: Disabled, Test-Blocked, Test

The C70 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. It is accessible in the software.

The test mode can be in any of three states: Disabled, Test-Blocked, or Test.

The Disabled mode is intended for normal in service operation; relay protection, control and communication function is normal. Test features are disabled, except channel tests and phasor measurement unit tests remain usable when provided.

The Test-Blocked mode is intended to allow the relay to be quickly placed in a state where the relay cannot negatively impact the power system or other parts of the substation automation system. This is to allow changing settings, loading new firmware, changing hardware modules, and changing communication connections. As far as practical all relay output signals are blocked. Contact outputs are de-energized, latching outputs are frozen. Commands to HardFiber Bricks are blocked. GOOSE transmissions have their "simulation" flag (also known as "test" flag) set, which results in the messages not being accepted by compliant receiving devices that do not have a "Sim" data attribute set. The quality attribute of values that can be output via IEC 61850 MMS services are set to "invalid," which results in the values not being used for operational purposes by compliant receiving devices. Direct I/O channel tests and PMU tests are usable on applicable models.

The Test mode is intended for testing involving forcing relay operation by test signal injection and verifying correct relay output. This mode is also for tests to verify the relay outputs (both contact and communications) have the intended impact on specific power system devices or on specific other substation automation devices. Contact outputs can be selectively enabled or forced as described in the following two sections. Shared outputs to Bricks have their test mode flag raised, which results in their value only being accepted by relays also in forcible/test mode. GOOSE transmissions have the "simulation" flag set, which results in these only being accepted by other devices that have their "Sim" data attribute set. The "Sim" data attribute in the relay is set, so that if GOOSE messages are received with the "simulation" flag set, these are used in place of the normal messages. The quality attribute of values that are output via IEC 61850 MMS services are set to "valid" + "test," which signals that the values are not to be used for operational purposes.

Otherwise, the UR remains fully operational while in Test mode, allowing for various testing procedures. In particular, the protection and control elements, and FlexLogic function normally. Other than the IEC 61850 protocol, communications based inputs and outputs remain fully operational. The test procedure must take this into account. Direct I/O channel tests and PMU tests are usable on applicable models.

The test mode can be selected either through the front panel, through EnerVista UR Setup, or through IEC 61850 control to LLN0.Mod. LLN0.Mod.ctlVal "on" selects Disabled, "test/blocked" selects Test-Blocked, and "test" selects Test. 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 remains at the last programmed value. This allows a UR that has been placed in test-blocked mode to remain isolated during testing and maintenance activities.

5.11.2 Test mode forcing

SETTINGS ⇨⇩ TESTING ⇨ TEST MODE FORCING

■ TESTING ■	⇔	TEST MODE FORCING: On	Range: FlexLogic operand

When in Test mode, the operand selected by the **TEST MODE FORCING** setting dictates further response of the UR to testing conditions, as described in the following two 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 5-38: Test mode operation

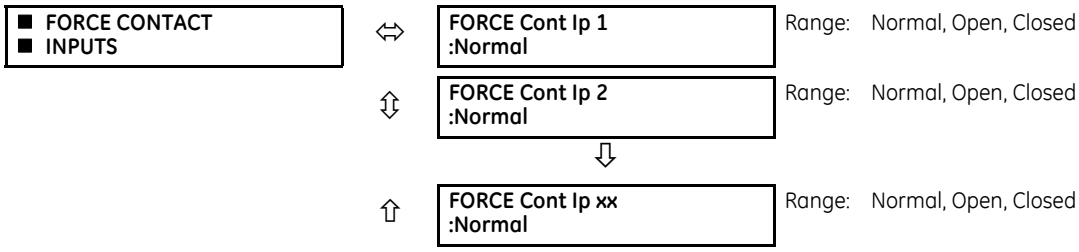
TEST MODE FUNCTION	In-service LED	Test mode LED	Critical fail relay	TEST MODE FORCING	Contact input and output behavior
Disabled	Unaffected	Off	Normal	No effect	Normal
Test-Blocked	Off	On	De-energized	No effect	Contact outputs disabled
Test	Off	Flashing	De-energized	Off	Normal
				On	Controlled by forcing features

NOTE

On restart, the **TEST MODE FORCING** setting and the force contact input and force contact output settings revert to their default states.

5.11.3 Force contact inputs

SETTINGS ⇨⇩ TESTING ⇨⇩ FORCE CONTACT INPUTS



The force contact inputs feature provides a method of performing checks on the function of all contact inputs.

While in Test mode, the relay contact inputs can be pre-programmed to respond in the following ways:

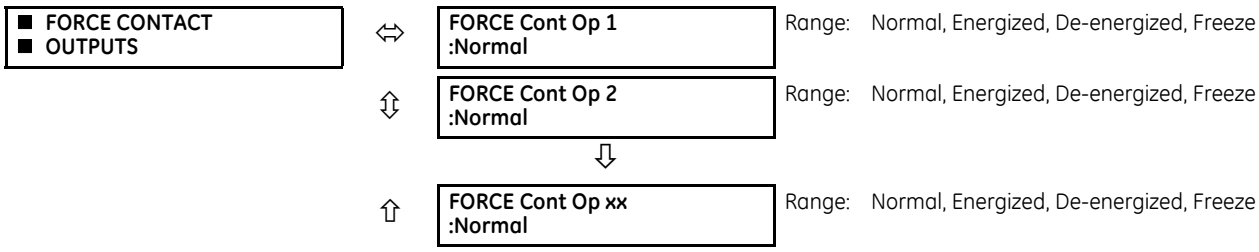
- If set to "Normal," the input remains fully operational. It is controlled by the voltage across its input terminals and can be turned on and off by external circuitry. Select this value if a given input must be operational during the test. This includes, for example, an input initiating the test, or being a part of a user pre-programmed test sequence.
- If set to "Open," the input is forced to report as opened (Logic 0) while the operand selected by **TEST MODE FORCING** setting is On, regardless of the voltage across the input terminals. While the selected operand is Off, the input behaves as it does when in service.
- If set to "Closed," the input is forced to report as closed (Logic 1) while the operand selected by **TEST MODE FORCING** setting is On regardless of the voltage across the input terminals. While the selected operand is Off, the input behaves as it does when in service.

NOTE

On restart, the **TEST MODE FORCING** setting and the force contact input and force contact output settings revert to their default states.

5.11.4 Force contact outputs

SETTINGS ⇨⇩ TESTING ⇨⇩ FORCE CONTACT OUTPUTS



The force contact outputs feature provides a method of performing checks on the function of all contact outputs.

While in Test mode, the relay contact outputs can be pre-programmed to respond in the following ways:

- If set to "Normal," the contact output remains fully operational. It operates when its control operand is logic 1 and resets when its control operand is logic 0.
- If set to "Energized," the output closes and remains closed while the operand selected by the **TEST MODE FORCING** setting is On, regardless of the status of the operand configured to control the output contact. While the selected operand is Off, the output behaves as it does when in service.

- If set to "De-energized," the output opens and remains opened while the operand selected by the **TEST MODE FORCING** setting is On, regardless of the status of the operand configured to control the output contact. While the selected operand is Off, the output behaves as it does when in service.
- If set to "Freeze," the output retains its position at the instant before the **TEST MODE FUNCTION** was Test and the operand selected by the **TEST MODE FORCING** setting was On, regardless of later changes in the status of the operand configured to control the output contact. While the selected operand is Off, the output behaves as it does when in service.



On restart, the **TEST MODE FORCING** setting and the force contact input and force contact output settings revert to their default states.

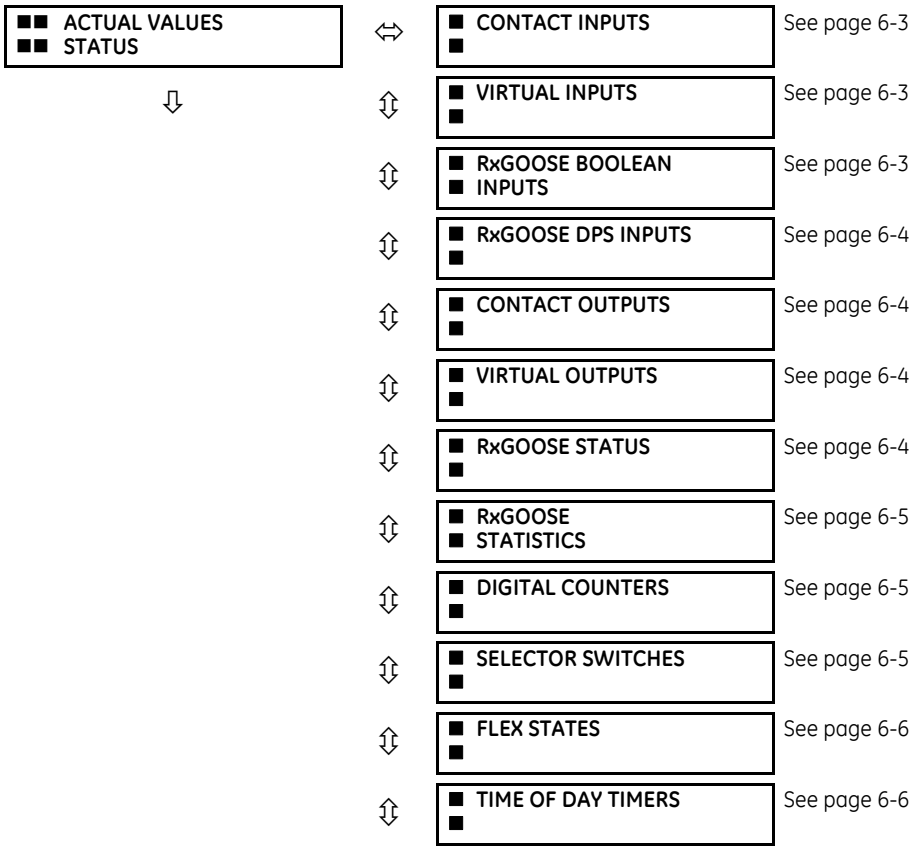
5

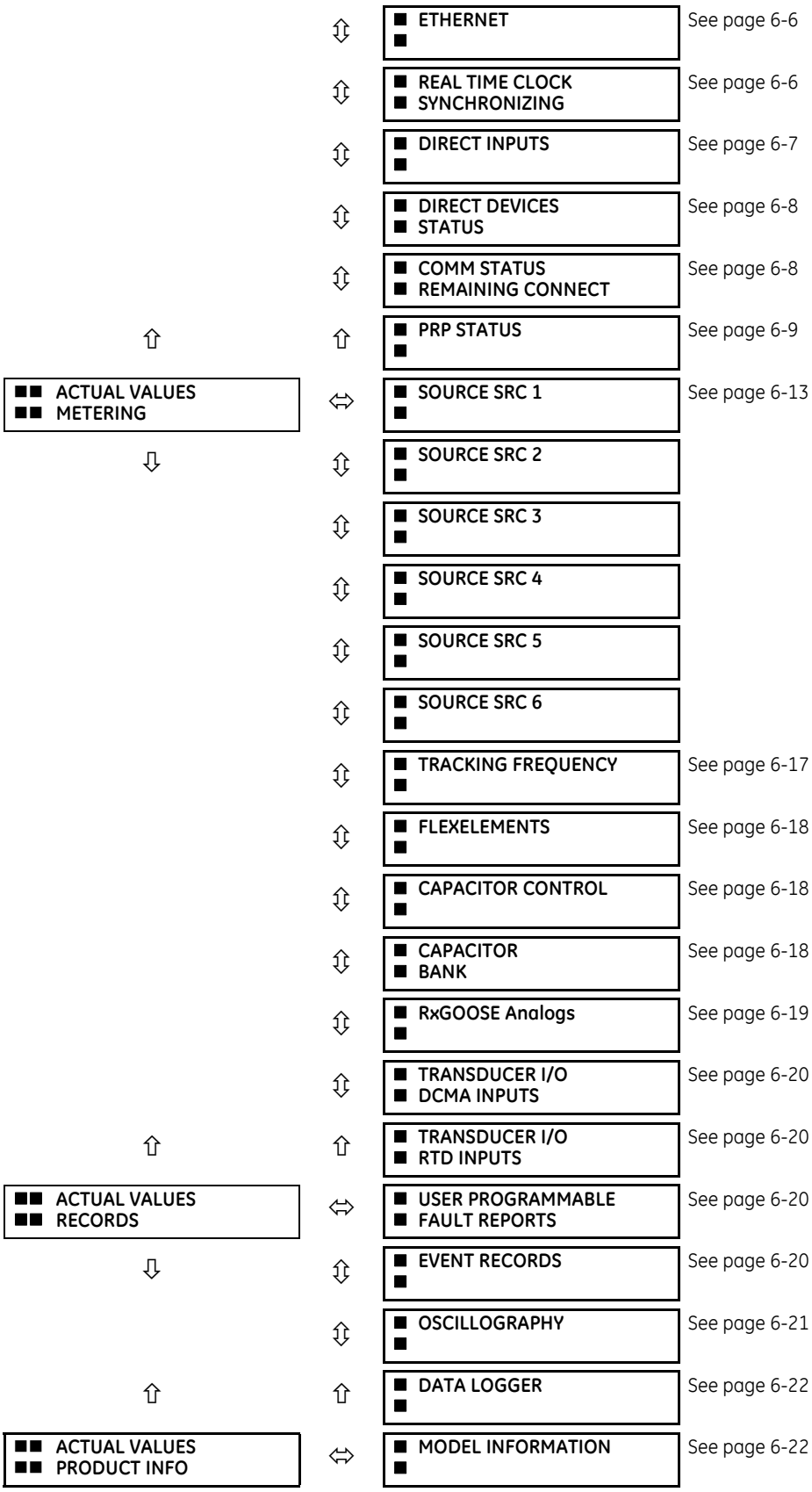
C70 Capacitor Bank Protection and Control System

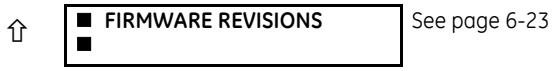
Chapter 6: Actual values

This chapter outlines viewing of data on the front panel and in the software.

6.1 Actual values menu




■■ ACTUAL VALUES
■■ METERING
■ ETHERNET
■
See page 6-6
■ REAL TIME CLOCK
■ SYNCHRONIZING
See page 6-6
■ DIRECT INPUTS
■
See page 6-7
■ DIRECT DEVICES
■ STATUS
See page 6-8
■ COMM STATUS
■ REMAINING CONNECT
See page 6-8
■ PRP STATUS
■
See page 6-9
■ SOURCE SRC 1
■
See page 6-13
■ SOURCE SRC 2
■
■ SOURCE SRC 3
■
■ SOURCE SRC 4
■
■ SOURCE SRC 5
■
■ SOURCE SRC 6
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■ TRACKING FREQUENCY
■
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■
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■ TRANSDUCER I/O
■ DCMA INPUTS
See page 6-20
■ TRANSDUCER I/O
■ RTD INPUTS
See page 6-20
■■ ACTUAL VALUES
■■ RECORDS
■ USER PROGRAMMABLE
■ FAULT REPORTS
See page 6-20
■ EVENT RECORDS
■
See page 6-20
■ OSCILLOGRAPHY
■
See page 6-21
■ DATA LOGGER
■
See page 6-22
■■ ACTUAL VALUES
■■ PRODUCT INFO
■ MODEL INFORMATION
■
See page 6-22

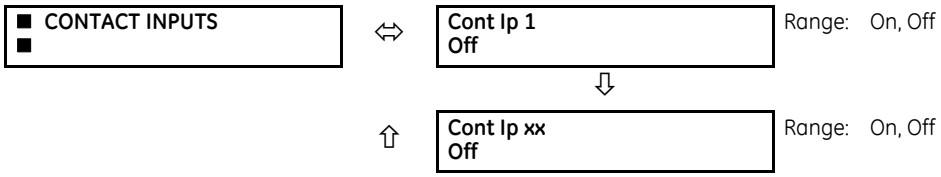


For status reporting, 'On' represents Logic 1 and 'Off' represents Logic 0.

6.2 Status

6.2.1 Contact inputs

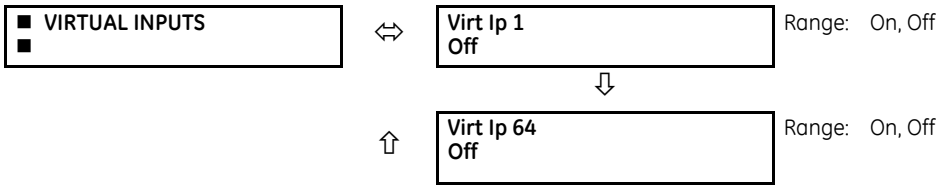
ACTUAL VALUES ⇨ STATUS ⇨ CONTACT INPUTS



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

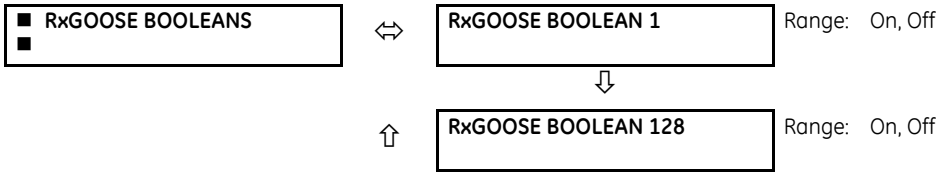
ACTUAL VALUES ⇨ STATUS ⇨⇩ VIRTUAL INPUTS



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 RxGOOSE boolean inputs

ACTUAL VALUES ⇨ STATUS ⇨⇩ RxGOOSE BOOLEANS





The C70 is provided with optional IEC 61850 capability. This feature is specified as a software option at the time of ordering. See the Order Codes section of chapter 2 for details.

6.2.4 RxGOOSE DPS inputs

ACTUAL VALUES ⇨ STATUS ⇨⇩ RxGOOSE DPS

■ RxGOOSE DPS ■	⇔	RxGOOSE DPS 1 Status: intermediate	Range: On, Off, Intermediate, Bad
		⇩	
	⇧	RxGOOSE DPS 5 Status: intermediate	Range: On, Off, Intermediate, Bad



The C70 is provided with optional IEC 61850 capability. This feature is specified as a software option at the time of ordering. See the Order Codes section of chapter 2 for details.

6.2.5 Contact outputs

ACTUAL VALUES ⇨ STATUS ⇨⇩ CONTACT OUTPUTS

■ CONTACT OUTPUTS ■	⇔	Cont Op 1 Off	Range: On, Off, VOff, VOn, IOn, IOff
		⇩	
	⇧	Cont Op xx Off	Range: On, Off, VOff, VOn, IOn, IOff

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.

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.

6.2.6 Virtual outputs

ACTUAL VALUES ⇨ STATUS ⇨⇩ VIRTUAL OUTPUTS

■ VIRTUAL OUTPUTS ■	⇔	Virt Op 1 Off	Range: On, Off
		⇩	
	⇧	Virt Op 96 Off	Range: On, Off

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.

6.2.7 RxGOOSE status

ACTUAL VALUES ⇨ STATUS ⇨⇩ RxGOOSE STATUS

■ RxGOOSE ■ STATUS	⇔	All RxGOOSE Online: Yes	Range: Yes, No
	⇳	RxGOOSE 1 Status: Offline	Range: Online, Offline
		⇩	

⇧ **RxGOOSE 16 Status: Offline** Range: Online, Offline



The C70 is provided with optional IEC 61850 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 **All RxGOOSE Online** actual value does not consider RxGOOSE that are not configured or are not used by any RxGOOSE Input.

6.2.8 RxGOOSE statistics

ACTUAL VALUES ⇨ STATUS ⇨⇩ RxGOOSE STATISTICS ⇨⇩ RxGOOSE 1(16)

■ **RxGOOSE 1**
■

⇔ **RxGOOSE 1 stNum: 0**

⇧ **RxGOOSE 1 sqNum: 0**



The C70 is provided with optional IEC 61850 capability. This feature is specified as a software option at the time of ordering. See the Order Codes section of chapter 2 for details.

stNum — State number. The most recently received value in GOOSE message field stNum. The publisher increments stNum each time that the state of one or more of the GOOSE message members is sent with a revised value.

sqNum — Sequence number. The most recently received value in GOOSE message field sqNum. The publisher sets sqNum to zero each time the state of one or more of the GOOSE message members is sent with a new value, and it increments it whenever a GOOSE message is resent without any member value change.

6.2.9 Digital counters

ACTUAL VALUES ⇨ STATUS ⇨⇩ DIGITAL COUNTERS ⇨ DIGITAL COUNTERS Counter 1(8)

■ **DIGITAL COUNTERS**
■ **Counter 1**

⇔ **Counter 1 ACCUM: 0**

⇳ **Counter 1 FROZEN: 0**

⇳ **Counter 1 FROZEN: YYYY/MM/DD HH:MM:SS**

⇧ **Counter 1 MICROS: 0**

The present status of the eight digital counters displays here. The status of each counter, with the user-defined counter name, includes the accumulated and frozen counts (the count units label also appears). 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.

6.2.10 Selector switches

ACTUAL VALUES ⇨ STATUS ⇨⇩ SELECTOR SWITCHES

■ **SELECTOR SWITCHES**
■

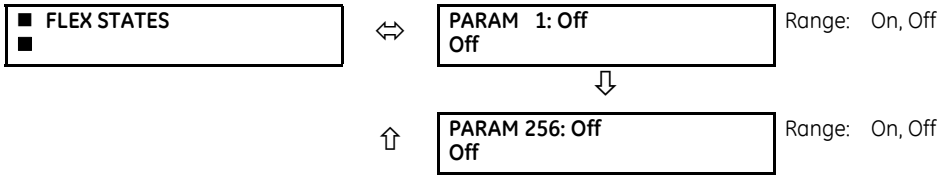
⇔ **SELECTOR SWITCH 1 POSITION: 0/7** Range: Current Position / 7



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.

6.2.11 Flex States

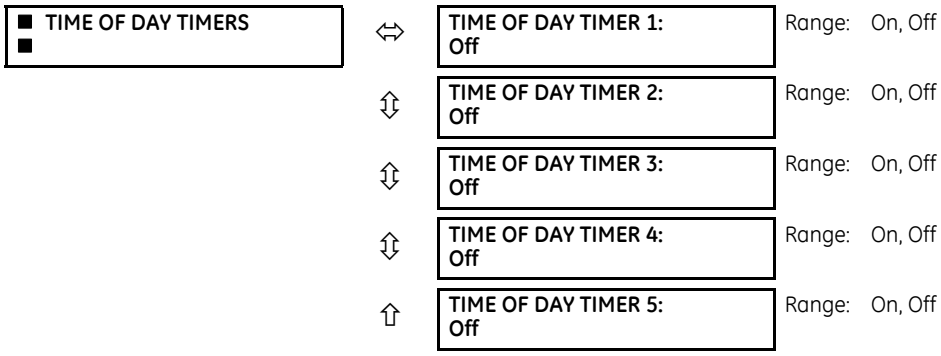
ACTUAL VALUES ⇨ STATUS ⇨⇩ FLEX STATES



There are 256 FlexState™ bits available. The second line value indicates the state of the given FlexState bit.

6.2.12 Time of day timers

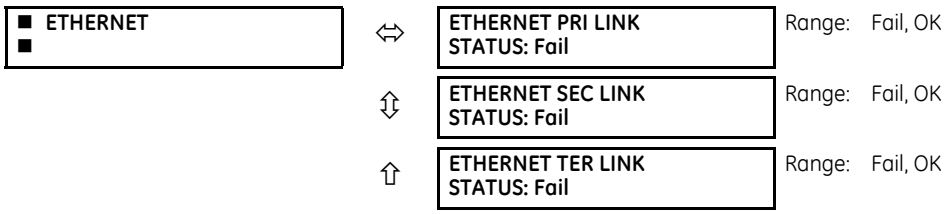
ACTUAL VALUES ⇨ STATUS ⇨⇩ TIME OF DAY TIMERS



This menu displays the current state of each time of day timer.

6.2.13 Ethernet

ACTUAL VALUES ⇨ STATUS ⇨⇩ ETHERNET



These values indicate the status of the first, second, and third Ethernet links.

6.2.14 Real time clock synchronizing

ACTUAL VALUES ⇨ STATUS ⇨⇩ REAL TIME CLOCK SYNCHRONIZING



⇳	**GRANDMASTER ID: 0X0000000000000000**	Range: any 8 octet value
⇳	**ACCURACY: 999,999,999 ns**	Range: 0 to 999, 999, 999 ns
⇳	**PORT 1 PTP STATE: NO SIGNAL**	Range: Disabled, No Signal, Calibrating, Synch'd (No Pdelay), Synchronized
⇳	**PORT 2 PTP STATE: NO SIGNAL**	Range: Disabled, No Signal, Calibrating, Synch'd (No Pdelay), Synchronized
⇳	**PORT 3 PTP STATE: NO SIGNAL**	Range: Disabled, No Signal, Calibrating, Synch'd (No Pdelay), Synchronized
⇳	**PTP - IRIG-B DELTA: 500,000,000 ns**	Range: -500,000,000 to +500,000,000 ns



This item displays when the product includes an IEEE 1588 software option.

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:

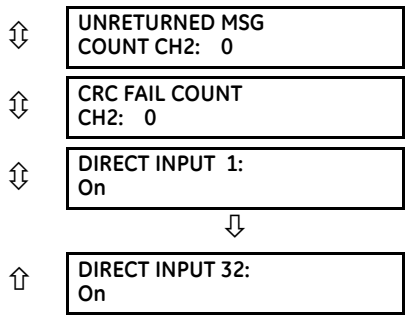
- **DISABLED** is the port's function setting is Disabled
- **NO SIGNAL** if enabled but no signal from an active master has been found and selected
- **CALIBRATING** if an active master has been selected but lock is not at present established
- **SYNCH'D (NO PDELAY)** if the port is synchronized, but the peer delay mechanism is non-operational
- **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.

6.2.15 Direct inputs

ACTUAL VALUES ⇨ STATUS ⇨⇳ DIRECT INPUTS

■ DIRECT INPUTS ■	⇔	**AVERAGE MSG RETURN TIME CH1: 0 ms**
	⇳	**UNRETURNED MSG COUNT CH1: 0**
	⇳	**CRC FAIL COUNT CH1: 0**
	⇳	**AVERAGE MSG RETURN TIME CH2: 0 ms**



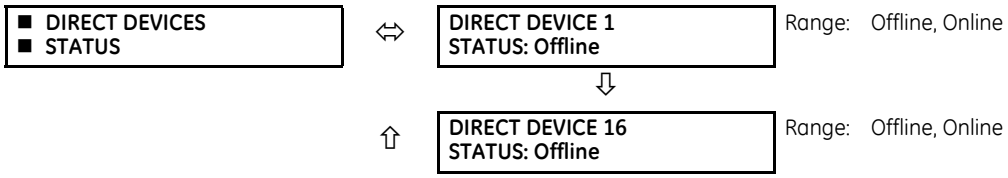
The **AVERAGE MSG RETURN TIME** is the time taken for direct output messages to return to the sender in a direct input/output ring configuration (this value is not applicable for non-ring configurations). This is a rolling average calculated for the last ten messages. There are two return times for dual-channel communications modules.

The **UNRETURNED MSG COUNT** values (one per communications channel) count the direct output messages that do not make the trip around the communications ring. The **CRC FAIL COUNT** values (one per communications channel) count the direct output messages that have been received but fail the CRC check. High values for either of these counts can indicate on a problem with wiring, the communication channel, or one or more relays. The **UNRETURNED MSG COUNT** and **CRC FAIL COUNT** values can be cleared using the **CLEAR DIRECT I/O COUNTERS** command.

The **DIRECT INPUT 1** to **DIRECT INPUT (32)** values represent the state of each direct input.

6.2.16 Direct devices status

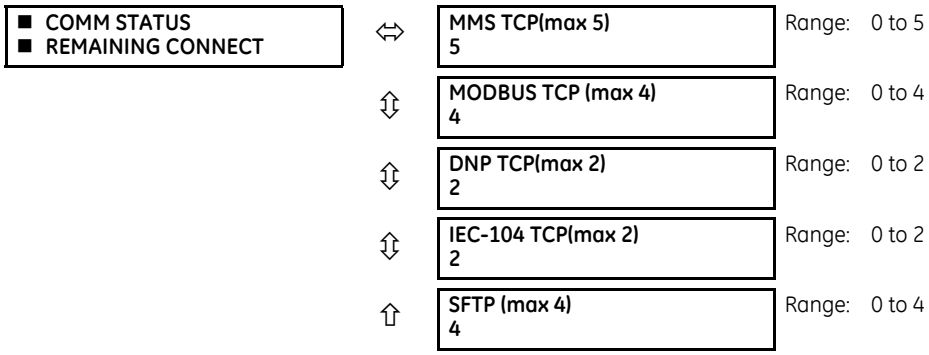
ACTUAL VALUES ⇨ STATUS ⇨⇩ DIRECT DEVICES STATUS



These actual values represent the state of direct devices 1 through 16.

6.2.17 Remaining connection status

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. 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.

6.2.18 Parallel Redundancy Protocol (PRP)

The Parallel Redundancy Protocol (PRP) defines a redundancy protocol for high availability in substation automation networks.

ACTUAL VALUES ⇨ STATUS ⇨⇩ PRP

■ PRP STATUS ■	⇔	Total Rx Port A: 0	Range: 0 to 4G, blank if PRP disabled
	⇳	Total Rx Port B: 0	Range: 0 to 4G, blank if PRP disabled
	⇳	Mismatches Port A: 0	Range: 0 to 4G, blank if PRP disabled
	⇳	Mismatches Port B: 0	Range: 0 to 4G, blank if PRP disabled
	⇧	Total Errors: 0	Range: 0 to 4G, blank if PRP disabled



The C70 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.

Total Errors is a counter for total messages received with an error (bad port code, frame length too short).

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).

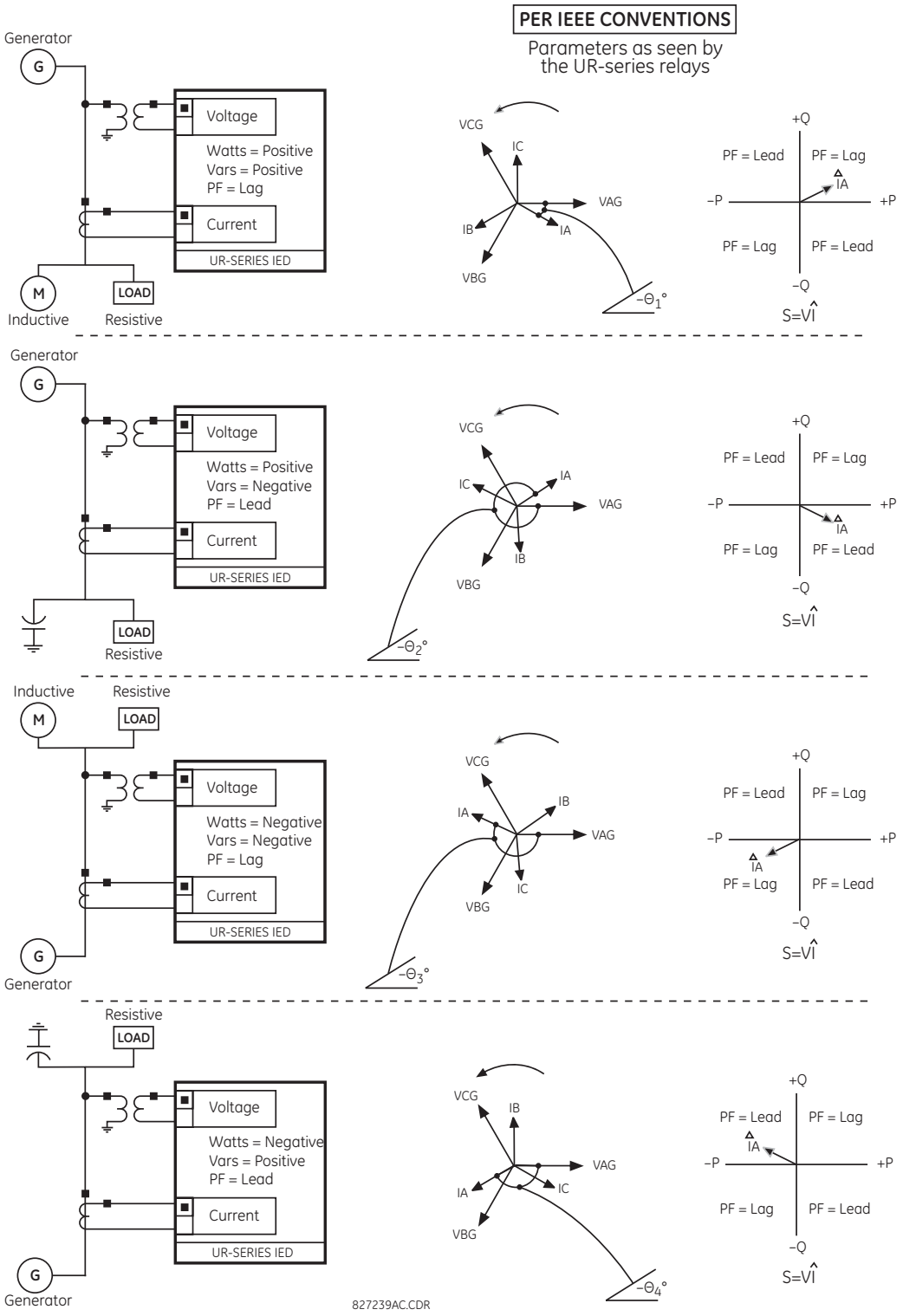
6.3 Metering

6.3.1 Metering conventions

6.3.1.1 UR convention for measuring power and energy

The figure illustrates the conventions established for use in UR devices.

Figure 6-1: Flow direction of signed values for watts and VARs



6.3.1.2 UR convention for measuring phase angles

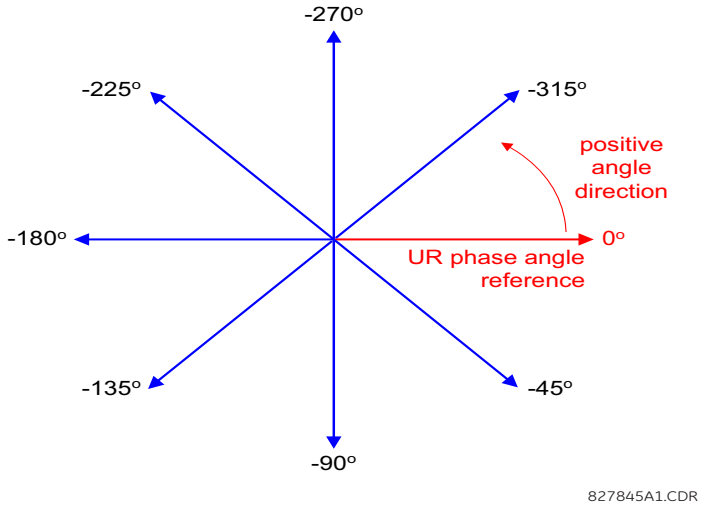
All phasors calculated by URs and used for protection, control and metering functions are rotating phasors that maintain the correct phase angle relationships with each other at all times.

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 first determines 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. The figure illustrates this.

Figure 6-2: UR phase angle measurement convention



6.3.1.3 UR convention for measuring symmetrical components

The URs 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:

$$V\_0 = N/A$$
$$V\_1 = \frac{1\angle -30°}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA})$$
$$V\_2 = \frac{1\angle 30°}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA})$$

- ACB phase rotation:

$$V\_0 = N/A$$
$$V\_1 = \frac{1\angle 30°}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA})$$
$$V\_2 = \frac{1\angle -30°}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA})$$

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.

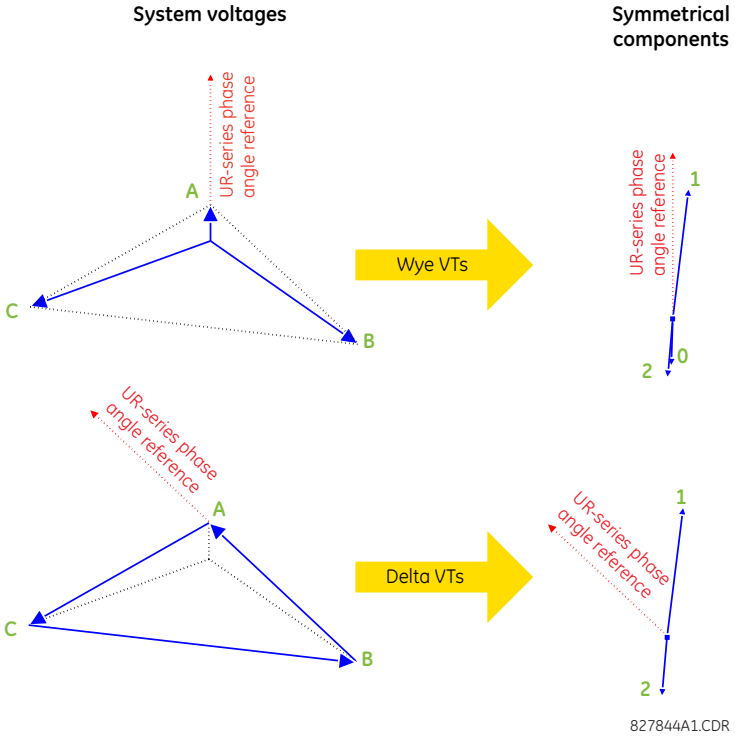
Table 6-1: Symmetrical components calculation example

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 V_{AG} and V_{AB}, respectively. This, however, is a relative matter. It is important to remember that the C70 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.

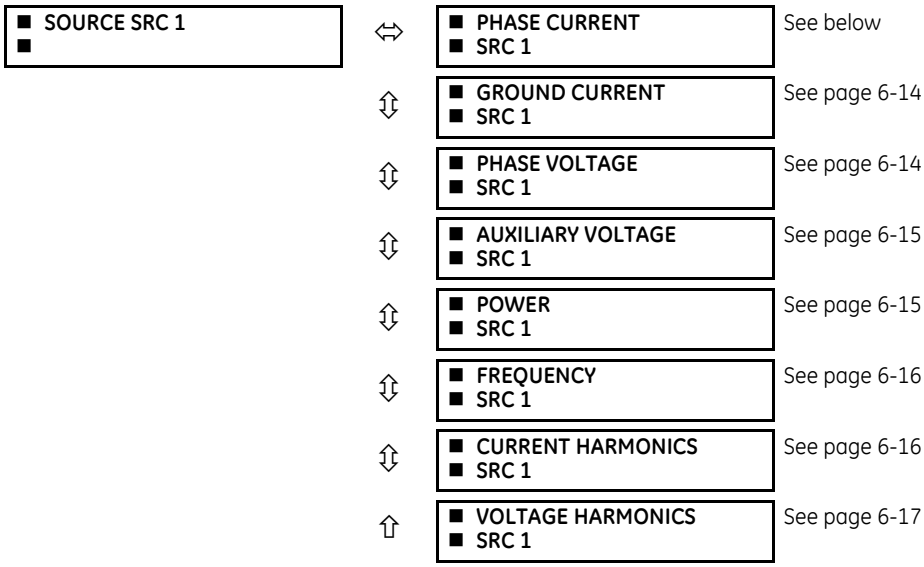
Figure 6-3: Measurement convention for symmetrical components



6.3.2 Sources

6.3.2.1 Menu

ACTUAL VALUES ⇨⇩ METERING ⇨⇩ SOURCE SRC 1

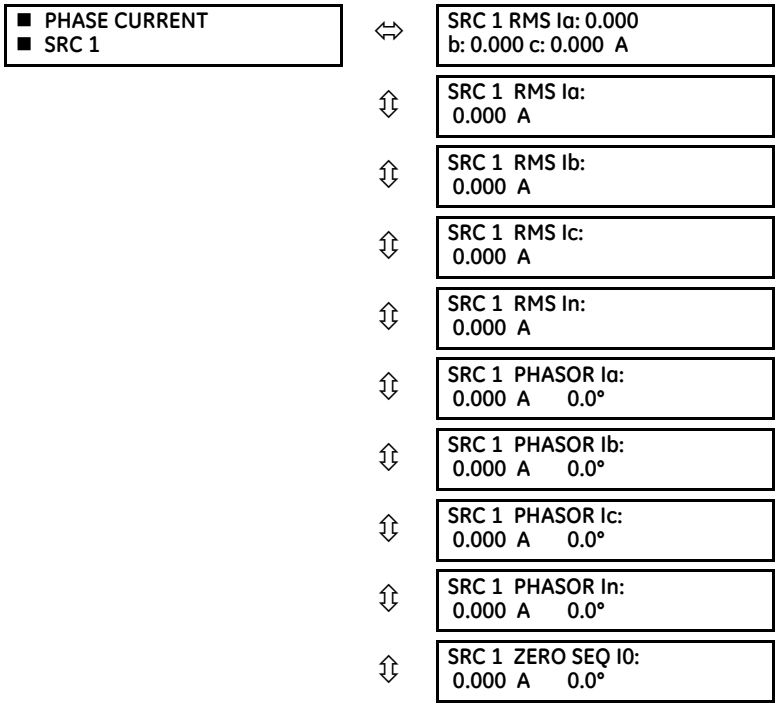


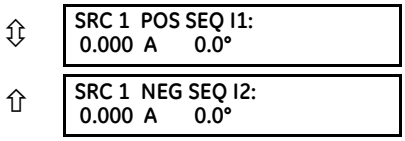
This menu displays the metered values available for each source.

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 are unavailable.

6.3.2.2 Phase current metering

ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨ PHASE CURRENT

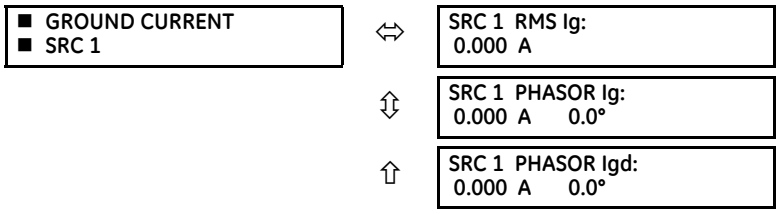




The metered phase current values are displayed in this menu. The "SRC 1" text gets replaced by whatever name was programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

6.3.2.3 Ground current metering

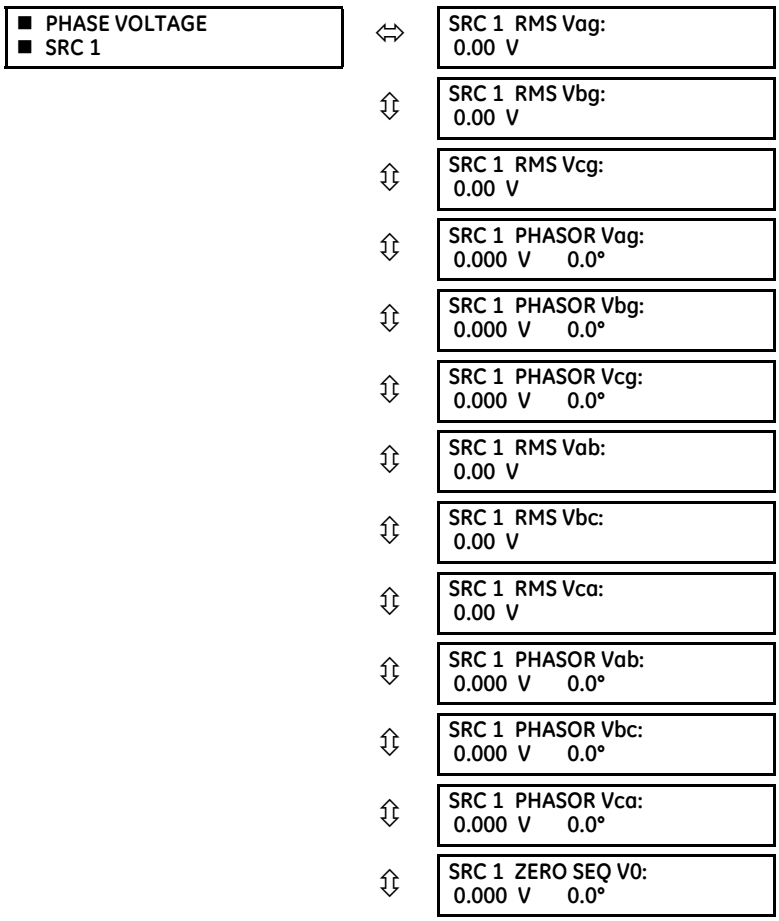
ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨ GROUND CURRENT

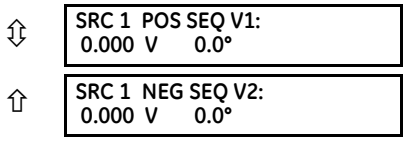


The metered ground current values are displayed in this menu. The "SRC 1" text is replaced by the name programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

6.3.2.4 Phase voltage metering

ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨ PHASE VOLTAGE

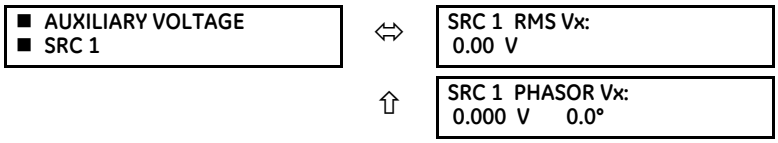




The metered phase voltage values are displayed in this menu. The "SRC 1" text is replaced by the name programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

6.3.2.5 Auxiliary voltage metering

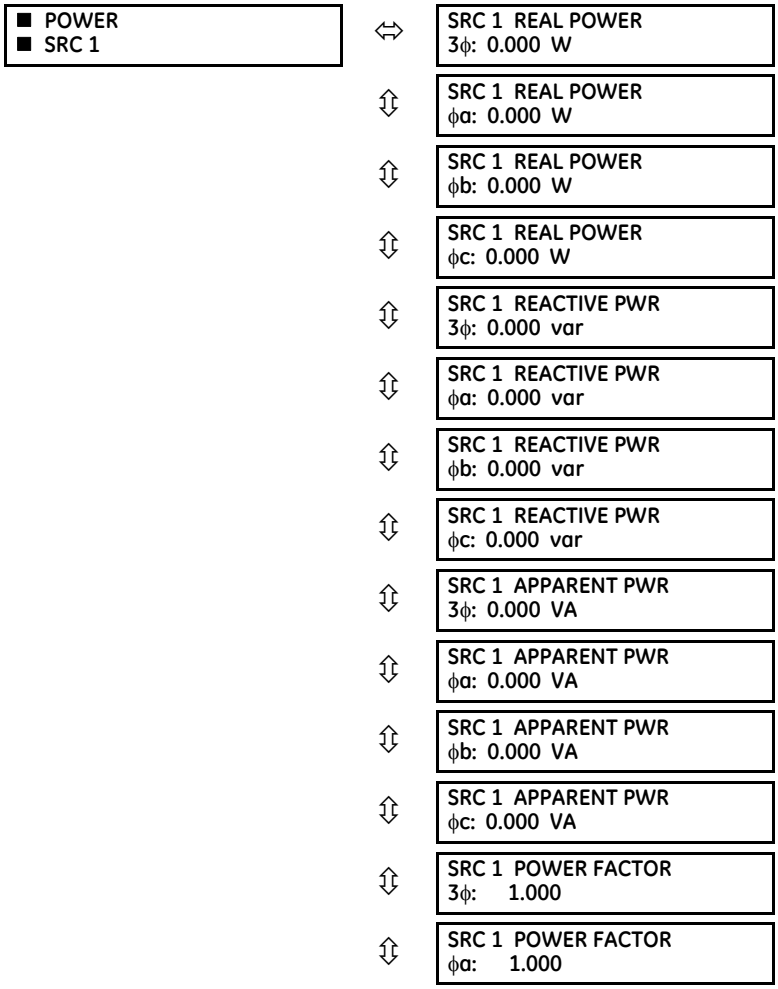
ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨⇩ AUXILIARY VOLTAGE

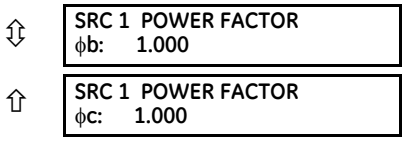


The metered auxiliary voltage values are displayed in this menu. The "SRC 1" text is replaced by the name programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

6.3.2.6 Power metering

ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨⇩ POWER





This menu displays metered values for real, reactive, and apparent power, as well as power factor. The "SRC 1" text is replaced by the name programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

When VTs are configured in wye, the C70 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 C70 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

6.3.2.7 Frequency metering

ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨⇩ FREQUENCY

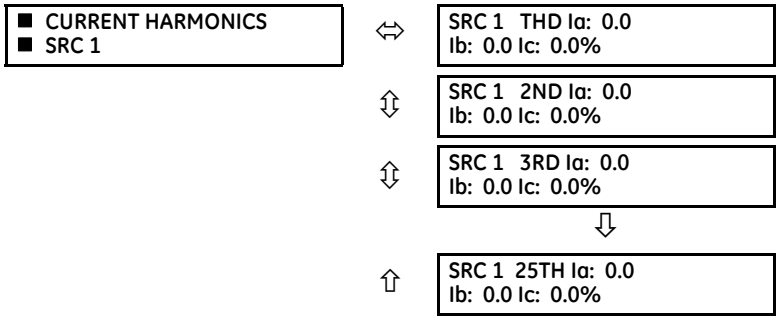


The metered frequency values are displayed in this menu. The "SRC 1" text is replaced by the name programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

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.

6.3.2.8 Current harmonics and THD metering

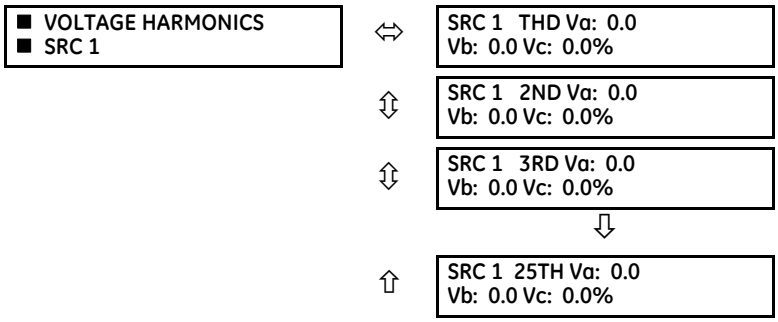
ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨⇩ CURRENT HARMONICS



This menu displays metered current harmonics values. The "SRC 1" text is replaced by the name was programmed for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**). Current harmonics are measured for each source for the total harmonic distortion (THD) and 2nd to 25th harmonics per phase.

6.3.2.9 Voltage harmonics and THD metering

ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨⇩ VOLTAGE HARMONICS



This menu displays metered voltage harmonics values. The "SRC 1" text is replaced by the programmed name for the associated source (see the **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES** menu).

To extract the 2nd to 25th voltage harmonics, each harmonic is computed on a per-phase basis, where:

N = 64 is the number of samples per cycle
$\omega_0 = 2\pi f$ is the angular frequency based on the system frequency (50 or 60 Hz)
k = 1, 2,..., N – 1 is the index over one cycle for the Fast Fourier Transform (FFT)
m is the last sample number for the sliding window
h = 1, 2,..., 25 is the harmonic number

The short-time Fourier transform is applied to the unfiltered signal:

$$F_{real}(m,h) = \frac{2}{N}\sum_{k}(f(m-k)\cdot\cos(h\cdot\omega_0\cdot t(k)))$$

$$F_{imag}(m,h) = \frac{2}{N}\sum_{k}(f(m-k)\cdot\sin(h\cdot\omega_0\cdot t(k))) \quad \textbf{Eq. 6-3}$$

$$F_{ampl}(m,h) = \sqrt{F_{real}(m,h)^2 + F_{imag}(m,h)^2}$$

The harmonics are a percentage of the fundamental signal obtained as a ratio of harmonic amplitude to fundamental amplitude multiplied by 100%. The total harmonic distortion (THD) is the ratio of the total harmonic content to the fundamental:

$$THD = \sqrt{F_2^2 + F_3^2 + \ldots + F_{25}^2} \quad \textbf{Eq. 6-4}$$

NOTE

Voltage harmonics are calculated only for Wye connected phase VTs. Ensure that the **SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK F5 ⇨⇩ PHASE VT XX CONNECTION** setting is "Wye" to enable voltage harmonics metering.

6.3.3 Tracking frequency

ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRACKING FREQUENCY



The tracking frequency displays here. The frequency is tracked based on the selection of the reference source with the **FREQUENCY AND PHASE REFERENCE** setting in the **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM** menu. See the Power System section of chapter 5 for details.

6.3.4 FlexElements

ACTUAL VALUES ⇨⇩ METERING ⇨⇩ FLEXELEMENTS ⇨ FLEXELEMENT 1(16)



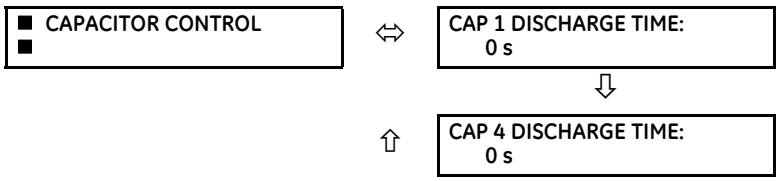
The operating signals for the FlexElements are displayed in pu values using the following definitions of the base units.

Table 6-2: FlexElement base units

Base unit	Description
BREAKER ARCING AMPS (Brk X Arc Amp A, B, and C)	BASE = 1 kA^2 × 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	φ_{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 THD & HARMONICS	BASE = 1%
SOURCE VOLTAGE	V_{BASE} = maximum nominal primary RMS value of the +IN and –IN inputs

6.3.5 Capacitor control

ACTUAL VALUES ⇨⇩ METERING ⇨⇩ CAPACITOR CONTROL

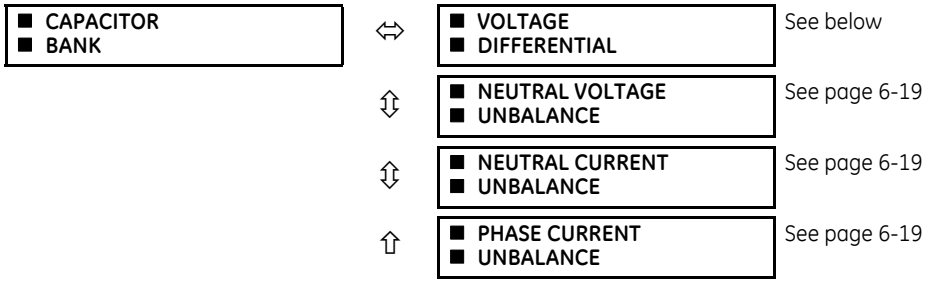


These values indicate the time remaining before the next permissible close operation for each of the four capacitor banks.

6.3.6 Capacitor bank

6.3.6.1 Menu

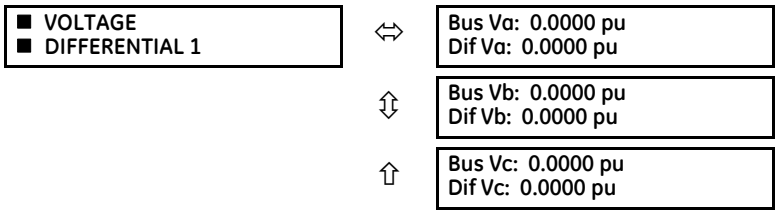
ACTUAL VALUES ⇨⇩ METERING ⇨⇩ CAPACITOR BANK



The capacitor bank menu contains the actual values for the voltage differential, neutral voltage unbalance, phase current unbalance, and neutral current unbalance elements.

6.3.6.2 Voltage differential

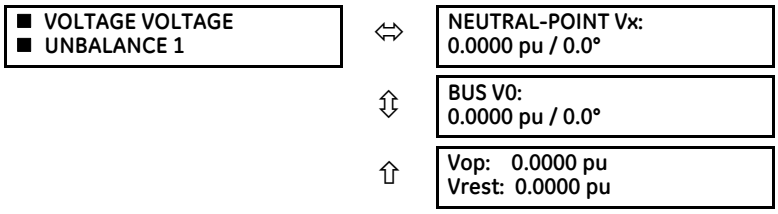
ACTUAL VALUES ⇨⇩ METERING ⇨⇩ CAPACITOR BANK ⇨ VOLTAGE DIFFERENTIAL ⇨ VOLTAGE DIFFERENTIAL 1(3)



These actual values display the bus and differential signals in per-unit values of the nominal bus voltage for phases A, B, and C.

6.3.6.3 Neutral voltage unbalance

ACTUAL VALUES ⇨⇩ METERING ⇨⇩ CAPACITOR BANK ⇨ NEUTRAL VOLTAGE... ⇨ NEUTRAL VOLTAGE UNBALANCE 1(3)



This menu displays the magnitudes (in pu) and angles of the neutral point and bus V0 voltages for the neutral voltage unbalance elements. The magnitudes of the compensating operating voltage and restraining voltage (in pu) also display.

6.3.6.4 Neutral current unbalance

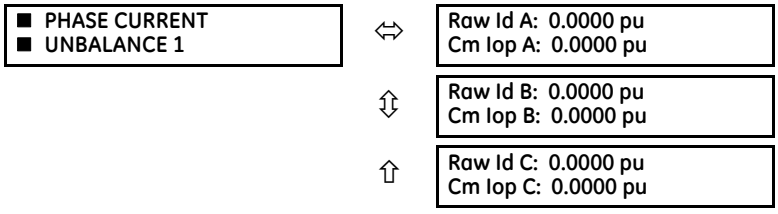
ACTUAL VALUES ⇨⇩ METERING ⇨⇩ CAPACITOR BANK ⇨ NEUTRAL CURRENT... ⇨ NEUTRAL CURRENT UNBALANCE 1(3)



This menu displays the magnitudes of the raw neutral split-phase current and compensated operating current (in per-units of the ground CT input).

6.3.6.5 Phase current unbalance

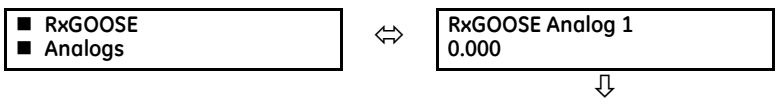
ACTUAL VALUES ⇨⇩ METERING ⇨⇩ CAPACITOR BANK ⇨ PHASE CURRENT... ⇨ PHASE CURRENT UNBALANCE 1(3)

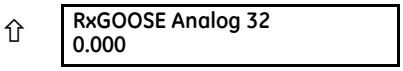


This menu displays the magnitudes of the raw differential current and compensated operating currents (in per-units of the differential CT) for each phase.

6.3.7 RxGOOSE analogs

ACTUAL VALUES ⇨⇩ METERING ⇨⇩ RxGOOSE Analogs







The C70 is provided with optional GOOSE 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 RxGOOSE Analog values display in this menu. The RxGOOSE Analog values are received via IEC 61850 GOOSE messages sent from other devices.

6.3.8 Transducer inputs/outputs

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.

ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRANSDUCER I/O RTD INPUTS ⇨ RTD INPUT xx

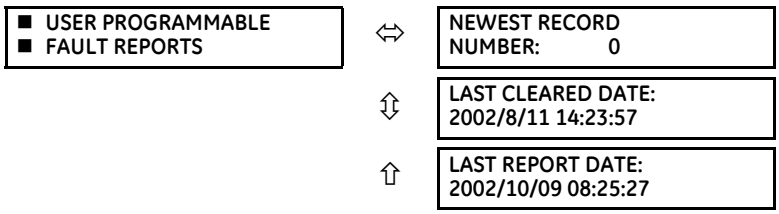


Actual values for each RTD input channel that is enabled are displayed with the top line as the programmed channel ID and the bottom line as the value.

6.4 Records

6.4.1 User programmable fault reports

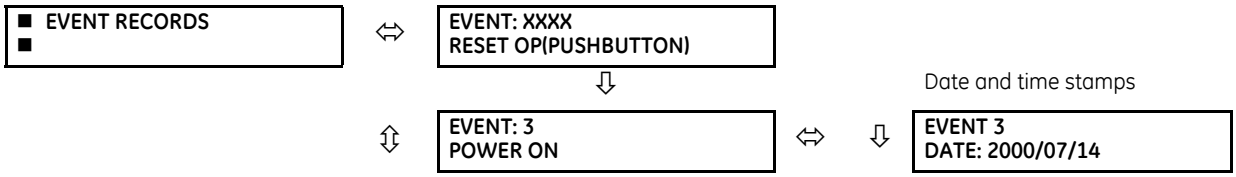
ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ USER PROGRAMMABLE FAULT REPORTS



This menu displays the user-programmable fault report actual values. See the User-Programmable Fault Report section in chapter 5 for information on this feature.

6.4.2 Event records

ACTUAL VALUES ⇨⇩ RECORDS ⇨ EVENT RECORDS



⇳ EVENT: 2
POWER OFF

⇧ EVENT 3
TIME: 14:53:00.03405

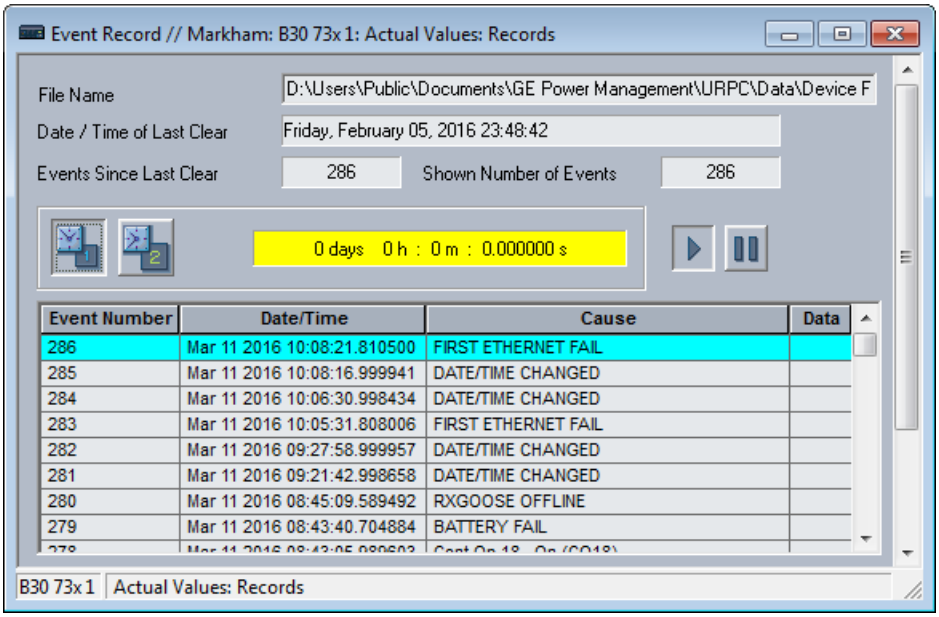
⇧ EVENT: 1
EVENTS CLEARED

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. When all 1024 event records have been filled, the oldest record is 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.

The event records are also viewable in the software and in a web browser. The figure shows the event records in the software. To view them in a web browser, enter the IP address of the device.

Figure 6-4: Event records viewed in EnerVista software



6.4.3 Oscillography

ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ OSCILLOGRAPHY

■ OSCILLOGRAPHY
■

⇔ FORCE TRIGGER?
No

Range: No, Yes

⇳ NUMBER OF TRIGGERS:
0

⇳ AVAILABLE RECORDS:
0

⇳ CYCLES PER RECORD:
0

⇧ LAST CLEARED DATE:
2000/07/14 15:40:16

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 details.

A trigger can be forced here at any time by setting "Yes" to the FORCE TRIGGER? command. See the **COMMANDS ⇨⇩ CLEAR RECORDS** menu for information on clearing the oscillography records.

6.4.4 Data logger

ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ DATA LOGGER

■ DATA LOGGER ■	⇔	OLDEST SAMPLE TIME: 2000/01/14 13:45:51
	⇧	NEWEST SAMPLE TIME: 2000/01/14 15:21:19

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.

See the **COMMANDS ⇨⇩ CLEAR RECORDS** menu for clearing data logger records.

6.5 Product information

6.5.1 Model information

ACTUAL VALUES ⇨⇩ PRODUCT INFO ⇨ MODEL INFORMATION

■ MODEL INFORMATION ■	⇔	ORDER CODE LINE 1: C70-A00-AAA-A0A-A0A	Range: standard GE order code format (lines 1 to 4)
	⇩	ORDER CODE LINE 2: A0A-A0A-A0A	Range: up to 20 alphanumeric characters
	⇩	ORDER CODE LINE 3:	Range: up to 20 alphanumeric characters
	⇩	ORDER CODE LINE 4:	Range: up to 20 alphanumeric characters
	⇩	SERIAL NUMBER:	Range: standard GE serial number format
	⇩	ETHERNET MAC ADDRESS 000000000000	Range: standard Ethernet MAC address format
	⇩	MANUFACTURING DATE:	Range: YYYY/MM/DD HH:MM:SS
	⇩	OPERATING TIME: 0:00:00	Range: operating time in HH:MM:SS
	⇩	CT/ VT ADVANCED DIAG ACTIVE: No	Range: Yes, No
	⇧	LAST SETTING CHANGE: 1970/01/01 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. The rear panel on the device contains similar information.

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.

6.5.2 Firmware revisions

ACTUAL VALUES ⇨⇩ PRODUCT INFO ⇨ FIRMWARE REVISIONS

■ FIRMWARE REVISIONS ■	⇔	C70 Relay REVISION: 7.3x	Range: 0.00 to 655.35 Revision number of the application firmware.
	⇩	MODIFICATION FILE NUMBER: 0	Range: 0 to 65535 (ID of the MOD FILE) Value is 0 for each standard firmware release.
	⇩	BOOT PROGRAM REVISION: 7.01	Range: 0.00 to 655.35 Revision number of the boot program firmware.
	⇩	FRONT PANEL PROGRAM REVISION: 2.01	Range: 0.00 to 655.35 Revision number of faceplate program firmware.
	⇩	COMPILE DATE: 2013/09/15 04:55:16	Range: YYYY/MM/DD HH:MM:SS Date and time when product firmware was built.
	⇩	BOOT DATE: 2013/09/15 16:41:32	Range: YYYY/MM/DD HH:MM:SS Date and time when the boot program was built.
	⇩	FPGA PROGRAM: REVISION: 01.05	Range: 0.00 to 655.35 Revision number for FPGA.
	⇧	FPGA DATA: 2013/09/15 16:41:32	Range: YYYY/MM/DD HH:MM:SS Date and time when the FPGA was built.

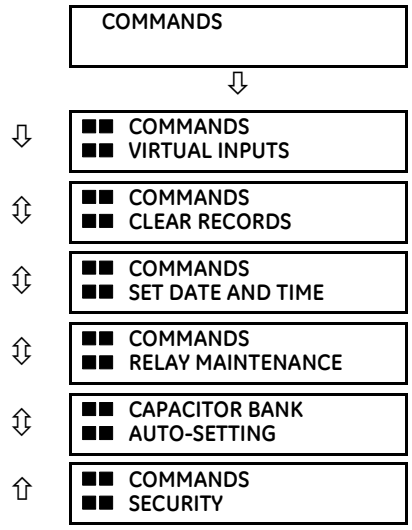
The shown data is illustrative only. A modification file number of 0 indicates that, currently, no modifications have been installed.

C70 Capacitor Bank Protection and Control System

Chapter 7: Commands and targets

This chapter outlines the Commands and Targets menus and self-tests/error messages. Commands related to the IEC 61850 protocol are outlined in the IEC 61850 section of the Settings chapter. Log/error messages for IEC 61850 are outlined in the UR Series Communications Guide.

7.1 Commands menu

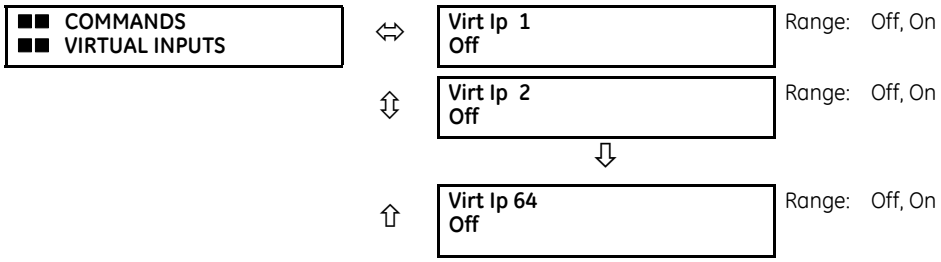


The commands menu contains relay directives intended for operations personnel. All commands can be protected from unauthorized access via the command password; see the Security section of chapter 5 for details. The following flash message appears after successfully command entry.



7.1.1 Virtual inputs

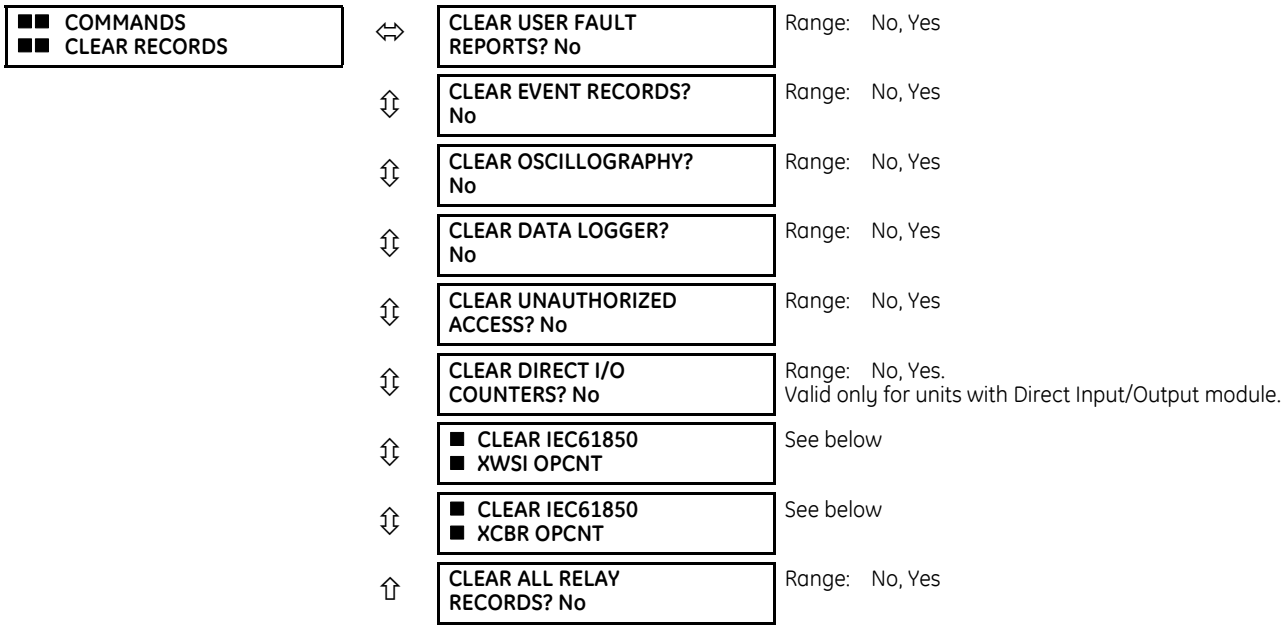
COMMANDS ⇨ VIRTUAL INPUTS



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 is a state off (logic 0) or on (logic 1).

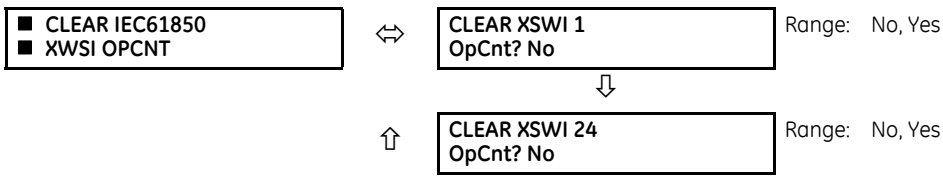
7.1.2 Clear records

COMMANDS ⇨ CLEAR RECORDS

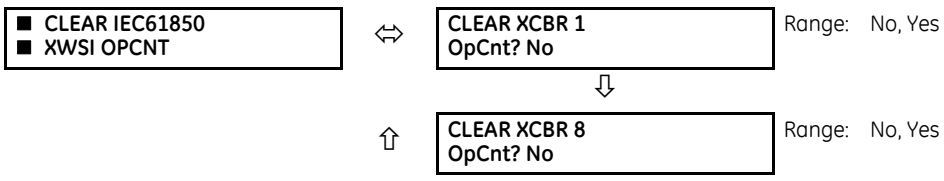


This menu contains commands for clearing historical data such as the event records. Data is cleared by changing a command setting to "Yes" and pressing the **ENTER** key. After clearing data, the command setting automatically reverts to "No."

COMMANDS ⇨ CLEAR RECORDS ⇨⇩ CLEAR IEC61850 XWSI OPCNT



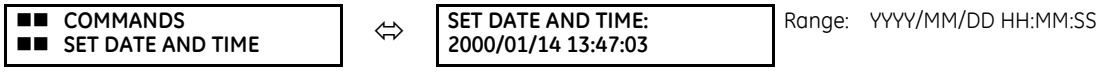
COMMANDS ⇨ CLEAR RECORDS ⇨⇩ CLEAR IEC61850 XCBR OPCNT



The Clear XSWI commands clear the disconnect operation counters for each phase and the three-phase counter. Similarly, the Clear XCBR commands clear the circuit breaker operation counters for each phase and the three-phase counter.

7.1.3 Set date and time

COMMANDS ⇨⇩ SET DATE AND TIME



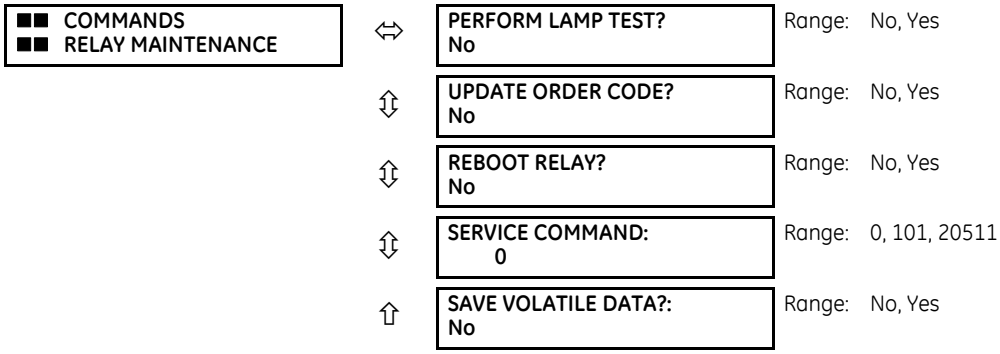
The date and time can be entered on the faceplate keypad. The time setting is based on the 24-hour clock. The complete date, as a minimum, must be entered to allow execution of this command. The new time and date take effect when the **ENTER** key is pressed.

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.

7.1.4 Relay maintenance

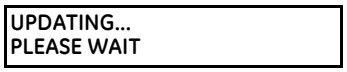
COMMANDS ⇨⇩ RELAY MAINTENANCE



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 then automatically reverts to "No." The service command is activated by entering a numerical code and pressing the **ENTER** key.

PERFORM LAMP TEST — Turns on all faceplate LEDs and display pixels for a short duration.

UPDATE ORDER CODE — This 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 displays.



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 displays.

REBOOT RELAY — Restarts 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.

SERVICE COMMAND — Performs specific C70 service actions. Presently, there are two service actions available. Code "20511" returns all settings to their factory default value and restarts the relay (you then re-enter IP addresses, 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 C70 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 C70 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.

7.1.5 Capacitor bank automatic setting

7.1.5.1 Menu

■■ CAPACITOR BANK ■■ AUTO-SETTING	⇔	■ VOLTAGE ■ DIFFERENTIAL	See below
	⇳	■ NEUTRAL VOLTAGE ■ UNBALANCE	See page 7-5
	⇧	■ PHASE CURRENT ■ UNBALANCE	See page 7-6
	⇳	■ NEUTRAL CURRENT ■ UNBALANCE	See page 7-7

The relay provides for automatic calculations of proper balancing (matching) factors of the sensitive capacitor bank protection functions. The following screens display the suggested values of the balancing factors and prompt the user to apply them. If applied from this command level, a given value is placed into the setting file and applied instantaneously in all setting groups of the relay with the same source as the active group during the auto-setting procedure.

7

7.1.5.2 Voltage differential

COMMANDS ⇨ CAPACITOR BANK AUTO SETTING ⇨ VOLTAGE DIFFERENTIAL ⇨ VOLTAGE DIFFERENITAL 1(3)

■ VOLTAGE ■ DIFFERENTIAL 1	⇔	VOLTAGE DIF 1 AUTO SETTING: Disabled	Range: Disabled, Manual, Auto
	⇳	V DIF 1A k=####.#### APPLY IN PHS A? No	Range: Yes, No
	⇳	V DIF 1A k=####.#### APPLY IN PHS B? No	Range: Yes, No
	⇧	V DIF 1A k=####.#### APPLY IN PHS C? No	Range: Yes, No

Use the automatic setting feature when the capacitor bank is online and the 87V function is enabled. For security reasons, consider applying less sensitive settings during the auto-setting process. Switching temporarily to a different setting group with less sensitive pickup thresholds is a way to provide the extra security.

The feature can be used with a manual acceptance of the auto-calculated coefficients (the **VOLTAGE DIF 1 AUTO SETTING** command switched to "Manual"), or with an automatic acceptance of the calculated factors (the **VOLTAGE DIF 1 AUTO SETTING** command switched to "Auto").

The feature is used as follows.

Application with manual supervision of the automatically calculated factors

When the **VOLTAGE DIF 1 AUTO SETTING** command is switched to "Manual", the auto-setting screens, one for each phase, display the values that balance best the function in a given phase and prompt for permission to apply the calculated value as a new setting. When confirmed, the auto-selected value gets applied to all setting groups configured with the same source as the active group during the auto-setting procedure.

After consent to apply the calculated coefficient is received, the "k =?.???? APPLIED" confirmation message displays for the duration of the flash message time in the second line of the screen. The time-out period is provided for the field staff to make a note of the newly applied coefficient. However, it is possible to navigate from this screen immediately. The new setting values can be viewed under the setting menu at any time.

After the process finishes, it is recommended to disable the auto-setting feature. If not disabled by the user, the feature disables itself when user-initiated front panel interface activity ceases and the C70 display dims itself.

Certain security conditions are checked during the auto-setting process. This includes deviation from the nominal frequency and verifying that the magnitudes of all three bus voltages are between 0.85 and 1.15 pu. If these conditions are violated. the SUPV FAIL message displays in the second line.

If the voltage differential function is disabled or blocked, then the auto-setting process is not functional and the 87V NOT RUNNING message displays in the second line.

Application with automatic supervision of the automatically calculated factors

When the **VOLTAGE DIF 1 AUTO SETTING** command is switched to "Auto," the process of calculating and applying the balancing coefficients is fully automatic. Typical applications require setting this function to "Auto" with the bank de-energized, then energizing the capacitor bank. When the bank is energized and the five-cycle timer of the 87V function expires, the balancing coefficients are calculated and automatically applied. After the new balancing factors are applied, the function switches automatically from "Auto" to "Disabled" and 87V becomes operational. In essence, when in the "Auto" mode, the user confirmation is processed immediately after the balancing values become available. The C70 does not display the applied coefficients in "Auto" mode; rather, they are be viewed in the **SETTINGS** menu.

If the supervisory conditions are not satisfied in the "Auto" mode within the time specified by the **DEFAULT MESSAGE TIMEOUT** setting, the AUTO FAIL message displays and the 87V function starts running with the pre-existing settings for the balancing factors.

The advantage of automatically calculating factors is that the bank is immediately protected after energization. However, due to energization inrush and distortion of voltages, the factors may not be accurate enough for the most sensitive stages. Therefore, it is good practice to block the most sensitive stages on energization, manually adjust the factors to reduce the differential signal, and then enable the most sensitive stages.

7.1.5.3 Neutral voltage unbalance

COMMANDS ⇨ CAPACITOR BANK AUTO SETTING ⇨ NEUTRAL VOLTAGE UNBALANCE ⇨ NEUTRAL VOLTAGE UNBALANCE 1(3)

■ NEUTRAL VOLTAGE ■ UNBALANCE 1	⇔	NTRL VOL UNBAL 1 AUTO SET: Disabled	Range: Disabled, Manual, Auto
	⇳	XA/XB RATIO k=0.0000 APPLY? No	Range: Yes, No
	⇧	XA/XC RATIO k=0.0000 APPLY? No	Range: Yes, No

Use the auto-setting feature when the capacitor bank is online and the 59NU function is enabled. For security reasons, consider applying less sensitive settings during the auto-setting process. Switching temporarily to a different setting group with less sensitive pickup thresholds is a method to provide the extra security.

This feature can be used with a manual acceptance of the auto-calculated coefficients (the **NTRL VOL UNBAL 1 AUTO SET** command switched to "Manual"), or with an automatic acceptance of the calculated factors (the **NTRL VOL UNBAL 1 AUTO SET** command switched to "Auto").

The feature is used as follows.

Manual supervision of automatically calculated factors

When the **NTRL VOL UNBAL 1 AUTO SET** command is switched to "Manual," the auto-setting screens (one for each of the two factors) display values that best balance the function and prompt for permission to apply the calculated value as a new setting. When confirmed, the auto-selected value is applied to all setting groups having same source as the active group during auto-setting procedure. Both ratios (XA / XB and XA / XC) must be set correctly to clear the inherent bank unbalance. After consent to apply the calculated coefficient is received via the keypad, the "k =?.???? APPLIED" confirmation message idisplays for the duration of the flash message time. The time-out period is intended for field staff to make note of the newly applied coefficient. However, it is possible to immediately navigate from this screen. The new setting values can be viewed in the **SETTINGS** menu at any time.

After the process finishes, it is recommended to disable the auto-setting feature. If not manually disabled, the feature automatically disables itself when user-initiated front panel interface activity ceases and the C70 display is dimmed.

Certain security conditions are checked during the auto-setting process, such as the frequency deviation from the nominal frequency and the magnitude of the positive-sequence current above 0.1 pu. If any of these conditions are violated, the SUPV FAIL message displays in the second line.

If the neutral voltage unbalance function is disabled or blocked, the auto-setting process is not functional and the 59NU NOT RUNNING message displays in the second line.

Automatic supervision of automatically calculated factors

When the **NTRL VOL UNBAL 1 AUTO SET** command is switched to "Auto", the process of calculating and applying the balancing coefficients is fully automatic. Typical applications require setting this function to "Auto" with the bank de-energized, then energizing the capacitor bank. After the function is set to "Auto," it expects to read valid input signals as a result of bank energization within the display flash message time duration to calculate and apply factors; otherwise, the function is returned to "Disabled." When the bank is energized and the five-cycle timer of the 59NU function expires, the balancing coefficients are calculated and automatically applied. When the new balancing factors are applied, the function switches automatically from "Auto" to "Disabled" and the 59NU function becomes operational. In essence, when in the "Auto" mode, the confirmation command executes automatically immediately after the balancing values are available. The C70 does not display the applied coefficients in the "Auto" mode; rather, they are be viewed in the **SETTINGS** menu.

When the supervisory conditions are not satisfied in "Auto" mode, the AUTO FAIL message displays and the 59NU function starts running with the pre-existing settings for the balancing factors.

7.1.5.4 Phase current unbalance

COMMANDS ⇨ CAPACITOR BANK AUTO SETTING ⇨ PHASE CURRENT UNBALANCE ⇨ PHASE CURRENT UNBALANCE 1(3)

■ PHASE CURRENT ■ UNBALANCE 1	⇔	CUR UNBALACE 1 AUTO SETTING: Disabled	Range: Disabled, Manual, Auto
	⇳	CUR UNB 1A k=0.0000 APPLY IN PHS A? No	Range: Yes, No
	⇳	CUR UNB 1A k=0.0000 APPLY IN PHS B? No	Range: Yes, No
	⇧	CUR UNB 1A k=0.0000 APPLY IN PHS C? No	Range: Yes, No

Use the auto-setting feature when the capacitor bank is online and the 60P function is enabled. For security reasons, apply less sensitive settings during the auto-setting process. Switching temporarily to an alternate setting group with less sensitive pickup thresholds is a method to provide the extra security.

The feature can be used with by manual accepting the auto-calculated coefficients (the **CUR UNBALACE 1 AUTO SETTING** command switched to "Manual") or by automatic acceptance of the calculated factors (the **CUR UNBALACE 1 AUTO SETTING** command switched to "Auto").

The feature is used as follows.

Application with manual supervision of the automatically calculated factors

When the **CUR UNBALACE 1 AUTO SETTING** command is switched to "Manual," the auto-setting screens (one for each phase) display values that best balance the function in a given phase and prompt for permission to apply the calculated value as a new setting. When confirmed, the auto-selected value is applied to all setting groups having same source as active group during the auto-setting procedure. The balancing factors can be either positive or negative, depending on which of the two banks has a lower impedance, and on the polarity of the differential CTs connected to the relay.

After user consent to apply the calculated coefficient is received, the "k =?.???? APPLIED" confirmation message displays for the duration of the flash message time. The timeout period allows field staff to make note of the newly applied coefficient. However, it is possible to immediately navigate from this screen. The new setting values can be viewed in the **SETTINGS** menu at any time.

After the process finishes, it is recommended to disable the auto-setting feature. If not disabled, the feature automatically disables itself when user-initiated front panel interface activity ceases and the C70 display is dimmed.

Certain security conditions are checked during the auto-setting process, such as frequency deviation from the nominal and the magnitude of the phase currents above 0.1 pu. If any of these conditions are violated, the SUPV FAIL message displays in the second line.

If the phase unbalance function is disabled or blocked, the auto-setting process is not functional and the 60P NOT RUNNING message displays in the second line.

Application with automatic supervision of the automatically calculated factors

When the **CUR UNBALACE 1 AUTO SETTING** command is switched to "Manual," the process of calculating and applying the balancing coefficients is fully automatic. Typical applications require setting this function to "Auto" with the bank de-energized, then subsequently energizing the capacitor bank. If the function is set to "Auto," it expects to read valid input signals as a result of bank energization within the flash message duration time to calculate and apply factors. Otherwise, the value is switched backed to "Disabled." When the bank is energized and the five-cycle timer of the 60P function expires, the balancing coefficients are calculated and automatically applied. After the new balancing factors are applied, the auto-setting function switches "Auto" to "Disabled" and the 60P element becomes operational. When in "Auto" mode, the automatic confirmation command executes immediately after the balancing values are available. The C70 does not display the applied coefficients in "Auto" mode; rather, they can be viewed in the **SETTINGS** menu.

If the supervisory conditions are not satisfied in the "Auto" mode within time defined by the **DEFAULT MESSAGE TIMEOUT** setting, the AUTO FAIL message displays and the 60P function starts running with the pre-existing settings for the balancing factors.

7.1.5.5 Neutral current unbalance

COMMANDS ⇨ CAPACITOR BANK AUTO SETTING ⇨ NEUTRAL CURRENT UNBALANCE ⇨ NEUTRAL CURRENT UNBALANCE 1(3)

■ NEUTRAL CURRENT ■ UNBALANCE 1	⇔	NTRL CUR UNBALANCE 1 AUTO-SET: Disabled	Range: Disabled, Manual, Auto
	⇳	NTRL CUR 1 k=0.0000 APPLY MAGNITUDE? No	Range: Yes, No
	⇧	NTRL CUR 1 k=0° APPLY ANGLE? No	Range: Yes, No

Use the auto-setting feature when the capacitor bank is online and the 60N function is enabled. For security reasons, apply less sensitive settings during the auto-setting process. Temporarily switching to an alternate setting group with less sensitive pickup thresholds is a method of providing the extra security.

The feature can be used with manual acceptance of the auto-calculated coefficients (the **NTRL CUR UNBALANCE 1 AUTO-SET** command switched to "Manual"), or with automatic acceptance of the calculated factors (the **NTRL CUR UNBALANCE 1 AUTO-SET** command switched to "Auto").

The feature is used as follows.

Application with manual supervision of the automatically calculated factors

When the **NTRL CUR UNBALANCE 1 AUTO-SET** command is switched to "Manual," the auto-setting screens (one for magnitude and one for angle of the compensating factor) display the values that best balance the function and prompt for permission to apply the calculated value as a new setting. When confirmed, the auto-selected value is applied to all setting groups.

After user consent to apply the calculated coefficient is received, the "k =?.???? APPLIED" confirmation message displays for the duration of the flash message time. The timeout period allows field staff to make note of the newly applied coefficient. However, it is possible to immediately navigate from this screen. The new setting values can be viewed in the **SETTINGS** menu at any time.

After the process finishes, it is recommended to disable the auto-setting feature. If not disabled by the user, the feature is automatically disabled when user-initiated front panel interface activity ceases and the C70 display is dimmed.

Certain security conditions are checked during the auto-setting process. If these conditions are violated, the SUPV FAIL message displays in the second line.

If the neutral voltage unbalance function is disabled or blocked, the auto-setting process is not functional and the 60N NOT RUNNING message displays in the second line.

Application with automatic supervision of the automatically calculated factors

When the **NTRL CUR UNBALANCE 1 AUTO-SET** command is switched to "Auto," the process of calculating and applying the balancing coefficients is fully automatic. Typical applications require setting this function to "Auto" with the bank de-energized, then subsequently energizing the capacitor bank. After the function is set to "Auto," it expects to read valid input signals as a result of bank energization within the display flash message time duration to calculate and apply factors. Otherwise, the function is switched backed to "Disabled." When the bank is energized and the five-cycle timer of the 60N function expires, the balancing coefficients are calculated and automatically applied. After the new balancing factors are applied, the auto-setting function switches automatically from "Auto" to "Disabled," and the 60N element becomes operational. In essence, when in "Auto" mode, the confirmation command executes automatically immediately after the balancing values become available. The C70 does not display the applied coefficients in the "Auto" mode; instead, they can be viewed in the **SETTINGS** menu.

If the supervisory conditions are not satisfied in the "Auto" mode within time defined by the **DEFAULT MESSAGE TIMEOUT** setting, the AUTO FAIL message displays and the 60N function starts running with the pre-existing settings for the balancing factors.

7.1.6 Security

COMMANDS ⇨⇩ SECURITY

■■ SECURITY ■■	⇔	**ADMINISTRATOR LOGOFF: No**	Range: Yes, No
	⇩	**ENGINEER LOGOFF: No**	Range: Yes, No
	⇩	**OPERATOR LOGOFF: No**	Range: Yes, No
	⇧	**CLEAR SECURITY DATA: No**	Range: Yes, No

With the CyberSentry option, this setting is available to enable or disable the following commands.

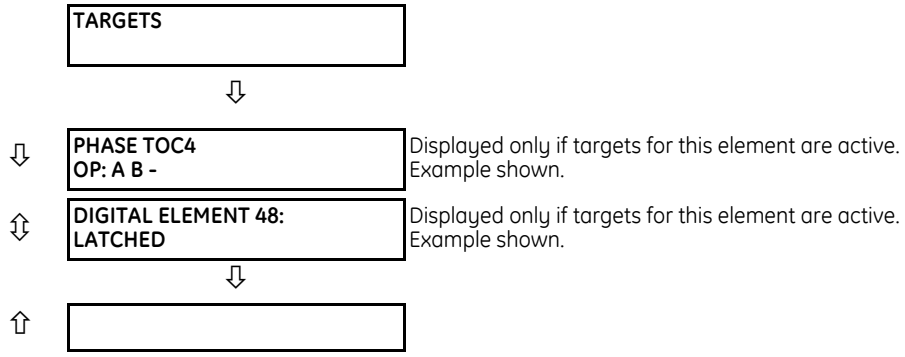
ADMINISTRATOR LOGOFF — Selecting 'Yes' allows the Supervisor to forcefully logoff an administrator session.

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 Targets menu



A target enables the EnerVista UR Setup software to monitor automatically and display the status of any active target messages of all the devices inserted into that site.

Each C70 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 ACTIVE TARGETS**.

7.2.1 Target messages

When there are no active targets, the first target to become active causes 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 again defaults back to the target message.

The range of variables for the target messages is described below. Phase information is included if applicable. If a target message status changes, the status with the highest priority displays.

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.

7.2.2 Relay self-tests

7.2.2.1 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 following tables. When either type of error occurs, the Trouble LED Indicator turns on and a target message displays. 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 de-energizes
- All other output relays de-energize and are prevented from further operation
- The faceplate In Service LED indicator turns off
- A RELAY OUT OF SERVICE event is recorded

7.2.2.2 Major self-test error messages

The major self-test errors are outlined in this section.

INCOMPATIBLE H/W:
Contact Factory (xxx)

- *Latched target message*: Yes.
- *Description of problem*: One or more installed hardware modules is not compatible with the C70 order code.
- *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).

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 C70. 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 C70 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*: Contact the factory and supply the failure code noted in the display. The "xxx" text identifies the failed module (for example, F8L).

7.2.2.3 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.

MAINTENANCE ALERT:
Replace Battery

- *Latched target message*: Yes.
- *Description of problem*: The battery is weak or not functioning. It powers the real time clock. This message displays as Battery Fail in the event records. When the battery weakness reaches a critical level, the message displays persistently on the front panel and no front panel key navigation is possible.
- *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.

MAINTENANCE ALERT:
Direct I/O Ring Break

- *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 can 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:
GGIO Ind xxx oscill

- *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*: The "xxx" text denotes the data item that has been detected as oscillating. Evaluate all logic pertaining to this item.

DIRECT I/O FAILURE:
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 FAIL:
Missing messages

- *Latched target message*: No.
- *Description of problem*: One or more RxGOOSE messages are not being received.
- *How often the test is performed*: The self-test is activated when no message is received within the expected time interval, which is the time-to-live time in the previous message. This time can be from milliseconds to minutes.
- *What to do*: Check GOOSE setup.

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.

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 C70 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 C70 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.

FIRST ETHERNET FAIL

SECOND ETHERNET FAIL

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.

WRONG TRANSCEIVER

- *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.

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.

AUTHENTICATION FAIL

- *Latched target message*: No.
- *Description of problem*: The number of failures threshold was exceeded.
- *What to do*: Wait for the lockout interval and try to authenticate again.

FIRMWARE LOCK

- *Message*: "Unauthorized firmware attempt"
- *Latched target message*: No.
- *Description of problem*: A firmware upgrade operation was attempted while the lock relay setting was enabled.
- *What to do*: Ask the Supervisor to unlock the relay and try again.

SETTING LOCK

- *Message*: "Unauthorized setting write"
- *Latched target message*: No.
- *Description of problem*: A setting write was attempted while the lock relay setting was enabled.
- *What to do*: Ask the Supervisor to unlock the settings and try again.

SERVER UNAVAILABLE

- *Message*: "An attempt to contact the Radius server has failed"
- *Latched target message*: No.
- *Description of problem*: The RADIUS authentication server is unavailable.
- *What to do*: Verify network connectivity and try again.

STORAGE MEDIA ALARM:
Self Test Error

- *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.
- *Latched target message*: No.
- *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.

7.2.2.4 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 here. 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 of problem*: 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.
- *What to do*: 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 of problem*: UR-series device module hardware failure detected.
- *Severity*: Protection is not available and all contact outputs and shared outputs are de-asserted.
- *What to do*: 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 of problem*: 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.
- *What to do*: 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.

  If the problem persists 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 of problem*: 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.
- *What to do*: 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 of problem*: 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.
- *What to do*: 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 can still be non-functional.

C70 Capacitor Bank Protection and Control System

Chapter 8: Application of settings

This chapter provides example(s) of use.

8.1 Arrangement of shunt capacitor banks

8.1.1 Overview

The appropriate protection is dependent on the capacitor bank type, configuration, CTs and VTs location and connections. IEEE Standard C37.99-2000: Guide for Protection of Shunt Capacitor Banks specifies methods used for protecting different types of banks.

There are four types of arrangements and individual capacitors connections used to form a capacitor bank.

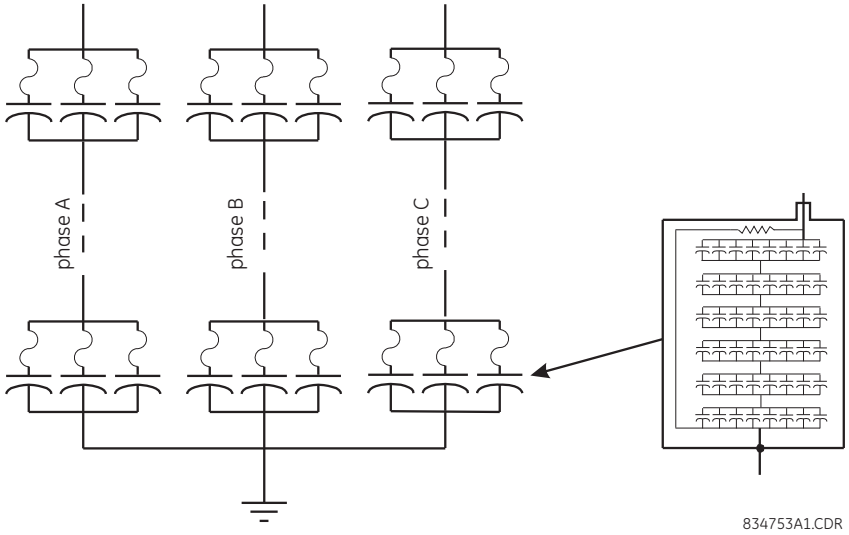
- Externally fused capacitors
- Internally fused capacitors
- Fuseless capacitors
- Unfused capacitors

These arrangements are described in the following sections.

8.1.2 Externally fused capacitors

An individual fuse, externally mounted between the capacitor unit and the capacitor bank fuse bus, protects each capacitor unit. The capacitor unit can be designed for a relatively high voltage since the external fuse is capable of interrupting a high-voltage fault. However, the kvar rating of the individual capacitor unit is usually smaller because a minimum number of parallel units are required to limit the voltage rise on remaining units and thus allow the bank to remain in service with a capacitor can out of service. A capacitor bank using fused capacitors is configured using one or more series groups of parallel-connected capacitor units per-phase, as shown.

Figure 8-1: Externally fused shunt capacitor bank and capacitor unit

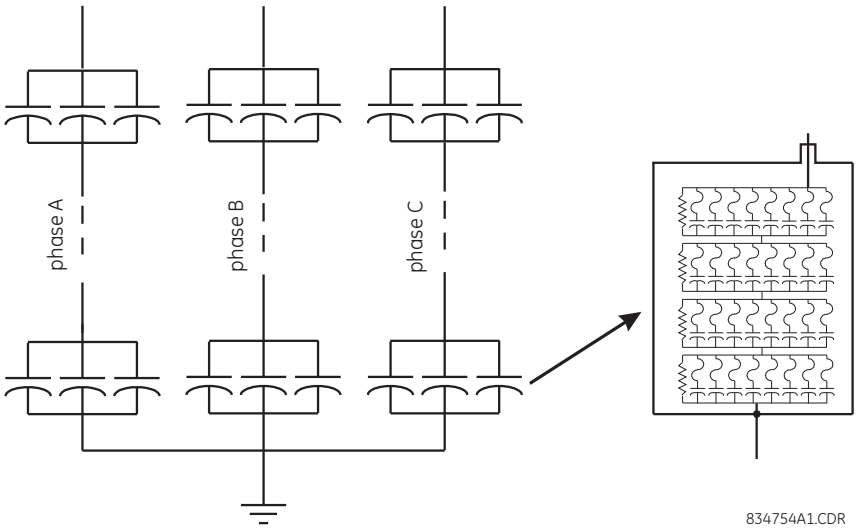


8.1.3 Internally fused capacitors

Each capacitor element is fused inside the capacitor unit. A simplified fuse is a piece of wire sized to melt under the fault current, and encapsulated in a wrapper able to withstand the heat produced by the arc during the current interruption. Upon the capacitor failure, the fuse removes the affected element only. The other elements, connected in parallel in the same group, remain in service but with a slightly higher voltage across them.

The figure illustrates a typical capacitor bank utilizing internally fused capacitor units. In general, banks employing internally fused capacitor units are configured with fewer capacitor units in parallel, and more series groups of units than are used in banks employing externally fused capacitor units. The capacitor units are built larger because the entire unit is not expected to fail.

Figure 8-2: Internally fused shunt capacitor bank and capacitor unit



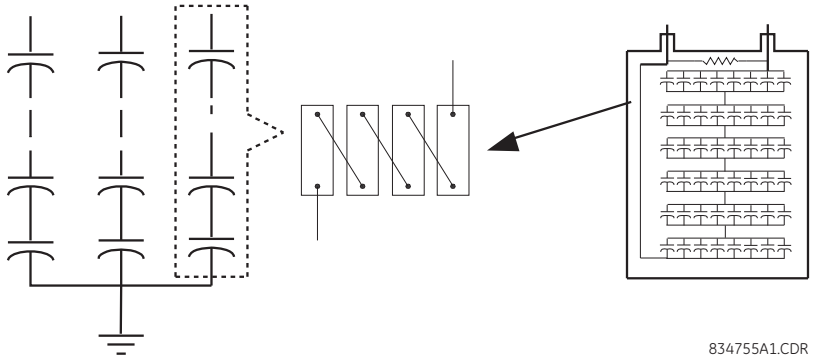
8.1.4 Fuseless capacitors

A fuseless capacitor bank typically is the most prevalent design. The capacitor units in the bank are connected in series strings between phase and neutral. The higher the bank voltage, the more capacitor elements in series.

The expected failure of the capacitor unit element is a short circuit, where the remaining capacitor elements absorb the additional voltage. For example, if there are six capacitor units in series and each unit has eight element groups in series, then there is a total of 48 element groups in the string. If one capacitor element fails, this element is shorted and the voltage across the remaining elements is 48 / 47 of the previous value, or about 2% higher. The capacitor bank remains in service; however, successive failures of elements aggravate the problem and eventually lead to the removal of the bank.

The fuseless design is usually applied for applications at or above 34.5 kV where each string has more than 10 elements in series to ensure the remaining elements do not exceed 110% rating if an element in the string shorts.

Figure 8-3: Fuseless shunt capacitor bank and series string



8.1.5 Unfused capacitors

Contrary to the fuseless configuration, where the units are connected in series, the unfused shunt capacitor bank uses a series or parallel connection of capacitor units. The unfused approach is normally used on banks below 34.5 kV, where series strings of capacitor units are not practical, or on higher voltage banks with modest parallel energy. This design does not require as many capacitor units in parallel as an externally fused bank.

8.2 Connections of shunt capacitor banks

8.2.1 Grounded wye-connected banks

Grounded wye capacitor banks are a series and parallel-connected capacitor units per-phase and provide a low impedance path to ground. This offers some protection from surge overvoltages and transient overcurrents.

When a capacitor bank becomes too large, making the parallel energy of a series group too high for the capacitor units or fuses (greater than 4650 kvar), the bank can be split into two wye sections. The characteristics of the grounded double wye are similar to a grounded single wye bank. Connect the two neutrals directly with a single path to ground.

The double-wye design facilitates better protection methods. Even with inherent unbalances, the two banks respond similarly to system events, and therefore, methods based on comparing one split-phase versus the other are more sensitive and less prone to system events (phase current balance technique, for example).

8.2.2 Ungrounded wye-connected banks

Ungrounded wye banks do not permit zero sequence currents, third harmonic currents, or large capacitor discharge currents during system ground faults (phase-to-phase faults can still occur and results in large discharge currents). Another advantage is that overvoltages appearing at the CT secondaries are not as high as in the case of grounded banks. However, the neutral should be insulated for full line voltage because it is momentarily at phase potential when the bank is switched or when one capacitor unit fails in a bank configured with a single group of units.

8.2.3 Delta connected banks

Delta-connected banks are generally used only at distribution voltages and are configured with a single series group of capacitors rated at line-to-line voltage. With only one series group of units, no overvoltage occurs across the remaining capacitor units from the isolation of a faulted capacitor unit.

8.2.4 H-configuration

Some larger banks use an H-configuration in each phase with a current transformer connected between the two legs to compare the current down each leg. As long as all capacitors are balanced, no current flows through the current transformer. If a capacitor fuse operates or an element shorts, some current flows through the current transformer. This bridge connection facilitates very sensitive protection. The H-arrangement is used on large banks with many capacitor units in parallel.

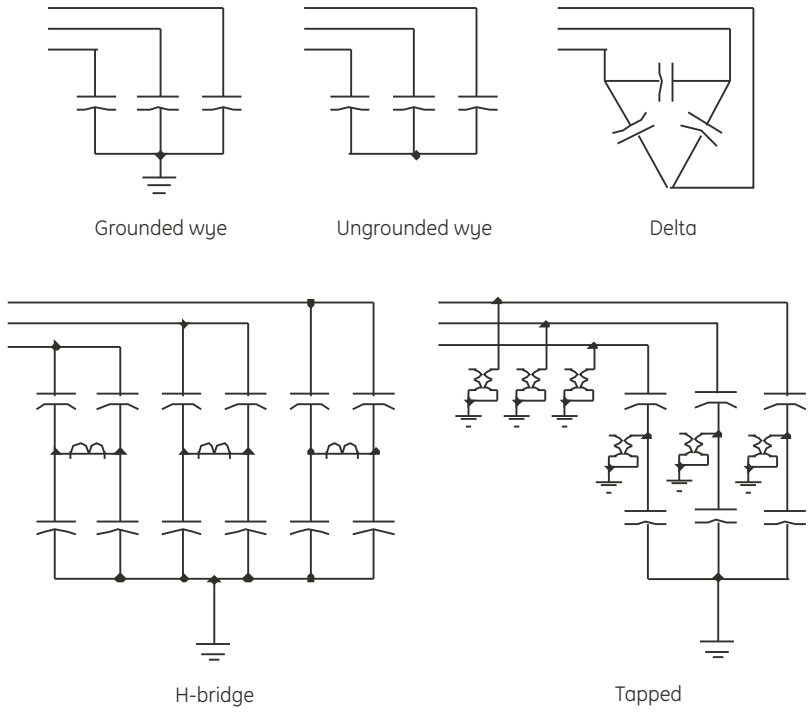
8.2.5 Tapped configuration

Some larger banks use a tapped configuration in each phase with voltage transformers connected from the phase to ground and from the tap to ground. As long as no fuses have opened and no elements have shorted, the ratio of these two voltages remains constant. The ratio changes with any capacitor failure in the phase, providing sensitive protection.

8.2.6 Summary

The figure summarizes the grounded wye, ungrounded wye, delta, H-bridge, and tapped connection types for capacitor banks.

Figure 8-4: Capacitor bank connections



8.3 Protection methods for capacitor banks

8.3.1 Overview

The protection of shunt capacitor banks involves both bank and system protection schemes.

Bank protection schemes are provided for faults within the capacitor bank itself. Bank protection include items such as a means to disconnect a faulted capacitor unit or capacitor elements, a means to initiate a shutdown of the bank in case of faults that can lead to a catastrophic failure, and alarms to indicate unbalance within the bank.

System protection schemes are provided to protect the capacitor bank from stresses caused by the system and to protect the substation and system from stresses that can be caused by the operation of the capacitor bank. System protection includes items such as a means to limit overvoltage and excessive transient overcurrents, and to disconnect the bank in the event of a major fault within the capacitor installation. System protection can also include alarms and methods to disconnect the entire shunt capacitor bank to prevent further damage to the capacitors due to abnormal system conditions.

In externally fused capacitor banks, several capacitor element breakdowns can occur before the fuse removes the entire unit. The external fuse operates when a capacitor unit becomes (essentially) short circuited, isolating the faulted unit. Unbalance protection removes the bank from service when the resulting overvoltage becomes excessive on the remaining healthy capacitor units.

Internally fused capacitors have individual capacitor elements within a capacitor unit that are disconnected when an element breakdown occurs. The risk of successive faults is minimized because the fuse isolates the faulty element within a few cycles. Unbalance protection removes the bank from service when the resulting unbalanced voltage becomes excessive on the remaining healthy capacitor elements or units.

For fuseless or unfused capacitor banks, a failed element is short-circuited by the weld that naturally occurs at the point of failure. Unbalance protection removes the bank from service when the resulting voltage becomes excessive on the remaining healthy capacitor elements or units.

8.3.2 Capacitor unbalance protection

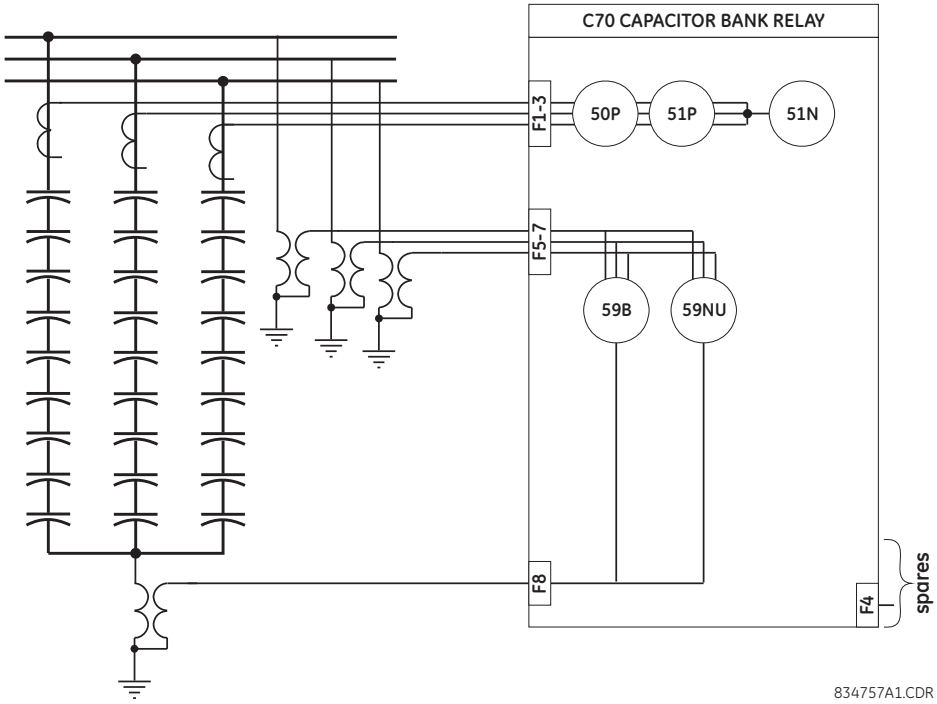
8.3.2.1 Connections

Unbalance protection utilizes the unbalance that occurs in a normally balanced capacitor bank to detect an abnormality and initiate appropriate action. The most important function is to promptly remove the bank from service for any fault that can result in further damage. Capacitor unbalance protection is provided in many ways, depending on the capacitor bank arrangement.

A variety of unbalance protection schemes can be applied with the C70 for internally fused, externally fused, fuseless, or unfused shunt capacitor banks, as shown in the rest of this section.

The following figure illustrates a single capacitor bank, ungrounded, with no tap available. In this case, a single CT/VT module is required.

Figure 8-5: Single bank, ungrounded, no tap available



The following figure illustrates a single capacitor bank, ungrounded, with a tap. In this case, two CT/VT modules are required.

Figure 8-6: Single bank, ungrounded, with a tap

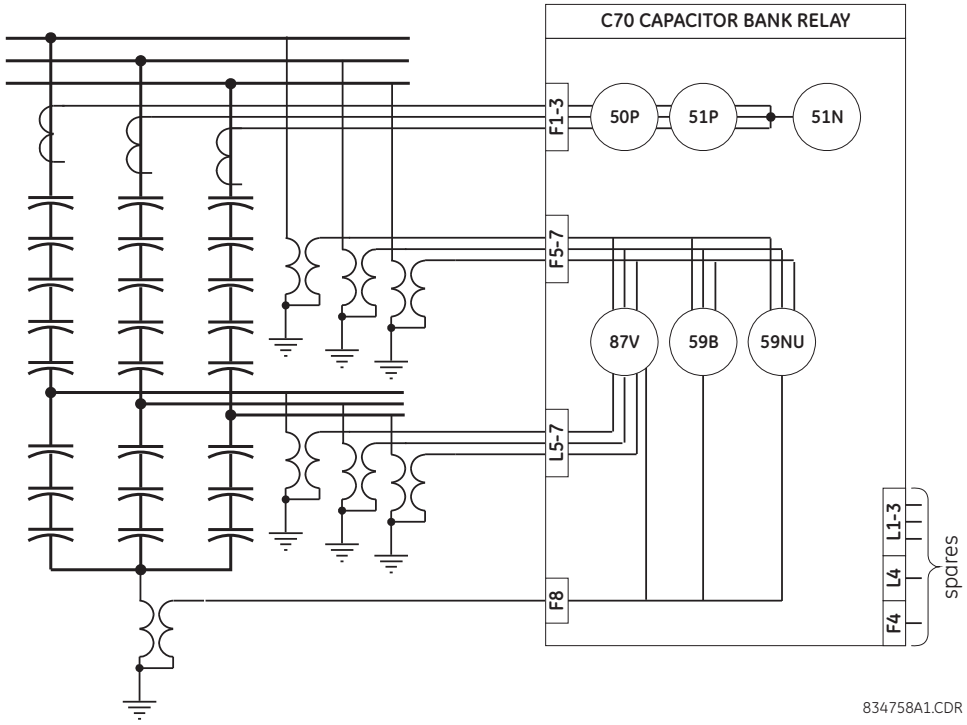
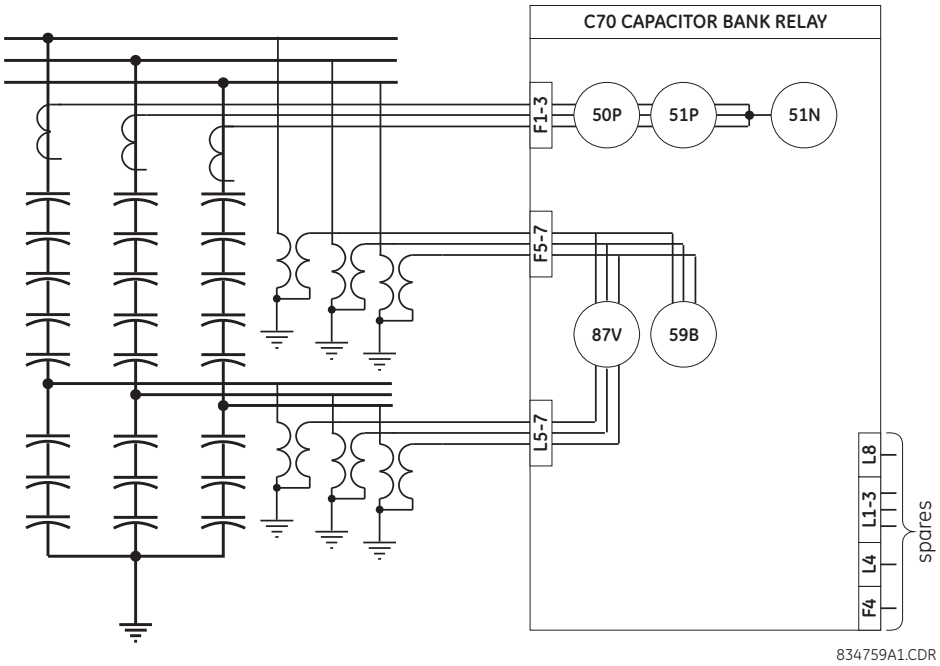
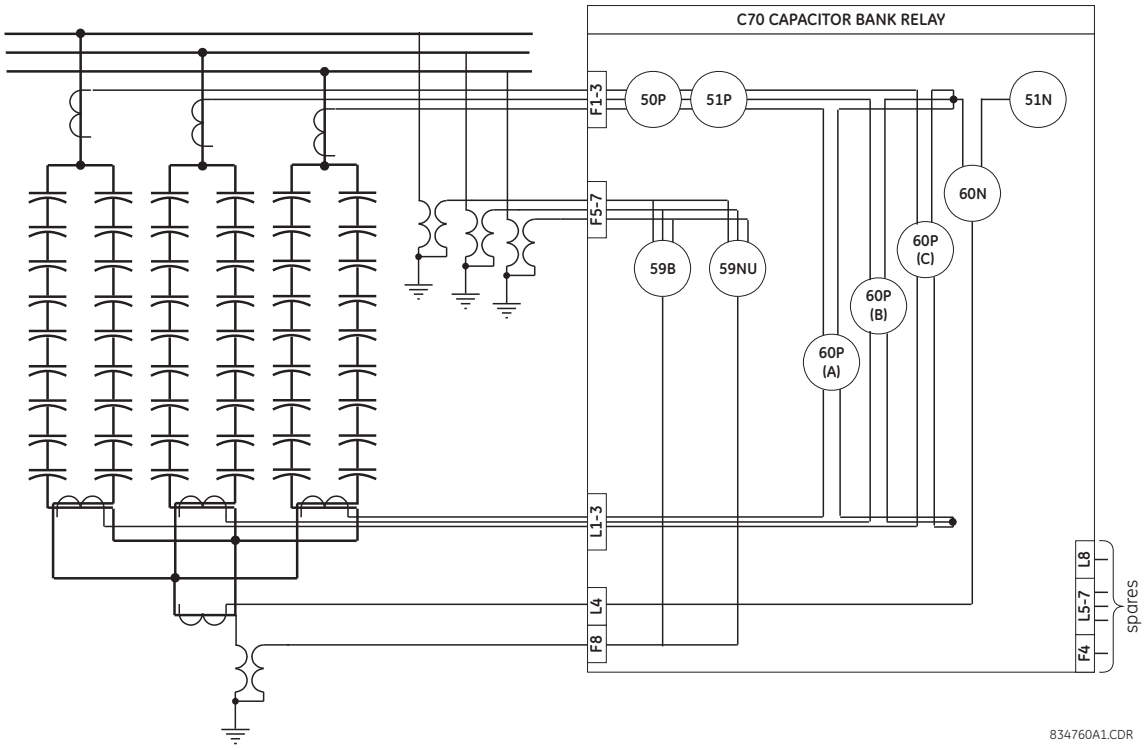


Figure 8-7: Single bank, grounded, with a tap



The following figure illustrates parallel capacitor banks, ungrounded, no tap available, and with current unbalance protection. In this case, two CT/VT modules are required.

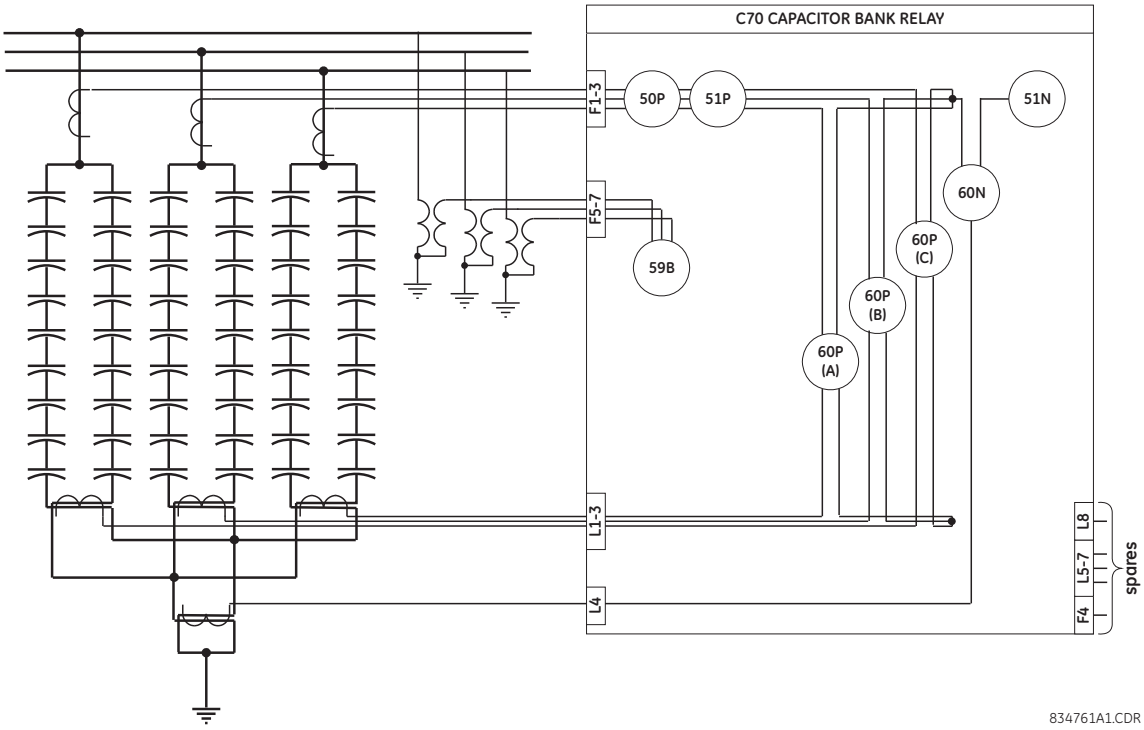
Figure 8-8: Parallel banks, ungrounded, no tap available, current unbalance protection



The following figure illustrates parallel capacitor banks, grounded, no tap available, and with current unbalance protection. In this case, two CT/VT modules are required.

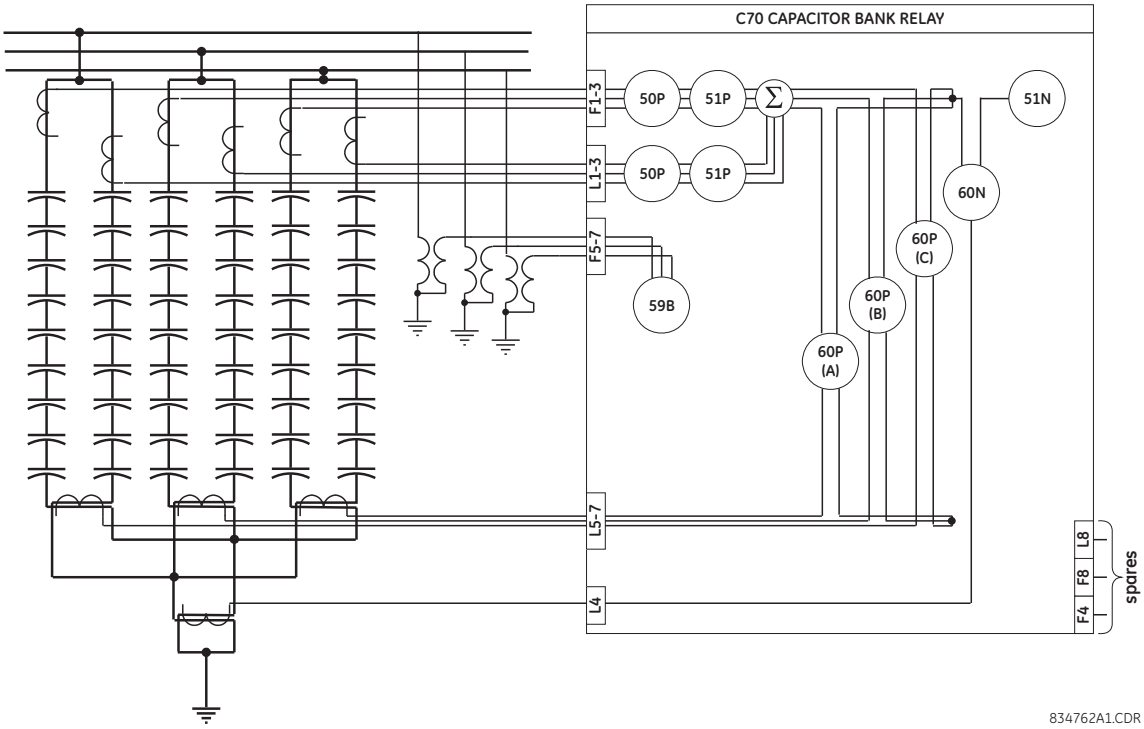
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Figure 8-9: Parallel banks, grounded, no tap available, current balance protection



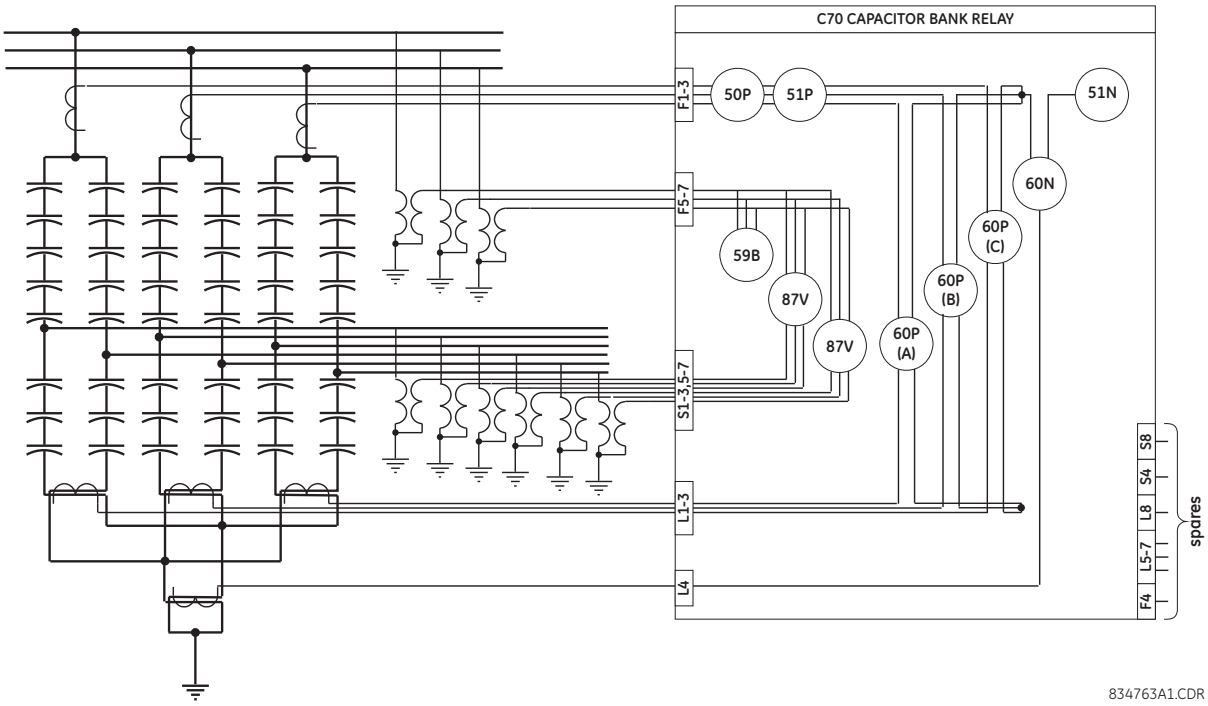
The following figure illustrates parallel capacitor banks, grounded, no tap available, with current unbalance protection and high-side CTs for each bank. In this case, two CT/VT modules are required.

Figure 8-10: Parallel banks, grounded, no tap, with current balance protection and high-side CTs



The following figure illustrates parallel capacitor banks, grounded, with taps and current unbalance protection. In this case, three CT/VT modules are required.

Figure 8-11: Parallel banks, grounded, with taps and current unbalance protection



The normal functions of unbalance relaying are as follows:

- Trip the bank promptly if an unbalance indicates the possible presence of external arcing or a cascading fault within the capacitor bank
- Provide early unbalance alarm signal(s) to indicate the operation of fuses (internally or externally fused capacitors) or failure of capacitor elements (fuseless or unfused capacitors)
- Trip the bank for unbalances that are large enough to indicate that continuing operation can result in the following:
  - Damage to remaining good capacitor units or elements from overvoltage
  - Fuse malfunction
  - Inappropriate filter operation (for capacitor banks that are a part of a harmonic filter)
  - Other undesirable consequences

Note that there can be undetectable failure modes for each type of unbalance protection. These need to be backed up by other types of protection.

8.3.2.2 Unbalance trip element considerations

Note the following points when using the unbalance trip element.

- Minimize the unbalance trip element time delay to reduce damage from an arcing fault within the bank structure and prevent exposure of the remaining capacitor units to overvoltage conditions beyond their permissible limits. For a single-phase or an open-phase condition, keep the time delay short enough to avoid damage to the current transformer or voltage transformer and to the relay system.
- Have enough time delay on the unbalance trip element to avoid false operations due to inrush, system ground faults, switching of nearby equipment, and non-simultaneous pole operation of the energizing switch. For most applications, 0.1 seconds is adequate. For unbalance relaying systems that operate on a system voltage unbalance (ground fault), a delay slightly longer than the upstream protection fault clearing time is required to avoid tripping due to a system fault. Longer delays increase the probability of catastrophic bank failure.

- With grounded capacitor banks, the failure of one pole of the switching device or the single phasing from a blown bank fuse allows zero sequence currents to flow in system ground relays. Coordinate capacitor bank relaying, including the operating time of the switching device, with the operation of the system ground relays to avoid tripping system load.
- The unbalance trip element can need to be delayed to account for the settling time of the protection system on initial energization and for the transient response of certain capacitor voltage transformers, and so on, which can be a part of the unbalance protection system
- The unbalance trip scheme can include a lockout feature to prevent inadvertent closing of the capacitor bank switching device if an unbalance trip has occurred
- To allow for the effects of inherent unbalance, set the unbalance element trip to operate at a signal level halfway between the critical step and the next lower step. The critical step is the number of fuse operations or shorted elements that cause an overvoltage on healthy capacitor units in excess of 110% of the capacitor unit rated voltage or the capacitor unit manufacturer's recommended maximum continuous operating voltage. In addition, for internally fused capacitor units, the critical step can be the number of internal fuse operations at which tripping should occur as recommended by the capacitor manufacturer.
- If switch failure or single phasing due to a blown main fuse can result in the continuous voltage exceeding the relay or VT rating, configure additional elements in the relay to trip the bank for this condition
- The unbalance element detects only the unbalance in the capacitor bank and in supply voltage and does not respond to capacitor overvoltage due to a balanced system voltage above nominal. Configure the bank phase overvoltage to trip the bank for this condition.
- Use the maximum system operating voltage, with capacitor bank energized, for setting unbalance relays

8.3.2.3 Unbalance alarm element considerations

To allow for the effects of inherent unbalance within the bank, set the unbalance relay alarm to operate at about one-half the level of the unbalance signal determined by the calculated alarm condition based on an idealized bank. Set the alarm with sufficient time delay to override external disturbances.

8.3.3 Protection for rack faults (arc-over within capacitor banks)

The most effective protection for an arc-over within the capacitor bank is provided by a fast unbalance element. A short time delay for the unbalance elements minimizes the damage caused by rack faults. Intentional delays as short as 0.05 seconds have been used. This short unbalance time delay, however, should not be less than the maximum clearing time of the capacitor-unit or element fuse. Although the unbalance trip element is the most effective protection for arc detection of a series section, do not rely on the neutral voltage type of unbalance element for rack fault protection on capacitor banks where all three phases are not well separated.

Negative sequence elements can be used for inter-phase fault detection as they can be set to be more sensitive than phase overcurrent relays, but tripping should be delayed to coordinate with the other relays in the system. A setting of 10% of the rated capacitor current, taking into consideration the maximum system voltage unbalance and the maximum capacitance variation together with a time delay setting of 15 to 25 cycles, can provide adequate coordination for faults external to the bank. However, it may not prevent damage due to arcing faults within the bank structure.

8.3.4 Overvoltage

The capacitor bank and other equipment in the vicinity can be subject to overvoltages resulting from abnormal system operating conditions. If the system voltage exceeds the capacitor or equipment capability with the capacitor bank on line, remove the bank with minimum time delay. Removing the capacitor bank from the system lowers the system voltage in the vicinity of the capacitor, reducing the overvoltage on other system elements.

Especially for very large EHV capacitor banks, it is advisable to install three-phase overvoltage protection (ANSI 59B) to trip the bank quickly for extreme overvoltage conditions. To avoid nuisance tripping during transient overvoltage conditions, in some cases, tripping is delayed by a timer. The C70 provides inverse time overvoltage characteristics required to decrease tripping time for large overvoltages.

Because this tripping is not due to a fault within the capacitor bank, the capacitor bank is not locked out.

8.3.5 Overcurrent

Phase and neutral time overcurrent elements can be applied with normal settings without encountering false operations due to inrush currents. The desirable minimum pickup is 135% of nominal phase current for grounded wye banks or 125% for ungrounded banks. Set the instantaneous elements (if used) high to override inrush or outrush transients.

For effectively grounded systems with grounded wye capacitor banks, the high-frequency outrush current into an external ground fault does not normally operate the 51N ground element. The unbalanced capacitor bank load current caused by an external ground fault can be sufficient to cause the element to pick up and trip the capacitor bank if the 51N is set too low. To prevent this inadvertent tripping, the trip of the 51N element is normally set above the capacitor phase current.

8.3.6 Loss of bus voltage

In some cases, it is necessary to trip a shunt capacitor bank if the supply bus voltage is lost. Two conditions that need to be considered are:

- Re-energizing a bank with a trapped charge
- Energizing a capacitor bank without parallel load through a previously unenergized transformer

The undervoltage element (ANSI device 27B) detects loss of system voltage and trip the capacitor bank after a time delay. This delay prevents tripping of the bank for system faults external to the bank. Set the undervoltage element so that the element does not operate for voltages that require the capacitor bank to remain in service. Because this tripping is also not due to a fault within the capacitor bank (like system overvoltage tripping), the bank is not locked out.

8.4 Settings example

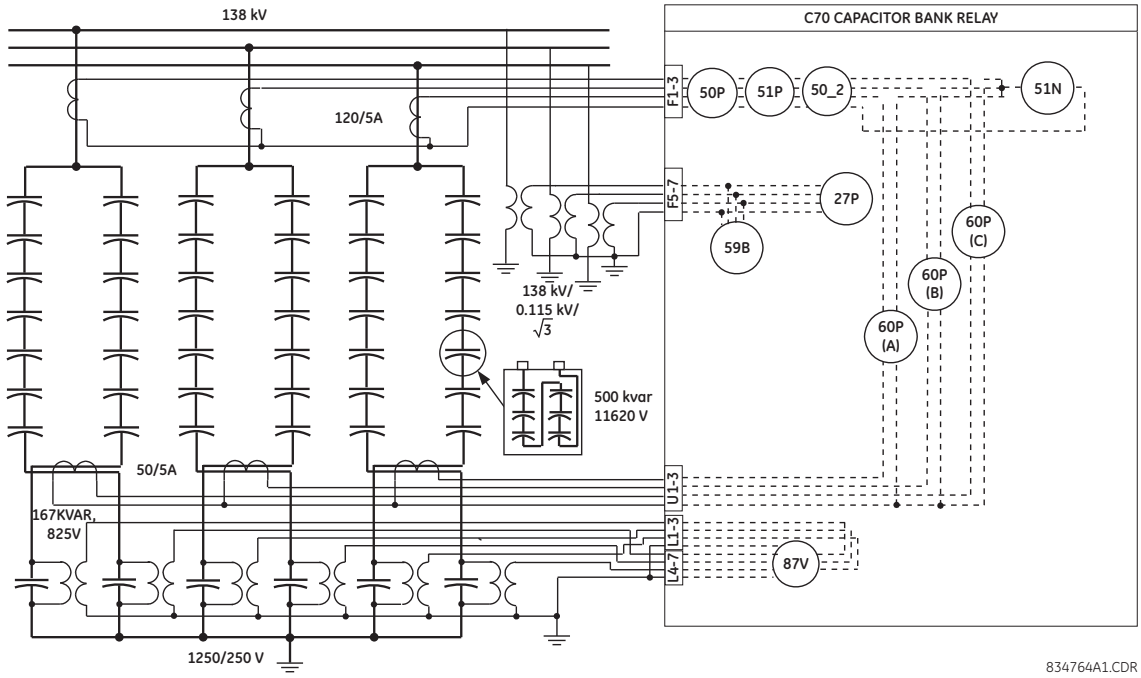
8.4.1 Overview

Consider protection of a capacitor bank with the following characteristics:

- V_{LL} = 138 kV fuseless
- Q_B = 21 Mvar
- Two parallel strings (S = 2) in each phase with N = 7 capacitor units rated Q_C = 500 kvar, V_C = 11.62 kV
- Each capacitor unit consisting of n = 6 series capacitors

The figure shows details. Phase capacitors are connected to ground through a neutral capacitor rated Q_{CN} = 167 kvar, V_{CN} = 0.825 kV.

Figure 8-12: Sample capacitor bank configuration



Based on the bank configuration, CT connections, and VTs connections, a C70 model is chosen with three CT/VT modules: two type 8L modules (in slots F and U) and one type 8V module (in slot M) to provide following protection functionality.

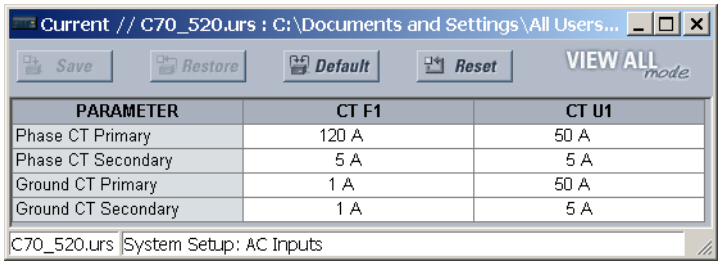
- Negative-sequence instantaneous overcurrent (ANSI 50_2) to provide fast backup protection against arcing within capacitor bank
- Phase overvoltage (ANSI 59B) to provide protection against overvoltages
- Bank overcurrent protection, phase instantaneous overcurrent (ANSI 50P), neutral instantaneous overcurrent (ANSI 50N) and phase time overcurrent (ANSI 51P) to provide protection against major faults within the capacitor bank
- Bank undervoltage (ANSI 27P) to detect loss of bus voltage and trip the bank
- Voltage differential (ANSI 87V) to detect failure of one or more capacitor elements in a given string. Three voltage differential elements can be set for this application: one between two tap voltages (ANSI 87V-1) and two between the bus voltage and tap voltage in both strings (ANSI 87V-2 and 87V-3).
- Phase current unbalance (ANSI 60P) to detect failure of one or more capacitor elements in a given string

8.4.2 VT and CT setup

The CT and VT connections are shown in the previous figure. The CT channels are connected as follows:

- The type 8L CT/VT module F1 to F3 three-phase CT channels are connected to the bus side three-phase CTs with a 120 / 5 A ratio
- The type 8L CT/VT module U1 to U3 three-phase CT channels are connected to the neutral side window CTs with a 50 / 5 A ratio

The following settings are applied in the EnerVista UR Setup software.



PARAMETER	CT F1	CT U1
Phase CT Primary	120 A	50 A
Phase CT Secondary	5 A	5 A
Ground CT Primary	1 A	50 A
Ground CT Secondary	1 A	5 A

The VT channels are connected as follows:

- The type 8L CT/VT module F5 to F7 three-phase VT channels are connected to the bus side three-phase VTs with a 138 / 0.115 kV ratio
- The type 8V CT/VT module M1 to M3 and M5 to M7 three-phase VT channels are connected to two tap VTs with a 1.25 / 0.25 kV ratio. The nominal voltage is calculated below for normal bank conditions and a nominal system voltage of 138 kV (see impedance calculations the following sub-section).

The nominal bus phase VT voltage is:

$$V_{tap(bus)} = \frac{13800}{\sqrt{3}} = 79674.34 \text{ V} \quad \textbf{Eq. 8-1}$$

The nominal tap VT voltage is:

$$V_{tap(nominal)} = \frac{138000 \times Z_C^b}{\sqrt{3} \times Z_C^t} = \frac{13800 \times 4.08}{\sqrt{3} \times 1894.42} = 171.41 \text{ V} \quad \textbf{Eq. 8-2}$$

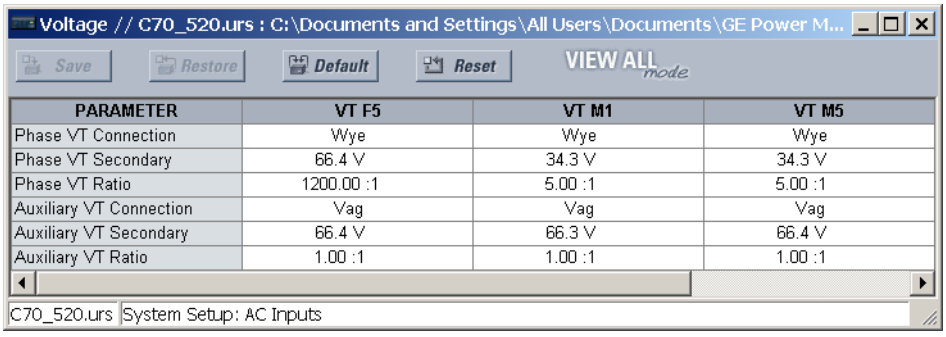
Therefore, the tap VT secondary voltage is set as:

$$V_{tap(secondary)} = \frac{V_{tap(nominal)}}{N_{tap(VT)}} = \frac{171.41 \text{ V}}{5} = 34.28 \text{ V} \quad \textbf{Eq. 8-3}$$

Where the VT ratio $N_{tap(VT)}$ is calculated as:

$$N_{tap(VT)} = \frac{125 \text{ kV}}{0.25 \text{ kV}} = 5 \quad \textbf{Eq. 8-4}$$

The following settings are applied in the EnerVista UR Setup software.



PARAMETER	VT F5	VT M1	VT M5
Phase VT Connection	Wye	Wye	Wye
Phase VT Secondary	66.4 V	34.3 V	34.3 V
Phase VT Ratio	1200.00 :1	5.00 :1	5.00 :1
Auxiliary VT Connection	Vag	Vag	Vag
Auxiliary VT Secondary	66.4 V	66.3 V	66.4 V
Auxiliary VT Ratio	1.00 :1	1.00 :1	1.00 :1

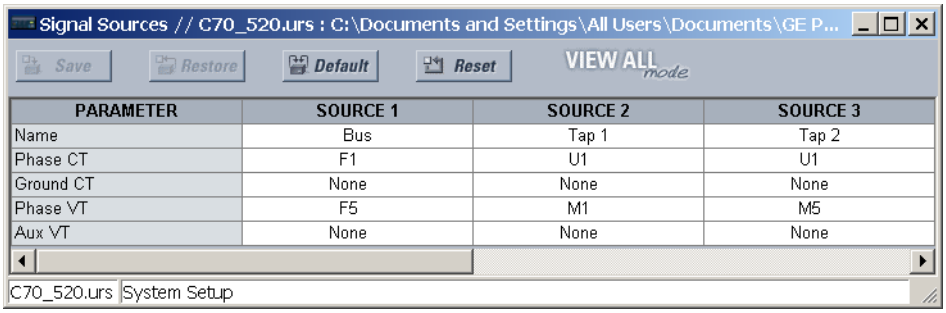
8.4.3 Source assignment

The following sources must be assigned for the protection functions indicated:

- Source 1 (bus) is assigned with CT and VT banks connected to the bus, providing a signal source for overcurrent, phase current unbalance, overvoltage, and undervoltage functions

- Source 2 (tap 1) and source 3 (tap 2) are assigned with the VT banks and split window CT bank connected to the tap point of two strings of the bank, providing a signal source for the voltage differential and phase unbalance functions

The CT and VT connections shown in the earlier figure are assigned the following values in EnerVista UR Setup.



PARAMETER	SOURCE 1	SOURCE 2	SOURCE 3
Name	Bus	Tap 1	Tap 2
Phase CT	F1	U1	U1
Ground CT	None	None	None
Phase VT	F5	M1	M5
Aux VT	None	None	None

8.4.4 Bank unbalance calculations

The following values are used in unbalance calculations.

The impedance of one capacitor can:

$$Z_C^c = \frac{V_C^2}{Q_C} = \frac{(11.62\ \text{V})^2}{500 \times 10^{-3}\ \text{vars}} = 270.05\Omega \qquad \textbf{Eq. 8-5}$$

The impedance of one capacitor element, with $n = 6$ capacitor elements per can:

$$Z_C^e = \frac{Z_C^c}{n} = \frac{270.05\Omega}{6} = 45.01\Omega \qquad \textbf{Eq. 8-6}$$

The impedance of the top healthy capacitor string:

$$Z_C^s = Z_C^c \times N = 270.05\Omega \times 7 = 1890.34\Omega \qquad \textbf{Eq. 8-7}$$

The impedance of the bottom capacitor can:

$$Z_C^b = \frac{V_{CN}^2}{Q_{CN}} = \frac{(0.825\ \text{V})^2}{0.167\ \text{var}} = 4.08\ \Omega \qquad \textbf{Eq. 8-8}$$

The total impedance of the healthy capacitor string:

$$Z_C^t = Z_C^s + Z_C^b = 1890.34\Omega + 4.08\Omega = 1894.42\Omega \qquad \textbf{Eq. 8-9}$$

The maximum rated line-to-neutral system voltage:

$$V_{max} = V_C \times N + \frac{V_C \times N}{Z_C^s} \times Z_C^b = 11620\ \text{V} \times 7 + \frac{11620\ \text{V} \times 7}{1890.34\Omega} \times 4.08\ \Omega = 81515.37\ \text{V} \qquad \textbf{Eq. 8-10}$$

The maximum rated phase current of the healthy bank:

$$I_{max} = \frac{V_{max}}{Z_C^t/2} = \frac{81515.37\ \text{V}}{1894.92\Omega/2} = 86.06\ \text{A} \qquad \textbf{Eq. 8-11}$$

The maximum rated voltage across the healthy top section:

$$V_{top} = \frac{V_{max} \times Z_C^s}{Z_C^t} = \frac{81515.37\ \text{V} \times 1890.34\Omega}{1894.92\Omega} = 81340.40\ \text{V} \qquad \textbf{Eq. 8-12}$$

The maximum rated voltage across the healthy bottom section:

$$V_{bottom} = \frac{V_{max} \times Z_C^b}{Z_C^t} = \frac{81515.37\ V \times 4.08\ \Omega}{1894.92\Omega} = 175.37\ V \quad \textbf{Eq. 8-13}$$

The voltage distribution factor for the healthy perfectly balanced bank for the 87V-2 and 87V-3 elements:

$$K_{tap} = \frac{V_{top}}{V_{bottom}} = \frac{81340.40\ V}{175.37\ V} = 463.8194 \quad \textbf{Eq. 8-14}$$

The impedance of the string for the failed capacitors elements (for one failed element, $n_f = 1$:

$$Z_C^{sf} = Z_C^e(N \times n - n_f) + Z_C^b = 45.01\Omega \times (7 \times 6 - 1) + 4.08\ \Omega = 1849.41\Omega \quad \textbf{Eq. 8-15}$$

The voltage at the tap in the section with one failed capacitor element in the string:

$$V_{tap2} = \frac{V_{max} \times Z_C^b}{Z_C^{sf}} = \frac{81515.37\ V \times 4.08\ \Omega}{1849.91\ \Omega} = 179.64\ V \quad \textbf{Eq. 8-16}$$

The voltage of the top section with one capacitor element failed:

$$V_{top} = V_{max} - V_{tap2} \quad \textbf{Eq. 8-17}$$

The overvoltage at the affected capacitors with one capacitor element failed:

$$OV = \frac{V_{f(top)} \times N \times n}{V_{top} \times (N \times n - n_f)} = \frac{81335.74\ V \times 7 \times 6}{81340.40\ V \times (7 \times 6 - 1)} = 1.024\ pu \quad \textbf{Eq. 8-18}$$

The differential voltage between two taps with one failed capacitor element in the upper string, assuming $K = 1$ for 87V-1, in per-unit values is:

$$V_{diff(tap)} = \left|\frac{V_{tap1} - 1 \times V_{tap2}}{VT_{nom(tap)}}\right| = \left|\frac{175.374\ V - 1 \times 179.64\ V}{171.59\ V}\right| = 0.0249\ pu \quad \textbf{Eq. 8-19}$$

The differential voltage between the bus voltage and the tap with one failed capacitor element in the upper string, assuming $K = 1$, for 87V-3 in per-unit values is:

$$V_{diff(string)} = \left|\frac{V_{f(top)} - K_{tap} \times V_{tap2}}{VT_{nom(bus)}}\right| = \left|\frac{175.374\ V - 463.8194 \times 179.64\ V}{79674.34\ V}\right| = 0.0249\ pu \quad \textbf{Eq. 8-20}$$

The unbalance current in the window type CT between two strings with one failed capacitor element in the upper string:

$$I_{unbal} = \left|\frac{V_{max}}{Z_C^{sf} \times CT_{tap}} - \frac{V_{max}}{Z_C^{s} \times CT_{tap}}\right| = \left|\frac{81515.37\ V}{1845.33\Omega \times 50} - \frac{81515.37\ V}{1890.34\Omega \times 50}\right| = 0.0209\ pu \quad \textbf{Eq. 8-21}$$

The following table summarizes the calculated values for the number of failed capacitors used to set the protection elements.

Table 8-1: Unbalance values for maximum system conditions

n_f	Z_C^s	Z_C^{sf}	V_{tap1}	V_{tap2}	V_{top}	OV	$V_{diff(tap)}$	$V_{diff(string)}$	I_{unbal}
0	1894.42 Ω	1894.42 Ω	175.37 V	175.37 V	81340.00 V	1.000 pu	0.0000 pu	0.0000 pu	0.0000 pu
1	1894.42 Ω	1849.41 Ω	175.37 V	179.64 V	81335.73 V	1.024 pu	0.0249 pu	0.0249 pu	0.0209 pu
2	1894.42 Ω	1804.40 Ω	175.37 V	184.12 V	81331.25 V	1.050 pu	0.0510 pu	0.0510 pu	0.0429 pu
3	1894.42 Ω	1759.39 Ω	175.37 V	188.83 V	81326.54 V	1.077 pu	0.0785 pu	0.0785 pu	0.0660 pu
4	1894.42 Ω	1714.38 Ω	175.37 V	193.79 V	81321.58 V	1.105 pu	0.1074 pu	0.1074 pu	0.0904 pu
5	1894.42 Ω	1669.38 Ω	175.37 V	199.01 V	81316.36 V	1.135 pu	0.1379 pu	0.1379 pu	0.1160 pu
6	1894.42 Ω	1624.37 Ω	175.37 V	204.52 V	81310.85 V	1.167 pu	0.1701 pu	0.1701 pu	0.1431 pu
7	1894.42 Ω	1579.36 Ω	175.37 V	210.35 V	81305.02 V	1.200 pu	0.2041 pu	0.2041 pu	0.1717 pu
8	1894.42 Ω	1534.35 Ω	175.37 V	216.52 V	81298.85 V	1.235 pu	0.2401 pu	0.2401 pu	0.2020 pu
9	1894.42 Ω	1489.34 Ω	175.37 V	223.07 V	81292.30 V	1.273 pu	0.2783 pu	0.2783 pu	0.2341 pu
10	1894.42 Ω	1444.34 Ω	175.37 V	230.02 V	81285.35 V	1.313 pu	0.3188 pu	0.3188 pu	0.2682 pu

To check the limits of protection sensitivity, the same calculations are repeated for the minimum system conditions, which are considered to be 0.85 pu of nominal system voltage.

The minimum line to neutral system voltage is:

$$V_{min} = \frac{0.85 \times V_{nom}}{\sqrt{3}} = \frac{0.85 \times 138000\ V}{\sqrt{3}} = 67723\ V \qquad \textbf{Eq. 8-22}$$

The following table summarizes the unbalance values during minimum system conditions.

Table 8-2: Unbalance values for minimum system conditions

n_f	Z_C^s	Z_C^{sf}	V_{tap1}	V_{tap2}	V_{top}	OV	$V_{diff(tap)}$	$V_{diff(string)}$	I_{unbal}
0	1894.42 Ω	1894.42 Ω	145.70 V	145.70 V	67577.30 V	1.000 pu	0.0000 pu	0.0000 pu	0.0000 pu
1	1894.42 Ω	1849.41 Ω	145.70 V	149.24 V	67573.76 V	1.024 pu	0.0207 pu	0.0207 pu	0.0174 pu
2	1894.42 Ω	1804.40 Ω	145.70 V	152.97 V	67570.03 V	1.050 pu	0.0424 pu	0.0424 pu	0.0357 pu
3	1894.42 Ω	1759.39 Ω	145.70 V	156.88 V	67566.12 V	1.077 pu	0.0652 pu	0.0652 pu	0.0549 pu
4	1894.42 Ω	1714.38 Ω	145.70 V	161.00 V	67562.00 V	1.105 pu	0.0893 pu	0.0893 pu	0.0751 pu
5	1894.42 Ω	1669.38 Ω	145.70 V	165.34 V	67557.66 V	1.135 pu	0.1146 pu	0.1146 pu	0.0964 pu
6	1894.42 Ω	1624.37 Ω	145.70 V	169.92 V	67553.08 V	1.167 pu	0.1413 pu	0.1413 pu	0.1189 pu
7	1894.42 Ω	1579.36 Ω	145.70 V	174.76 V	67548.24 V	1.200 pu	0.1696 pu	0.1696 pu	0.1426 pu
8	1894.42 Ω	1534.35 Ω	145.70 V	179.89 V	67543.11 V	1.235 pu	0.1995 pu	0.1995 pu	0.1678 pu
9	1894.42 Ω	1489.34 Ω	145.70 V	185.32 V	67537.68 V	1.273 pu	0.2312 pu	0.2312 pu	0.1945 pu
10	1894.42 Ω	1444.34 Ω	145.70 V	191.10 V	67531.90 V	1.313 pu	0.2649 pu	0.2649 pu	0.2228 pu

The balance values during minimum operating conditions can be used to check sensitivity.

8.4.5 Bank voltage differential settings

The bank configuration, CT location, and VT locations allow applying three voltage differential elements:

- An 87V-1 differential element measuring the differential voltage between the two bottom taps
- An 87V-2 differential element measuring the differential voltage between the upper capacitor string and bottom capacitor can for string 1
- An 87V-3 differential element measuring the differential voltage between the upper capacitor string and bottom capacitor can for string 2

Two voltage differential (87V) stages provide trip and alarm levels during capacitor unit failures in each differential element. The capacitor units are subject to overvoltage if one or more capacitors units are shorted out. The voltage differential trip pickup setting is programmed for value of 110% of capacitor rated voltage. As seen from the previous Unbalance Values for Maximum System Conditions table, a failure of four capacitor elements causes a 10.5% overvoltage.

The pickup setting for the stage 1 differential alarm element is chosen for one element failure.

$$87V\ \text{alarm} = 0.9V_{diff(f1\_max)} = 0.9 \times 0.0249\ \text{pu} = 0.0224\ \text{pu} \quad \textbf{Eq. 8-23}$$

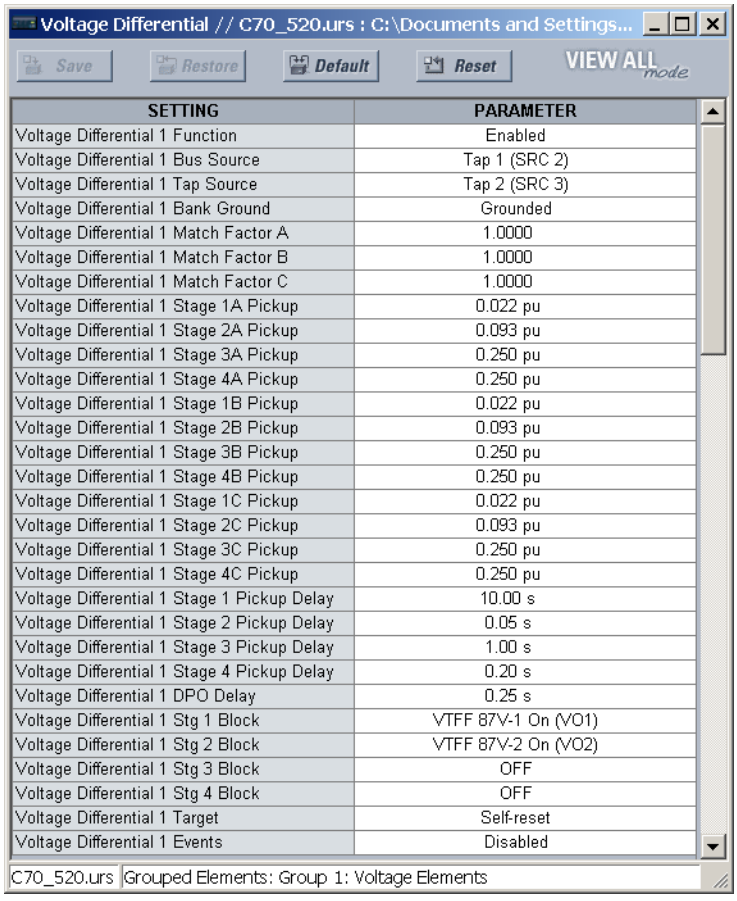
The alarm delay is set to 10 seconds to avoid alarming during transient conditions.

The pickup setting for the stage 2 differential trip element is programmed as the differential voltage during maximum system conditions midway between the third and fourth capacitor element failure differential voltages.

$$87V\ \text{trip} = \frac{V_{diff(f4\_max)} + V_{diff(f3\_max)}}{2} = \frac{0.1074\ \text{pu} + 0.0785\ \text{pu}}{2} = 0.093\ \text{pu} \quad \textbf{Eq. 8-24}$$

Therefore, the trip delay is set to 50 ms.

The following setting values for the voltage differential 1 element between two tap voltages are programmed in the EnerVista UR Setup software.

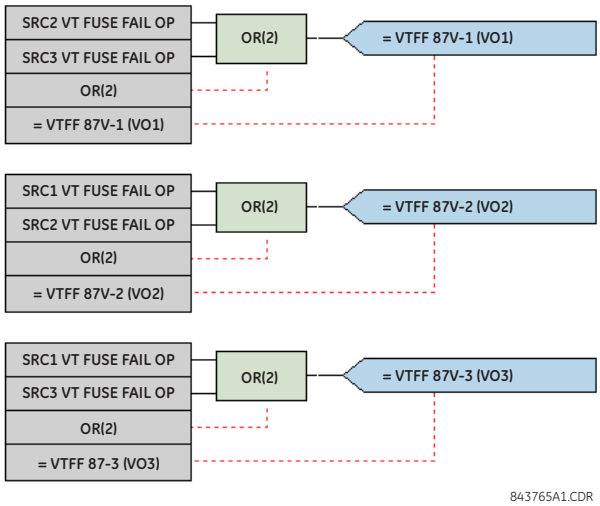


SETTING	PARAMETER
Voltage Differential 1 Function	Enabled
Voltage Differential 1 Bus Source	Tap 1 (SRC 2)
Voltage Differential 1 Tap Source	Tap 2 (SRC 3)
Voltage Differential 1 Bank Ground	Grounded
Voltage Differential 1 Match Factor A	1.0000
Voltage Differential 1 Match Factor B	1.0000
Voltage Differential 1 Match Factor C	1.0000
Voltage Differential 1 Stage 1A Pickup	0.022 pu
Voltage Differential 1 Stage 2A Pickup	0.093 pu
Voltage Differential 1 Stage 3A Pickup	0.250 pu
Voltage Differential 1 Stage 4A Pickup	0.250 pu
Voltage Differential 1 Stage 1B Pickup	0.022 pu
Voltage Differential 1 Stage 2B Pickup	0.093 pu
Voltage Differential 1 Stage 3B Pickup	0.250 pu
Voltage Differential 1 Stage 4B Pickup	0.250 pu
Voltage Differential 1 Stage 1C Pickup	0.022 pu
Voltage Differential 1 Stage 2C Pickup	0.093 pu
Voltage Differential 1 Stage 3C Pickup	0.250 pu
Voltage Differential 1 Stage 4C Pickup	0.250 pu
Voltage Differential 1 Stage 1 Pickup Delay	10.00 s
Voltage Differential 1 Stage 2 Pickup Delay	0.05 s
Voltage Differential 1 Stage 3 Pickup Delay	1.00 s
Voltage Differential 1 Stage 4 Pickup Delay	0.20 s
Voltage Differential 1 DPO Delay	0.25 s
Voltage Differential 1 Stg 1 Block	VTFF 87V-1 On (VO1)
Voltage Differential 1 Stg 2 Block	VTFF 87V-2 On (VO2)
Voltage Differential 1 Stg 3 Block	OFF
Voltage Differential 1 Stg 4 Block	OFF
Voltage Differential 1 Target	Self-reset
Voltage Differential 1 Events	Disabled

Note that match factor shown above assumes perfect bank balance. This must be adjusted when the bank is energized during the differential function auto-setting procedure tune up.

The voltage differential element must be blocked during a VT fuse failure at any tap. The voltage differential element is dependent on both source VTs. These VTs must be blocked if one or both of them has a VT fuse failure condition. Therefore, as shown in the following figure, a blocking input for each element is created with FlexLogic.

Figure 8-13: Voltage differential blocking during VT fuse failure



The 87V-2 and 87V-3 differential elements for the strings against tap voltage are created in a similar manner. In these cases, the K factor is different, reflecting the voltage division of K = 463.8194 between the string and tap capacitor voltages.

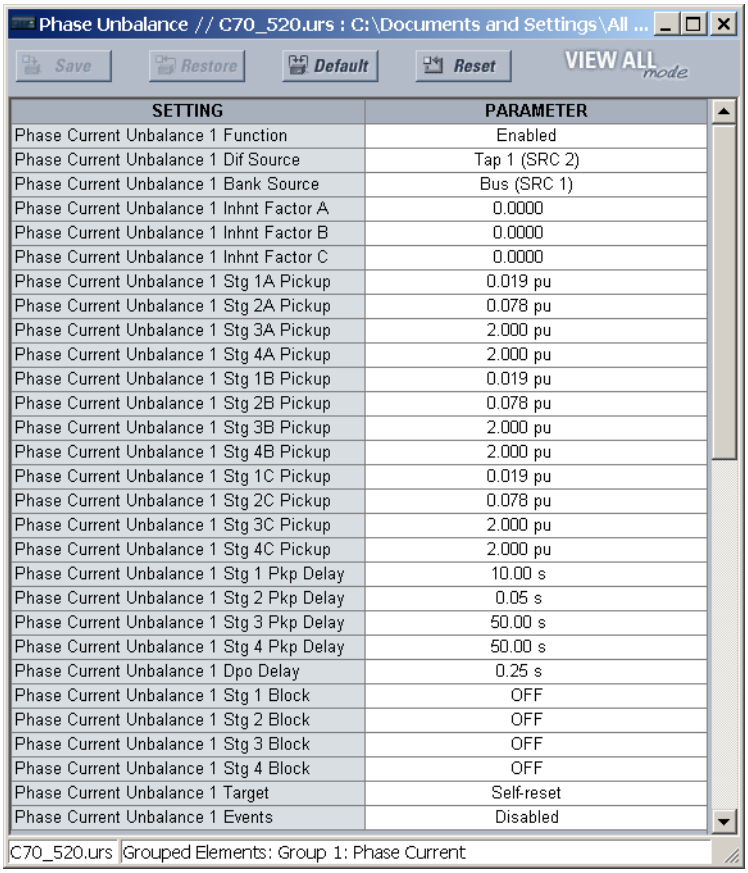
8.4.6 Bank phase current unbalance settings

Two phase current unbalance (ANSI 60P) stages are used to provide trip and alarm levels during capacitor unit failures in each differential element.

The pickup setting for the stage 1 phase current unbalance alarm element is programmed for one element failure.

$$60P\ \text{alarm} = 0.9 I_{unbal(f1\_max)} = 0.9 \times 0.0209\ \text{pu} = 0.019\ \text{pu} \qquad \textbf{Eq. 8-25}$$

Therefore, the alarm delay is specified as 10 seconds. The following setting values are programmed in the EnerVista UR Setup software.



SETTING	PARAMETER
Phase Current Unbalance 1 Function	Enabled
Phase Current Unbalance 1 Dif Source	Tap 1 (SRC 2)
Phase Current Unbalance 1 Bank Source	Bus (SRC 1)
Phase Current Unbalance 1 Inhnt Factor A	0.0000
Phase Current Unbalance 1 Inhnt Factor B	0.0000
Phase Current Unbalance 1 Inhnt Factor C	0.0000
Phase Current Unbalance 1 Stg 1A Pickup	0.019 pu
Phase Current Unbalance 1 Stg 2A Pickup	0.078 pu
Phase Current Unbalance 1 Stg 3A Pickup	2.000 pu
Phase Current Unbalance 1 Stg 4A Pickup	2.000 pu
Phase Current Unbalance 1 Stg 1B Pickup	0.019 pu
Phase Current Unbalance 1 Stg 2B Pickup	0.078 pu
Phase Current Unbalance 1 Stg 3B Pickup	2.000 pu
Phase Current Unbalance 1 Stg 4B Pickup	2.000 pu
Phase Current Unbalance 1 Stg 1C Pickup	0.019 pu
Phase Current Unbalance 1 Stg 2C Pickup	0.078 pu
Phase Current Unbalance 1 Stg 3C Pickup	2.000 pu
Phase Current Unbalance 1 Stg 4C Pickup	2.000 pu
Phase Current Unbalance 1 Stg 1 Pkp Delay	10.00 s
Phase Current Unbalance 1 Stg 2 Pkp Delay	0.05 s
Phase Current Unbalance 1 Stg 3 Pkp Delay	50.00 s
Phase Current Unbalance 1 Stg 4 Pkp Delay	50.00 s
Phase Current Unbalance 1 Dpo Delay	0.25 s
Phase Current Unbalance 1 Stg 1 Block	OFF
Phase Current Unbalance 1 Stg 2 Block	OFF
Phase Current Unbalance 1 Stg 3 Block	OFF
Phase Current Unbalance 1 Stg 4 Block	OFF
Phase Current Unbalance 1 Target	Self-reset
Phase Current Unbalance 1 Events	Disabled

The pickup setting for the stage 2 current unbalance trip element is specified as the unbalance current during maximum system conditions midway between the third and fourth capacitor element failure unbalance currents.

$$60P\ trip = \frac{I_{unbal(f4\_max)} + I_{unbal(f3\_max)}}{2} = \frac{0.0904\ pu + 0.0660\ pu}{2} = 0.078\ pu \qquad \textbf{Eq. 8-26}$$

Therefore, the trip delay is chosen 50 ms.

8.4.7 Bank phase overvoltage settings

To protect the capacitor bank from overvoltage resulting from abnormal system conditions, the capability of the bank to withstand transient overvoltages must be evaluated according to the IEEE 1036-1992 standard or to manufacturer specifications. For example, consider the following manufacturer overvoltage data:

- 2 pu overvoltage toleration for 0.25 second
- 1.5 pu overvoltage toleration for 15 seconds
- 1.25 pu overvoltage toleration for 5 minutes

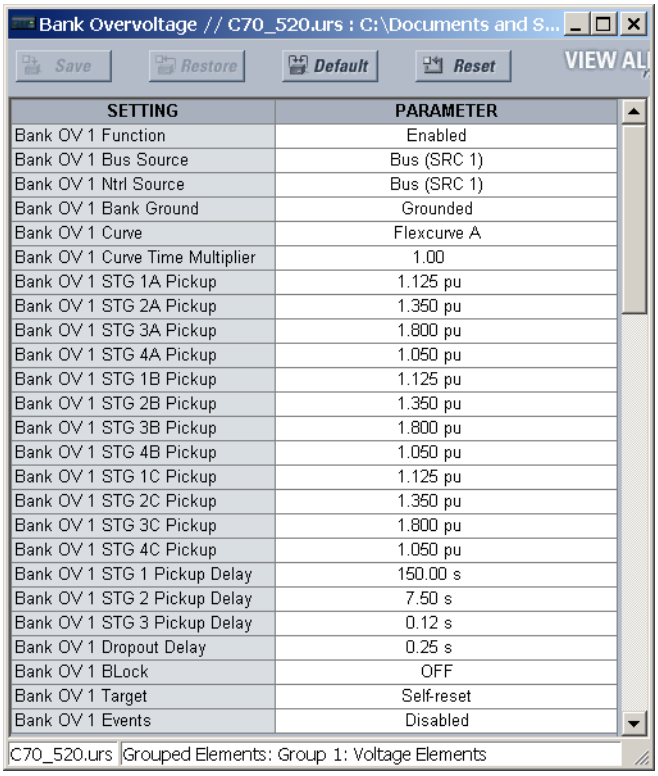
When the relay settings are calculated, the number of prospective overvoltage transients stressing the capacitor insulation during the bank lifetime must be taken into account. As such, it is preferable to set the relay conservatively.

Based on the manufacturer overvoltage data outlined, three overvoltage trip stages are applied using a factor of 0.9 for the stage pickup overvoltage levels and half of the allowable time outlined.

$$\begin{aligned} \text{59B pickup (stage 1)} &= 0.9 \times 1.25 = 1.125 \text{ pu} \\ \text{59B pickup (stage 2)} &= 0.9 \times 1.5 = 1.35 \text{ pu} \\ \text{59B pickup (stage 3)} &= 0.9 \times 2 = 1.80 \text{ pu} \end{aligned} \quad \textbf{Eq. 8-27}$$

$$\begin{aligned} \text{59B delay (stage 1)} &= 0.5 \times 5 \times 60 = 150 \text{ seconds} \\ \text{59B delay (stage 2)} &= 0.5 \times 15 = 7.5 \text{ seconds} \\ \text{59B delay (stage 3)} &= 0.5 \times 0.25 = 0.125 \text{ seconds} \end{aligned} \quad \textbf{Eq. 8-28}$$

The following setting values are programmed in the EnerVista UR Setup software.

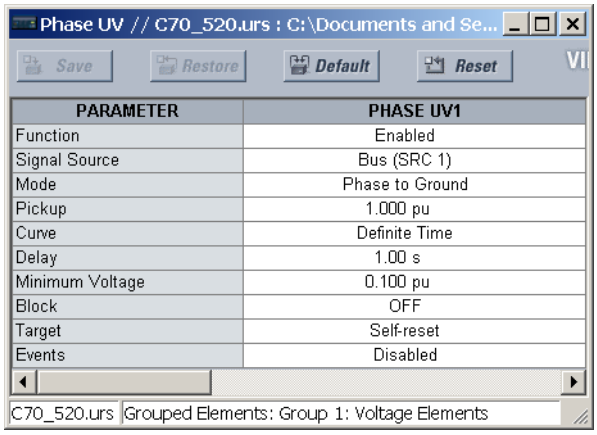


SETTING	PARAMETER
Bank OV 1 Function	Enabled
Bank OV 1 Bus Source	Bus (SRC 1)
Bank OV 1 Ntrl Source	Bus (SRC 1)
Bank OV 1 Bank Ground	Grounded
Bank OV 1 Curve	Flexcurve A
Bank OV 1 Curve Time Multiplier	1.00
Bank OV 1 STG 1A Pickup	1.125 pu
Bank OV 1 STG 2A Pickup	1.350 pu
Bank OV 1 STG 3A Pickup	1.800 pu
Bank OV 1 STG 4A Pickup	1.050 pu
Bank OV 1 STG 1B Pickup	1.125 pu
Bank OV 1 STG 2B Pickup	1.350 pu
Bank OV 1 STG 3B Pickup	1.800 pu
Bank OV 1 STG 4B Pickup	1.050 pu
Bank OV 1 STG 1C Pickup	1.125 pu
Bank OV 1 STG 2C Pickup	1.350 pu
Bank OV 1 STG 3C Pickup	1.800 pu
Bank OV 1 STG 4C Pickup	1.050 pu
Bank OV 1 STG 1 Pickup Delay	150.00 s
Bank OV 1 STG 2 Pickup Delay	7.50 s
Bank OV 1 STG 3 Pickup Delay	0.12 s
Bank OV 1 Dropout Delay	0.25 s
Bank OV 1 BLock	OFF
Bank OV 1 Target	Self-reset
Bank OV 1 Events	Disabled

8.4.8 Bank phase undervoltage settings

Bank undervoltage protection is required to take bank out-of-service when the supply bus voltage is lost. The pickup setting is specified as 0.7 pu with a time delay of 1 second, based on maximum fault clearing time. The bank undervoltage element is blocked during VT fuse fail conditions.

The following setting values are programmed in the EnerVista UR Setup software.



PARAMETER	PHASE UV1
Function	Enabled
Signal Source	Bus (SRC 1)
Mode	Phase to Ground
Pickup	1.000 pu
Curve	Definite Time
Delay	1.00 s
Minimum Voltage	0.100 pu
Block	OFF
Target	Self-reset
Events	Disabled

8.4.9 Bank overcurrent protection

Bank overcurrent protection is required to protect capacitor banks against major faults, such as line-to-line or line-to-ground faults. Set overcurrent protection to be as low and as fast as possible, with only enough delay to avoid tripping on external system disturbances.

During bank energization, the capacitor charge current inrush can cause significant neutral currents approaching the bank phase current levels. Also, during a system SLG fault, unbalanced bank neutral currents can be as high as bank phase currents. Because of these considerations, the neutral time overcurrent pickup is programmed equal to the phase time overcurrent pickup and is set to 1.25 pu. Specify the delay for these elements to be longer than the maximum system fault clearing time (for example 0.5 second).

The phase instantaneous overcurrent element can be set to a value three to four times the capacitor bank rated current to override back-to-back bank switching.

Negative-sequence instantaneous overcurrent protection is required to provide backup protection for phase current unbalance during rack faults in the banks where phase capacitors are not well separated. Programming the negative-sequence instantaneous overcurrent pickup at 10% of the nominal bank phase current with a delay of 250 to 400 ms typically provides adequate coordination for faults external to the bank and protection for internal rack faults.

C70 Capacitor Bank Protection and Control System

Chapter 9: Theory of operation

This chapter outlines advanced information on operation.

9.1 Overview

9.1.1 General operation

Static capacitor banks are constructed with a large number of individual capacitor elements connected in a series/parallel arrangement designed to distribute the system voltage equally among the elements. Equal distribution of voltage is important as the rate of internal insulation degradation is a highly non-linear function of element voltage, with degradation accelerating very rapidly with overvoltage greater than 10%. To obtain balanced voltages in spite of manufacturing tolerances in the capacitance of the elements, the elements are positioned in the bank according to their actual capacitance such that parallel groups have a uniform total capacitance, and a good voltage balance is obtained. However, once in service, individual elements can fail randomly upsetting the balance, increasing the stress on other elements, and causing their early failure. Early failure of an element due to unbalanced voltage predictably further unbalances the bank, leading to cascading failure.

The purpose of capacitor unbalance protection is to detect unbalance caused by element failures as soon as practical, and to either alarm the condition so that repair can be scheduled for a convenient time, or to automatically remove the bank from service to prevent deterioration in the healthy elements pending repair. A brut force method is to directly measure the voltage across each element, operating on detecting an abnormally high voltage on any element. However, this approach is seldom economic due to the large number of voltage transducers required. Thus, the C70 supports various other methods, the suitability of each dependant on the capacitor bank configuration, and on the VTs and CTs available.

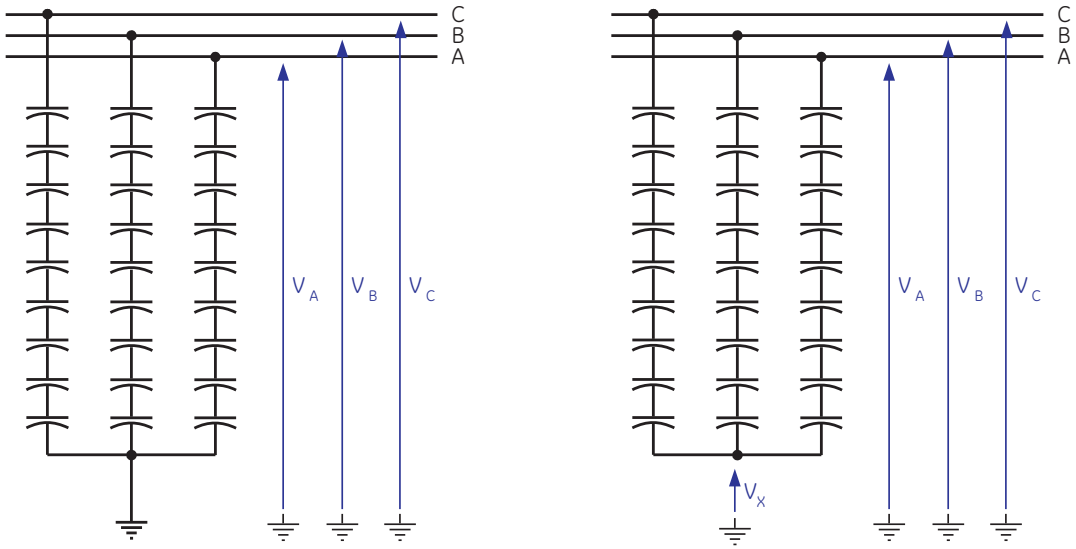
The challenge faced by all capacitor unbalance protections not using the brut force method is the increased sensitivity required due to the less than ideal number of monitoring points, and compensation for the increased effects of inherent unbalance due to manufacturing tolerance and due to system voltage unbalance.

9.1.2 Bank phase overvoltage (ANSI 59B)

The capacitor unbalance protection functions discussed in the following sections are intended to detect failures in the capacitor bank itself that can result in a few capacitor elements being overstressed. However, these unbalance protection functions do not detect overstressed elements in a healthy bank that can result from external problems. Protection against overstressing elements from system overvoltages is instead provided by the bank phase overvoltage protection.

Ideally, a bank overvoltage protection measures the voltage across each capacitor string, allowing an accurate inference of the voltage across each element in the string, assuming that the string voltage is equally divided across the elements. This is readily done in grounded wye capacitor banks by simply measuring the three system phase-to-ground voltages. For instance, assuming that the bank is healthy, the elements shown in the grounded banks of the following figure are each stressed at one-ninth of system phase-to-ground voltage, allowing the inference that the elements are overstressed when the system phase-to-ground voltage exceeds nine times the element safe operating voltage limit. The true RMS value of these phase-to-ground quantities are what the bank phase overvoltage protection measures when the bus source is set for wye VTs and the bank overvoltage protection ground setpoint is set to grounded.

Figure 9-1: Bank overvoltage protection for grounded and ungrounded banks



For a capacitor bank that is ungrounded, the voltage across the string is equal to the difference between the system phase-to-ground voltage and the bank neutral voltage. Elements shown in the ungrounded banks in the preceding figure are overstressed when the following quantities exceed nine times the element safe operating voltage limit.

$$|V_A - V_X|_{RMS},\ |V_B - V_X|_{RMS},\ \text{or}\ |V_C - V_X|_{RMS} \qquad \textbf{Eq. 9-1}$$

These quantities are what the bank phase overvoltage protection measures when the bus source is set for wye VTs, the auxiliary channel of the neutral source is set for a neutral voltage, and the bank overvoltage protection ground setpoint is set to ungrounded.

When the neutral voltage of an ungrounded wye capacitor bank is not measured or you do not want to use the neutral voltage measurement, the string voltage can still be determined using the assumption that the bank is balanced. For an balanced ungrounded bank the neutral voltage V_X is:

$$V_X = \frac{1}{3}(V_A + V_B + V_C) \qquad \textbf{Eq. 9-2}$$

As such, the A-string voltage is:

$$\begin{aligned} |V_A - V_X|_{RMS} &= \left|V_A - \frac{1}{3}(V_A + V_B + V_C)\right|_{RMS} \\ &= \frac{1}{3}|2V_A - V_B - V_C|_{RMS} \\ &= \frac{1}{3}|V_{AB} - V_{CA}|_{RMS} \end{aligned} \qquad \textbf{Eq. 9-3}$$

Similarly, the B-string and C-string voltages are:

$$\frac{1}{3}\left|V_{BC} - V_{AB}\right|_{RMS} \quad \text{and} \quad \frac{1}{3}\left|V_{CA} - V_{BC}\right|_{RMS} \qquad \textbf{Eq. 9-4}$$

These quantities are what the bank phase overvoltage protection measures when the bus source is set for wye VTs, and the bank overvoltage protection ground setpoint is set to "Ungrd w/o Vn."

In applications where the bus VTs are delta-connected, the bus phase-to-ground voltages and therefore the bus zero sequence voltage are unknown. However, as shown in the preceding equations, string voltages can be determined for an ungrounded balanced bank using only phase-to-phase bus voltages. In the case of a grounded bank, we can calculate that the A-string voltage is:

$$\begin{aligned} \left|V_A\right|_{RMS} &= \frac{1}{3}\left|3V_A + (V_B - V_B) + (V_C - V_C)\right|_{RMS} \\ &= \frac{1}{3}\left|V_A - V_B - V_C + V_A + (V_A + V_B + V_C)\right|_{RMS} \\ &= \frac{1}{3}\left|V_{AB} - V_{CA} + 3V_0\right|_{RMS} \end{aligned} \qquad \textbf{Eq. 9-5}$$

If we make the assumption that the zero-sequence voltage is negligible, which is reasonable when the system is normal (non-faulted), then the string voltages for grounded banks are the same as for the ungrounded balanced banks:

$$\frac{1}{3}\left|V_{AB} - V_{CA}\right|_{RMS}, \frac{1}{3}\left|V_{BC} - V_{AB}\right|_{RMS}, \text{ or } \frac{1}{3}\left|V_{CA} - V_{BC}\right|_{RMS} \qquad \textbf{Eq. 9-6}$$

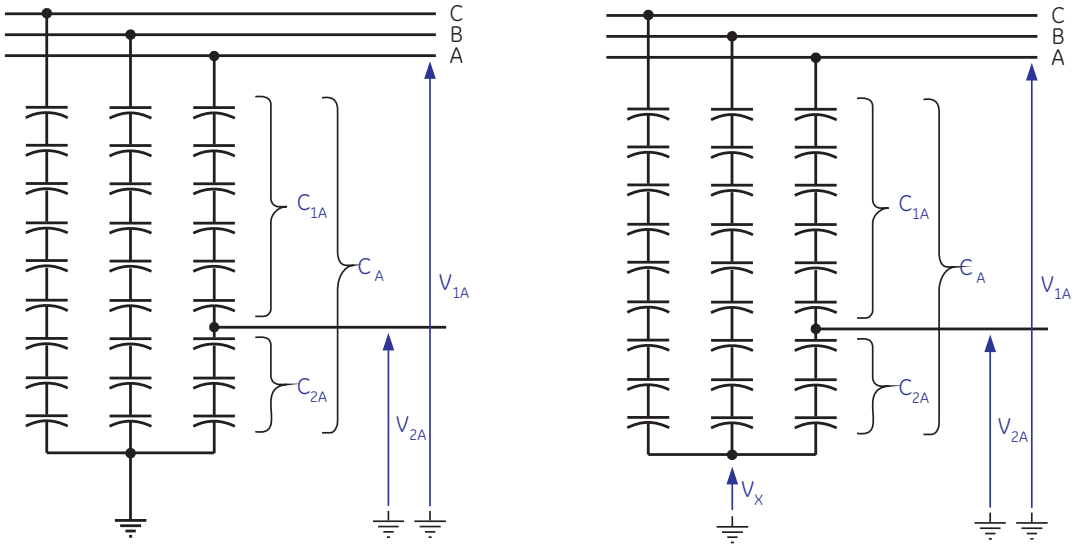
These quantities are what the bank phase overvoltage protection measures whenever the bus source is set for delta VTs.

9.1.3 Voltage differential (ANSI 87V)

9.1.3.1 Operating principle

The voltage differential function is based on a voltage divider principle. A healthy capacitor string has a constant and known match factor between its full tap (typically the bus voltage) and an auxiliary tap used by the protection. Any single element failure results in a difference between the measured factor and its value when the bank is healthy. The protection can be used on both grounded and ungrounded banks. For ungrounded banks, the neutral point voltage (V_X) must be measured by the relay and used to derive the voltage across the string.

Figure 9-2: Voltage differential application to grounded and ungrounded banks



The voltage differential protection uses the following operating signal for grounded banks:

$$V_{OP(A)} = |V_{1A} - k_A V_{2A}| \quad \textbf{Eq. 9-7}$$

The voltage differential protection uses the following operating signal for ungrounded banks:

$$V_{OP(A)} = |(V_{1A} - V_X) - k_A(V_{2A} - V_X)| \quad \textbf{Eq. 9-8}$$

In these equations, k_A is a match factor setting for the A-leg of the bank. The voltages are as defined in the preceding figure and are in per-unit values on the nominal bus phase-to-ground voltage base. The first equation is implemented using primary voltage magnitudes, while the second equation is implemented using primary voltage phasors. The protection operates when the operate signal is greater than the set pickup level for the set pickup delay.

Identical relations apply to phases B and C.

Sensitivity is the key performance parameter. The applied comparator uses a simple integration method in addition to the standard hysteresis approach, to deal with chattering of the operating signal at the boundary of operation.

9.1.3.2 Balanced case

To understand how the voltage differential protection works, consider for simplicity the following grounded bank operating equation:

$$V_{OP(A)} = |V_{1A} - k_A V_{2A}| \quad \textbf{Eq. 9-9}$$

The ungrounded case is similar except that all voltages have V_X subtracted. If the initial factory balanced A-leg string has an initial capacitance of C_A, divided into sub-strings with initial capacitances of C_{1A} and C_{2A}, and the bank is energized with system phase-to-ground voltage V_{Spg}, then the string forms a voltage divider and the initial measured voltages are:

$$V_{1A} = V_{Spg} \quad \textbf{Eq. 9-10}$$

$$V_{2A} = V_{Spg} \times \frac{C_A}{C_{2A}} \quad \textbf{Eq. 9-11}$$

Substituting these results into the first equation, the initial operating signal is:

$$V_{OP(A)} = |V_{1A} - k_A V_{2A}| = \left|V_{Spg} - k_A V_{Spg} \times \frac{C_A}{C_{2A}}\right| = V_{Spg} \times \left|1 - k_A \times \frac{C_A}{C_{2A}}\right| \quad \text{Eq. 9-12}$$

The match factor setting k_A is chosen as:

$$k_A = \frac{C_{2A}}{C_A} \quad \text{Eq. 9-13}$$

Therefore, as can be seen from the previous two equations, the initial operating signal is zero.

9.1.3.3 Sensitivity

Now consider the consequences of an element failure in the upper sub-string of leg A, making a small capacitance change in C_{1A}. The effect on the operating signal can be calculated by taking the derivative of equation 9-12 with respect to C_A, holding C_{2A} constant. In the general case, the derivative of the absolute value function is messy, but in our case where the initial value is zero, the derivative of the absolute function is simply the absolute value of the derivative of its argument. The derivative is thus:

$$\frac{d}{dC_A} V_{OP(1A)} = V_{Spg} \times \left|\frac{d}{dC_A}\left(1 - k_A \frac{C_A}{C_{2A}}\right)\right| = V_{Spg} \times \left|-\frac{k_A}{C_{2A}}\right| = V_{Spg} \times \frac{k_A}{C_{2A}} \quad \text{Eq. 9-14}$$

Substituting equation 9-13, we have:

$$\frac{d}{dC_A} V_{OP(1A)} = V_{Spg} \times \frac{1}{C_A} \quad \text{or} \quad dV_{OP(1A)} = V_{Spg} \times \frac{dC_A}{C_A} \quad \text{Eq. 9-15}$$

This can be written as:

$$V_{OP(1A)}(pu) = V_{Spg}(pu) \times \Delta C_A(pu) \quad \text{Eq. 9-16}$$

In this equation, $\Delta C_A(pu)$ is the capacitance change as a per-unit of the leg capacitance, V_{Spg} is the system phase-to-ground voltage, and $V_{OP(1A)}(pu)$ is the operating signal resulting from the failure in the upper sub-string. Both voltages are in per-unit of nominal bus phase-to-ground voltage, so V_{Spg} can be taken as 1 when the system is normal (not faulted). Note however that under external fault conditions, sensitivity can be much different from the non-fault sensitivity.

Instead of a failure in the upper sub-string, now suppose a failure in the lower sub-string. The same approach is used, except to make the algebra easier, the initial operating signal is converted to be in terms of C_{1A} using:

$$C_A = \frac{C_{1A} C_{2A}}{C_{1A} + C_{2A}} \quad \text{or} \quad C_{2A} = \frac{C_A C_{1A}}{C_{1A} - C_A} \quad \text{Eq. 9-17}$$

In this case, we have:

$$V_{OP(A)} = V_{Spg} \times \left|1 - k_A \times \frac{C_A}{C_{2A}}\right| = V_{Spg} \times \left|1 - k_A \times \frac{C_{1A} - C_A}{C_{1A}}\right| \quad \text{Eq. 9-18}$$

The derivative is thus:

$$\frac{d}{dC_A}V_{OP(2A)} = V_{Spg} \times \left| \frac{d}{dC_A}\left(1 - k_A \frac{C_{1A} - C_A}{C_{1A}}\right) \right| = V_{Spg} \times \left| \frac{k_A}{C_{1A}} \right| = V_{Spg} \times \frac{k_A}{C_{1A}} \quad \text{Eq. 9-19}$$

Substituting equation 9-17 into equation 9-13, we have:

$$k_A = \frac{C_{2A}}{C_A} = \frac{C_{1A}}{C_{1A} - C_A} \quad \text{or} \quad C_{1A} = k_A C_{1A} - k_A C_A \quad \text{Eq. 9-20}$$

Therefore:

$$C_{1A} = \frac{k_A C_A}{k_A - 1} \quad \text{Eq. 9-21}$$

Substituting this value into equation 9-19, we get:

$$\frac{d}{dC_A}V_{OP(2A)} = V_{Spg} \times \frac{k_A}{C_{1A}} = V_{Spg} \times \frac{k_A - 1}{C_A} \quad \text{Eq. 9-22}$$

Or alternately,

$$dV_{OP(2A)} = V_{Spg} \times (k_A - 1) \times \frac{dC_A}{C_A} \quad \text{Eq. 9-23}$$

The value can be expressed as:

$$V_{OP(2A)}(pu) = V_{Spg}(pu) \times (k_A - 1) \times \Delta C_A(pu) \quad \text{Eq. 9-24}$$

In this equation, ΔC_A(pu) is the capacitance change as a per-unit of the leg capacitance, V_{Spg} is the system phase-to-ground voltage, and $V_{OP(2A)}$(pu) is the operating signal resulting from the failure in the lower sub-string. Both voltages are in per-unit of nominal bus phase-to-ground voltage, so V_{Spg} can be taken as 1 when the system is normal (not faulted). Note however that under external fault conditions sensitivity can be much different from the non-fault sensitivity.

In practice, k_A is no less than 2.0 as the tap is no more than half way up the phase string. Comparing equation 9-16 with equation 9-24, it can be seen that $V_{OP(2A)}(pu) \geq V_{OP(1A)}(pu)$, and thus that an element failure in the lower substring produces a operating signal no smaller than the same failure in the upper sub-string. Thus $V_{OP(1A)}$(pu) represents the worse case sensitivity. A failure resulting in a 0.01 pu capacitance change in the leg capacitance results in an operating signal of at least 0.01 pu of bus phase-to-ground voltage.

9.1.3.4 Auto-setting

While a capacitor bank can be designed to have a tap at say the mid-point or the one-third point, manufacturing tolerances result in the actual tap ratio being slightly different from the design target. To prevent a spurious component in the operating signal, the match factor settings must correspond to the actual rather than the design tap ratio. As a convenient alternative to manually determining the optimum match factor settings, the relay can automatically calculate these settings from its own measurements while the capacitor is in-service, as described in the Commands and Targets chapter. The C70 sets the operate signal to zero in equation 9.7 or 9.8 and solves for the match factor k_A using the average of several successive voltage measurements. This technique has the further advantage that it to a large degree compensates for instrumentation error. However, the assumption made here is that when the auto-set command is executed, the capacitor is in an acceptably balanced state, wherein the operating signal ought to be zero. Following the auto-set command, the protection measures changes from the state that existed at the time the auto-set command executed.

9.1.4 Compensated bank neutral voltage unbalance (ANSI 59NU)

9.1.4.1 Operating principle

The neutral voltage unbalance function is applicable to ungrounded banks. Fundamentally, this function responds to an overvoltage condition of the neutral-point voltage. If the capacitor bank and the power system voltages are balanced, the neutral-point voltage is zero. If a capacitor element in the bank fails, then the bank becomes unbalanced and the neutral voltage increases.

The operate signal for the neutral voltage unbalance protection is:

$$V_{OP} = \frac{1}{3}\left|V_X(1 + k_{AB} + k_{AC}) - 3V_0 + V_B(1 - k_{AB}) + V_C(1 - k_{AC})\right| \quad \textbf{Eq. 9-25}$$

The restraint signal for the neutral voltage unbalance protection is:

$$V_{REST} = \left|V_X + V_0\right| \quad \textbf{Eq. 9-26}$$

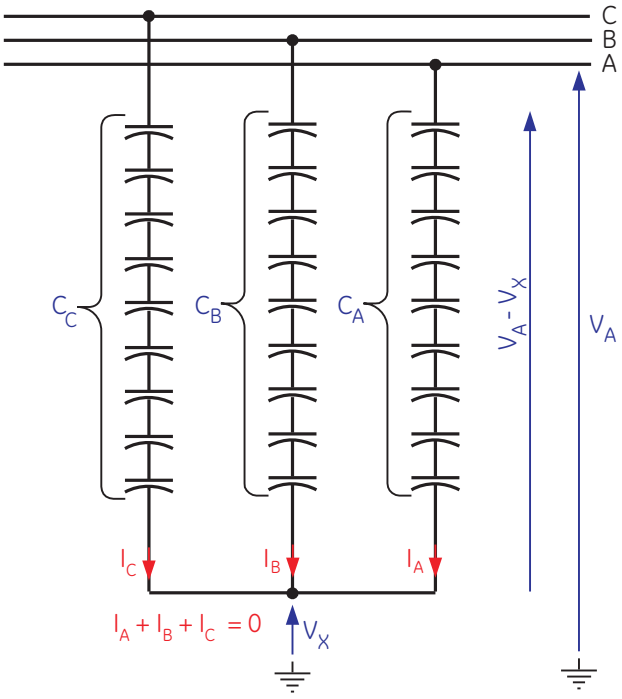
In these equations, k_{AB} and k_{AC} represent capacitor bank unbalance ratio settings. The voltages are as defined in the following figure and are expressed in per-units of the nominal value of the neutral-point VT.

These equations involve phasors, not magnitudes. That is, the vector sum of the voltages is created by the protection function implementing the method.

The neutral voltage unbalance protection operates when the operate signal is greater than the set pickup level and the operate signal is greater than the set percentage of the restraint signal, all for the set pickup delay.

Sensitivity is the key performance parameter. The applied comparator uses a simple integration method in addition to the standard hysteresis approach to deal with chattering of the operating signal at the boundary of operation. In addition, a slope characteristic is used to deal with measurement errors for the involved voltages under large system unbalances, such as during a close-in external fault.

Figure 9-3: Compensated bank neutral overvoltage application



9.1.4.2 Balanced case

To understand neutral voltage unbalance protection, we can start with Kirchhoff's current law for the neutral node of the bank:

$$I_A + I_B + I_C = j\omega C_A(V_A - V_X) + j\omega C_B(V_B - V_X) + j\omega C_C(V_C - V_X) = 0 \quad \text{Eq. 9-27}$$

This expression can be rearranged as follows.

$$\begin{aligned} &-V_X(C_A + C_B + C_C) + V_A C_A + V_B C_B + V_C C_C = 0 \\ \Rightarrow &-V_X(C_A + C_B + C_C) + V_A C_A + V_B C_A + V_C C_A + V_B C_B - V_B C_A + V_C C_C - V_C C_A = 0 \\ \Rightarrow &-V_X(C_A + C_B + C_C) + C_A(V_A + V_B + V_C) + V_B(C_B - C_A) + V_C(C_C - C_A) = 0 \end{aligned} \quad \text{Eq. 9-28}$$

Multiplying both sides by $-1 / C_A$ and substituting the sum of the phase voltages with $3V_0$ yields:

$$V_X\left(1 + \frac{C_B + C_C}{C_A}\right) - 3V_0 + V_B\left(1 - \frac{C_B}{C_A}\right) + V_C\left(1 - \frac{C_C}{C_A}\right) = 0 \quad \text{Eq. 9-29}$$

As the left hand side of this equation is equal to zero, we can subtract it from the expression inside the absolute value brackets in equation 9.25 to get:

$$\begin{aligned} V_{OP} &= \frac{1}{3}\left|V_X(1 + k_{AB} + k_{AC}) - 3V_0 + V_B(1 - k_{AB}) + V_C(1 - k_{AC}) - V_X\left(1 + \frac{C_B + C_C}{C_A}\right) + 3V_0 - V_B\left(1 - \frac{C_B}{C_A}\right) - V_C\left(1 - \frac{C_C}{C_A}\right)\right| \\ &= \frac{1}{3}\left|V_X\left(k_{AB} - \frac{C_B}{C_A} + k_{AC} - \frac{C_C}{C_A}\right) + V_B\left(\frac{C_B}{C_A} - k_{AB}\right) + V_C\left(\frac{C_C}{C_A} - k_{AC}\right)\right| \end{aligned} \quad \text{Eq. 9-30}$$

The unbalance ratio k-values that reflect the initial or inherent bank unbalance are chosen as:

$$k_{AB} = \frac{C_B}{C_A},\ k_{AC} = \frac{C_C}{C_A} \quad \text{Eq. 9-31}$$

Therefore, as seen from the previous two equations, the initial operating signal is zero.

Note that the ratios of the capacitances between phase A and the two other phases are close to unity, and therefore the correcting factors in equation 9.25 for the B and C-phase voltages are small numbers, while the factor for the V_X voltage is close to 3. If so, equation 9.25 takes a familiar simplified form:

$$V_{OP} = |V_X - V_0| \quad \text{Eq. 9-32}$$

The V_0 term in the operate equation can be either the neutral component in the bus voltages (one-third of the vectorial sum of the phase voltages calculated by the relay), or directly measured neutral voltage component (open-corner-delta VT voltage).

9.1.4.3 Sensitivity

Now consider the consequences of a capacitor element failure in one leg, most conveniently leg C, making a small capacitance change in leg-C capacitance. The effect on the operating signal can be calculated by taking the derivative of equation 9.25 with respect to C_C. In the general case, the derivative of the absolute value function is messy, but in our case where the initial value is zero, the derivative of the absolute function is simply the absolute value of the derivative of its argument. As such, the derivative is:

$$\begin{aligned} \frac{d}{dC_C}V_{OP} &= \frac{1}{3}\frac{d}{dC_C}\left|(V_X(1 + k_{AB} + k_{AC}) - 3V_0 + V_B(1 - k_{AB}) + V_C(1 - k_{AC}))\right| \\ &= \frac{1}{3}\left|(1 + k_{AB} + k_{AC})\frac{dV_X}{dC_C}\right| \end{aligned} \quad \text{Eq. 9-33}$$

Recall equation 9.29:

$$V_X\left(1 + \frac{C_B + C_C}{C_A}\right) - 3V_0 + V_B\left(1 - \frac{C_B}{C_A}\right) + V_C\left(1 - \frac{C_C}{C_A}\right) = 0 \quad \text{Eq. 9-34}$$

Differentiating this gives:

$$\frac{dV_X}{dC_C}\left(1+\frac{C_B+C_C}{C_A}\right)+V_X\left(\frac{1}{C_A}\right)-V_C\left(\frac{1}{C_A}\right)=0$$

$$\Rightarrow \frac{d}{dC_C}V_X=-\frac{V_X-V_C}{C_A\left(1+\frac{C_B+C_C}{C_A}\right)} \qquad \text{Eq. 9-35}$$

$$\Rightarrow \frac{d}{dC_C}V_X=-\frac{V_X-V_C}{C_A(1+k_{AB}+k_{AC})}$$

Substituting for V_X from equation 9.34 gives:

$$\frac{d}{dC_C}V_X=\frac{3V_0-V_B(1-k_{AB})-V_C(2+k_{AB})}{C_A(1+k_{AB}+k_{AC})^2} \qquad \text{Eq. 9-36}$$

This can be substituted into equation 9.33 to obtain:

$$\frac{d}{dC_C}V_{OP}=\frac{1}{3}\left|(1+k_{AB}+k_{AC})\frac{dV_X}{dC_C}\right| \qquad \text{Eq. 9-37}$$

$$=\frac{1}{3}\left|\frac{3V_0-V_B(1-k_{AB})-V_C(2+k_{AB})}{C_A(1+k_{AB}+k_{AC})}\right|$$

For our purposes, $C_A \cong C_B \cong C_C$, so $k_{AB} \cong 1$ and $k_{AC} \cong 1$. This results in:

$$\frac{d}{dC_C}V_{OP}\cong\frac{1}{3}\left|\frac{V_C-V_0}{C_C}\right| \qquad \text{Eq. 9-38}$$

$$=\frac{1}{3}\times\frac{1}{C_C}\times|V_C-V_0|$$

Under normal system conditions (non-fault), $V_C >> V_0$, and V_C is the system phase-to-ground voltage. The system voltage V_{Spg}, which by convention is on the bus voltage base, converted to the base of nominal value of the neutral-point VT used in these equations, is:

$$\frac{n_{bus\_phs}}{n_{ntrl\_aux}}\times V_{Spg} \qquad \text{Eq. 9-39}$$

This gives:

$$\frac{d}{dC_C}V_{OP}\cong\frac{1}{3}\times\frac{1}{C_C}\times\frac{n_{bus\_phs}}{n_{ntrl\_aux}}\times V_{Spg} \qquad \text{Eq. 9-40}$$

$$dV_{OP}\cong\frac{1}{3}\times\frac{n_{bus\_phs}}{n_{ntrl\_aux}}\times V_{Spg}\times\frac{dC_C}{C_C}$$

This can be written as:

$$V_{OP}(pu)\cong\frac{1}{3}\times\frac{n_{bus\_phs}}{n_{ntrl\_aux}}\times V_{Spg}\times\Delta C(pu) \qquad \text{Eq. 9-41}$$

In these equations, $\Delta C(pu)$ is the capacitance change as a per-unit of the leg capacitance, and $V_{OP}(pu)$ is the operating signal resulting from the failure in per-unit of the nominal value of the neutral-point VT. V_{Spg} is the system phase-to-ground voltage in per-unit of the nominal system phase-to-ground voltage, so can be taken as 1 when the system is normal (not faulted). Note however that under external fault conditions sensitivity can be much different from the non-fault sensitivity. n_{bus_phs} and n_{ntrl_aux} are the VT ratios of the phase VT bank of the bus source and of the auxiliary VT channel of the neutral source, respectively.

Note that under external fault conditions sensitivity can be much different form the non-fault sensitivity. To prevent mis-operation, use a restraint and/or coordinating time delay.

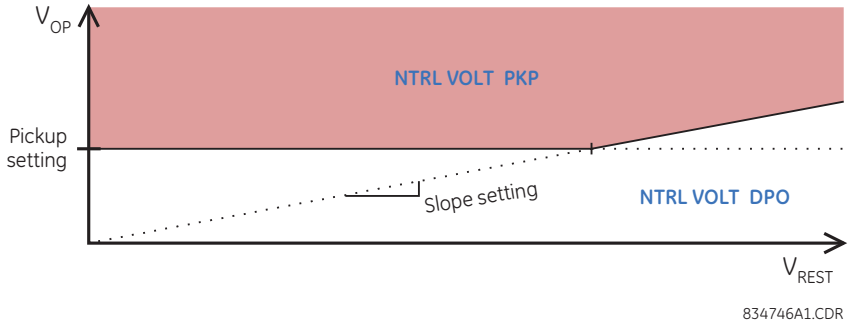
9.1.4.4 Restraint

Severe system voltage unbalance, such as can occur during near-by bolted ground faults, can exacerbate measurement error in V_X or V_0, resulting in spurious operating signal. In addition, as discussed, the sensitivity can be affected. To prevent operation under these conditions, percent restraint supervision is provided using a restraint signal that is the magnitude of the vector sum of V_X and V_0, defined as follows.

$$V_{REST} = |V_X + V_0| \quad \text{Eq. 9-42}$$

During external ground faults, these two voltages are approximately in phase generating a large restraining signal being twice the zero-sequence voltage at the bus. A slope of few percent is typically sufficient to provide good security under large system unbalances.

Figure 9-4: Neutral overvoltage restraint



9.1.4.5 Auto-setting command

As a convenient alternative to manually determining the unbalance ratio settings, the relay can automatically calculate these settings from its own measurements while the capacitor is in-service, as described in the Commands and Targets chapter. The technique the relay uses is to set the operate signal variable in equation 9.25 to zero and solve for the unbalance ratio k-values using the average of several successive measurements of the voltages.

Determination of the two k-values using only one equation is possible as the k-values are known to be real-valued, so the complex-valued equation can be separated into real and imaginary parts, with the same two k-values in each. A solution exists as long as the cross product of the B and C-phase voltages is non-zero; that is, the capacitor bank is in-service. However, the assumption made here is that when the auto-set command is executed, the capacitor is in an acceptably balanced state, wherein the operating signal ought to be zero. Following the auto-set command, the protection measures changes from the state that existed at the time the auto-set command executed.

9.1.5 Phase current unbalance (ANSI 60P)

9.1.5.1 Operating principle

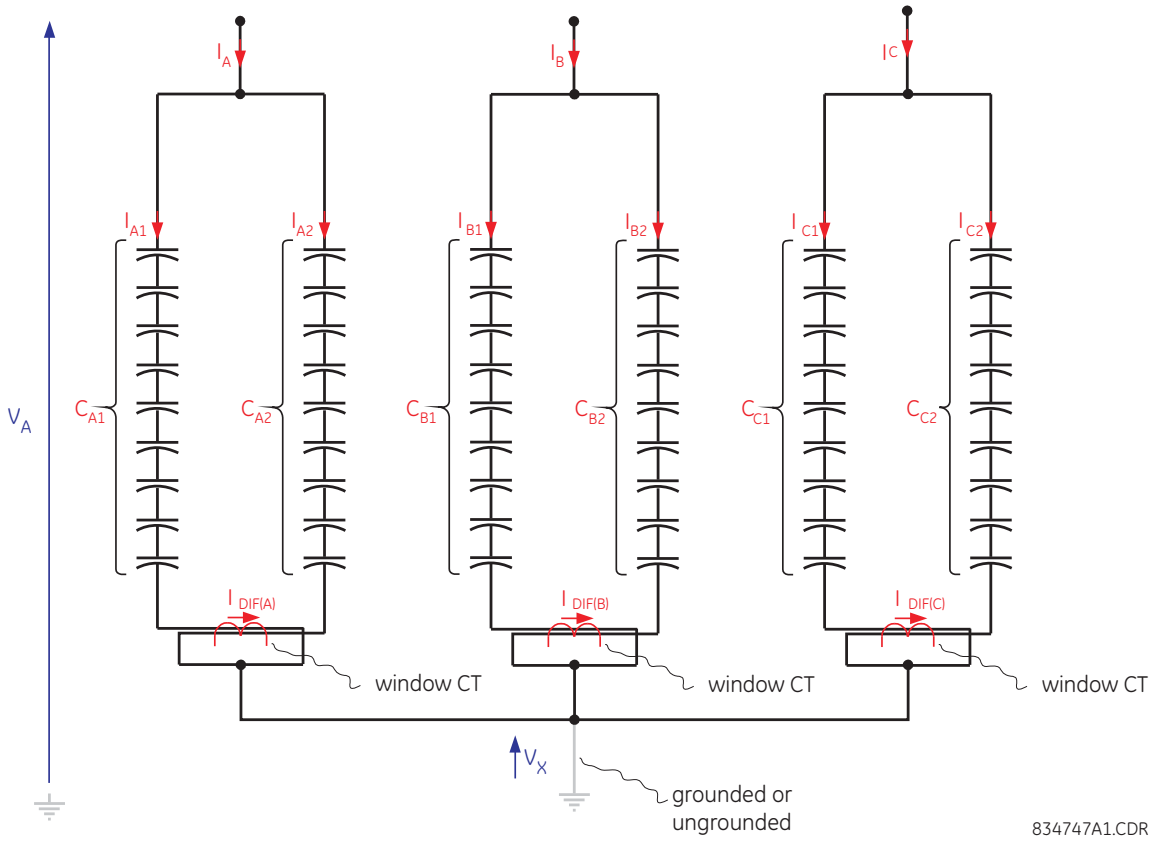
The phase current unbalance function is based on the balance between interconnected and nominally identical phase strings, and is applicable to both grounded and ungrounded installations. A window CT measuring the vectorial difference between the two phase currents is required for each phase as shown. While the two phase strings are actually identical, the measured current is zero. The failure of an element in either string results in a difference current, which is sensed by the relay. However, with the two strings slightly mismatched due to manufacturing tolerances, an inherent difference current can be present. Compensation for this inherent unbalance current is available to increase the sensitivity of the function.

The phase current unbalance function uses the following operate signal:

$$I_{OP(A)} = |I_{DIF(A)} - k_A I_A| \quad \text{Eq. 9-43}$$

In this equation, k_A is the capacitor bank leg-A inherent unbalance factor setting. The currents are as defined in the following figure and are in per-unit on the nominal current of the differential source. This equation involves phasors, not magnitudes; that is, the vector sum of the currents is created by the protection function implementing the method.

Figure 9-5: Phase current unbalance application



The protection operates when the operate signal is greater than the set pickup level for the set pickup delay. Identical relations apply to phases B and C.

Sensitivity is the key performance parameter. The applied comparator uses a simple integration method in addition to the standard hysteresis approach, to deal with chattering of the operating signal at the boundary of operation.

9.1.5.2 Balanced case

To understand phase current unbalance protection, first note that the currents are driven by the individual admittances in each string:

$$I_{A1} = \frac{j\omega C_{A1}(V_A - V_X)}{I_{base}}; \quad I_{A2} = \frac{j\omega C_{A2}(V_A - V_X)}{I_{base}} \qquad \text{Eq. 9-44}$$

In these equations, I_{base} represents the differential CT primary current rating. This places the string currents on the same per-unit base used by the C70. Voltages are expressed in primary volts, capacitances in Farads, and frequency in radians per second.

The differential current is the vector difference between the two currents:

$$I_{DIF(A)} = I_{A1} - I_{A2} = \frac{j\omega(V_A - V_X)(C_{A1} - C_{A2})}{I_{base}} \qquad \text{Eq. 9-45}$$

The total phase current is the vector sum of the two currents:

$$I_A = I_{A1} + I_{A2} = \frac{j\omega(V_A - V_X)(C_{A1} + C_{A2})}{I_{base}} \qquad \text{Eq. 9-46}$$

Inserting equation 9.46 into equation 9.45, to eliminate the voltages, we get:

$$I_{DIF(A)} = I_A \times \frac{C_{A1} - C_{A2}}{C_{A1} + C_{A2}} \quad \textbf{Eq. 9-47}$$

Inserting this value into equation 9.43, we have:

$$\begin{aligned} I_{OP(A)} &= \left| I_{DIF(A)} - k_A I_A \right| \\ &= \left| I_A \times \frac{C_{A1} - C_{A2}}{C_{A1} + C_{A2}} - k_A I_A \right| \end{aligned} \quad \textbf{Eq. 9-48}$$

The capacitor bank leg-A inherent unbalance factor setting k_A is chosen to be:

$$k_A = \frac{C_{A1} - C_{A2}}{C_{A1} + C_{A2}} \quad \textbf{Eq. 9-49}$$

As can be seen from the previous two equations, the initial operating signal is zero.

9.1.5.3 Sensitivity

Now consider the consequences of an element failure in a typical string, say string A1, making a small capacitance change in C_{A1} capacitance. The effect on the operating signal can be calculated by taking the derivative of equation 9.48 with respect to C_{A1}.

In the general case, the derivative of the absolute value function is messy, but in our case where the initial value is zero, the derivative of the absolute function is simply the absolute value of the derivative of its argument. We assume here that I_A is constant, which investigation has shown results in negligible error. The derivative is thus:

$$\begin{aligned} \frac{d}{dC_{A1}} I_{OP(A)} &= \left| \frac{d}{dC_{A1}} \left(I_A \times \frac{C_{A1} - C_{A2}}{C_{A1} + C_{A2}} - k_A I_A \right) \right| \\ &= \left| I_A \times \frac{(C_{A1} + C_{A2}) - (C_{A1} - C_{A2})}{(C_{A1} + C_{A2})^2} \right| \\ &= \left| I_A \right| \times \frac{2C_{A2}}{(C_{A1} + C_{A2})^2} \\ &\cong \frac{I_A}{2} \times \frac{1}{C_{A1}} \end{aligned} \quad \textbf{Eq. 9-50}$$

The last step assumes $C_{A1} \cong C_{A2}$ and replaces the phase current vector with its magnitude. This can be written as:

$$dI_{OP(A)} = \frac{I_A}{2} \times \frac{dC_{A1}}{C_{A1}} \quad \textbf{Eq. 9-51}$$

Alternatively, we can say:

$$I_{OP(A)}(pu) = \frac{I_A}{2} \times \Delta C(pu) \quad \textbf{Eq. 9-52}$$

where $\Delta C(pu)$ represents the capacitance change as a per-unit of the string capacitance, and $I_{OP(A)}(pu)$ represents the operating signal resulting from the failure in per-unit of the nominal current of the differential source. I_A is phase A terminal current on the same base. When the system is normal (no fault), I_A can be taken as the capacitor bank rated primary per-phase current I_{rated} converted to the differential source base. For example, $I_A = I_{rated} / I_{base}$, where I_{base} is again the differential CT primary current rating, or:

$$I_{OP(A)}(pu) = \frac{I_{rated}}{2I_{base}} \times \Delta C(pu) \quad \textbf{Eq. 9-53}$$

Note that under external fault conditions, sensitivity can be much different from the non-fault sensitivity.

9.1.5.4 Auto-setting

As a convenient alternative to manually determining inherent unbalance factor settings, the relay can automatically calculate these settings from its own measurements while the capacitor is in-service, as described in the Commands chapter. The technique that the relay uses is to set the operate signal variable to zero in equation 9.43 and solve for the inherent unbalance factor k_A using the average of several successive measurements of the currents. However, the assumption made here is that when the auto-set command is executed, the capacitor is in an acceptably balanced state, wherein the operating signal ought to be zero. Following the auto-set command, the protection measures changes from the state that existed at the time the auto-set command executed.

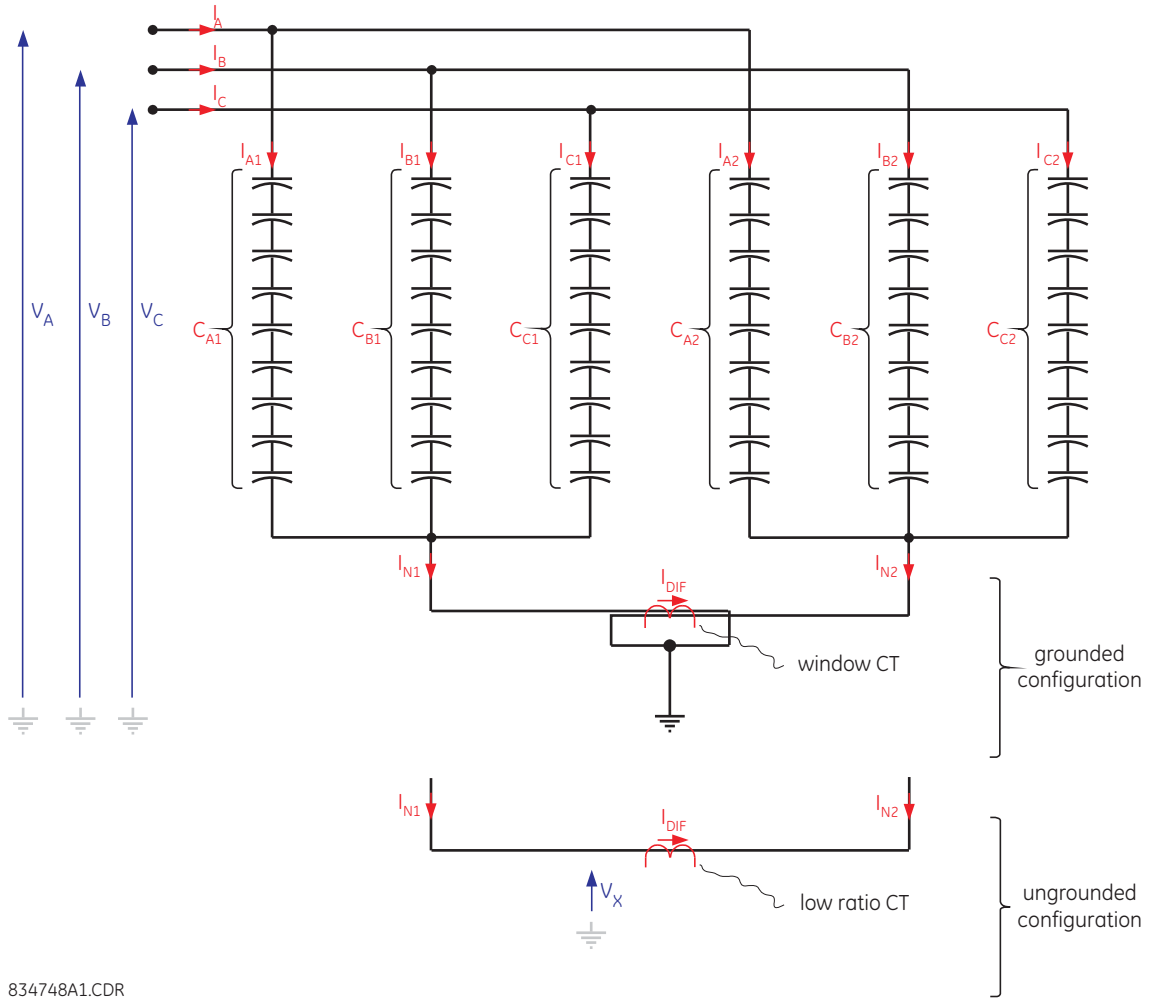
9.1.6 Neutral current unbalance (ANSI 60N)

9.1.6.1 Operating principle

The neutral current unbalance function is based on the balance between interconnected neutral currents of two parallel banks, and is applicable to both grounded and ungrounded installations. This section deals first with grounded applications, with a section at the end that discusses the differences with ungrounded applications. A window CT measuring the vector difference between the two neutral currents is required for grounded-wye configurations.

If the two banks were identical, then the inter-neutral current is zero. The failure of an element in either bank then results in inter-neutral current, which is sensed by the relay. However, with the two banks slightly mismatched due to manufacturing tolerances, a circulating zero-sequence current can be present. Compensation for this inherent unbalance current is available to increase the sensitivity of the function.

Figure 9-6: Neutral current unbalance application



The neutral current unbalance protection uses the following operate signal:

$$I_{OP} = \left| I_{DIF} - k_1 I_1 - k_1^* I_2 \right| \qquad \textbf{Eq. 9-54}$$

The neutral current unbalance protection uses the following restraint signal:

$$I_{REST} = \left| I_0 \right| \qquad \textbf{Eq. 9-55}$$

where k_1 represents the vector capacitor bank positive sequence inherent unbalance factor setting, and k_1* represents the complex conjugate of k_1. The currents are as defined in the figure and are in per-unit values of the nominal current of the bank source ground current channel.

These equations involve phasors, not magnitudes; that is, the vector sum of the currents is created by the protection function implementing the method. The protection operates when the operate signal is greater than the set pickup level for the set pickup delay.

Sensitivity is the key performance parameter. The applied comparator uses a simple integration method in addition to the standard hysteresis approach, to deal with chattering of the operating signal at the boundary of operation.

9.1.6.2 Balanced case

The currents in the neutral current unbalance protection are driven by the individual admittances in each string:

$$I_{A1} = \frac{V_A \times j\omega C_{A1}}{I_{base}}; \quad I_{A2} = \frac{V_A \times j\omega C_{A2}}{I_{base}}$$
$$I_{B1} = \frac{V_B \times j\omega C_{B1}}{I_{base}}; \quad I_{B2} = \frac{V_B \times j\omega C_{B2}}{I_{base}} \qquad \text{Eq. 9-56}$$
$$I_{C1} = \frac{V_C \times j\omega C_{C1}}{I_{base}}; \quad I_{C2} = \frac{V_C \times j\omega C_{C2}}{I_{base}}$$

In these equations, I_{base} represents the differential CT primary current rating, inserted here to put the string currents on the same per-unit base used by the relay. Voltages are in primary volts, capacitances in Farads, and frequency in radians per second.

The two neutral currents can be derived from these equations, as follows:

$$I_{N1} = I_{A1} + I_{B1} + I_{C1} = \frac{j\omega C_{A1}V_A + j\omega C_{B1}V_B + j\omega C_{C1}V_C}{I_{base}}$$
$$I_{N2} = I_{A2} + I_{B2} + I_{C2} = \frac{j\omega C_{A2}V_A + j\omega C_{B2}V_B + j\omega C_{C2}V_C}{I_{base}} \qquad \text{Eq. 9-57}$$

The differential current is the vector difference between the two currents. By subtracting I_{N2} from I_{N1}, one obtains:

$$I_{DIF} = I_{N1} - I_{N2}$$
$$= \frac{j\omega[V_A(C_{A1} - C_{A2}) + V_B(C_{B1} - C_{B2}) + V_C(C_{C1} - C_{C2})]}{I_{base}} \qquad \text{Eq. 9-58}$$

At the same time the total currents in each phase are driven by the total admittance of the two banks in each phase:

$$I_A = I_{A1} + I_{A2} = \frac{j\omega V_A(C_{A1} + C_{A2})}{I_{base}}$$
$$I_B = I_{B1} + I_{B2} = \frac{j\omega V_B(C_{B1} + C_{B2})}{I_{base}} \qquad \text{Eq. 9-59}$$
$$I_C = I_{C1} + I_{C2} = \frac{j\omega V_C(C_{C1} + C_{C2})}{I_{base}}$$

Inserting the equations above into equation 9.58 so as to eliminate the voltages:

$$I_{DIF} = \frac{j\omega[V_A(C_{A1} - C_{A2}) + V_B(C_{B1} - C_{B2}) + V_C(C_{C1} - C_{C2})]}{I_{base}}$$
$$= I_A \times \frac{C_{A1} - C_{A2}}{C_{A1} + C_{A2}} + I_B \times \frac{C_{B1} - C_{B2}}{C_{B1} + C_{B2}} + I_C \times \frac{C_{C1} - C_{C2}}{C_{C1} + C_{C2}} \qquad \text{Eq. 9-60}$$

Label k_A, k_B, and k_C as follows:

$$k_A = \frac{C_{A1} - C_{A2}}{C_{A1} + C_{A2}}, \quad k_B = \frac{C_{B1} - C_{B2}}{C_{B1} + C_{B2}}, \quad k_C = \frac{C_{C1} - C_{C2}}{C_{C1} + C_{C2}} \qquad \text{Eq. 9-61}$$

Also, convert from phase coordinates into sequence components as follows, and equation 9.60 becomes:

$$I_{DIF} = k_A(I_1 + I_2 + I_0) + k_B(\hat{a}^2 I_1 + \hat{a} I_2 + I_0) + k_C(\hat{a} I_1 + \hat{a}^2 I_2 + I_0)$$
$$= I_1(k_A + \hat{a}^2 k_B + \hat{a} k_C) + I_2(k_A + \hat{a} k_B + \hat{a}^2 k_C) + I_0(k_A + k_B + k_C) \qquad \text{Eq. 9-62}$$

Substituting this into equation 9.54, we get:

$$\begin{aligned} I_{OP} &= \left| I_{DIF} - (k_1 I_1 - k_1^* I_2) \right| \\ &= \left| I_1(k_A + \hat{a}^2 k_B + \hat{a} k_C) + I_2(k_A + \hat{a} k_B + \hat{a}^2 k_C) + I_0(k_A + k_B + k_C) - k_1 I_1 - k_1^* I_2 \right| \\ &= \left| I_1(k_A + \hat{a}^2 k_B + \hat{a} k_C - k_1) + I_2(k_A + \hat{a} k_B + \hat{a}^2 k_C - k_1^*) + I_0(k_A + k_B + k_C) \right| \\ &= \left| I_1(k_A + \hat{a}^2 k_B + \hat{a} k_C - k_1) + I_2(k_A + \hat{a}^2 k_B + \hat{a} k_C - k_1)^* + I_0(k_A + k_B + k_C) \right| \end{aligned} \quad \text{Eq. 9-63}$$

The capacitor bank positive sequence inherent unbalance factor setting k_1 is chosen to be:

$$\begin{aligned} k_1 &= k_A + \hat{a}^2 k_B + \hat{a} k_C \\ &= \frac{C_{A1} - C_{A2}}{C_{A1} + C_{A2}} + \hat{a}^2 \frac{C_{B1} - C_{B2}}{C_{B1} + C_{B2}} + \hat{a} \frac{C_{C1} - C_{C2}}{C_{C1} + C_{C2}} \end{aligned} \quad \text{Eq. 9-64}$$

This allows the first and second terms in the I_{OP} equation to vanish. The last term, being the product of two small numbers, virtually vanishes as well. Under normal system conditions (non-fault), the zero-sequence voltage and thus the zero-sequence current is small. The k_A, k_B, and k_C value involve the difference between two capacitances that are factory matched, and so are also small. In addition, it is very likely that they are of varying signs, and thus their sum is doubly small. Thus the initial operating signal under normal operating conditions is seen to be virtually zero.

9.1.6.3 Sensitivity

Now consider the consequences of an element failure in a typical string, say string A1, making a small capacitance change in the C_{A1} capacitance. The effect on the operating signal can be calculated by taking the derivative of equation 9.63 with respect to C_{A1}.

In the general case, the derivative of the absolute value function is messy, but in our case where the initial value is zero, the derivative of the absolute function is simply the absolute value of the derivative of its argument. We assume here that the currents remain constant, which investigation has shown results in negligible error. The derivative is thus:

$$\begin{aligned} \frac{d}{dC_{A1}} I_{OP} &= \left| \frac{d}{dC_{A1}} (I_1(k_A + \hat{a}^2 k_B + \hat{a} k_C - k_1) + I_2(k_A + \hat{a}^2 k_B + \hat{a} k_C - k_1)^* + I_0(k_A + k_B + k_C)) \right| \\ &= \left| \frac{dk_A}{dC_{A1}} I_1 + \frac{dk_A}{dC_{A1}} I_2 + \frac{dk_A}{dC_{A1}} I_0 \right| \\ &= \left| \frac{dk_A}{dC_{A1}} I_A \right| \\ &= \left| \frac{(C_{A1} + C_{A2}) - (C_{A1} - C_{A2})}{(C_{A1} + C_{A2})^2} I_A \right| \\ &= \frac{2 C_{A2} I_A}{(C_{A1} + C_{A2})^2} \\ &\cong \frac{I_A}{2} \times \frac{1}{C_{A1}} \end{aligned} \quad \text{Eq. 9-65}$$

The final step assumes $C_{A1} \cong C_{A2}$ and replaces the phase current vector with its magnitude. This can be written as:

$$dI_{OP} = \frac{I_A}{2} \times \frac{dC_{A1}}{C_{A1}} \quad \text{Eq. 9-66}$$

Alternately, we can say:

$$I_{OP}(pu) = \frac{I_A}{2} \times \Delta C(pu) \quad \text{Eq. 9-67}$$

where ΔC(pu) represents the capacitance change as a per-unit value of the string capacitance, and I_{OP}(pu) represents the operating signal resulting from the failure in per-unit of the nominal current of the differential source. I_A represents the phase A terminal current on the same base. When the system is normal (no fault), I_A can be taken as the capacitor bank's rated primary per-phase current I_{rated} converted to the differential source base. For example, $I_A = I_{rated} / I_{base}$, where I_{base} is again the differential CT primary current rating, or with system normal:

$$I_{OP}(pu) = \frac{I_{rated}}{2I_{base}} \times \Delta C(pu) \qquad \textbf{Eq. 9-68}$$

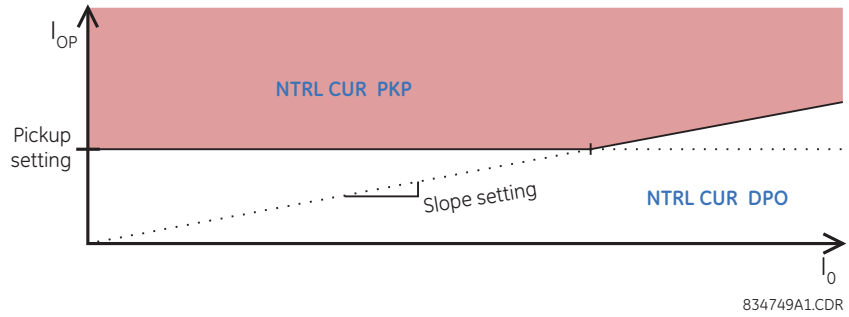
Note that under external fault conditions, sensitivity can be much different from the non-fault sensitivity.

9.1.6.4 Restraint

Severe system voltage unbalance, such as can occur during near-by bolted ground faults, can exacerbate measurement error, resulting in spurious operating signal. To prevent operation under these conditions, percent restraint supervision is applied using a restraint signal that is the magnitude of the zero-sequence current.

Typically, a few percent of slope is enough to ensure security of the function. The factor compensating for the inherent bank unbalance zeroes out the operating signal under relatively balanced bank currents. If the said currents contain a significant zero sequence component, the quality of compensation is lower, hence the need for the restraint, and this slope setting.

Figure 9-7: Neutral current unbalance restraint



9.1.6.5 Auto-setting

As a convenient alternative to manually determining the unbalance k-factor settings, the relay can automatically calculate these settings from its own measurements while the capacitor is in-service, as described in the Commands and Targets chapter. The technique that the relay uses is to set the operate signal variable to zero in equation 9.54 and solve for the unbalance factor k_1 using the average of several successive measurements of the currents.

However, the assumption made here is that when the auto-set command is executed, the capacitor is in an acceptably balanced state, wherein the operating signal ought to be zero. Following the auto-set command, the protection measures changes from the state that existed at the time the auto-set command executed.

9.1.6.6 Application to ungrounded capacitor banks

The forgoing discussion of the neutral current balance protection applied to the ground configuration. When applied to ungrounded configurations, all of it applies, with the following exceptions:

- The phase voltages in equations 9.54 through 9.59 must have the neutral voltage V_X subtracted. However, as these voltages are eventually eliminated from the calculations, the outcome is unaffected.
- A low ratio CT can be used for ungrounded-wye configurations in place of a window type CT as there is no requirement to form the difference of the primary neutral currents
- Whereas with the grounded configuration $I_{DIF} = I_{N1} - I_{N2}$, with the ungrounded configuration $I_{DIF} = I_{N1} = -I_{N2}$. This results in the $-C_{A2}$, $-C_{B2}$, and $-C_{C2}$ terms disappearing from equations 9.58 through 9.65. This results in the following changes.

Equation 9.64 becomes:

$$k_1 = k_A + \hat{a}^2 k_B + \hat{a} k_C = \frac{C_{A1}}{C_{A1}+C_{A2}} + \hat{a}^2 \frac{C_{B1}}{C_{B1}+C_{B2}} + \hat{a} \frac{C_{C1}}{C_{C1}+C_{C2}} \quad \text{Eq. 9-69}$$

Equation 9.65 becomes:

$$\frac{d}{dC_{A1}} I_{OP} = \left| \frac{(C_{A1}+C_{A2}) - C_{A1}}{(C_{A1}+C_{A2})^2} I_A \right| = \frac{C_{A2} I_A}{(C_{A1}+C_{A2})^2} \cong \frac{I_A}{4} \times \frac{1}{C_{A1}} \quad \text{Eq. 9-70}$$

Equation 9.67 becomes:

$$I_{OP}(pu) = \frac{I_A}{4} \times \Delta C(pu) \quad \text{Eq. 9-71}$$

Equation 9.68 becomes:

$$I_{OP}(pu) = \frac{I_{rated}}{4 I_{base}} \times \Delta C(pu) \quad \text{Eq. 9-72}$$

Note that in the ungrounded case, the operating signal is half of that for the grounded case.

- With the grounded configuration, the two banks must be nominally identical. With the ungrounded configuration the two banks need not be the identical though each ideally are balanced. In this situation, the base for $\Delta C(pu)$ is the capacitance of the string that has the element failure, so the larger bank has a lower sensitivity than the smaller bank.

C70 Capacitor Bank Protection and Control System

Chapter 10: Maintenance

This chapter outlines maintenance, repair, storage, and disposal of the hardware and software.

10.1 General maintenance

The C70 requires minimal maintenance. As a microprocessor-based relay, its characteristics do not change over time. 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.

While the C70 performs continual self-tests, it is recommended that maintenance be scheduled with other system maintenance. This maintenance can involve in-service, out-of-service, or unscheduled maintenance.

10.1.1 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.

10.1.2 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.

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.

10.1.3 Unscheduled maintenance (system interruption)

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

10.2 Back up and restore settings

Back up a copy of the in-service settings for each commissioned UR device, so as to revert to the commissioned settings after inadvertent, unauthorized, or temporary setting changes are made, after the settings defaulted due to firmware upgrade, or when the device has to be replaced. This section describes how to backup settings to a file and how to use that file to restore the settings to the original relay or to a replacement relay.

10.2.1 Back up settings

UR device settings can be saved in a backup URS file using the EnerVista UR Setup software. The URS file is the standard UR settings file. For an introduction to settings files in the URS format, see the beginning of the Interfaces chapter. When the IEC 61850 option is present, the settings can alternatively be saved in a backup IID file either using the EnerVista UR Setup software in online mode or by using any of the supported file transfer protocols. The IID file is one of several IEC 61850 Substation Configuration Language (SCL) file types; see the IEC 61850 chapter in the UR Series Communications Guide for an introduction to SCL.

"TBD" displays when a setting in a modeled element is configured with a non-modeled operand. For example, Phase IOC is modeled in a firmware release, while the LED operands are not modeled. If the block setting of the Phase IOC is configured with LED operands, its displays as TBD in IID and CID files, the web interface, or in an MMS client.

The options that display in the EnerVista software when right-clicking depend on device options.

To save a settings file in the URS format:

1. In EnerVista, connect to the device in the Online Window area.
2. Right-click the device name in the Online Window area and select **Read Device Settings**. A window opens.
3. Select or enter a file name and location, and click the **Receive** button. A .urs file is created in the Offline Window area.

To save settings in the IID format in EnerVista:

1. In EnerVista, connect to the device in the Online Window area.
2. Right-click the device name in the Online Window area and select **Read IID File**. The option is not present when the device does not have the IEC 61850 option. A window opens when successful.
3. Select or enter a file name and location, and click the **Receive** button. A .iid file is created.

To save settings in the IID format using TFTP:

1. On a computer on the same subnetwork as the UR device, open a command window.
2. Enter

   ```
   TFTP <IP address> GET ur.iid <destination>
   ```

   where

   <IP address> is the IP address of the UR device
   ur.iid is the internal name of the IID file in the UR device
   <destination> is the path and file name of the IID file. If omitted, the file is saved as ur.iid in the command window default directory.

   An example is

```
TFTP 192.168.1.101 GET ur.iid Feeder1.iid
```

10.2.2 Restore settings

UR device settings can be restored to the values they were at when a URS backup file was created using the EnerVista UR Setup software. When the IEC 61850 option is present, the settings can alternatively be to the values they were at when an IID type backup was created either using the EnerVista UR Setup software in online mode or by using any of the supported file transfer protocols. Note that TFTP cannot be used here, as TFTP "put" mode is disabled for security reasons.

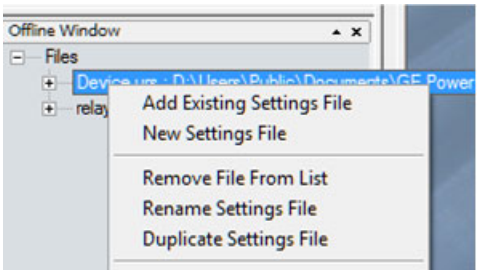
To restore completely, a few settings need to be entered manually either via EnerVista UR Setup or via the UR device front panel. If the restore operation is to be via Ethernet, first the UR device must have its IP address settings entered via the front panel. These are located at **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ NETWORK 1(3)** and **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IPv4 ROUTE TABLE 1(6) ⇨ DEFAULT IPv4 ROUTE ⇨ GATEWAY ADDRESS**.

When importing a file, it cannot have a blank numeric value. All numeric values must be non-blank, otherwise the file is rejected.

To restore settings from a URS file:

1. In EnerVista, connect to the device in the Online Window area.
2. Right-click the .urs file in the Offline Window area and select **Add Existing Settings File** to locate a file, and/or drag-and-drop the file from the Offline Window area to the device in the Online Window area.

Figure 10-1: Restoring a URS settings file

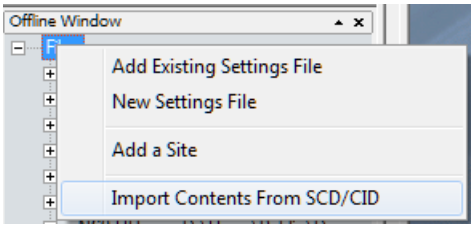


3. Manually copy the remaining settings, outlined as follows.

To restore settings from an IID file using EnerVista software:

1. In Windows, make a copy of the .iid backup file, and change the extension to .cid on the new copy.
2. In the Online Window area of the UR EnerVista Setup software, connect to the device to establish communication.
3. In the Offline Window area, right-click **Files** and select **Import Contents From SCD/CID**.

Figure 10-2: Importing a CID file



4. Navigate to and select the file with .cid extension. When prompted, enter a file name to give to an intermediate URS file. The URS file is added to the Offline Window area.
5. Drag the imported file in the Offline Window to the device in the Online Window.
6. Manually copy the remaining settings, outlined as follows.

To restore settings from an IID using SFTP:

1. Close EnerVista UR Setup software.
2. In Windows, make a copy of the .iid backup file, and change the extension to .cid on the new copy.
3. On a computer on the same subnetwork as the UR device, open an SFTP client application, such as WinSCP. Note that TFTP cannot be used here.
4. Use the device's IP address as the host name.
5. If the device has the CyberSentry option, use the User Name of "Administrator" or "Engineer," and the password programmed for the selected role. The default password is "ChangeMe1#" (without quotation marks). Log in to the device.
6. If the device does not have the CyberSentry option, use the User Name of "Setting," and the password programmed for the Setting role. The default password is "ChangeMe1#" (without quotation marks). Log in to the device.
7. Upload the backup file copy with the .cid extension. WinSCP uses drag-and-drop or copy-and-paste for this file transfer.
8. Manually copy the remaining settings, outlined as follows.

To manually copy remaining settings:

1. Settings listed in section 4.1.2 Settings Files are not transferred to the UR device with settings files. Enter them manually either via the front panel or via EnerVista UR Setup software. The values that these settings had at the time the backup was created are contained within the backup file, accessed through EnerVista UR Setup software.

10.3 Upgrade firmware

The firmware of the C70 device can be upgraded, locally or remotely, using the EnerVista software. Instructions are outlined here and in the Help file under the topic “Upgrading Firmware.”

Upgrades are possible for the same release (such as 7.01 to 7.02) and from one firmware version to another (such as 7.2 to 7.3). When upgrading to another firmware version, check the release notes on the GE Multilin website for compatibility.

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.

To upgrade the firmware:

1. If required, download the boot file and/or firmware from http://www.gegridsolutions.com/app/ViewFiles.aspx?prod=urfamily&type=7
   The boot file is a .bin file.
2. Navigate to **Settings > Product Setup > Security** and ensure that the **Remote Setting Authorized** and **Local Setting Authorized** settings are "ON." On the front panel of the device, the path is **Settings ⇨ Product Setup ⇨ Security ⇨⇩ Dual Permission Security Access**.

   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.
3. In EnerVista, back up the device settings by right-clicking the device and selecting **Read Device Settings**. In the window that displays, select an existing file to overwrite, or enter a name for a new settings file and optionally a location for the new file. Click the **Receive** button to start the backup.

   If an "Incompatible device order codes or versions" message displays, it means that you are trying to overwrite a file for another product. You access the **Convert Settings File** option by right-clicking the file in the **Offline Window** area at the lower left.
4. In EnerVista, navigate to **Maintenance > Update Firmware**.

   First select the boot file if applicable, locating the .bin file, and proceed. Restart the device, the EnerVista software, and refresh the order code in EnerVista under the **Device Setup** button.

   To update the firmware, click **Maintenance > Update Firmware**, select the firmware update by locating the file, and proceed with the update.

When asked if upgrading over the Internet, the difference is the flash memory buffer size each time the software sends data to the relay. Yes means that the flash memory buffer size is 256 bytes. No means that it is 1024 bytes, which is faster.

If an "Unable to put relay in flash mode" message displays, set the **Settings > Product Setup > Security > Dual Permission Security Access > Remote Setting Authorized** and **Local Setting Authorized** settings to "ON" and try again.

When the update is finished, restart the device by clicking **Maintenance > Reboot Relay Command**, restart the EnerVista software, and refresh the order code in EnerVista under the **Device Setup** button. As the device is starting up, verify the boot and firmware version, or in EnerVista check them under **Actual Values > Product Info > Firmware Revisions**. The boot version is not the same as the firmware revision, and the firmware revision reflects the UR release, for example firmware revision 7.3 is UR release 7.3.

5. Set the device to "programmed" under **Settings > Product Setup > Installation**.
6. If you changed the **Remote Setting Authorized**, the **Local Setting Authorized** settings, or relay lock settings, return them to their previous settings.
7. To apply any previously saved settings, right-click the saved settings file in the **Offline Window** area and select **Write to Device**.

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.

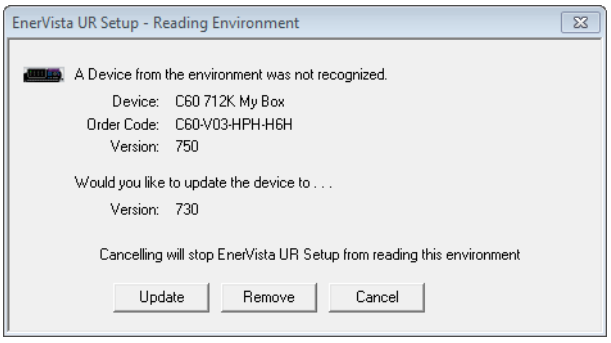
10.4 Upgrade software

The latest EnerVista software and firmware can be downloaded from http://www.gegridsolutions.com/app/ViewFiles.aspx?prod=urfamily&type=7

After upgrading, check the version number under **Help > About**. If the new version does not display, try uninstalling the software and reinstalling the new versions.

A message can display in the EnerVista software upon launch that "a device from the environment was not recognized." This means that a device is online and its firmware version conflicts with the software version. In the example shown, a C60 with firmware version 7.5x is online, but the software version is 7.3x. Updating removed incompatible files and changes the device to version 7.3x, after which you need to make the order codes consistent as outlined next.

Figure 10-3: Mismatch in order code between software and device



To make the order codes consistent:

1. In EnerVista, click the **Device Setup** button. The window opens.

2. Expand the entry for the UR device.
3. Click the **Read Order Code** button. The order code and version of the device are populated to the software.
4. Click the **OK** button to save the change.

10.5 Replace module

This section outlines how to replace a module.

⚠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. Replace modules only with like modules in their original factory configured slots.

To replace a module:

1. Open the enhanced faceplate to the left once the thumb screw has been removed. This allows for easy access 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 C70.

Figure 10-4: Modules inside relay with front cover open (enhanced faceplate)



842812A1.CDR

The basic faceplate can be opened to the left once the black plastic sliding latch on the right side has been pushed up, as shown below.

Figure 10-5: Removing module (basic faceplate)



842760A1.CDR

2. With power to the unit off, disconnect individually the connections at the front and back of the module before removing the module from the chassis.

   For any Process Card/process bus module in slot H for use with a HardFiber Brick, also remove the two screws at the back that attach the module to the chassis.

3. To properly remove a module, pull simultaneously the ejector/inserter clips, located at the top and bottom of the module. 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 is fully inserted.

10.6 Battery

A battery powers the real time clock on startup of the device.

When required, the battery can be replaced. The battery type is 3 V cylindrical.

The power supply module contains the battery. 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.

10.6.1 Replace battery for RH/RL power supply

When required, the battery can be replaced. The power supply module contains the battery.

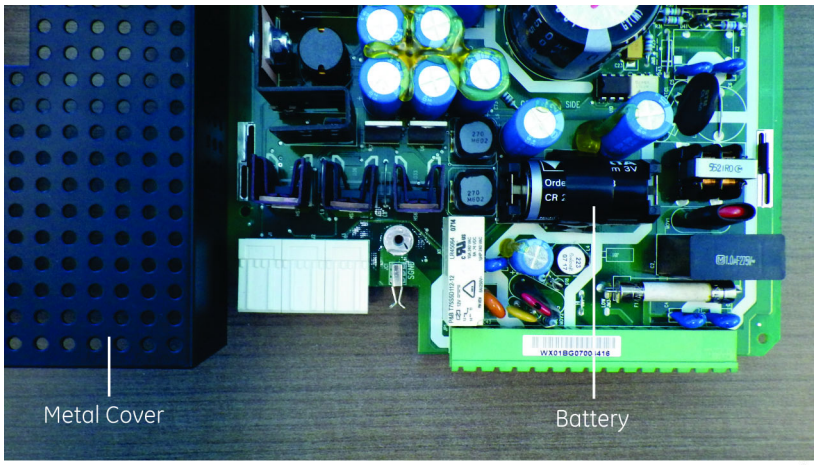
⚠CAUTION **To avoid injury, ensure that the unit has been powered off for a minimum of three minutes before replacing the battery.**

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 its 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 10-6: 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.

10.6.2 Replace battery for SH/SL power supply

When required, the battery can be replaced. 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.

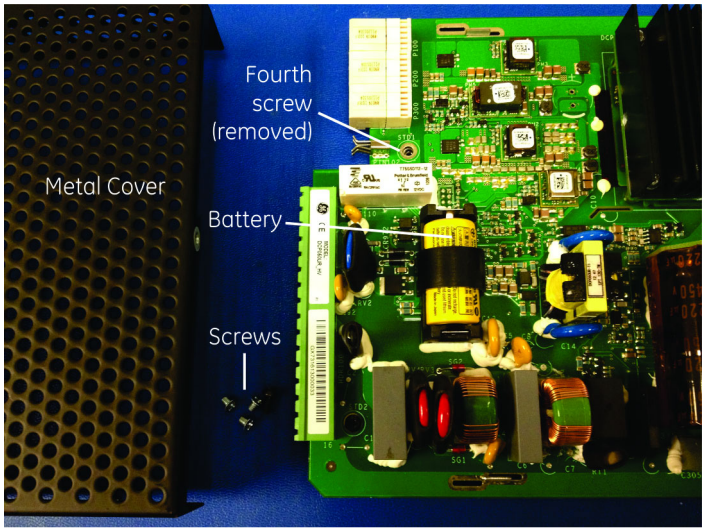
To replace the battery:

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 left side of the unit.

5. Remove the power supply module by simultaneously pulling the ejector clips at the top and bottom of the module and sliding it out.
6. 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).
7. Slide the metal cover away from the clips about 0.5 cm (1/8 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—pull the plastic away from the battery. Use a flat-head screwdriver if you cannot unclip the plastic with your fingers.
9. 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 10-7: Battery location on SH/SL power supply module



859717A1.cdr

10. Reinstall the battery holder 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.

10.6.3 Dispose of battery



10.6.3.1 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.

10.6.3.2 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.

10.6.3.3 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.

10.6.3.4 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.

10.6.3.5 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.

10.6.3.6 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.

10.6.3.7 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.

10.6.3.8 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.

10.6.3.9 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.

10.6.3.10 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.

10.6.3.11 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.

10.6.3.12 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.

10.6.3.13 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.

10.6.3.14 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.

10.6.3.15 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.

10.6.3.16 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.

10.6.3.17 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.

10.6.3.18 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.

10.6.3.19 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.

10.6.3.20 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.

10.6.3.21 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.

10.6.3.22 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.

10.6.3.23 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

10.7 Clear files and data after uninstall

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

10.8 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.

Files can be requested for use by technical support staff, for example the Service Report (click the icon in the software) or under **Maintenance > Retrieve File**, as outlined elsewhere in this document.

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

10.9 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.

10.10 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.

C70 Capacitor Bank Protection and Control System

Appendix A: FlexAnalog operands

This appendix outlines FlexAnalog parameters.

A.1 FlexAnalog items

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

Decimal address	FlexAnalog name	Units	Description
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

A

Decimal address	FlexAnalog name	Units	Description
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
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
6272	SRC 3 Ia RMS	Amps	Source 3 phase A current RMS
6274	SRC 3 Ib RMS	Amps	Source 3 phase B current RMS
6276	SRC 3 Ic RMS	Amps	Source 3 phase C current RMS
6278	SRC 3 In RMS	Amps	Source 3 neutral current RMS

Decimal address	FlexAnalog name	Units	Description
6280	SRC 3 Ia Mag	Amps	Source 3 phase A current magnitude
6282	SRC 3 Ia Angle	Degrees	Source 3 phase A current angle
6283	SRC 3 Ib Mag	Amps	Source 3 phase B current magnitude
6285	SRC 3 Ib Angle	Degrees	Source 3 phase B current angle
6286	SRC 3 Ic Mag	Amps	Source 3 phase C current magnitude
6288	SRC 3 Ic Angle	Degrees	Source 3 phase C current angle
6289	SRC 3 In Mag	Amps	Source 3 neutral current magnitude
6291	SRC 3 In Angle	Degrees	Source 3 neutral current angle
6292	SRC 3 Ig RMS	Amps	Source 3 ground current RMS
6294	SRC 3 Ig Mag	Amps	Source 3 ground current magnitude
6296	SRC 3 Ig Angle	Degrees	Source 3 ground current angle
6297	SRC 3 I_0 Mag	Amps	Source 3 zero-sequence current magnitude
6299	SRC 3 I_0 Angle	Degrees	Source 3 zero-sequence current angle
6300	SRC 3 I_1 Mag	Amps	Source 3 positive-sequence current magnitude
6302	SRC 3 I_1 Angle	Degrees	Source 3 positive-sequence current angle
6303	SRC 3 I_2 Mag	Amps	Source 3 negative-sequence current magnitude
6305	SRC 3 I_2 Angle	Degrees	Source 3 negative-sequence current angle
6306	SRC 3 Igd Mag	Amps	Source 3 differential ground current magnitude
6308	SRC 3 Igd Angle	Degrees	Source 3 differential ground current angle
6336	SRC 4 Ia RMS	Amps	Source 4 phase A current RMS
6338	SRC 4 Ib RMS	Amps	Source 4 phase B current RMS
6340	SRC 4 Ic RMS	Amps	Source 4 phase C current RMS
6342	SRC 4 In RMS	Amps	Source 4 neutral current RMS
6344	SRC 4 Ia Mag	Amps	Source 4 phase A current magnitude
6346	SRC 4 Ia Angle	Degrees	Source 4 phase A current angle
6347	SRC 4 Ib Mag	Amps	Source 4 phase B current magnitude
6349	SRC 4 Ib Angle	Degrees	Source 4 phase B current angle
6350	SRC 4 Ic Mag	Amps	Source 4 phase C current magnitude
6352	SRC 4 Ic Angle	Degrees	Source 4 phase C current angle
6353	SRC 4 In Mag	Amps	Source 4 neutral current magnitude
6355	SRC 4 In Angle	Degrees	Source 4 neutral current angle
6356	SRC 4 Ig RMS	Amps	Source 4 ground current RMS
6358	SRC 4 Ig Mag	Amps	Source 4 ground current magnitude
6360	SRC 4 Ig Angle	Degrees	Source 4 ground current angle
6361	SRC 4 I_0 Mag	Amps	Source 4 zero-sequence current magnitude
6363	SRC 4 I_0 Angle	Degrees	Source 4 zero-sequence current angle
6364	SRC 4 I_1 Mag	Amps	Source 4 positive-sequence current magnitude
6366	SRC 4 I_1 Angle	Degrees	Source 4 positive-sequence current angle
6367	SRC 4 I_2 Mag	Amps	Source 4 negative-sequence current magnitude
6369	SRC 4 I_2 Angle	Degrees	Source 4 negative-sequence current angle
6370	SRC 4 Igd Mag	Amps	Source 4 differential ground current magnitude
6372	SRC 4 Igd Angle	Degrees	Source 4 differential ground current angle
6400	SRC 5 Ia RMS	Amps	Source 5 phase A current RMS
6402	SRC 5 Ib RMS	Amps	Source 5 phase B current RMS
6404	SRC 5 Ic RMS	Amps	Source 5 phase C current RMS
6406	SRC 5 In RMS	Amps	Source 5 neutral current RMS

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Decimal address	FlexAnalog name	Units	Description
6408	SRC 5 Ia Mag	Amps	Source 5 phase A current magnitude
6410	SRC 5 Ia Angle	Degrees	Source 5 phase A current angle
6411	SRC 5 Ib Mag	Amps	Source 5 phase B current magnitude
6413	SRC 5 Ib Angle	Degrees	Source 5 phase B current angle
6414	SRC 5 Ic Mag	Amps	Source 5 phase C current magnitude
6416	SRC 5 Ic Angle	Degrees	Source 5 phase C current angle
6417	SRC 5 In Mag	Amps	Source 5 neutral current magnitude
6419	SRC 5 In Angle	Degrees	Source 5 neutral current angle
6420	SRC 5 Ig RMS	Amps	Source 5 ground current RMS
6422	SRC 5 Ig Mag	Amps	Source 5 ground current magnitude
6424	SRC 5 Ig Angle	Degrees	Source 5 ground current angle
6425	SRC 5 I_0 Mag	Amps	Source 5 zero-sequence current magnitude
6427	SRC 5 I_0 Angle	Degrees	Source 5 zero-sequence current angle
6428	SRC 5 I_1 Mag	Amps	Source 5 positive-sequence current magnitude
6430	SRC 5 I_1 Angle	Degrees	Source 5 positive-sequence current angle
6431	SRC 5 I_2 Mag	Amps	Source 5 negative-sequence current magnitude
6433	SRC 5 I_2 Angle	Degrees	Source 5 negative-sequence current angle
6434	SRC 5 Igd Mag	Amps	Source 5 differential ground current magnitude
6436	SRC 5 Igd Angle	Degrees	Source 5 differential ground current angle
6464	SRC 6 Ia RMS	Amps	Source 6 phase A current RMS
6466	SRC 6 Ib RMS	Amps	Source 6 phase B current RMS
6468	SRC 6 Ic RMS	Amps	Source 6 phase C current RMS
6470	SRC 6 In RMS	Amps	Source 6 neutral current RMS
6472	SRC 6 Ia Mag	Amps	Source 6 phase A current magnitude
6474	SRC 6 Ia Angle	Degrees	Source 6 phase A current angle
6475	SRC 6 Ib Mag	Amps	Source 6 phase B current magnitude
6477	SRC 6 Ib Angle	Degrees	Source 6 phase B current angle
6478	SRC 6 Ic Mag	Amps	Source 6 phase C current magnitude
6480	SRC 6 Ic Angle	Degrees	Source 6 phase C current angle
6481	SRC 6 In Mag	Amps	Source 6 neutral current magnitude
6483	SRC 6 In Angle	Degrees	Source 6 neutral current angle
6484	SRC 6 Ig RMS	Amps	Source 6 ground current RMS
6486	SRC 6 Ig Mag	Amps	Source 6 ground current magnitude
6488	SRC 6 Ig Angle	Degrees	Source 6 ground current angle
6489	SRC 6 I_0 Mag	Amps	Source 6 zero-sequence current magnitude
6491	SRC 6 I_0 Angle	Degrees	Source 6 zero-sequence current angle
6492	SRC 6 I_1 Mag	Amps	Source 6 positive-sequence current magnitude
6494	SRC 6 I_1 Angle	Degrees	Source 6 positive-sequence current angle
6495	SRC 6 I_2 Mag	Amps	Source 6 negative-sequence current magnitude
6497	SRC 6 I_2 Angle	Degrees	Source 6 negative-sequence current angle
6498	SRC 6 Igd Mag	Amps	Source 6 differential ground current magnitude
6500	SRC 6 Igd Angle	Degrees	Source 6 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

Decimal address	FlexAnalog name	Units	Description
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
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

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Decimal address	FlexAnalog name	Units	Description
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
6784	SRC 3 Vag RMS	Volts	Source 3 phase AG voltage RMS
6786	SRC 3 Vbg RMS	Volts	Source 3 phase BG voltage RMS
6788	SRC 3 Vcg RMS	Volts	Source 3 phase CG voltage RMS
6790	SRC 3 Vag Mag	Volts	Source 3 phase AG voltage magnitude
6792	SRC 3 Vag Angle	Degrees	Source 3 phase AG voltage angle
6793	SRC 3 Vbg Mag	Volts	Source 3 phase BG voltage magnitude
6795	SRC 3 Vbg Angle	Degrees	Source 3 phase BG voltage angle
6796	SRC 3 Vcg Mag	Volts	Source 3 phase CG voltage magnitude
6798	SRC 3 Vcg Angle	Degrees	Source 3 phase CG voltage angle
6799	SRC 3 Vab RMS	Volts	Source 3 phase AB voltage RMS
6801	SRC 3 Vbc RMS	Volts	Source 3 phase BC voltage RMS
6803	SRC 3 Vca RMS	Volts	Source 3 phase CA voltage RMS
6805	SRC 3 Vab Mag	Volts	Source 3 phase AB voltage magnitude
6807	SRC 3 Vab Angle	Degrees	Source 3 phase AB voltage angle
6808	SRC 3 Vbc Mag	Volts	Source 3 phase BC voltage magnitude
6810	SRC 3 Vbc Angle	Degrees	Source 3 phase BC voltage angle
6811	SRC 3 Vca Mag	Volts	Source 3 phase CA voltage magnitude
6813	SRC 3 Vca Angle	Degrees	Source 3 phase CA voltage angle
6814	SRC 3 Vx RMS	Volts	Source 3 auxiliary voltage RMS
6816	SRC 3 Vx Mag	Volts	Source 3 auxiliary voltage magnitude
6818	SRC 3 Vx Angle	Degrees	Source 3 auxiliary voltage angle
6819	SRC 3 V_0 Mag	Volts	Source 3 zero-sequence voltage magnitude
6821	SRC 3 V_0 Angle	Degrees	Source 3 zero-sequence voltage angle
6822	SRC 3 V_1 Mag	Volts	Source 3 positive-sequence voltage magnitude
6824	SRC 3 V_1 Angle	Degrees	Source 3 positive-sequence voltage angle
6825	SRC 3 V_2 Mag	Volts	Source 3 negative-sequence voltage magnitude
6827	SRC 3 V_2 Angle	Degrees	Source 3 negative-sequence voltage angle
6848	SRC 4 Vag RMS	Volts	Source 4 phase AG voltage RMS
6850	SRC 4 Vbg RMS	Volts	Source 4 phase BG voltage RMS
6852	SRC 4 Vcg RMS	Volts	Source 4 phase CG voltage RMS
6854	SRC 4 Vag Mag	Volts	Source 4 phase AG voltage magnitude
6856	SRC 4 Vag Angle	Degrees	Source 4 phase AG voltage angle
6857	SRC 4 Vbg Mag	Volts	Source 4 phase BG voltage magnitude
6859	SRC 4 Vbg Angle	Degrees	Source 4 phase BG voltage angle
6860	SRC 4 Vcg Mag	Volts	Source 4 phase CG voltage magnitude
6862	SRC 4 Vcg Angle	Degrees	Source 4 phase CG voltage angle
6863	SRC 4 Vab RMS	Volts	Source 4 phase AB voltage RMS
6865	SRC 4 Vbc RMS	Volts	Source 4 phase BC voltage RMS
6867	SRC 4 Vca RMS	Volts	Source 4 phase CA voltage RMS
6869	SRC 4 Vab Mag	Volts	Source 4 phase AB voltage magnitude
6871	SRC 4 Vab Angle	Degrees	Source 4 phase AB voltage angle
6872	SRC 4 Vbc Mag	Volts	Source 4 phase BC voltage magnitude

Decimal address	FlexAnalog name	Units	Description
6874	SRC 4 Vbc Angle	Degrees	Source 4 phase BC voltage angle
6875	SRC 4 Vca Mag	Volts	Source 4 phase CA voltage magnitude
6877	SRC 4 Vca Angle	Degrees	Source 4 phase CA voltage angle
6878	SRC 4 Vx RMS	Volts	Source 4 auxiliary voltage RMS
6880	SRC 4 Vx Mag	Volts	Source 4 auxiliary voltage magnitude
6882	SRC 4 Vx Angle	Degrees	Source 4 auxiliary voltage angle
6883	SRC 4 V_0 Mag	Volts	Source 4 zero-sequence voltage magnitude
6885	SRC 4 V_0 Angle	Degrees	Source 4 zero-sequence voltage angle
6886	SRC 4 V_1 Mag	Volts	Source 4 positive-sequence voltage magnitude
6888	SRC 4 V_1 Angle	Degrees	Source 4 positive-sequence voltage angle
6889	SRC 4 V_2 Mag	Volts	Source 4 negative-sequence voltage magnitude
6891	SRC 4 V_2 Angle	Degrees	Source 4 negative-sequence voltage angle
6912	SRC 5 Vag RMS	Volts	Source 5 phase AG voltage RMS
6914	SRC 5 Vbg RMS	Volts	Source 5 phase BG voltage RMS
6916	SRC 5 Vcg RMS	Volts	Source 5 phase CG voltage RMS
6918	SRC 5 Vag Mag	Volts	Source 5 phase AG voltage magnitude
6920	SRC 5 Vag Angle	Degrees	Source 5 phase AG voltage angle
6921	SRC 5 Vbg Mag	Volts	Source 5 phase BG voltage magnitude
6923	SRC 5 Vbg Angle	Degrees	Source 5 phase BG voltage angle
6924	SRC 5 Vcg Mag	Volts	Source 5 phase CG voltage magnitude
6926	SRC 5 Vcg Angle	Degrees	Source 5 phase CG voltage angle
6927	SRC 5 Vab RMS	Volts	Source 5 phase AB voltage RMS
6929	SRC 5 Vbc RMS	Volts	Source 5 phase BC voltage RMS
6931	SRC 5 Vca RMS	Volts	Source 5 phase CA voltage RMS
6933	SRC 5 Vab Mag	Volts	Source 5 phase AB voltage magnitude
6935	SRC 5 Vab Angle	Degrees	Source 5 phase AB voltage angle
6936	SRC 5 Vbc Mag	Volts	Source 5 phase BC voltage magnitude
6938	SRC 5 Vbc Angle	Degrees	Source 5 phase BC voltage angle
6939	SRC 5 Vca Mag	Volts	Source 5 phase CA voltage magnitude
6941	SRC 5 Vca Angle	Degrees	Source 5 phase CA voltage angle
6942	SRC 5 Vx RMS	Volts	Source 5 auxiliary voltage RMS
6944	SRC 5 Vx Mag	Volts	Source 5 auxiliary voltage magnitude
6946	SRC 5 Vx Angle	Degrees	Source 5 auxiliary voltage angle
6947	SRC 5 V_0 Mag	Volts	Source 5 zero-sequence voltage magnitude
6949	SRC 5 V_0 Angle	Degrees	Source 5 zero-sequence voltage angle
6950	SRC 5 V_1 Mag	Volts	Source 5 positive-sequence voltage magnitude
6952	SRC 5 V_1 Angle	Degrees	Source 5 positive-sequence voltage angle
6953	SRC 5 V_2 Mag	Volts	Source 5 negative-sequence voltage magnitude
6955	SRC 5 V_2 Angle	Degrees	Source 5 negative-sequence voltage angle
6976	SRC 6 Vag RMS	Volts	Source 6 phase AG voltage RMS
6978	SRC 6 Vbg RMS	Volts	Source 6 phase BG voltage RMS
6980	SRC 6 Vcg RMS	Volts	Source 6 phase CG voltage RMS
6982	SRC 6 Vag Mag	Volts	Source 6 phase AG voltage magnitude
6984	SRC 6 Vag Angle	Degrees	Source 6 phase AG voltage angle
6985	SRC 6 Vbg Mag	Volts	Source 6 phase BG voltage magnitude
6987	SRC 6 Vbg Angle	Degrees	Source 6 phase BG voltage angle

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Decimal address	FlexAnalog name	Units	Description
6988	SRC 6 Vcg Mag	Volts	Source 6 phase CG voltage magnitude
6990	SRC 6 Vcg Angle	Degrees	Source 6 phase CG voltage angle
6991	SRC 6 Vab RMS	Volts	Source 6 phase AB voltage RMS
6993	SRC 6 Vbc RMS	Volts	Source 6 phase BC voltage RMS
6995	SRC 6 Vca RMS	Volts	Source 6 phase CA voltage RMS
6997	SRC 6 Vab Mag	Volts	Source 6 phase AB voltage magnitude
6999	SRC 6 Vab Angle	Degrees	Source 6 phase AB voltage angle
7000	SRC 6 Vbc Mag	Volts	Source 6 phase BC voltage magnitude
7002	SRC 6 Vbc Angle	Degrees	Source 6 phase BC voltage angle
7003	SRC 6 Vca Mag	Volts	Source 6 phase CA voltage magnitude
7005	SRC 6 Vca Angle	Degrees	Source 6 phase CA voltage angle
7006	SRC 6 Vx RMS	Volts	Source 6 auxiliary voltage RMS
7008	SRC 6 Vx Mag	Volts	Source 6 auxiliary voltage magnitude
7010	SRC 6 Vx Angle	Degrees	Source 6 auxiliary voltage angle
7011	SRC 6 V_0 Mag	Volts	Source 6 zero-sequence voltage magnitude
7013	SRC 6 V_0 Angle	Degrees	Source 6 zero-sequence voltage angle
7014	SRC 6 V_1 Mag	Volts	Source 6 positive-sequence voltage magnitude
7016	SRC 6 V_1 Angle	Degrees	Source 6 positive-sequence voltage angle
7017	SRC 6 V_2 Mag	Volts	Source 6 negative-sequence voltage magnitude
7019	SRC 6 V_2 Angle	Degrees	Source 6 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
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

Decimal address	FlexAnalog name	Units	Description
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
7232	SRC 3 P	Watts	Source 3 three-phase real power
7234	SRC 3 Pa	Watts	Source 3 phase A real power
7236	SRC 3 Pb	Watts	Source 3 phase B real power
7238	SRC 3 Pc	Watts	Source 3 phase C real power
7240	SRC 3 Q	Vars	Source 3 three-phase reactive power
7242	SRC 3 Qa	Vars	Source 3 phase A reactive power
7244	SRC 3 Qb	Vars	Source 3 phase B reactive power
7246	SRC 3 Qc	Vars	Source 3 phase C reactive power
7248	SRC 3 S	VA	Source 3 three-phase apparent power
7250	SRC 3 Sa	VA	Source 3 phase A apparent power
7252	SRC 3 Sb	VA	Source 3 phase B apparent power
7254	SRC 3 Sc	VA	Source 3 phase C apparent power
7256	SRC 3 PF	---	Source 3 three-phase power factor
7257	SRC 3 Phase A PF	---	Source 3 phase A power factor
7258	SRC 3 Phase B PF	---	Source 3 phase B power factor
7259	SRC 3 Phase C PF	---	Source 3 phase C power factor
7264	SRC 4 P	Watts	Source 4 three-phase real power
7266	SRC 4 Pa	Watts	Source 4 phase A real power
7268	SRC 4 Pb	Watts	Source 4 phase B real power
7270	SRC 4 Pc	Watts	Source 4 phase C real power
7272	SRC 4 Q	Vars	Source 4 three-phase reactive power
7274	SRC 4 Qa	Vars	Source 4 phase A reactive power
7276	SRC 4 Qb	Vars	Source 4 phase B reactive power
7278	SRC 4 Qc	Vars	Source 4 phase C reactive power
7280	SRC 4 S	VA	Source 4 three-phase apparent power
7282	SRC 4 Sa	VA	Source 4 phase A apparent power
7284	SRC 4 Sb	VA	Source 4 phase B apparent power
7286	SRC 4 Sc	VA	Source 4 phase C apparent power
7288	SRC 4 PF	---	Source 4 three-phase power factor
7289	SRC 4 Phase A PF	---	Source 4 phase A power factor
7290	SRC 4 Phase B PF	---	Source 4 phase B power factor
7291	SRC 4 Phase C PF	---	Source 4 phase C power factor
7296	SRC 5 P	Watts	Source 5 three-phase real power
7298	SRC 5 Pa	Watts	Source 5 phase A real power
7300	SRC 5 Pb	Watts	Source 5 phase B real power
7302	SRC 5 Pc	Watts	Source 5 phase C real power
7304	SRC 5 Q	Vars	Source 5 three-phase reactive power
7306	SRC 5 Qa	Vars	Source 5 phase A reactive power
7308	SRC 5 Qb	Vars	Source 5 phase B reactive power
7310	SRC 5 Qc	Vars	Source 5 phase C reactive power

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Decimal address	FlexAnalog name	Units	Description
7312	SRC 5 S	VA	Source 5 three-phase apparent power
7314	SRC 5 Sa	VA	Source 5 phase A apparent power
7316	SRC 5 Sb	VA	Source 5 phase B apparent power
7318	SRC 5 Sc	VA	Source 5 phase C apparent power
7320	SRC 5 PF	---	Source 5 three-phase power factor
7321	SRC 5 Phase A PF	---	Source 5 phase A power factor
7322	SRC 5 Phase B PF	---	Source 5 phase B power factor
7323	SRC 5 Phase C PF	---	Source 5 phase C power factor
7328	SRC 6 P	Watts	Source 6 three-phase real power
7330	SRC 6 Pa	Watts	Source 6 phase A real power
7332	SRC 6 Pb	Watts	Source 6 phase B real power
7334	SRC 6 Pc	Watts	Source 6 phase C real power
7336	SRC 6 Q	Vars	Source 6 three-phase reactive power
7338	SRC 6 Qa	Vars	Source 6 phase A reactive power
7340	SRC 6 Qb	Vars	Source 6 phase B reactive power
7342	SRC 6 Qc	Vars	Source 6 phase C reactive power
7344	SRC 6 S	VA	Source 6 three-phase apparent power
7346	SRC 6 Sa	VA	Source 6 phase A apparent power
7348	SRC 6 Sb	VA	Source 6 phase B apparent power
7350	SRC 6 Sc	VA	Source 6 phase C apparent power
7352	SRC 6 PF	---	Source 6 three-phase power factor
7353	SRC 6 Phase A PF	---	Source 6 phase A power factor
7354	SRC 6 Phase B PF	---	Source 6 phase B power factor
7355	SRC 6 Phase C PF	---	Source 6 phase C power factor
7552	SRC 1 Frequency	Hz	Source 1 frequency
7554	SRC 2 Frequency	Hz	Source 2 frequency
7556	SRC 3 Frequency	Hz	Source 3 frequency
7558	SRC 4 Frequency	Hz	Source 4 frequency
7560	SRC 5 Frequency	Hz	Source 5 frequency
7562	SRC 6 Frequency	Hz	Source 6 frequency
8064	SRC 1 Va THD	%	Source 1 phase A voltage total harmonic distortion (THD)
8065	SRC 1 Va Harm[2]	%	Source 1 phase A voltage second harmonic
8066	SRC 1 Va Harm[3]	%	Source 1 phase A voltage third harmonic
8067	SRC 1 Va Harm[4]	%	Source 1 phase A voltage fourth harmonic
8068	SRC 1 Va Harm[5]	%	Source 1 phase A voltage fifth harmonic
8069	SRC 1 Va Harm[6]	%	Source 1 phase A voltage sixth harmonic
8070	SRC 1 Va Harm[7]	%	Source 1 phase A voltage seventh harmonic
8071	SRC 1 Va Harm[8]	%	Source 1 phase A voltage eighth harmonic
8072	SRC 1 Va Harm[9]	%	Source 1 phase A voltage ninth harmonic
8073	SRC 1 Va Harm[10]	%	Source 1 phase A voltage tenth harmonic
8074	SRC 1 Va Harm[11]	%	Source 1 phase A voltage eleventh harmonic
8075	SRC 1 Va Harm[12]	%	Source 1 phase A voltage twelfth harmonic
8076	SRC 1 Va Harm[13]	%	Source 1 phase A voltage thirteenth harmonic
8077	SRC 1 Va Harm[14]	%	Source 1 phase A voltage fourteenth harmonic
8078	SRC 1 Va Harm[15]	%	Source 1 phase A voltage fifteenth harmonic
8079	SRC 1 Va Harm[16]	%	Source 1 phase A voltage sixteenth harmonic

Decimal address	FlexAnalog name	Units	Description
8080	SRC 1 Va Harm[17]	%	Source 1 phase A voltage seventeenth harmonic
8081	SRC 1 Va Harm[18]	%	Source 1 phase A voltage eighteenth harmonic
8082	SRC 1 Va Harm[19]	%	Source 1 phase A voltage nineteenth harmonic
8083	SRC 1 Va Harm[20]	%	Source 1 phase A voltage twentieth harmonic
8084	SRC 1 Va Harm[21]	%	Source 1 phase A voltage twenty-first harmonic
8085	SRC 1 Va Harm[22]	%	Source 1 phase A voltage twenty-second harmonic
8086	SRC 1 Va Harm[23]	%	Source 1 phase A voltage twenty-third harmonic
8087	SRC 1 Va Harm[24]	%	Source 1 phase A voltage twenty-fourth harmonic
8088	SRC 1 Va Harm[25]	%	Source 1 phase A voltage twenty-fifth harmonic
8089	SRC 1 Vb THD	%	Source 1 phase B voltage total harmonic distortion (THD)
8090	SRC 1 Vb Harm[2]	%	Source 1 phase B voltage second harmonic
8091	SRC 1 Vb Harm[3]	%	Source 1 phase B voltage third harmonic
8092	SRC 1 Vb Harm[4]	%	Source 1 phase B voltage fourth harmonic
8093	SRC 1 Vb Harm[5]	%	Source 1 phase B voltage fifth harmonic
8094	SRC 1 Vb Harm[6]	%	Source 1 phase B voltage sixth harmonic
8095	SRC 1 Vb Harm[7]	%	Source 1 phase B voltage seventh harmonic
8096	SRC 1 Vb Harm[8]	%	Source 1 phase B voltage eighth harmonic
8097	SRC 1 Vb Harm[9]	%	Source 1 phase B voltage ninth harmonic
8098	SRC 1 Vb Harm[10]	%	Source 1 phase B voltage tenth harmonic
8099	SRC 1 Vb Harm[11]	%	Source 1 phase B voltage eleventh harmonic
8100	SRC 1 Vb Harm[12]	%	Source 1 phase B voltage twelfth harmonic
8101	SRC 1 Vb Harm[13]	%	Source 1 phase B voltage thirteenth harmonic
8102	SRC 1 Vb Harm[14]	%	Source 1 phase B voltage fourteenth harmonic
8103	SRC 1 Vb Harm[15]	%	Source 1 phase B voltage fifteenth harmonic
8104	SRC 1 Vb Harm[16]	%	Source 1 phase B voltage sixteenth harmonic
8105	SRC 1 Vb Harm[17]	%	Source 1 phase B voltage seventeenth harmonic
8106	SRC 1 Vb Harm[18]	%	Source 1 phase B voltage eighteenth harmonic
8107	SRC 1 Vb Harm[19]	%	Source 1 phase B voltage nineteenth harmonic
8108	SRC 1 Vb Harm[20]	%	Source 1 phase B voltage twentieth harmonic
8109	SRC 1 Vb Harm[21]	%	Source 1 phase B voltage twenty-first harmonic
8110	SRC 1 Vb Harm[22]	%	Source 1 phase B voltage twenty-second harmonic
8111	SRC 1 Vb Harm[23]	%	Source 1 phase B voltage twenty-third harmonic
8112	SRC 1 Vb Harm[24]	%	Source 1 phase B voltage twenty-fourth harmonic
8113	SRC 1 Vb Harm[25]	%	Source 1 phase B voltage twenty-fifth harmonic
8114	SRC 1 Vc THD	%	Source 1 phase C voltage total harmonic distortion (THD)
8115	SRC 1 Vc Harm[2]	%	Source 1 phase C voltage second harmonic
8116	SRC 1 Vc Harm[3]	%	Source 1 phase C voltage third harmonic
8117	SRC 1 Vc Harm[4]	%	Source 1 phase C voltage fourth harmonic
8118	SRC 1 Vc Harm[5]	%	Source 1 phase C voltage fifth harmonic
8119	SRC 1 Vc Harm[6]	%	Source 1 phase C voltage sixth harmonic
8120	SRC 1 Vc Harm[7]	%	Source 1 phase C voltage seventh harmonic
8121	SRC 1 Vc Harm[8]	%	Source 1 phase C voltage eighth harmonic
8122	SRC 1 Vc Harm[9]	%	Source 1 phase C voltage ninth harmonic
8123	SRC 1 Vc Harm[10]	%	Source 1 phase C voltage tenth harmonic
8124	SRC 1 Vc Harm[11]	%	Source 1 phase C voltage eleventh harmonic
8125	SRC 1 Vc Harm[12]	%	Source 1 phase C voltage twelfth harmonic

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Decimal address	FlexAnalog name	Units	Description
8126	SRC 1 Vc Harm[13]	%	Source 1 phase C voltage thirteenth harmonic
8127	SRC 1 Vc Harm[14]	%	Source 1 phase C voltage fourteenth harmonic
8128	SRC 1 Vc Harm[15]	%	Source 1 phase C voltage fifteenth harmonic
8129	SRC 1 Vc Harm[16]	%	Source 1 phase C voltage sixteenth harmonic
8130	SRC 1 Vc Harm[17]	%	Source 1 phase C voltage seventeenth harmonic
8131	SRC 1 Vc Harm[18]	%	Source 1 phase C voltage eighteenth harmonic
8132	SRC 1 Vc Harm[19]	%	Source 1 phase C voltage nineteenth harmonic
8133	SRC 1 Vc Harm[20]	%	Source 1 phase C voltage twentieth harmonic
8134	SRC 1 Vc Harm[21]	%	Source 1 phase C voltage twenty-first harmonic
8135	SRC 1 Vc Harm[22]	%	Source 1 phase C voltage twenty-second harmonic
8136	SRC 1 Vc Harm[23]	%	Source 1 phase C voltage twenty-third harmonic
8137	SRC 1 Vc Harm[24]	%	Source 1 phase C voltage twenty-fourth harmonic
8138	SRC 1 Vc Harm[25]	%	Source 1 phase C voltage twenty-fifth harmonic
8139	SRC 2 Va THD	%	Source 2 phase A voltage total harmonic distortion (THD)
8140	SRC 2 Va Harm[2]	%	Source 2 phase A voltage second harmonic
8141	SRC 2 Va Harm[3]	%	Source 2 phase A voltage third harmonic
8142	SRC 2 Va Harm[4]	%	Source 2 phase A voltage fourth harmonic
8143	SRC 2 Va Harm[5]	%	Source 2 phase A voltage fifth harmonic
8144	SRC 2 Va Harm[6]	%	Source 2 phase A voltage sixth harmonic
8145	SRC 2 Va Harm[7]	%	Source 2 phase A voltage seventh harmonic
8146	SRC 2 Va Harm[8]	%	Source 2 phase A voltage eighth harmonic
8147	SRC 2 Va Harm[9]	%	Source 2 phase A voltage ninth harmonic
8148	SRC 2 Va Harm[10]	%	Source 2 phase A voltage tenth harmonic
8149	SRC 2 Va Harm[11]	%	Source 2 phase A voltage eleventh harmonic
8150	SRC 2 Va Harm[12]	%	Source 2 phase A voltage twelfth harmonic
8151	SRC 2 Va Harm[13]	%	Source 2 phase A voltage thirteenth harmonic
8152	SRC 2 Va Harm[14]	%	Source 2 phase A voltage fourteenth harmonic
8153	SRC 2 Va Harm[15]	%	Source 2 phase A voltage fifteenth harmonic
8154	SRC 2 Va Harm[16]	%	Source 2 phase A voltage sixteenth harmonic
8155	SRC 2 Va Harm[17]	%	Source 2 phase A voltage seventeenth harmonic
8156	SRC 2 Va Harm[18]	%	Source 2 phase A voltage eighteenth harmonic
8157	SRC 2 Va Harm[19]	%	Source 2 phase A voltage nineteenth harmonic
8158	SRC 2 Va Harm[20]	%	Source 2 phase A voltage twentieth harmonic
8159	SRC 2 Va Harm[21]	%	Source 2 phase A voltage twenty-first harmonic
8160	SRC 2 Va Harm[22]	%	Source 2 phase A voltage twenty-second harmonic
8161	SRC 2 Va Harm[23]	%	Source 2 phase A voltage twenty-third harmonic
8162	SRC 2 Va Harm[24]	%	Source 2 phase A voltage twenty-fourth harmonic
8163	SRC 2 Va Harm[25]	%	Source 2 phase A voltage twenty-fifth harmonic
8164	SRC 2 Vb THD	%	Source 2 phase B voltage total harmonic distortion (THD)
8165	SRC 2 Vb Harm[2]	%	Source 2 phase B voltage second harmonic
8166	SRC 2 Vb Harm[3]	%	Source 2 phase B voltage third harmonic
8167	SRC 2 Vb Harm[4]	%	Source 2 phase B voltage fourth harmonic
8168	SRC 2 Vb Harm[5]	%	Source 2 phase B voltage fifth harmonic
8169	SRC 2 Vb Harm[6]	%	Source 2 phase B voltage sixth harmonic
8170	SRC 2 Vb Harm[7]	%	Source 2 phase B voltage seventh harmonic
8171	SRC 2 Vb Harm[8]	%	Source 2 phase B voltage eighth harmonic

Decimal address	FlexAnalog name	Units	Description
8172	SRC 2 Vb Harm[9]	%	Source 2 phase B voltage ninth harmonic
8173	SRC 2 Vb Harm[10]	%	Source 2 phase B voltage tenth harmonic
8174	SRC 2 Vb Harm[11]	%	Source 2 phase B voltage eleventh harmonic
8175	SRC 2 Vb Harm[12]	%	Source 2 phase B voltage twelfth harmonic
8176	SRC 2 Vb Harm[13]	%	Source 2 phase B voltage thirteenth harmonic
8177	SRC 2 Vb Harm[14]	%	Source 2 phase B voltage fourteenth harmonic
8178	SRC 2 Vb Harm[15]	%	Source 2 phase B voltage fifteenth harmonic
8179	SRC 2 Vb Harm[16]	%	Source 2 phase B voltage sixteenth harmonic
8180	SRC 2 Vb Harm[17]	%	Source 2 phase B voltage seventeenth harmonic
8181	SRC 2 Vb Harm[18]	%	Source 2 phase B voltage eighteenth harmonic
8182	SRC 2 Vb Harm[19]	%	Source 2 phase B voltage nineteenth harmonic
8183	SRC 2 Vb Harm[20]	%	Source 2 phase B voltage twentieth harmonic
8184	SRC 2 Vb Harm[21]	%	Source 2 phase B voltage twenty-first harmonic
8185	SRC 2 Vb Harm[22]	%	Source 2 phase B voltage twenty-second harmonic
8186	SRC 2 Vb Harm[23]	%	Source 2 phase B voltage twenty-third harmonic
8187	SRC 2 Vb Harm[24]	%	Source 2 phase B voltage twenty-fourth harmonic
8188	SRC 2 Vb Harm[25]	%	Source 2 phase B voltage twenty-fifth harmonic
8189	SRC 2 Vc THD	%	Source 2 phase C voltage total harmonic distortion (THD)
8190	SRC 2 Vc Harm[2]	%	Source 2 phase C voltage second harmonic
8191	SRC 2 Vc Harm[3]	%	Source 2 phase C voltage third harmonic
8192	SRC 2 Vc Harm[4]	%	Source 2 phase C voltage fourth harmonic
8193	SRC 2 Vc Harm[5]	%	Source 2 phase C voltage fifth harmonic
8194	SRC 2 Vc Harm[6]	%	Source 2 phase C voltage sixth harmonic
8195	SRC 2 Vc Harm[7]	%	Source 2 phase C voltage seventh harmonic
8196	SRC 2 Vc Harm[8]	%	Source 2 phase C voltage eighth harmonic
8197	SRC 2 Vc Harm[9]	%	Source 2 phase C voltage ninth harmonic
8198	SRC 2 Vc Harm[10]	%	Source 2 phase C voltage tenth harmonic
8199	SRC 2 Vc Harm[11]	%	Source 2 phase C voltage eleventh harmonic
8200	SRC 2 Vc Harm[12]	%	Source 2 phase C voltage twelfth harmonic
8201	SRC 2 Vc Harm[13]	%	Source 2 phase C voltage thirteenth harmonic
8202	SRC 2 Vc Harm[14]	%	Source 2 phase C voltage fourteenth harmonic
8203	SRC 2 Vc Harm[15]	%	Source 2 phase C voltage fifteenth harmonic
8204	SRC 2 Vc Harm[16]	%	Source 2 phase C voltage sixteenth harmonic
8205	SRC 2 Vc Harm[17]	%	Source 2 phase C voltage seventeenth harmonic
8206	SRC 2 Vc Harm[18]	%	Source 2 phase C voltage eighteenth harmonic
8207	SRC 2 Vc Harm[19]	%	Source 2 phase C voltage nineteenth harmonic
8208	SRC 2 Vc Harm[20]	%	Source 2 phase C voltage twentieth harmonic
8209	SRC 2 Vc Harm[21]	%	Source 2 phase C voltage twenty-first harmonic
8210	SRC 2 Vc Harm[22]	%	Source 2 phase C voltage twenty-second harmonic
8211	SRC 2 Vc Harm[23]	%	Source 2 phase C voltage twenty-third harmonic
8212	SRC 2 Vc Harm[24]	%	Source 2 phase C voltage twenty-fourth harmonic
8213	SRC 2 Vc Harm[25]	%	Source 2 phase C voltage twenty-fifth harmonic
8214	SRC 3 Va THD	%	Source 3 phase A voltage total harmonic distortion (THD)
8215	SRC 3 Va Harm[2]	%	Source 3 phase A voltage second harmonic
8216	SRC 3 Va Harm[3]	%	Source 3 phase A voltage third harmonic
8217	SRC 3 Va Harm[4]	%	Source 3 phase A voltage fourth harmonic

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Decimal address	FlexAnalog name	Units	Description
8218	SRC 3 Va Harm[5]	%	Source 3 phase A voltage fifth harmonic
8219	SRC 3 Va Harm[6]	%	Source 3 phase A voltage sixth harmonic
8220	SRC 3 Va Harm[7]	%	Source 3 phase A voltage seventh harmonic
8221	SRC 3 Va Harm[8]	%	Source 3 phase A voltage eighth harmonic
8222	SRC 3 Va Harm[9]	%	Source 3 phase A voltage ninth harmonic
8223	SRC 3 Va Harm[10]	%	Source 3 phase A voltage tenth harmonic
8224	SRC 3 Va Harm[11]	%	Source 3 phase A voltage eleventh harmonic
8225	SRC 3 Va Harm[12]	%	Source 3 phase A voltage twelfth harmonic
8226	SRC 3 Va Harm[13]	%	Source 3 phase A voltage thirteenth harmonic
8227	SRC 3 Va Harm[14]	%	Source 3 phase A voltage fourteenth harmonic
8228	SRC 3 Va Harm[15]	%	Source 3 phase A voltage fifteenth harmonic
8229	SRC 3 Va Harm[16]	%	Source 3 phase A voltage sixteenth harmonic
8230	SRC 3 Va Harm[17]	%	Source 3 phase A voltage seventeenth harmonic
8231	SRC 3 Va Harm[18]	%	Source 3 phase A voltage eighteenth harmonic
8232	SRC 3 Va Harm[19]	%	Source 3 phase A voltage nineteenth harmonic
8233	SRC 3 Va Harm[20]	%	Source 3 phase A voltage twentieth harmonic
8234	SRC 3 Va Harm[21]	%	Source 3 phase A voltage twenty-first harmonic
8235	SRC 3 Va Harm[22]	%	Source 3 phase A voltage twenty-second harmonic
8236	SRC 3 Va Harm[23]	%	Source 3 phase A voltage twenty-third harmonic
8237	SRC 3 Va Harm[24]	%	Source 3 phase A voltage twenty-fourth harmonic
8238	SRC 3 Va Harm[25]	%	Source 3 phase A voltage twenty-fifth harmonic
8239	SRC 3 Vb THD	%	Source 3 phase B voltage total harmonic distortion (THD)
8240	SRC 3 Vb Harm[2]	%	Source 3 phase B voltage second harmonic
8241	SRC 3 Vb Harm[3]	%	Source 3 phase B voltage third harmonic
8242	SRC 3 Vb Harm[4]	%	Source 3 phase B voltage fourth harmonic
8243	SRC 3 Vb Harm[5]	%	Source 3 phase B voltage fifth harmonic
8244	SRC 3 Vb Harm[6]	%	Source 3 phase B voltage sixth harmonic
8245	SRC 3 Vb Harm[7]	%	Source 3 phase B voltage seventh harmonic
8246	SRC 3 Vb Harm[8]	%	Source 3 phase B voltage eighth harmonic
8247	SRC 3 Vb Harm[9]	%	Source 3 phase B voltage ninth harmonic
8248	SRC 3 Vb Harm[10]	%	Source 3 phase B voltage tenth harmonic
8249	SRC 3 Vb Harm[11]	%	Source 3 phase B voltage eleventh harmonic
8250	SRC 3 Vb Harm[12]	%	Source 3 phase B voltage twelfth harmonic
8251	SRC 3 Vb Harm[13]	%	Source 3 phase B voltage thirteenth harmonic
8252	SRC 3 Vb Harm[14]	%	Source 3 phase B voltage fourteenth harmonic
8253	SRC 3 Vb Harm[15]	%	Source 3 phase B voltage fifteenth harmonic
8254	SRC 3 Vb Harm[16]	%	Source 3 phase B voltage sixteenth harmonic
8255	SRC 3 Vb Harm[17]	%	Source 3 phase B voltage seventeenth harmonic
8256	SRC 3 Vb Harm[18]	%	Source 3 phase B voltage eighteenth harmonic
8257	SRC 3 Vb Harm[19]	%	Source 3 phase B voltage nineteenth harmonic
8258	SRC 3 Vb Harm[20]	%	Source 3 phase B voltage twentieth harmonic
8259	SRC 3 Vb Harm[21]	%	Source 3 phase B voltage twenty-first harmonic
8260	SRC 3 Vb Harm[22]	%	Source 3 phase B voltage twenty-second harmonic
8261	SRC 3 Vb Harm[23]	%	Source 3 phase B voltage twenty-third harmonic
8262	SRC 3 Vb Harm[24]	%	Source 3 phase B voltage twenty-fourth harmonic
8263	SRC 3 Vb Harm[25]	%	Source 3 phase B voltage twenty-fifth harmonic

Decimal address	FlexAnalog name	Units	Description
8264	SRC 3 Vc THD	%	Source 3 phase C voltage total harmonic distortion (THD)
8265	SRC 3 Vc Harm[2]	%	Source 3 phase C voltage second harmonic
8266	SRC 3 Vc Harm[3]	%	Source 3 phase C voltage third harmonic
8267	SRC 3 Vc Harm[4]	%	Source 3 phase C voltage fourth harmonic
8268	SRC 3 Vc Harm[5]	%	Source 3 phase C voltage fifth harmonic
8269	SRC 3 Vc Harm[6]	%	Source 3 phase C voltage sixth harmonic
8270	SRC 3 Vc Harm[7]	%	Source 3 phase C voltage seventh harmonic
8271	SRC 3 Vc Harm[8]	%	Source 3 phase C voltage eighth harmonic
8272	SRC 3 Vc Harm[9]	%	Source 3 phase C voltage ninth harmonic
8273	SRC 3 Vc Harm[10]	%	Source 3 phase C voltage tenth harmonic
8274	SRC 3 Vc Harm[11]	%	Source 3 phase C voltage eleventh harmonic
8275	SRC 3 Vc Harm[12]	%	Source 3 phase C voltage twelfth harmonic
8276	SRC 3 Vc Harm[13]	%	Source 3 phase C voltage thirteenth harmonic
8277	SRC 3 Vc Harm[14]	%	Source 3 phase C voltage fourteenth harmonic
8278	SRC 3 Vc Harm[15]	%	Source 3 phase C voltage fifteenth harmonic
8279	SRC 3 Vc Harm[16]	%	Source 3 phase C voltage sixteenth harmonic
8280	SRC 3 Vc Harm[17]	%	Source 3 phase C voltage seventeenth harmonic
8281	SRC 3 Vc Harm[18]	%	Source 3 phase C voltage eighteenth harmonic
8282	SRC 3 Vc Harm[19]	%	Source 3 phase C voltage nineteenth harmonic
8283	SRC 3 Vc Harm[20]	%	Source 3 phase C voltage twentieth harmonic
8284	SRC 3 Vc Harm[21]	%	Source 3 phase C voltage twenty-first harmonic
8285	SRC 3 Vc Harm[22]	%	Source 3 phase C voltage twenty-second harmonic
8286	SRC 3 Vc Harm[23]	%	Source 3 phase C voltage twenty-third harmonic
8287	SRC 3 Vc Harm[24]	%	Source 3 phase C voltage twenty-fourth harmonic
8288	SRC 3 Vc Harm[25]	%	Source 3 phase C voltage twenty-fifth harmonic
8289	SRC 4 Va THD	%	Source 4 phase A voltage total harmonic distortion (THD)
8290	SRC 4 Va Harm[2]	%	Source 4 phase A voltage second harmonic
8291	SRC 4 Va Harm[3]	%	Source 4 phase A voltage third harmonic
8292	SRC 4 Va Harm[4]	%	Source 4 phase A voltage fourth harmonic
8293	SRC 4 Va Harm[5]	%	Source 4 phase A voltage fifth harmonic
8294	SRC 4 Va Harm[6]	%	Source 4 phase A voltage sixth harmonic
8295	SRC 4 Va Harm[7]	%	Source 4 phase A voltage seventh harmonic
8296	SRC 4 Va Harm[8]	%	Source 4 phase A voltage eighth harmonic
8297	SRC 4 Va Harm[9]	%	Source 4 phase A voltage ninth harmonic
8298	SRC 4 Va Harm[10]	%	Source 4 phase A voltage tenth harmonic
8299	SRC 4 Va Harm[11]	%	Source 4 phase A voltage eleventh harmonic
8300	SRC 4 Va Harm[12]	%	Source 4 phase A voltage twelfth harmonic
8301	SRC 4 Va Harm[13]	%	Source 4 phase A voltage thirteenth harmonic
8302	SRC 4 Va Harm[14]	%	Source 4 phase A voltage fourteenth harmonic
8303	SRC 4 Va Harm[15]	%	Source 4 phase A voltage fifteenth harmonic
8304	SRC 4 Va Harm[16]	%	Source 4 phase A voltage sixteenth harmonic
8305	SRC 4 Va Harm[17]	%	Source 4 phase A voltage seventeenth harmonic
8306	SRC 4 Va Harm[18]	%	Source 4 phase A voltage eighteenth harmonic
8307	SRC 4 Va Harm[19]	%	Source 4 phase A voltage nineteenth harmonic
8308	SRC 4 Va Harm[20]	%	Source 4 phase A voltage twentieth harmonic
8309	SRC 4 Va Harm[21]	%	Source 4 phase A voltage twenty-first harmonic

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Decimal address	FlexAnalog name	Units	Description
8310	SRC 4 Va Harm[22]	%	Source 4 phase A voltage twenty-second harmonic
8311	SRC 4 Va Harm[23]	%	Source 4 phase A voltage twenty-third harmonic
8312	SRC 4 Va Harm[24]	%	Source 4 phase A voltage twenty-fourth harmonic
8313	SRC 4 Va Harm[25]	%	Source 4 phase A voltage twenty-fifth harmonic
8314	SRC 4 Vb THD	%	Source 4 phase B voltage total harmonic distortion (THD)
8315	SRC 4 Vb Harm[2]	%	Source 4 phase B voltage second harmonic
8316	SRC 4 Vb Harm[3]	%	Source 4 phase B voltage third harmonic
8317	SRC 4 Vb Harm[4]	%	Source 4 phase B voltage fourth harmonic
8318	SRC 4 Vb Harm[5]	%	Source 4 phase B voltage fifth harmonic
8319	SRC 4 Vb Harm[6]	%	Source 4 phase B voltage sixth harmonic
8320	SRC 4 Vb Harm[7]	%	Source 4 phase B voltage seventh harmonic
8321	SRC 4 Vb Harm[8]	%	Source 4 phase B voltage eighth harmonic
8322	SRC 4 Vb Harm[9]	%	Source 4 phase B voltage ninth harmonic
8323	SRC 4 Vb Harm[10]	%	Source 4 phase B voltage tenth harmonic
8324	SRC 4 Vb Harm[11]	%	Source 4 phase B voltage eleventh harmonic
8325	SRC 4 Vb Harm[12]	%	Source 4 phase B voltage twelfth harmonic
8326	SRC 4 Vb Harm[13]	%	Source 4 phase B voltage thirteenth harmonic
8327	SRC 4 Vb Harm[14]	%	Source 4 phase B voltage fourteenth harmonic
8328	SRC 4 Vb Harm[15]	%	Source 4 phase B voltage fifteenth harmonic
8329	SRC 4 Vb Harm[16]	%	Source 4 phase B voltage sixteenth harmonic
8330	SRC 4 Vb Harm[17]	%	Source 4 phase B voltage seventeenth harmonic
8331	SRC 4 Vb Harm[18]	%	Source 4 phase B voltage eighteenth harmonic
8332	SRC 4 Vb Harm[19]	%	Source 4 phase B voltage nineteenth harmonic
8333	SRC 4 Vb Harm[20]	%	Source 4 phase B voltage twentieth harmonic
8334	SRC 4 Vb Harm[21]	%	Source 4 phase B voltage twenty-first harmonic
8335	SRC 4 Vb Harm[22]	%	Source 4 phase B voltage twenty-second harmonic
8336	SRC 4 Vb Harm[23]	%	Source 4 phase B voltage twenty-third harmonic
8337	SRC 4 Vb Harm[24]	%	Source 4 phase B voltage twenty-fourth harmonic
8338	SRC 4 Vb Harm[25]	%	Source 4 phase B voltage twenty-fifth harmonic
8339	SRC 4 Vc THD	%	Source 4 phase C voltage total harmonic distortion (THD)
8340	SRC 4 Vc Harm[2]	%	Source 4 phase C voltage second harmonic
8341	SRC 4 Vc Harm[3]	%	Source 4 phase C voltage third harmonic
8342	SRC 4 Vc Harm[4]	%	Source 4 phase C voltage fourth harmonic
8343	SRC 4 Vc Harm[5]	%	Source 4 phase C voltage fifth harmonic
8344	SRC 4 Vc Harm[6]	%	Source 4 phase C voltage sixth harmonic
8345	SRC 4 Vc Harm[7]	%	Source 4 phase C voltage seventh harmonic
8346	SRC 4 Vc Harm[8]	%	Source 4 phase C voltage eighth harmonic
8347	SRC 4 Vc Harm[9]	%	Source 4 phase C voltage ninth harmonic
8348	SRC 4 Vc Harm[10]	%	Source 4 phase C voltage tenth harmonic
8349	SRC 4 Vc Harm[11]	%	Source 4 phase C voltage eleventh harmonic
8350	SRC 4 Vc Harm[12]	%	Source 4 phase C voltage twelfth harmonic
8351	SRC 4 Vc Harm[13]	%	Source 4 phase C voltage thirteenth harmonic
8352	SRC 4 Vc Harm[14]	%	Source 4 phase C voltage fourteenth harmonic
8353	SRC 4 Vc Harm[15]	%	Source 4 phase C voltage fifteenth harmonic
8354	SRC 4 Vc Harm[16]	%	Source 4 phase C voltage sixteenth harmonic
8355	SRC 4 Vc Harm[17]	%	Source 4 phase C voltage seventeenth harmonic

Decimal address	FlexAnalog name	Units	Description
8356	SRC 4 Vc Harm[18]	%	Source 4 phase C voltage eighteenth harmonic
8357	SRC 4 Vc Harm[19]	%	Source 4 phase C voltage nineteenth harmonic
8358	SRC 4 Vc Harm[20]	%	Source 4 phase C voltage twentieth harmonic
8359	SRC 4 Vc Harm[21]	%	Source 4 phase C voltage twenty-first harmonic
8360	SRC 4 Vc Harm[22]	%	Source 4 phase C voltage twenty-second harmonic
8361	SRC 4 Vc Harm[23]	%	Source 4 phase C voltage twenty-third harmonic
8362	SRC 4 Vc Harm[24]	%	Source 4 phase C voltage twenty-fourth harmonic
8363	SRC 4 Vc Harm[25]	%	Source 4 phase C voltage twenty-fifth harmonic
8364	SRC 5 Va THD	%	Source 5 phase A voltage total harmonic distortion (THD)
8365	SRC 5 Va Harm[2]	%	Source 5 phase A voltage second harmonic
8366	SRC 5 Va Harm[3]	%	Source 5 phase A voltage third harmonic
8367	SRC 5 Va Harm[4]	%	Source 5 phase A voltage fourth harmonic
8368	SRC 5 Va Harm[5]	%	Source 5 phase A voltage fifth harmonic
8369	SRC 5 Va Harm[6]	%	Source 5 phase A voltage sixth harmonic
8370	SRC 5 Va Harm[7]	%	Source 5 phase A voltage seventh harmonic
8371	SRC 5 Va Harm[8]	%	Source 5 phase A voltage eighth harmonic
8372	SRC 5 Va Harm[9]	%	Source 5 phase A voltage ninth harmonic
8373	SRC 5 Va Harm[10]	%	Source 5 phase A voltage tenth harmonic
8374	SRC 5 Va Harm[11]	%	Source 5 phase A voltage eleventh harmonic
8375	SRC 5 Va Harm[12]	%	Source 5 phase A voltage twelfth harmonic
8376	SRC 5 Va Harm[13]	%	Source 5 phase A voltage thirteenth harmonic
8377	SRC 5 Va Harm[14]	%	Source 5 phase A voltage fourteenth harmonic
8378	SRC 5 Va Harm[15]	%	Source 5 phase A voltage fifteenth harmonic
8379	SRC 5 Va Harm[16]	%	Source 5 phase A voltage sixteenth harmonic
8380	SRC 5 Va Harm[17]	%	Source 5 phase A voltage seventeenth harmonic
8381	SRC 5 Va Harm[18]	%	Source 5 phase A voltage eighteenth harmonic
8382	SRC 5 Va Harm[19]	%	Source 5 phase A voltage nineteenth harmonic
8383	SRC 5 Va Harm[20]	%	Source 5 phase A voltage twentieth harmonic
8384	SRC 5 Va Harm[21]	%	Source 5 phase A voltage twenty-first harmonic
8385	SRC 5 Va Harm[22]	%	Source 5 phase A voltage twenty-second harmonic
8386	SRC 5 Va Harm[23]	%	Source 5 phase A voltage twenty-third harmonic
8387	SRC 5 Va Harm[24]	%	Source 5 phase A voltage twenty-fourth harmonic
8388	SRC 5 Va Harm[25]	%	Source 5 phase A voltage twenty-fifth harmonic
8389	SRC 5 Vb THD	%	Source 5 phase B voltage total harmonic distortion (THD)
8390	SRC 5 Vb Harm[2]	%	Source 5 phase B voltage second harmonic
8391	SRC 5 Vb Harm[3]	%	Source 5 phase B voltage third harmonic
8392	SRC 5 Vb Harm[4]	%	Source 5 phase B voltage fourth harmonic
8393	SRC 5 Vb Harm[5]	%	Source 5 phase B voltage fifth harmonic
8394	SRC 5 Vb Harm[6]	%	Source 5 phase B voltage sixth harmonic
8395	SRC 5 Vb Harm[7]	%	Source 5 phase B voltage seventh harmonic
8396	SRC 5 Vb Harm[8]	%	Source 5 phase B voltage eighth harmonic
8397	SRC 5 Vb Harm[9]	%	Source 5 phase B voltage ninth harmonic
8398	SRC 5 Vb Harm[10]	%	Source 5 phase B voltage tenth harmonic
8399	SRC 5 Vb Harm[11]	%	Source 5 phase B voltage eleventh harmonic
8400	SRC 5 Vb Harm[12]	%	Source 5 phase B voltage twelfth harmonic
8401	SRC 5 Vb Harm[13]	%	Source 5 phase B voltage thirteenth harmonic

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Decimal address	FlexAnalog name	Units	Description
8402	SRC 5 Vb Harm[14]	%	Source 5 phase B voltage fourteenth harmonic
8403	SRC 5 Vb Harm[15]	%	Source 5 phase B voltage fifteenth harmonic
8404	SRC 5 Vb Harm[16]	%	Source 5 phase B voltage sixteenth harmonic
8405	SRC 5 Vb Harm[17]	%	Source 5 phase B voltage seventeenth harmonic
8406	SRC 5 Vb Harm[18]	%	Source 5 phase B voltage eighteenth harmonic
8407	SRC 5 Vb Harm[19]	%	Source 5 phase B voltage nineteenth harmonic
8408	SRC 5 Vb Harm[20]	%	Source 5 phase B voltage twentieth harmonic
8409	SRC 5 Vb Harm[21]	%	Source 5 phase B voltage twenty-first harmonic
8410	SRC 5 Vb Harm[22]	%	Source 5 phase B voltage twenty-second harmonic
8411	SRC 5 Vb Harm[23]	%	Source 5 phase B voltage twenty-third harmonic
8412	SRC 5 Vb Harm[24]	%	Source 5 phase B voltage twenty-fourth harmonic
8413	SRC 5 Vb Harm[25]	%	Source 5 phase B voltage twenty-fifth harmonic
8414	SRC 5 Vc THD	%	Source 5 phase C voltage total harmonic distortion (THD)
8415	SRC 5 Vc Harm[2]	%	Source 5 phase C voltage second harmonic
8416	SRC 5 Vc Harm[3]	%	Source 5 phase C voltage third harmonic
8417	SRC 5 Vc Harm[4]	%	Source 5 phase C voltage fourth harmonic
8418	SRC 5 Vc Harm[5]	%	Source 5 phase C voltage fifth harmonic
8419	SRC 5 Vc Harm[6]	%	Source 5 phase C voltage sixth harmonic
8420	SRC 5 Vc Harm[7]	%	Source 5 phase C voltage seventh harmonic
8421	SRC 5 Vc Harm[8]	%	Source 5 phase C voltage eighth harmonic
8422	SRC 5 Vc Harm[9]	%	Source 5 phase C voltage ninth harmonic
8423	SRC 5 Vc Harm[10]	%	Source 5 phase C voltage tenth harmonic
8424	SRC 5 Vc Harm[11]	%	Source 5 phase C voltage eleventh harmonic
8425	SRC 5 Vc Harm[12]	%	Source 5 phase C voltage twelfth harmonic
8426	SRC 5 Vc Harm[13]	%	Source 5 phase C voltage thirteenth harmonic
8427	SRC 5 Vc Harm[14]	%	Source 5 phase C voltage fourteenth harmonic
8428	SRC 5 Vc Harm[15]	%	Source 5 phase C voltage fifteenth harmonic
8429	SRC 5 Vc Harm[16]	%	Source 5 phase C voltage sixteenth harmonic
8430	SRC 5 Vc Harm[17]	%	Source 5 phase C voltage seventeenth harmonic
8431	SRC 5 Vc Harm[18]	%	Source 5 phase C voltage eighteenth harmonic
8432	SRC 5 Vc Harm[19]	%	Source 5 phase C voltage nineteenth harmonic
8433	SRC 5 Vc Harm[20]	%	Source 5 phase C voltage twentieth harmonic
8434	SRC 5 Vc Harm[21]	%	Source 5 phase C voltage twenty-first harmonic
8435	SRC 5 Vc Harm[22]	%	Source 5 phase C voltage twenty-second harmonic
8436	SRC 5 Vc Harm[23]	%	Source 5 phase C voltage twenty-third harmonic
8437	SRC 5 Vc Harm[24]	%	Source 5 phase C voltage twenty-fourth harmonic
8438	SRC 5 Vc Harm[25]	%	Source 5 phase C voltage twenty-fifth harmonic
8439	SRC 6 Va THD	%	Source 6 phase A voltage total harmonic distortion (THD)
8440	SRC 6 Va Harm[2]	%	Source 6 phase A voltage second harmonic
8441	SRC 6 Va Harm[3]	%	Source 6 phase A voltage third harmonic
8442	SRC 6 Va Harm[4]	%	Source 6 phase A voltage fourth harmonic
8443	SRC 6 Va Harm[5]	%	Source 6 phase A voltage fifth harmonic
8444	SRC 6 Va Harm[6]	%	Source 6 phase A voltage sixth harmonic
8445	SRC 6 Va Harm[7]	%	Source 6 phase A voltage seventh harmonic
8446	SRC 6 Va Harm[8]	%	Source 6 phase A voltage eighth harmonic
8447	SRC 6 Va Harm[9]	%	Source 6 phase A voltage ninth harmonic

Decimal address	FlexAnalog name	Units	Description
8448	SRC 6 Va Harm[10]	%	Source 6 phase A voltage tenth harmonic
8449	SRC 6 Va Harm[11]	%	Source 6 phase A voltage eleventh harmonic
8450	SRC 6 Va Harm[12]	%	Source 6 phase A voltage twelfth harmonic
8451	SRC 6 Va Harm[13]	%	Source 6 phase A voltage thirteenth harmonic
8452	SRC 6 Va Harm[14]	%	Source 6 phase A voltage fourteenth harmonic
8453	SRC 6 Va Harm[15]	%	Source 6 phase A voltage fifteenth harmonic
8454	SRC 6 Va Harm[16]	%	Source 6 phase A voltage sixteenth harmonic
8455	SRC 6 Va Harm[17]	%	Source 6 phase A voltage seventeenth harmonic
8456	SRC 6 Va Harm[18]	%	Source 6 phase A voltage eighteenth harmonic
8457	SRC 6 Va Harm[19]	%	Source 6 phase A voltage nineteenth harmonic
8458	SRC 6 Va Harm[20]	%	Source 6 phase A voltage twentieth harmonic
8459	SRC 6 Va Harm[21]	%	Source 6 phase A voltage twenty-first harmonic
8460	SRC 6 Va Harm[22]	%	Source 6 phase A voltage twenty-second harmonic
8461	SRC 6 Va Harm[23]	%	Source 6 phase A voltage twenty-third harmonic
8462	SRC 6 Va Harm[24]	%	Source 6 phase A voltage twenty-fourth harmonic
8463	SRC 6 Va Harm[25]	%	Source 6 phase A voltage twenty-fifth harmonic
8464	SRC 6 Vb THD	%	Source 6 phase B voltage total harmonic distortion (THD)
8465	SRC 6 Vb Harm[2]	%	Source 6 phase B voltage second harmonic
8466	SRC 6 Vb Harm[3]	%	Source 6 phase B voltage third harmonic
8467	SRC 6 Vb Harm[4]	%	Source 6 phase B voltage fourth harmonic
8468	SRC 6 Vb Harm[5]	%	Source 6 phase B voltage fifth harmonic
8469	SRC 6 Vb Harm[6]	%	Source 6 phase B voltage sixth harmonic
8470	SRC 6 Vb Harm[7]	%	Source 6 phase B voltage seventh harmonic
8471	SRC 6 Vb Harm[8]	%	Source 6 phase B voltage eighth harmonic
8472	SRC 6 Vb Harm[9]	%	Source 6 phase B voltage ninth harmonic
8473	SRC 6 Vb Harm[10]	%	Source 6 phase B voltage tenth harmonic
8474	SRC 6 Vb Harm[11]	%	Source 6 phase B voltage eleventh harmonic
8475	SRC 6 Vb Harm[12]	%	Source 6 phase B voltage twelfth harmonic
8476	SRC 6 Vb Harm[13]	%	Source 6 phase B voltage thirteenth harmonic
8477	SRC 6 Vb Harm[14]	%	Source 6 phase B voltage fourteenth harmonic
8478	SRC 6 Vb Harm[15]	%	Source 6 phase B voltage fifteenth harmonic
8479	SRC 6 Vb Harm[16]	%	Source 6 phase B voltage sixteenth harmonic
8480	SRC 6 Vb Harm[17]	%	Source 6 phase B voltage seventeenth harmonic
8481	SRC 6 Vb Harm[18]	%	Source 6 phase B voltage eighteenth harmonic
8482	SRC 6 Vb Harm[19]	%	Source 6 phase B voltage nineteenth harmonic
8483	SRC 6 Vb Harm[20]	%	Source 6 phase B voltage twentieth harmonic
8484	SRC 6 Vb Harm[21]	%	Source 6 phase B voltage twenty-first harmonic
8485	SRC 6 Vb Harm[22]	%	Source 6 phase B voltage twenty-second harmonic
8486	SRC 6 Vb Harm[23]	%	Source 6 phase B voltage twenty-third harmonic
8487	SRC 6 Vb Harm[24]	%	Source 6 phase B voltage twenty-fourth harmonic
8488	SRC 6 Vb Harm[25]	%	Source 6 phase B voltage twenty-fifth harmonic
8489	SRC 6 Vc THD	%	Source 6 phase C voltage total harmonic distortion (THD)
8490	SRC 6 Vc Harm[2]	%	Source 6 phase C voltage second harmonic
8491	SRC 6 Vc Harm[3]	%	Source 6 phase C voltage third harmonic
8492	SRC 6 Vc Harm[4]	%	Source 6 phase C voltage fourth harmonic
8493	SRC 6 Vc Harm[5]	%	Source 6 phase C voltage fifth harmonic

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Decimal address	FlexAnalog name	Units	Description
8494	SRC 6 Vc Harm[6]	%	Source 6 phase C voltage sixth harmonic
8495	SRC 6 Vc Harm[7]	%	Source 6 phase C voltage seventh harmonic
8496	SRC 6 Vc Harm[8]	%	Source 6 phase C voltage eighth harmonic
8497	SRC 6 Vc Harm[9]	%	Source 6 phase C voltage ninth harmonic
8498	SRC 6 Vc Harm[10]	%	Source 6 phase C voltage tenth harmonic
8499	SRC 6 Vc Harm[11]	%	Source 6 phase C voltage eleventh harmonic
8500	SRC 6 Vc Harm[12]	%	Source 6 phase C voltage twelfth harmonic
8501	SRC 6 Vc Harm[13]	%	Source 6 phase C voltage thirteenth harmonic
8502	SRC 6 Vc Harm[14]	%	Source 6 phase C voltage fourteenth harmonic
8503	SRC 6 Vc Harm[15]	%	Source 6 phase C voltage fifteenth harmonic
8504	SRC 6 Vc Harm[16]	%	Source 6 phase C voltage sixteenth harmonic
8505	SRC 6 Vc Harm[17]	%	Source 6 phase C voltage seventeenth harmonic
8506	SRC 6 Vc Harm[18]	%	Source 6 phase C voltage eighteenth harmonic
8507	SRC 6 Vc Harm[19]	%	Source 6 phase C voltage nineteenth harmonic
8508	SRC 6 Vc Harm[20]	%	Source 6 phase C voltage twentieth harmonic
8509	SRC 6 Vc Harm[21]	%	Source 6 phase C voltage twenty-first harmonic
8510	SRC 6 Vc Harm[22]	%	Source 6 phase C voltage twenty-second harmonic
8511	SRC 6 Vc Harm[23]	%	Source 6 phase C voltage twenty-third harmonic
8512	SRC 6 Vc Harm[24]	%	Source 6 phase C voltage twenty-fourth harmonic
8513	SRC 6 Vc Harm[25]	%	Source 6 phase C voltage twenty-fifth harmonic
10240	SRC 1 Ia THD	%	Source 1 phase A current total harmonic distortion
10241	SRC 1 Ia Harm[2]	%	Source 1 phase A current second harmonic
10242	SRC 1 Ia Harm[3]	%	Source 1 phase A current third harmonic
10243	SRC 1 Ia Harm[4]	%	Source 1 phase A current fourth harmonic
10244	SRC 1 Ia Harm[5]	%	Source 1 phase A current fifth harmonic
10245	SRC 1 Ia Harm[6]	%	Source 1 phase A current sixth harmonic
10246	SRC 1 Ia Harm[7]	%	Source 1 phase A current seventh harmonic
10247	SRC 1 Ia Harm[8]	%	Source 1 phase A current eighth harmonic
10248	SRC 1 Ia Harm[9]	%	Source 1 phase A current ninth harmonic
10249	SRC 1 Ia Harm[10]	%	Source 1 phase A current tenth harmonic
10250	SRC 1 Ia Harm[11]	%	Source 1 phase A current eleventh harmonic
10251	SRC 1 Ia Harm[12]	%	Source 1 phase A current twelfth harmonic
10252	SRC 1 Ia Harm[13]	%	Source 1 phase A current thirteenth harmonic
10253	SRC 1 Ia Harm[14]	%	Source 1 phase A current fourteenth harmonic
10254	SRC 1 Ia Harm[15]	%	Source 1 phase A current fifteenth harmonic
10255	SRC 1 Ia Harm[16]	%	Source 1 phase A current sixteenth harmonic
10256	SRC 1 Ia Harm[17]	%	Source 1 phase A current seventeenth harmonic
10257	SRC 1 Ia Harm[18]	%	Source 1 phase A current eighteenth harmonic
10258	SRC 1 Ia Harm[19]	%	Source 1 phase A current nineteenth harmonic
10259	SRC 1 Ia Harm[20]	%	Source 1 phase A current twentieth harmonic
10260	SRC 1 Ia Harm[21]	%	Source 1 phase A current twenty-first harmonic
10261	SRC 1 Ia Harm[22]	%	Source 1 phase A current twenty-second harmonic
10262	SRC 1 Ia Harm[23]	%	Source 1 phase A current twenty-third harmonic
10263	SRC 1 Ia Harm[24]	%	Source 1 phase A current twenty-fourth harmonic
10264	SRC 1 Ia Harm[25]	%	Source 1 phase A current twenty-fifth harmonic
10273	SRC 1 Ib THD	%	Source 1 phase B current total harmonic distortion

Decimal address	FlexAnalog name	Units	Description
10274	SRC 1 Ib Harm[2]	%	Source 1 phase B current second harmonic
10275	SRC 1 Ib Harm[3]	%	Source 1 phase B current third harmonic
10276	SRC 1 Ib Harm[4]	%	Source 1 phase B current fourth harmonic
10277	SRC 1 Ib Harm[5]	%	Source 1 phase B current fifth harmonic
10278	SRC 1 Ib Harm[6]	%	Source 1 phase B current sixth harmonic
10279	SRC 1 Ib Harm[7]	%	Source 1 phase B current seventh harmonic
10280	SRC 1 Ib Harm[8]	%	Source 1 phase B current eighth harmonic
10281	SRC 1 Ib Harm[9]	%	Source 1 phase B current ninth harmonic
10282	SRC 1 Ib Harm[10]	%	Source 1 phase B current tenth harmonic
10283	SRC 1 Ib Harm[11]	%	Source 1 phase B current eleventh harmonic
10284	SRC 1 Ib Harm[12]	%	Source 1 phase B current twelfth harmonic
10285	SRC 1 Ib Harm[13]	%	Source 1 phase B current thirteenth harmonic
10286	SRC 1 Ib Harm[14]	%	Source 1 phase B current fourteenth harmonic
10287	SRC 1 Ib Harm[15]	%	Source 1 phase B current fifteenth harmonic
10288	SRC 1 Ib Harm[16]	%	Source 1 phase B current sixteenth harmonic
10289	SRC 1 Ib Harm[17]	%	Source 1 phase B current seventeenth harmonic
10290	SRC 1 Ib Harm[18]	%	Source 1 phase B current eighteenth harmonic
10291	SRC 1 Ib Harm[19]	%	Source 1 phase B current nineteenth harmonic
10292	SRC 1 Ib Harm[20]	%	Source 1 phase B current twentieth harmonic
10293	SRC 1 Ib Harm[21]	%	Source 1 phase B current twenty-first harmonic
10294	SRC 1 Ib Harm[22]	%	Source 1 phase B current twenty-second harmonic
10295	SRC 1 Ib Harm[23]	%	Source 1 phase B current twenty-third harmonic
10296	SRC 1 Ib Harm[24]	%	Source 1 phase B current twenty-fourth harmonic
10297	SRC 1 Ib Harm[25]	%	Source 1 phase B current twenty-fifth harmonic
10306	SRC 1 Ic THD	%	Source 1 phase C current total harmonic distortion
10307	SRC 1 Ic Harm[2]	%	Source 1 phase C current second harmonic
10308	SRC 1 Ic Harm[3]	%	Source 1 phase C current third harmonic
10309	SRC 1 Ic Harm[4]	%	Source 1 phase C current fourth harmonic
10310	SRC 1 Ic Harm[5]	%	Source 1 phase C current fifth harmonic
10311	SRC 1 Ic Harm[6]	%	Source 1 phase C current sixth harmonic
10312	SRC 1 Ic Harm[7]	%	Source 1 phase C current seventh harmonic
10313	SRC 1 Ic Harm[8]	%	Source 1 phase C current eighth harmonic
10314	SRC 1 Ic Harm[9]	%	Source 1 phase C current ninth harmonic
10315	SRC 1 Ic Harm[10]	%	Source 1 phase C current tenth harmonic
10316	SRC 1 Ic Harm[11]	%	Source 1 phase C current eleventh harmonic
10317	SRC 1 Ic Harm[12]	%	Source 1 phase C current twelfth harmonic
10318	SRC 1 Ic Harm[13]	%	Source 1 phase C current thirteenth harmonic
10319	SRC 1 Ic Harm[14]	%	Source 1 phase C current fourteenth harmonic
10320	SRC 1 Ic Harm[15]	%	Source 1 phase C current fifteenth harmonic
10321	SRC 1 Ic Harm[16]	%	Source 1 phase C current sixteenth harmonic
10322	SRC 1 Ic Harm[17]	%	Source 1 phase C current seventeenth harmonic
10323	SRC 1 Ic Harm[18]	%	Source 1 phase C current eighteenth harmonic
10324	SRC 1 Ic Harm[19]	%	Source 1 phase C current nineteenth harmonic
10325	SRC 1 Ic Harm[20]	%	Source 1 phase C current twentieth harmonic
10326	SRC 1 Ic Harm[21]	%	Source 1 phase C current twenty-first harmonic
10327	SRC 1 Ic Harm[22]	%	Source 1 phase C current twenty-second harmonic

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Decimal address	FlexAnalog name	Units	Description
10328	SRC 1 Ic Harm[23]	%	Source 1 phase C current twenty-third harmonic
10329	SRC 1 Ic Harm[24]	%	Source 1 phase C current twenty-fourth harmonic
10330	SRC 1 Ic Harm[25]	%	Source 1 phase C current twenty-fifth harmonic
10339	SRC 2 Ia THD	%	Source 2 phase A current total harmonic distortion
10340	SRC 2 Ia Harm[2]	%	Source 2 phase A current second harmonic
10341	SRC 2 Ia Harm[3]	%	Source 2 phase A current third harmonic
10342	SRC 2 Ia Harm[4]	%	Source 2 phase A current fourth harmonic
10343	SRC 2 Ia Harm[5]	%	Source 2 phase A current fifth harmonic
10344	SRC 2 Ia Harm[6]	%	Source 2 phase A current sixth harmonic
10345	SRC 2 Ia Harm[7]	%	Source 2 phase A current seventh harmonic
10346	SRC 2 Ia Harm[8]	%	Source 2 phase A current eighth harmonic
10347	SRC 2 Ia Harm[9]	%	Source 2 phase A current ninth harmonic
10348	SRC 2 Ia Harm[10]	%	Source 2 phase A current tenth harmonic
10349	SRC 2 Ia Harm[11]	%	Source 2 phase A current eleventh harmonic
10350	SRC 2 Ia Harm[12]	%	Source 2 phase A current twelfth harmonic
10351	SRC 2 Ia Harm[13]	%	Source 2 phase A current thirteenth harmonic
10352	SRC 2 Ia Harm[14]	%	Source 2 phase A current fourteenth harmonic
10353	SRC 2 Ia Harm[15]	%	Source 2 phase A current fifteenth harmonic
10354	SRC 2 Ia Harm[16]	%	Source 2 phase A current sixteenth harmonic
10355	SRC 2 Ia Harm[17]	%	Source 2 phase A current seventeenth harmonic
10356	SRC 2 Ia Harm[18]	%	Source 2 phase A current eighteenth harmonic
10357	SRC 2 Ia Harm[19]	%	Source 2 phase A current nineteenth harmonic
10358	SRC 2 Ia Harm[20]	%	Source 2 phase A current twentieth harmonic
10359	SRC 2 Ia Harm[21]	%	Source 2 phase A current twenty-first harmonic
10360	SRC 2 Ia Harm[22]	%	Source 2 phase A current twenty-second harmonic
10361	SRC 2 Ia Harm[23]	%	Source 2 phase A current twenty-third harmonic
10362	SRC 2 Ia Harm[24]	%	Source 2 phase A current twenty-fourth harmonic
10363	SRC 2 Ia Harm[25]	%	Source 2 phase A current twenty-fifth harmonic
10372	SRC 2 Ib THD	%	Source 2 phase B current total harmonic distortion
10373	SRC 2 Ib Harm[2]	%	Source 2 phase B current second harmonic
10374	SRC 2 Ib Harm[3]	%	Source 2 phase B current third harmonic
10375	SRC 2 Ib Harm[4]	%	Source 2 phase B current fourth harmonic
10376	SRC 2 Ib Harm[5]	%	Source 2 phase B current fifth harmonic
10377	SRC 2 Ib Harm[6]	%	Source 2 phase B current sixth harmonic
10378	SRC 2 Ib Harm[7]	%	Source 2 phase B current seventh harmonic
10379	SRC 2 Ib Harm[8]	%	Source 2 phase B current eighth harmonic
10380	SRC 2 Ib Harm[9]	%	Source 2 phase B current ninth harmonic
10381	SRC 2 Ib Harm[10]	%	Source 2 phase B current tenth harmonic
10382	SRC 2 Ib Harm[11]	%	Source 2 phase B current eleventh harmonic
10383	SRC 2 Ib Harm[12]	%	Source 2 phase B current twelfth harmonic
10384	SRC 2 Ib Harm[13]	%	Source 2 phase B current thirteenth harmonic
10385	SRC 2 Ib Harm[14]	%	Source 2 phase B current fourteenth harmonic
10386	SRC 2 Ib Harm[15]	%	Source 2 phase B current fifteenth harmonic
10387	SRC 2 Ib Harm[16]	%	Source 2 phase B current sixteenth harmonic
10388	SRC 2 Ib Harm[17]	%	Source 2 phase B current seventeenth harmonic
10389	SRC 2 Ib Harm[18]	%	Source 2 phase B current eighteenth harmonic

Decimal address	FlexAnalog name	Units	Description
10390	SRC 2 Ib Harm[19]	%	Source 2 phase B current nineteenth harmonic
10391	SRC 2 Ib Harm[20]	%	Source 2 phase B current twentieth harmonic
10392	SRC 2 Ib Harm[21]	%	Source 2 phase B current twenty-first harmonic
10393	SRC 2 Ib Harm[22]	%	Source 2 phase B current twenty-second harmonic
10394	SRC 2 Ib Harm[23]	%	Source 2 phase B current twenty-third harmonic
10395	SRC 2 Ib Harm[24]	%	Source 2 phase B current twenty-fourth harmonic
10396	SRC 2 Ib Harm[25]	%	Source 2 phase B current twenty-fifth harmonic
10405	SRC 2 Ic THD	%	Source 2 phase C current total harmonic distortion
10406	SRC 2 Ic Harm[2]	%	Source 2 phase C current second harmonic
10407	SRC 2 Ic Harm[3]	%	Source 2 phase C current third harmonic
10408	SRC 2 Ic Harm[4]	%	Source 2 phase C current fourth harmonic
10409	SRC 2 Ic Harm[5]	%	Source 2 phase C current fifth harmonic
10410	SRC 2 Ic Harm[6]	%	Source 2 phase C current sixth harmonic
10411	SRC 2 Ic Harm[7]	%	Source 2 phase C current seventh harmonic
10412	SRC 2 Ic Harm[8]	%	Source 2 phase C current eighth harmonic
10413	SRC 2 Ic Harm[9]	%	Source 2 phase C current ninth harmonic
10414	SRC 2 Ic Harm[10]	%	Source 2 phase C current tenth harmonic
10415	SRC 2 Ic Harm[11]	%	Source 2 phase C current eleventh harmonic
10416	SRC 2 Ic Harm[12]	%	Source 2 phase C current twelfth harmonic
10417	SRC 2 Ic Harm[13]	%	Source 2 phase C current thirteenth harmonic
10418	SRC 2 Ic Harm[14]	%	Source 2 phase C current fourteenth harmonic
10419	SRC 2 Ic Harm[15]	%	Source 2 phase C current fifteenth harmonic
10420	SRC 2 Ic Harm[16]	%	Source 2 phase C current sixteenth harmonic
10421	SRC 2 Ic Harm[17]	%	Source 2 phase C current seventeenth harmonic
10422	SRC 2 Ic Harm[18]	%	Source 2 phase C current eighteenth harmonic
10423	SRC 2 Ic Harm[19]	%	Source 2 phase C current nineteenth harmonic
10424	SRC 2 Ic Harm[20]	%	Source 2 phase C current twentieth harmonic
10425	SRC 2 Ic Harm[21]	%	Source 2 phase C current twenty-first harmonic
10426	SRC 2 Ic Harm[22]	%	Source 2 phase C current twenty-second harmonic
10427	SRC 2 Ic Harm[23]	%	Source 2 phase C current twenty-third harmonic
10428	SRC 2 Ic Harm[24]	%	Source 2 phase C current twenty-fourth harmonic
10429	SRC 2 Ic Harm[25]	%	Source 2 phase C current twenty-fifth harmonic
10438	SRC 3 Ia THD	%	Source 3 phase A current total harmonic distortion
10439	SRC 3 Ia Harm[2]	%	Source 3 phase A current second harmonic
10440	SRC 3 Ia Harm[3]	%	Source 3 phase A current third harmonic
10441	SRC 3 Ia Harm[4]	%	Source 3 phase A current fourth harmonic
10442	SRC 3 Ia Harm[5]	%	Source 3 phase A current fifth harmonic
10443	SRC 3 Ia Harm[6]	%	Source 3 phase A current sixth harmonic
10444	SRC 3 Ia Harm[7]	%	Source 3 phase A current seventh harmonic
10445	SRC 3 Ia Harm[8]	%	Source 3 phase A current eighth harmonic
10446	SRC 3 Ia Harm[9]	%	Source 3 phase A current ninth harmonic
10447	SRC 3 Ia Harm[10]	%	Source 3 phase A current tenth harmonic
10448	SRC 3 Ia Harm[11]	%	Source 3 phase A current eleventh harmonic
10449	SRC 3 Ia Harm[12]	%	Source 3 phase A current twelfth harmonic
10450	SRC 3 Ia Harm[13]	%	Source 3 phase A current thirteenth harmonic
10451	SRC 3 Ia Harm[14]	%	Source 3 phase A current fourteenth harmonic

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Decimal address	FlexAnalog name	Units	Description
10452	SRC 3 Ia Harm[15]	%	Source 3 phase A current fifteenth harmonic
10453	SRC 3 Ia Harm[16]	%	Source 3 phase A current sixteenth harmonic
10454	SRC 3 Ia Harm[17]	%	Source 3 phase A current seventeenth harmonic
10455	SRC 3 Ia Harm[18]	%	Source 3 phase A current eighteenth harmonic
10456	SRC 3 Ia Harm[19]	%	Source 3 phase A current nineteenth harmonic
10457	SRC 3 Ia Harm[20]	%	Source 3 phase A current twentieth harmonic
10458	SRC 3 Ia Harm[21]	%	Source 3 phase A current twenty-first harmonic
10459	SRC 3 Ia Harm[22]	%	Source 3 phase A current twenty-second harmonic
10460	SRC 3 Ia Harm[23]	%	Source 3 phase A current twenty-third harmonic
10461	SRC 3 Ia Harm[24]	%	Source 3 phase A current twenty-fourth harmonic
10462	SRC 3 Ia Harm[25]	%	Source 3 phase A current twenty-fifth harmonic
10471	SRC 3 Ib THD	%	Source 3 phase B current total harmonic distortion
10472	SRC 3 Ib Harm[2]	%	Source 3 phase B current second harmonic
10473	SRC 3 Ib Harm[3]	%	Source 3 phase B current third harmonic
10474	SRC 3 Ib Harm[4]	%	Source 3 phase B current fourth harmonic
10475	SRC 3 Ib Harm[5]	%	Source 3 phase B current fifth harmonic
10476	SRC 3 Ib Harm[6]	%	Source 3 phase B current sixth harmonic
10477	SRC 3 Ib Harm[7]	%	Source 3 phase B current seventh harmonic
10478	SRC 3 Ib Harm[8]	%	Source 3 phase B current eighth harmonic
10479	SRC 3 Ib Harm[9]	%	Source 3 phase B current ninth harmonic
10480	SRC 3 Ib Harm[10]	%	Source 3 phase B current tenth harmonic
10481	SRC 3 Ib Harm[11]	%	Source 3 phase B current eleventh harmonic
10482	SRC 3 Ib Harm[12]	%	Source 3 phase B current twelfth harmonic
10483	SRC 3 Ib Harm[13]	%	Source 3 phase B current thirteenth harmonic
10484	SRC 3 Ib Harm[14]	%	Source 3 phase B current fourteenth harmonic
10485	SRC 3 Ib Harm[15]	%	Source 3 phase B current fifteenth harmonic
10486	SRC 3 Ib Harm[16]	%	Source 3 phase B current sixteenth harmonic
10487	SRC 3 Ib Harm[17]	%	Source 3 phase B current seventeenth harmonic
10488	SRC 3 Ib Harm[18]	%	Source 3 phase B current eighteenth harmonic
10489	SRC 3 Ib Harm[19]	%	Source 3 phase B current nineteenth harmonic
10490	SRC 3 Ib Harm[20]	%	Source 3 phase B current twentieth harmonic
10491	SRC 3 Ib Harm[21]	%	Source 3 phase B current twenty-first harmonic
10492	SRC 3 Ib Harm[22]	%	Source 3 phase B current twenty-second harmonic
10493	SRC 3 Ib Harm[23]	%	Source 3 phase B current twenty-third harmonic
10494	SRC 3 Ib Harm[24]	%	Source 3 phase B current twenty-fourth harmonic
10495	SRC 3 Ib Harm[25]	%	Source 3 phase B current twenty-fifth harmonic
10504	SRC 3 Ic THD	%	Source 3 phase C current total harmonic distortion
10505	SRC 3 Ic Harm[2]	%	Source 3 phase C current second harmonic
10506	SRC 3 Ic Harm[3]	%	Source 3 phase C current third harmonic
10507	SRC 3 Ic Harm[4]	%	Source 3 phase C current fourth harmonic
10508	SRC 3 Ic Harm[5]	%	Source 3 phase C current fifth harmonic
10509	SRC 3 Ic Harm[6]	%	Source 3 phase C current sixth harmonic
10510	SRC 3 Ic Harm[7]	%	Source 3 phase C current seventh harmonic
10511	SRC 3 Ic Harm[8]	%	Source 3 phase C current eighth harmonic
10512	SRC 3 Ic Harm[9]	%	Source 3 phase C current ninth harmonic
10513	SRC 3 Ic Harm[10]	%	Source 3 phase C current tenth harmonic

Decimal address	FlexAnalog name	Units	Description
10514	SRC 3 Ic Harm[11]	%	Source 3 phase C current eleventh harmonic
10515	SRC 3 Ic Harm[12]	%	Source 3 phase C current twelfth harmonic
10516	SRC 3 Ic Harm[13]	%	Source 3 phase C current thirteenth harmonic
10517	SRC 3 Ic Harm[14]	%	Source 3 phase C current fourteenth harmonic
10518	SRC 3 Ic Harm[15]	%	Source 3 phase C current fifteenth harmonic
10519	SRC 3 Ic Harm[16]	%	Source 3 phase C current sixteenth harmonic
10520	SRC 3 Ic Harm[17]	%	Source 3 phase C current seventeenth harmonic
10521	SRC 3 Ic Harm[18]	%	Source 3 phase C current eighteenth harmonic
10522	SRC 3 Ic Harm[19]	%	Source 3 phase C current nineteenth harmonic
10523	SRC 3 Ic Harm[20]	%	Source 3 phase C current twentieth harmonic
10524	SRC 3 Ic Harm[21]	%	Source 3 phase C current twenty-first harmonic
10525	SRC 3 Ic Harm[22]	%	Source 3 phase C current twenty-second harmonic
10526	SRC 3 Ic Harm[23]	%	Source 3 phase C current twenty-third harmonic
10527	SRC 3 Ic Harm[24]	%	Source 3 phase C current twenty-fourth harmonic
10528	SRC 3 Ic Harm[25]	%	Source 3 phase C current twenty-fifth harmonic
10537	SRC 4 Ia THD	%	Source 4 phase A current total harmonic distortion
10538	SRC 4 Ia Harm[2]	%	Source 4 phase A current second harmonic
10539	SRC 4 Ia Harm[3]	%	Source 4 phase A current third harmonic
10540	SRC 4 Ia Harm[4]	%	Source 4 phase A current fourth harmonic
10541	SRC 4 Ia Harm[5]	%	Source 4 phase A current fifth harmonic
10542	SRC 4 Ia Harm[6]	%	Source 4 phase A current sixth harmonic
10543	SRC 4 Ia Harm[7]	%	Source 4 phase A current seventh harmonic
10544	SRC 4 Ia Harm[8]	%	Source 4 phase A current eighth harmonic
10545	SRC 4 Ia Harm[9]	%	Source 4 phase A current ninth harmonic
10546	SRC 4 Ia Harm[10]	%	Source 4 phase A current tenth harmonic
10547	SRC 4 Ia Harm[11]	%	Source 4 phase A current eleventh harmonic
10548	SRC 4 Ia Harm[12]	%	Source 4 phase A current twelfth harmonic
10549	SRC 4 Ia Harm[13]	%	Source 4 phase A current thirteenth harmonic
10550	SRC 4 Ia Harm[14]	%	Source 4 phase A current fourteenth harmonic
10551	SRC 4 Ia Harm[15]	%	Source 4 phase A current fifteenth harmonic
10552	SRC 4 Ia Harm[16]	%	Source 4 phase A current sixteenth harmonic
10553	SRC 4 Ia Harm[17]	%	Source 4 phase A current seventeenth harmonic
10554	SRC 4 Ia Harm[18]	%	Source 4 phase A current eighteenth harmonic
10555	SRC 4 Ia Harm[19]	%	Source 4 phase A current nineteenth harmonic
10556	SRC 4 Ia Harm[20]	%	Source 4 phase A current twentieth harmonic
10557	SRC 4 Ia Harm[21]	%	Source 4 phase A current twenty-first harmonic
10558	SRC 4 Ia Harm[22]	%	Source 4 phase A current twenty-second harmonic
10559	SRC 4 Ia Harm[23]	%	Source 4 phase A current twenty-third harmonic
10560	SRC 4 Ia Harm[24]	%	Source 4 phase A current twenty-fourth harmonic
10561	SRC 4 Ia Harm[25]	%	Source 4 phase A current twenty-fifth harmonic
10570	SRC 4 Ib THD	%	Source 4 phase B current total harmonic distortion
10571	SRC 4 Ib Harm[2]	%	Source 4 phase B current second harmonic
10572	SRC 4 Ib Harm[3]	%	Source 4 phase B current third harmonic
10573	SRC 4 Ib Harm[4]	%	Source 4 phase B current fourth harmonic
10574	SRC 4 Ib Harm[5]	%	Source 4 phase B current fifth harmonic
10575	SRC 4 Ib Harm[6]	%	Source 4 phase B current sixth harmonic

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Decimal address	FlexAnalog name	Units	Description
10576	SRC 4 Ib Harm[7]	%	Source 4 phase B current seventh harmonic
10577	SRC 4 Ib Harm[8]	%	Source 4 phase B current eighth harmonic
10578	SRC 4 Ib Harm[9]	%	Source 4 phase B current ninth harmonic
10579	SRC 4 Ib Harm[10]	%	Source 4 phase B current tenth harmonic
10580	SRC 4 Ib Harm[11]	%	Source 4 phase B current eleventh harmonic
10581	SRC 4 Ib Harm[12]	%	Source 4 phase B current twelfth harmonic
10582	SRC 4 Ib Harm[13]	%	Source 4 phase B current thirteenth harmonic
10583	SRC 4 Ib Harm[14]	%	Source 4 phase B current fourteenth harmonic
10584	SRC 4 Ib Harm[15]	%	Source 4 phase B current fifteenth harmonic
10585	SRC 4 Ib Harm[16]	%	Source 4 phase B current sixteenth harmonic
10586	SRC 4 Ib Harm[17]	%	Source 4 phase B current seventeenth harmonic
10587	SRC 4 Ib Harm[18]	%	Source 4 phase B current eighteenth harmonic
10588	SRC 4 Ib Harm[19]	%	Source 4 phase B current nineteenth harmonic
10589	SRC 4 Ib Harm[20]	%	Source 4 phase B current twentieth harmonic
10590	SRC 4 Ib Harm[21]	%	Source 4 phase B current twenty-first harmonic
10591	SRC 4 Ib Harm[22]	%	Source 4 phase B current twenty-second harmonic
10592	SRC 4 Ib Harm[23]	%	Source 4 phase B current twenty-third harmonic
10593	SRC 4 Ib Harm[24]	%	Source 4 phase B current twenty-fourth harmonic
10594	SRC 4 Ib Harm[25]	%	Source 4 phase B current twenty-fifth harmonic
10603	SRC 4 Ic THD	%	Source 4 phase C current total harmonic distortion
10604	SRC 4 Ic Harm[2]	%	Source 4 phase C current second harmonic
10605	SRC 4 Ic Harm[3]	%	Source 4 phase C current third harmonic
10606	SRC 4 Ic Harm[4]	%	Source 4 phase C current fourth harmonic
10607	SRC 4 Ic Harm[5]	%	Source 4 phase C current fifth harmonic
10608	SRC 4 Ic Harm[6]	%	Source 4 phase C current sixth harmonic
10609	SRC 4 Ic Harm[7]	%	Source 4 phase C current seventh harmonic
10610	SRC 4 Ic Harm[8]	%	Source 4 phase C current eighth harmonic
10611	SRC 4 Ic Harm[9]	%	Source 4 phase C current ninth harmonic
10612	SRC 4 Ic Harm[10]	%	Source 4 phase C current tenth harmonic
10613	SRC 4 Ic Harm[11]	%	Source 4 phase C current eleventh harmonic
10614	SRC 4 Ic Harm[12]	%	Source 4 phase C current twelfth harmonic
10615	SRC 4 Ic Harm[13]	%	Source 4 phase C current thirteenth harmonic
10616	SRC 4 Ic Harm[14]	%	Source 4 phase C current fourteenth harmonic
10617	SRC 4 Ic Harm[15]	%	Source 4 phase C current fifteenth harmonic
10618	SRC 4 Ic Harm[16]	%	Source 4 phase C current sixteenth harmonic
10619	SRC 4 Ic Harm[17]	%	Source 4 phase C current seventeenth harmonic
10620	SRC 4 Ic Harm[18]	%	Source 4 phase C current eighteenth harmonic
10621	SRC 4 Ic Harm[19]	%	Source 4 phase C current nineteenth harmonic
10622	SRC 4 Ic Harm[20]	%	Source 4 phase C current twentieth harmonic
10623	SRC 4 Ic Harm[21]	%	Source 4 phase C current twenty-first harmonic
10624	SRC 4 Ic Harm[22]	%	Source 4 phase C current twenty-second harmonic
10625	SRC 4 Ic Harm[23]	%	Source 4 phase C current twenty-third harmonic
10626	SRC 4 Ic Harm[24]	%	Source 4 phase C current twenty-fourth harmonic
10627	SRC 4 Ic Harm[25]	%	Source 4 phase C current twenty-fifth harmonic
10636	SRC 5 Ia THD	%	Source 5 phase A current total harmonic distortion
10637	SRC 5 Ia Harm[2]	%	Source 5 phase A current second harmonic

Decimal address	FlexAnalog name	Units	Description
10638	SRC 5 Ia Harm[3]	%	Source 5 phase A current third harmonic
10639	SRC 5 Ia Harm[4]	%	Source 5 phase A current fourth harmonic
10640	SRC 5 Ia Harm[5]	%	Source 5 phase A current fifth harmonic
10641	SRC 5 Ia Harm[6]	%	Source 5 phase A current sixth harmonic
10642	SRC 5 Ia Harm[7]	%	Source 5 phase A current seventh harmonic
10643	SRC 5 Ia Harm[8]	%	Source 5 phase A current eighth harmonic
10644	SRC 5 Ia Harm[9]	%	Source 5 phase A current ninth harmonic
10645	SRC 5 Ia Harm[10]	%	Source 5 phase A current tenth harmonic
10646	SRC 5 Ia Harm[11]	%	Source 5 phase A current eleventh harmonic
10647	SRC 5 Ia Harm[12]	%	Source 5 phase A current twelfth harmonic
10648	SRC 5 Ia Harm[13]	%	Source 5 phase A current thirteenth harmonic
10649	SRC 5 Ia Harm[14]	%	Source 5 phase A current fourteenth harmonic
10650	SRC 5 Ia Harm[15]	%	Source 5 phase A current fifteenth harmonic
10651	SRC 5 Ia Harm[16]	%	Source 5 phase A current sixteenth harmonic
10652	SRC 5 Ia Harm[17]	%	Source 5 phase A current seventeenth harmonic
10653	SRC 5 Ia Harm[18]	%	Source 5 phase A current eighteenth harmonic
10654	SRC 5 Ia Harm[19]	%	Source 5 phase A current nineteenth harmonic
10655	SRC 5 Ia Harm[20]	%	Source 5 phase A current twentieth harmonic
10656	SRC 5 Ia Harm[21]	%	Source 5 phase A current twenty-first harmonic
10657	SRC 5 Ia Harm[22]	%	Source 5 phase A current twenty-second harmonic
10658	SRC 5 Ia Harm[23]	%	Source 5 phase A current twenty-third harmonic
10659	SRC 5 Ia Harm[24]	%	Source 5 phase A current twenty-fourth harmonic
10660	SRC 5 Ia Harm[25]	%	Source 5 phase A current twenty-fifth harmonic
10669	SRC 5 Ib THD	%	Source 5 phase B current total harmonic distortion
10670	SRC 5 Ib Harm[2]	%	Source 5 phase B current second harmonic
10671	SRC 5 Ib Harm[3]	%	Source 5 phase B current third harmonic
10672	SRC 5 Ib Harm[4]	%	Source 5 phase B current fourth harmonic
10673	SRC 5 Ib Harm[5]	%	Source 5 phase B current fifth harmonic
10674	SRC 5 Ib Harm[6]	%	Source 5 phase B current sixth harmonic
10675	SRC 5 Ib Harm[7]	%	Source 5 phase B current seventh harmonic
10676	SRC 5 Ib Harm[8]	%	Source 5 phase B current eighth harmonic
10677	SRC 5 Ib Harm[9]	%	Source 5 phase B current ninth harmonic
10678	SRC 5 Ib Harm[10]	%	Source 5 phase B current tenth harmonic
10679	SRC 5 Ib Harm[11]	%	Source 5 phase B current eleventh harmonic
10680	SRC 5 Ib Harm[12]	%	Source 5 phase B current twelfth harmonic
10681	SRC 5 Ib Harm[13]	%	Source 5 phase B current thirteenth harmonic
10682	SRC 5 Ib Harm[14]	%	Source 5 phase B current fourteenth harmonic
10683	SRC 5 Ib Harm[15]	%	Source 5 phase B current fifteenth harmonic
10684	SRC 5 Ib Harm[16]	%	Source 5 phase B current sixteenth harmonic
10685	SRC 5 Ib Harm[17]	%	Source 5 phase B current seventeenth harmonic
10686	SRC 5 Ib Harm[18]	%	Source 5 phase B current eighteenth harmonic
10687	SRC 5 Ib Harm[19]	%	Source 5 phase B current nineteenth harmonic
10688	SRC 5 Ib Harm[20]	%	Source 5 phase B current twentieth harmonic
10689	SRC 5 Ib Harm[21]	%	Source 5 phase B current twenty-first harmonic
10690	SRC 5 Ib Harm[22]	%	Source 5 phase B current twenty-second harmonic
10691	SRC 5 Ib Harm[23]	%	Source 5 phase B current twenty-third harmonic

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Decimal address	FlexAnalog name	Units	Description
10692	SRC 5 Ib Harm[24]	%	Source 5 phase B current twenty-fourth harmonic
10693	SRC 5 Ib Harm[25]	%	Source 5 phase B current twenty-fifth harmonic
10702	SRC 5 Ic THD	%	Source 5 phase C current total harmonic distortion
10703	SRC 5 Ic Harm[2]	%	Source 5 phase C current second harmonic
10704	SRC 5 Ic Harm[3]	%	Source 5 phase C current third harmonic
10705	SRC 5 Ic Harm[4]	%	Source 5 phase C current fourth harmonic
10706	SRC 5 Ic Harm[5]	%	Source 5 phase C current fifth harmonic
10707	SRC 5 Ic Harm[6]	%	Source 5 phase C current sixth harmonic
10708	SRC 5 Ic Harm[7]	%	Source 5 phase C current seventh harmonic
10709	SRC 5 Ic Harm[8]	%	Source 5 phase C current eighth harmonic
10710	SRC 5 Ic Harm[9]	%	Source 5 phase C current ninth harmonic
10711	SRC 5 Ic Harm[10]	%	Source 5 phase C current tenth harmonic
10712	SRC 5 Ic Harm[11]	%	Source 5 phase C current eleventh harmonic
10713	SRC 5 Ic Harm[12]	%	Source 5 phase C current twelfth harmonic
10714	SRC 5 Ic Harm[13]	%	Source 5 phase C current thirteenth harmonic
10715	SRC 5 Ic Harm[14]	%	Source 5 phase C current fourteenth harmonic
10716	SRC 5 Ic Harm[15]	%	Source 5 phase C current fifteenth harmonic
10717	SRC 5 Ic Harm[16]	%	Source 5 phase C current sixteenth harmonic
10718	SRC 5 Ic Harm[17]	%	Source 5 phase C current seventeenth harmonic
10719	SRC 5 Ic Harm[18]	%	Source 5 phase C current eighteenth harmonic
10720	SRC 5 Ic Harm[19]	%	Source 5 phase C current nineteenth harmonic
10721	SRC 5 Ic Harm[20]	%	Source 5 phase C current twentieth harmonic
10722	SRC 5 Ic Harm[21]	%	Source 5 phase C current twenty-first harmonic
10723	SRC 5 Ic Harm[22]	%	Source 5 phase C current twenty-second harmonic
10724	SRC 5 Ic Harm[23]	%	Source 5 phase C current twenty-third harmonic
10725	SRC 5 Ic Harm[24]	%	Source 5 phase C current twenty-fourth harmonic
10726	SRC 5 Ic Harm[25]	%	Source 5 phase C current twenty-fifth harmonic
10735	SRC 6 Ia THD	%	Source 6 phase A current total harmonic distortion
10736	SRC 6 Ia Harm[2]	%	Source 6 phase A current second harmonic
10737	SRC 6 Ia Harm[3]	%	Source 6 phase A current third harmonic
10738	SRC 6 Ia Harm[4]	%	Source 6 phase A current fourth harmonic
10739	SRC 6 Ia Harm[5]	%	Source 6 phase A current fifth harmonic
10740	SRC 6 Ia Harm[6]	%	Source 6 phase A current sixth harmonic
10741	SRC 6 Ia Harm[7]	%	Source 6 phase A current seventh harmonic
10742	SRC 6 Ia Harm[8]	%	Source 6 phase A current eighth harmonic
10743	SRC 6 Ia Harm[9]	%	Source 6 phase A current ninth harmonic
10744	SRC 6 Ia Harm[10]	%	Source 6 phase A current tenth harmonic
10745	SRC 6 Ia Harm[11]	%	Source 6 phase A current eleventh harmonic
10746	SRC 6 Ia Harm[12]	%	Source 6 phase A current twelfth harmonic
10747	SRC 6 Ia Harm[13]	%	Source 6 phase A current thirteenth harmonic
10748	SRC 6 Ia Harm[14]	%	Source 6 phase A current fourteenth harmonic
10749	SRC 6 Ia Harm[15]	%	Source 6 phase A current fifteenth harmonic
10750	SRC 6 Ia Harm[16]	%	Source 6 phase A current sixteenth harmonic
10751	SRC 6 Ia Harm[17]	%	Source 6 phase A current seventeenth harmonic
10752	SRC 6 Ia Harm[18]	%	Source 6 phase A current eighteenth harmonic
10753	SRC 6 Ia Harm[19]	%	Source 6 phase A current nineteenth harmonic

Decimal address	FlexAnalog name	Units	Description
10754	SRC 6 Ia Harm[20]	%	Source 6 phase A current twentieth harmonic
10755	SRC 6 Ia Harm[21]	%	Source 6 phase A current twenty-first harmonic
10756	SRC 6 Ia Harm[22]	%	Source 6 phase A current twenty-second harmonic
10757	SRC 6 Ia Harm[23]	%	Source 6 phase A current twenty-third harmonic
10758	SRC 6 Ia Harm[24]	%	Source 6 phase A current twenty-fourth harmonic
10759	SRC 6 Ia Harm[25]	%	Source 6 phase A current twenty-fifth harmonic
10768	SRC 6 Ib THD	%	Source 6 phase B current total harmonic distortion
10769	SRC 6 Ib Harm[2]	%	Source 6 phase B current second harmonic
10770	SRC 6 Ib Harm[3]	%	Source 6 phase B current third harmonic
10771	SRC 6 Ib Harm[4]	%	Source 6 phase B current fourth harmonic
10772	SRC 6 Ib Harm[5]	%	Source 6 phase B current fifth harmonic
10773	SRC 6 Ib Harm[6]	%	Source 6 phase B current sixth harmonic
10774	SRC 6 Ib Harm[7]	%	Source 6 phase B current seventh harmonic
10775	SRC 6 Ib Harm[8]	%	Source 6 phase B current eighth harmonic
10776	SRC 6 Ib Harm[9]	%	Source 6 phase B current ninth harmonic
10777	SRC 6 Ib Harm[10]	%	Source 6 phase B current tenth harmonic
10778	SRC 6 Ib Harm[11]	%	Source 6 phase B current eleventh harmonic
10779	SRC 6 Ib Harm[12]	%	Source 6 phase B current twelfth harmonic
10780	SRC 6 Ib Harm[13]	%	Source 6 phase B current thirteenth harmonic
10781	SRC 6 Ib Harm[14]	%	Source 6 phase B current fourteenth harmonic
10782	SRC 6 Ib Harm[15]	%	Source 6 phase B current fifteenth harmonic
10783	SRC 6 Ib Harm[16]	%	Source 6 phase B current sixteenth harmonic
10784	SRC 6 Ib Harm[17]	%	Source 6 phase B current seventeenth harmonic
10785	SRC 6 Ib Harm[18]	%	Source 6 phase B current eighteenth harmonic
10786	SRC 6 Ib Harm[19]	%	Source 6 phase B current nineteenth harmonic
10787	SRC 6 Ib Harm[20]	%	Source 6 phase B current twentieth harmonic
10788	SRC 6 Ib Harm[21]	%	Source 6 phase B current twenty-first harmonic
10789	SRC 6 Ib Harm[22]	%	Source 6 phase B current twenty-second harmonic
10790	SRC 6 Ib Harm[23]	%	Source 6 phase B current twenty-third harmonic
10791	SRC 6 Ib Harm[24]	%	Source 6 phase B current twenty-fourth harmonic
10792	SRC 6 Ib Harm[25]	%	Source 6 phase B current twenty-fifth harmonic
10801	SRC 6 Ic THD	%	Source 6 phase C current total harmonic distortion
10802	SRC 6 Ic Harm[2]	%	Source 6 phase C current second harmonic
10803	SRC 6 Ic Harm[3]	%	Source 6 phase C current third harmonic
10804	SRC 6 Ic Harm[4]	%	Source 6 phase C current fourth harmonic
10805	SRC 6 Ic Harm[5]	%	Source 6 phase C current fifth harmonic
10806	SRC 6 Ic Harm[6]	%	Source 6 phase C current sixth harmonic
10807	SRC 6 Ic Harm[7]	%	Source 6 phase C current seventh harmonic
10808	SRC 6 Ic Harm[8]	%	Source 6 phase C current eighth harmonic
10809	SRC 6 Ic Harm[9]	%	Source 6 phase C current ninth harmonic
10810	SRC 6 Ic Harm[10]	%	Source 6 phase C current tenth harmonic
10811	SRC 6 Ic Harm[11]	%	Source 6 phase C current eleventh harmonic
10812	SRC 6 Ic Harm[12]	%	Source 6 phase C current twelfth harmonic
10813	SRC 6 Ic Harm[13]	%	Source 6 phase C current thirteenth harmonic
10814	SRC 6 Ic Harm[14]	%	Source 6 phase C current fourteenth harmonic
10815	SRC 6 Ic Harm[15]	%	Source 6 phase C current fifteenth harmonic

A

Decimal address	FlexAnalog name	Units	Description
10816	SRC 6 Ic Harm[16]	%	Source 6 phase C current sixteenth harmonic
10817	SRC 6 Ic Harm[17]	%	Source 6 phase C current seventeenth harmonic
10818	SRC 6 Ic Harm[18]	%	Source 6 phase C current eighteenth harmonic
10819	SRC 6 Ic Harm[19]	%	Source 6 phase C current nineteenth harmonic
10820	SRC 6 Ic Harm[20]	%	Source 6 phase C current twentieth harmonic
10821	SRC 6 Ic Harm[21]	%	Source 6 phase C current twenty-first harmonic
10822	SRC 6 Ic Harm[22]	%	Source 6 phase C current twenty-second harmonic
10823	SRC 6 Ic Harm[23]	%	Source 6 phase C current twenty-third harmonic
10824	SRC 6 Ic Harm[24]	%	Source 6 phase C current twenty-fourth harmonic
10825	SRC 6 Ic Harm[25]	%	Source 6 phase C current twenty-fifth harmonic
12306	Oscill Num Triggers	---	Oscillography number of triggers
13504	DCmA Inputs 1 Value	mA	DCmA input 1 actual value
13506	DCmA Inputs 2 Value	mA	DCmA input 2 actual value
13508	DCmA Inputs 3 Value	mA	DCmA input 3 actual value
13510	DCmA Inputs 4 Value	mA	DCmA input 4 actual value
13512	DCmA Inputs 5 Value	mA	DCmA input 5 actual value
13514	DCmA Inputs 6 Value	mA	DCmA input 6 actual value
13516	DCmA Inputs 7 Value	mA	DCmA input 7 actual value
13518	DCmA Inputs 8 Value	mA	DCmA input 8 actual value
13520	DCmA Inputs 9 Value	mA	DCmA input 9 actual value
13522	DCmA Inputs 10 Value	mA	DCmA input 10 actual value
13524	DCmA Inputs 11 Value	mA	DCmA input 11 actual value
13526	DCmA Inputs 12 Value	mA	DCmA input 12 actual value
13528	DCmA Inputs 13 Value	mA	DCmA input 13 actual value
13530	DCmA Inputs 14 Value	mA	DCmA input 14 actual value
13532	DCmA Inputs 15 Value	mA	DCmA input 15 actual value
13534	DCmA Inputs 16 Value	mA	DCmA input 16 actual value
13536	DCmA Inputs 17 Value	mA	DCmA input 17 actual value
13538	DCmA Inputs 18 Value	mA	DCmA input 18 actual value
13540	DCmA Inputs 19 Value	mA	DCmA input 19 actual value
13542	DCmA Inputs 20 Value	mA	DCmA input 20 actual value
13544	DCmA Inputs 21 Value	mA	DCmA input 21 actual value
13546	DCmA Inputs 22 Value	mA	DCmA input 22 actual value
13548	DCmA Inputs 23 Value	mA	DCmA input 23 actual value
13550	DCmA Inputs 24 Value	mA	DCmA input 24 actual value
13552	RTD Inputs 1 Value	---	RTD input 1 actual value
13553	RTD Inputs 2 Value	---	RTD input 2 actual value
13554	RTD Inputs 3 Value	---	RTD input 3 actual value
13555	RTD Inputs 4 Value	---	RTD input 4 actual value
13556	RTD Inputs 5 Value	---	RTD input 5 actual value
13557	RTD Inputs 6 Value	---	RTD input 6 actual value
13558	RTD Inputs 7 Value	---	RTD input 7 actual value
13559	RTD Inputs 8 Value	---	RTD input 8 actual value
13560	RTD Inputs 9 Value	---	RTD input 9 actual value
13561	RTD Inputs 10 Value	---	RTD input 10 actual value
13562	RTD Inputs 11 Value	---	RTD input 11 actual value

Decimal address	FlexAnalog name	Units	Description
13563	RTD Inputs 12 Value	---	RTD input 12 actual value
13564	RTD Inputs 13 Value	---	RTD input 13 actual value
13565	RTD Inputs 14 Value	---	RTD input 14 actual value
13566	RTD Inputs 15 Value	---	RTD input 15 actual value
13567	RTD Inputs 16 Value	---	RTD input 16 actual value
13568	RTD Inputs 17 Value	---	RTD input 17 actual value
13569	RTD Inputs 18 Value	---	RTD input 18 actual value
13570	RTD Inputs 19 Value	---	RTD input 19 actual value
13571	RTD Inputs 20 Value	---	RTD input 20 actual value
13572	RTD Inputs 21 Value	---	RTD input 21 actual value
13573	RTD Inputs 22 Value	---	RTD input 22 actual value
13574	RTD Inputs 23 Value	---	RTD input 23 actual value
13575	RTD Inputs 24 Value	---	RTD input 24 actual value
13576	RTD Inputs 25 Value	---	RTD input 25 actual value
13577	RTD Inputs 26 Value	---	RTD input 26 actual value
13578	RTD Inputs 27 Value	---	RTD input 27 actual value
13579	RTD Inputs 28 Value	---	RTD input 28 actual value
13580	RTD Inputs 29 Value	---	RTD input 29 actual value
13581	RTD Inputs 30 Value	---	RTD input 30 actual value
13582	RTD Inputs 31 Value	---	RTD input 31 actual value
13583	RTD Inputs 32 Value	---	RTD input 32 actual value
13584	RTD Inputs 33 Value	---	RTD input 33 actual value
13585	RTD Inputs 34 Value	---	RTD input 34 actual value
13586	RTD Inputs 35 Value	---	RTD input 35 actual value
13587	RTD Inputs 36 Value	---	RTD input 36 actual value
13588	RTD Inputs 37 Value	---	RTD input 37 actual value
13589	RTD Inputs 38 Value	---	RTD input 38 actual value
13590	RTD Inputs 39 Value	---	RTD input 39 actual value
13591	RTD Inputs 40 Value	---	RTD input 40 actual value
13592	RTD Inputs 41 Value	---	RTD input 41 actual value
13593	RTD Inputs 42 Value	---	RTD input 42 actual value
13594	RTD Inputs 43 Value	---	RTD input 43 actual value
13595	RTD Inputs 44 Value	---	RTD input 44 actual value
13596	RTD Inputs 45 Value	---	RTD input 45 actual value
13597	RTD Inputs 46 Value	---	RTD input 46 actual value
13598	RTD Inputs 47 Value	---	RTD input 47 actual value
13599	RTD Inputs 48 Value	---	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
13824	60P 1 Raw Idiff A	Amps	Phase current unbalance raw phase A differential current actual value
13826	60P 1 Raw Idiff B	Amps	Phase current unbalance raw phase B differential current actual value
13828	60P 1 Raw Idiff C	Amps	Phase current unbalance raw phase C differential current actual value
13830	60P 1 Comp Iop A	Amps	Phase current unbalance composite phase A operating current actual value
13832	60P 1 Comp Iop B	Amps	Phase current unbalance composite phase B operating current actual value

A

Decimal address	FlexAnalog name	Units	Description
13834	60P 1 Comp Iop C	Amps	Phase current unbalance composite phase C operating current actual value
13836	60P 2 Raw Idiff A	pu	Phase current unbalance 2 raw phase A differential current actual value
13838	60P 2 Raw Idiff B	pu	Phase current unbalance 2 raw phase B differential current actual value
13840	60P 2 Raw Idiff C	pu	Phase current unbalance 2 raw phase C differential current actual value
13842	60P 2 Comp Iop A	pu	Phase current unbalance 2 composite phase A operating current actual value
13844	60P 2 Comp Iop B	pu	Phase current unbalance 2 composite phase B operating current actual value
13846	60P 2 Comp Iop C	pu	Phase current unbalance 2 composite phase C operating current actual value
13848	60P 3 Raw Idiff A	pu	Phase current unbalance 3 raw phase A differential current actual value
13850	60P 3 Raw Idiff B	pu	Phase current unbalance 3 raw phase B differential current actual value
13852	60P 3 Raw Idiff C	pu	Phase current unbalance 3 raw phase C differential current actual value
13854	60P 3 Comp Iop A	pu	Phase current unbalance 3 composite phase A operating current actual value
13856	60P 3 Comp Iop B	pu	Phase current unbalance 3 composite phase B operating current actual value
13858	60P 3 Comp Iop C	pu	Phase current unbalance 3 composite phase C operating current actual value
13888	87V 1 Bus Va	Volts	Voltage differential 1 phase A bus voltage actual
13890	87V 1 Diff Va	Volts	Voltage differential 1 phase A diff voltage actual
13892	87V 1 Diff Vb	Volts	Voltage differential 1 phase B bus voltage actual
13894	87V 1 Diff Vb	Volts	Voltage differential 1 phase B diff voltage actual
13896	87V 1 Bus Vc	Volts	Voltage differential 1 phase C bus voltage actual
13898	87V 1 Diff Vc	Volts	Voltage differential 1 phase C diff voltage actual
13900	87V 2 Bus Va	Volts	Voltage differential 2 phase A bus voltage actual
13902	87V 2 Diff Va	Volts	Voltage differential 2 phase A diff voltage actual
13904	87V 2 Bus Vb	Volts	Voltage differential 2 phase B bus voltage actual
13906	87V 2 Diff Vb	Volts	Voltage differential 2 phase B diff voltage actual
13908	87V 2 Bus Vc	Volts	Voltage differential 2 phase C bus voltage actual
13910	87V 2 Diff Vc	Volts	Voltage differential 2 phase C diff voltage actual
13912	87V 3 Bus Va	Volts	Voltage differential 3 phase A bus voltage actual
13914	87V 3 Diff Va	Volts	Voltage differential 3 phase A diff voltage actual
13916	87V 3 Bus Vb	Volts	Voltage differential 3 phase B buss voltage actual
13918	87V 3 Diff Vb	Volts	Voltage differential 3 phase B diff voltage actual
13920	87V 3 Bus Vc	Volts	Voltage differential 3 phase C bus voltage actual
13922	87V 3 Diff Vc	Volts	Voltage differential 3 phase C diff voltage actual
14020	60N 1 Raw INsp	Amps	Neutral current unbalance 1 INsp actual value
14022	60N 1 Comp Iop	Amps	Neutral current unbalance 1 Iop actual value
14024	60N 1 Raw INsp	Amps	Neutral current unbalance 2 INsp actual value
14026	60N 1 Comp Iop	Amps	Neutral current unbalance 2 Iop actual value
14028	60N 1 Raw INsp	Amps	Neutral current unbalance 3 INsp actual value
14030	60N 1 Comp Iop	Amps	Neutral current unbalance 3 Iop actual value
14064	59NU1Ntrl-p Vx Ang	Angle	Neutral voltage unbalance neutral-point Vx angle
14066	59NU1Bus V0 Ang	Angle	Neutral voltage unbalance 1 neutral-point Vx bus V0 angle
14068	59NU1Bus V0 Mag	Volts	Neutral voltage unbalance 1 neutral-point Vx bus V0 magnitude
14070	59NU1Ntrl-p Vx Mag	Volts	Neutral voltage unbalance 1 neutral-point Vx magnitude

A

Decimal address	FlexAnalog name	Units	Description
14072	59NU1Vop	Volts	Neutral voltage unbalance 1 neutral-point Vx operating voltage
14074	59NU1Vrest	Volts	Neutral voltage unbalance 1 neutral-point Vx restraining voltage
14076	59NU2Ntrl-p Vx Ang	Degrees	Neutral voltage unbalance 2 neutral-point Vx angle
14078	59NU2Bus V0 Ang	Degrees	Neutral voltage unbalance 2 neutral-point Vx bus V0 angle
14080	59NU2Bus V0 Mag	pu	Neutral voltage unbalance 2 neutral-point Vx bus V0 magnitude
14082	59NU2Ntrl-p Vx Mag	pu	Neutral voltage unbalance 2 neutral-point Vx magnitude
14084	59NU2Vop	pu	Neutral voltage unbalance 2 neutral-point Vx operating voltage
14086	59NU2Vrest	pu	Neutral voltage unbalance 2 neutral-point Vx restraining voltage
14088	59NU3Ntrl-p Vx Ang	Degrees	Neutral voltage unbalance 3 neutral-point Vx angle
14090	59NU3Bus V0 Ang	Degrees	Neutral voltage unbalance 3 neutral-point Vx bus V0 angle
14092	59NU3Bus V0 Mag	pu	Neutral voltage unbalance 3 neutral-point Vx bus V0 magnitude
14094	59NU3Ntrl-p Vx Mag	pu	Neutral voltage unbalance 3 neutral-point Vx magnitude
14096	59NU3Vop	pu	Neutral voltage unbalance 3 neutral-point Vx operating voltage
14098	59NU3Vrest	pu	Neutral voltage unbalance 3 neutral-point Vx restraining voltage
14112	SecondOfDay	---	Integer number of seconds past midnight (1000 seconds = 1 pu)
14114	DayOfMonth	---	Day of the current month (1 day = 1 pu)
14115	DayOfYear	---	Integer number of day of year (Julian date. 5 days = 1 pu)
14116	Year	---	Time of day, year (100 years = 1 pu)
14189	PTP–IRIG-B Delta	ns	PTP time minus IRIG-B time
14208	CAP 1 DISCHRG TIME	seconds	Capacitor control 1 discharge time in seconds
14209	CAP 2 DISCHRG TIME	seconds	Capacitor control 2 discharge time in seconds
14210	CAP 3 DISCHRG TIME	seconds	Capacitor control 3 discharge time in seconds
14211	CAP 4 DISCHRG TIME	seconds	Capacitor control 4 discharge time in seconds
24432	Communications Group	---	Groups communications group
24447	Active Setting Group	---	Current setting group
25488	59B 1 Vop A	Volts	Bank overvoltage 1 Vop phase A
25489	59B 1 Vop B	Volts	Bank overvoltage 1 Vop phase B
25490	59B 1 Vop C	Volts	Bank overvoltage 1 Vop phase C
25491	59B 2 Vop A	Volts	Bank overvoltage 2 Vop phase A
25492	59B 2 Vop B	Volts	Bank overvoltage 2 Vop phase B
25493	59B 2 Vop C	Volts	Bank overvoltage 2 Vop phase C
25494	59B 3 Vop A	Volts	Bank overvoltage 3 Vop phase A
25495	59B 3 Vop B	Volts	Bank overvoltage 3 Vop phase B
25496	59B 3 Vop C	Volts	Bank overvoltage 3 Vop phase C
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
39184	FlexElement 9 Value	---	FlexElement 9 actual value
39186	FlexElement 10 Value	---	FlexElement 10 actual value
39188	FlexElement 11 Value	---	FlexElement 11 actual value

A

Decimal address	FlexAnalog name	Units	Description
39190	FlexElement 12 Value	---	FlexElement 12 actual value
39192	FlexElement 13 Value	---	FlexElement 13 actual value
39194	FlexElement 14 Value	---	FlexElement 14 actual value
39196	FlexElement 15 Value	---	FlexElement 15 actual value
39198	FlexElement 16 Value	---	FlexElement 16 actual value
41138	V0 3rd Harmonic 1	Volts	VTFF 1 V0 3rd Harmonic
41140	V0 3rd Harmonic 2	Volts	VTFF 2 V0 3rd Harmonic
41142	V0 3rd Harmonic 3	Volts	VTFF 3 V0 3rd Harmonic
41144	V0 3rd Harmonic 4	Volts	VTFF 4 V0 3rd Harmonic
41146	V0 3rd Harmonic 5	Volts	VTFF 5 V0 3rd Harmonic
41148	V0 3rd Harmonic 6	Volts	VTFF 6 V0 3rd Harmonic
45584	RxGOOSE Analog1	---	RxGOOSE analog input 1
45586	RxGOOSE Analog2	---	RxGOOSE analog input 2
45588	RxGOOSE Analog3	---	RxGOOSE analog input 3
45590	RxGOOSE Analog4	---	RxGOOSE analog input 4
45592	RxGOOSE Analog5	---	RxGOOSE analog input 5
45594	RxGOOSE Analog6	---	RxGOOSE analog input 6
45596	RxGOOSE Analog7	---	RxGOOSE analog input 7
45598	RxGOOSE Analog8	---	RxGOOSE analog input 8
45600	RxGOOSE Analog9	---	RxGOOSE analog input 9
45602	RxGOOSE Analog10	---	RxGOOSE analog input 10
45604	RxGOOSE Analog11	---	RxGOOSE analog input 11
45606	RxGOOSE Analog12	---	RxGOOSE analog input 12
45608	RxGOOSE Analog13	---	RxGOOSE analog input 13
45610	RxGOOSE Analog14	---	RxGOOSE analog input 14
45612	RxGOOSE Analog15	---	RxGOOSE analog input 15
45614	RxGOOSE Analog16	---	RxGOOSE analog input 16
45616	RxGOOSE Analog17	---	RxGOOSE analog input 17
45618	RxGOOSE Analog18	---	RxGOOSE analog input 18
45620	RxGOOSE Analog19	---	RxGOOSE analog input 19
45622	RxGOOSE Analog20	---	RxGOOSE analog input 20
45624	RxGOOSE Analog21	---	RxGOOSE analog input 21
45626	RxGOOSE Analog22	---	RxGOOSE analog input 22
45628	RxGOOSE Analog23	---	RxGOOSE analog input 23
45630	RxGOOSE Analog24	---	RxGOOSE analog input 24
45632	RxGOOSE Analog25	---	RxGOOSE analog input 25
45634	RxGOOSE Analog26	---	RxGOOSE analog input 26
45636	RxGOOSE Analog27	---	RxGOOSE analog input 27
45638	RxGOOSE Analog28	---	RxGOOSE analog input 28
45640	RxGOOSE Analog29	---	RxGOOSE analog input 29
45642	RxGOOSE Analog30	---	RxGOOSE analog input 30
45644	RxGOOSE Analog31	---	RxGOOSE analog input 31
45646	RxGOOSE Analog32	---	RxGOOSE analog input 32

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Appendix B: RADIUS server configuration

B.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 from freeradius.net.
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 in this example 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 may specify one secret for a network of clients, where in the example below 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.

   8.1. If logging in, select **Device** for the **Authentication Type**, and use Administrator for the **User Name**. The default password is "ChangeMe1#".

   8.2. 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.

   Recall that if you tried another third-party tool and it did not work, you can use the FreeRADIUS software from freeradius.net.

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Appendix C: Command line interface

C.1 Command line interface

SetupCLI is a command line interface to communicate with the EnerVista UR Setup software. Commands can be sent from a DOS prompt or a Windows batch file.

The interface is installed with the EnerVista software. Its default location is similar to C:\Program Files\EnerVista\Tools\SetupCLI

The EnerVista software needs to be installed on a computer to run the command line interface. The command line interface does not provide a remote connection to a computer running the EnerVista software.

Items to note are as follows:

- Works with EnerVista UR Setup version 6.10 and later
- Available in English only
- The graphical user interface of the software is not available concurrently with the command line interface
- It does not support concurrent commands
- It has limited functionality with CyberSentry
- It does not interface with Engineer
- It does not work when EnerVista UR Setup security is enabled, meaning when login is required

Command syntax is as follows:

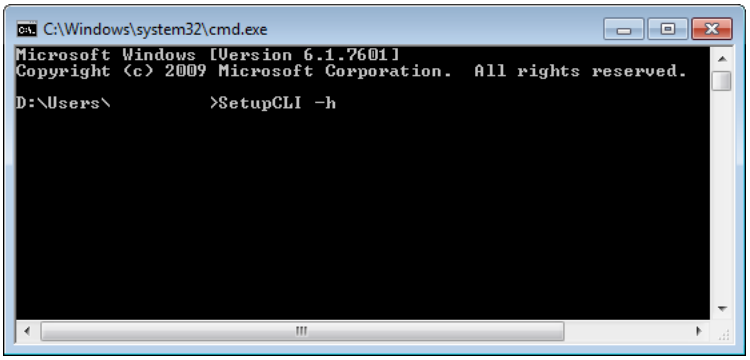
- Options enclosed in [ ] are optional
- Values enclosed in < > are replaced with your own values
- <Application> is replaced with the EnerVista software to receive the command. Use "URPC" for EnerVista UR Setup.
- <device> is the UR device name, as displayed in the **Device Name** field of the Device Setup window and listed in the Online Window. Use quotes with spaces, such as "B30 Belfort".
- "-s" can be used with any command to suppress error messages
- All commands, their return codes, and error description are logged in the All Users > Application Data folder
- When the Supervisor account is enabled, the 'Lock Relay' setting must first be changed to No before the putsettings, inservice, or reboot command can be used. This setting cannot be changed using the command line interface.
- Use quotes ("") to enclose any parameter containing a space
- Commands, options, and parameters are case sensitive

- All commands have a return code of 0-255. 0 indicates success and 1-255 indicate different errors
- If SetupCLI is automated (in a batch file), make sure that only a single batch is running at a time. SetupCLI does not support concurrent operations.

To run the command line interface:

1. In Windows, click the **Start** button, enter `cmd`, and press the **Enter** key. After prompting for permission, the Windows command window opens.
2. Enter `SetupCLI` followed by the action to execute. An example of use is to enter "SetupCLI -h" to display help, specifically the commands and explanations outlined here.

Figure C-1: Command line interface run in the command window



SetupCLI -h

Display help.

It displays the content outline here.

SetupCLI <Application> start [-c] [-s]

Launch application with name <Application>.

To start in client mode, which is the graphical user interface, include option '-c'. Before use, the software must be idle without any windows open. Any activity or open windows can cause unexpected behavior. When in client mode, do not use Launchpad's Site Management feature.

To suppress errors, include option -s.

Example: SetupCLI URPC start -c

SetupCLI <Application> exit [-s]

Exit application with name <Application>.

Example: SetupCLI URPC exit

SetupCLI <Application> login -d <device> [-A <authentication type>] [-a <account>] -w <password> [-s]

Authenticate with device <device> using password <password>.

For non-CyberSentry devices — Set <authentication type> to "traditional". Note that <authentication type> defaults to "traditional" if not specified. Set <account> to "COMMANDS" or "SETTINGS". If not specified, the SETTINGS account is used.

Example: SetupCLI URPC login -d "C30 Melbourne" -A traditional -a SETTINGS -w 1password1

Example of a batch file that checks for an error (this batch file uses standard batch file operations to check the return code (ERRORLEVEL) and jump to an error handler):

SetupCLI URPC start

```
SetupCLI URPC login -d demoDevice -a SETTINGS -w WrongPassword -A traditional
IF NOT ERRORLEVEL 0 GOTO FAILED
SetupCLI URPC putsettings -d demoDevice  -f "example file.urs"
SetupCLI URPC inservice -d demoDevice
SetupCLI URPC reboot -d demoDevice
SetupCLI URPC exit
exit

:FAILED
echo Please try again
exit
```

For CyberSentry devices with local authentication — Set <authentication type> to "local" . Set <account> to "Supervisor", "Administrator", "Engineer", "Operator", or "Observer".

For CyberArmor devices with RADIUS authentication — Set <authentication type> to "radius". Set <account> to the user's account on the radius server.

SetupCLI <Application> logout -d <device> [-s]

Log out of device <device>.

Example: SetupCLI URPC logout -d C30

SetupCLI <Application> getsettings -d <device> -f <File> [-s]

Read settings from device <device> and save them to the .urs file <File>. The <File> must not already exist. The default path to the output file is C:\Users\Public\Public Documents\GE Power Management\URPC\Data

Example: SetupCLI URPC getsettings -d C30 -f "C30 Markham.urs"

Example of a batch file to retrieve a settings file:

```
SetupCLI URPC start
SetupCLI URPC getsettings -d demoDevice -f C:\example.urs
SetupCLI URPC exit
```

Example of a batch file to retrieve a settings file from a relay that requires RADIUS authentication:

```
SetupCLI URPC start
SetupCLI URPC login -d demoDevice -a %1 -w %2 -A radius
SetupCLI URPC getsettings -d demoDevice -f "example file.urs"
SetupCLI URPC logout -d demoDevice
SetupCLI URPC exit
```

Although a user name and password could have been entered in this batch file, it would have created a security risk. Batch files allow you to pass in runtime parameters and refer to them in your script as %1, %2, and so on. For example, if this file is called example.bat, one calls it as follows: "example.bat MyUserName MyPassword"

SetupCLI <Application> putsettings -d <device> -f <File> [-s]

Write the settings file <File> to the device <device>.

For CyberSentry devices, putsettings is only supported for users with the "Administrator" role.

Example: SetupCLI URPC putsettings -d C30 -f "C30 Markham.urs"

SetupCLI <Application> compare -f <File1> -r <File2> -o <OutputFile> [-s]

Compare settings files <File1> and <File2>, and save output to <OutputFile>.

Example: SetupCLI URPC compare -f may.urs -r september.urs -o compared.txt

Batch file example that retrieves a settings file, compares it with an existing settings file, and opens the resulting comparison file:

```
SetupCLI URPC start
SetupCLI URPC getsettings -d demoDevice  -f devicefile.urs
SetupCLI URPC compare -f existingfile.urs -r devicefile.urs -o output.txt
```

The output is similar to the following:

```
Comparing settings file aaa.urs : C:\Users\Public\Public Documents\GE Power Management\URPC\Data\ with bbb.urs
: C:\Users\Public\Public Documents\GE Power Management\URPC\Data\

#    Setting Name              (Group,Module,Item)   Value

1 + Default Message Timeout          (1,1,1) = 299 s
2 - Default Message Timeout          (1,1,1) = 300 s
3 + Flash Message Time               (1,1,1) = 0.9 s
4 - Flash Message Time               (1,1,1) = 1.0 s
```

SetupCLI <Application> inservice -d <device> [-n] [-s]

Put the device in service. Include option -n to take the device out of service.

Example: SetupCLI URPC inservice -d C30

SetupCLI <Application> reboot -d <device> [-s]

Reboot the relay <device>. This is necessary after changing IEC 61850 settings and aggregator source settings.

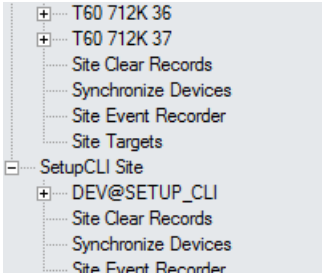
Example: SetupCLI URPC reboot -d "C30_Instanbul"

SetupCLI <Application> adddevice -I <IP Address> -S <Slave Address> -P <Modbus Port>

Connect to a device using its IP address, slave address, and Modbus port. Show the device in the EnerVista interface under the SetupCLI Site as DEV@SETUP_CLI.

EnerVista UR Setup 7.30 or higher supports this command.

Figure C-2: Device added using IP address



The device is named as DEV@SETUP_CLI, which is used as the device name required by the <device> parameter of other SetupCLI commands.

The device name DEV@SETUP_CLI is always assigned to the device that is connected most recently by performing 'adddevice' command. It means that the Application only keeps up to one device named as DEV@SETUP_CLI, the 'adddevice' command disconnects/deletes the device DEV@SETUP _CLI that was connected previously by performing 'adddevice' command.

The device name DEV@SETUP_CLI is never used to configure/connect to a device through the graphical user interface.

Example of a batch file using a device IP address to retrieve its settings file:

```
SetupCLI URPC start
SetupCLI URPC adddevice -I 192.168.140.113 -S 113 -P 502
SetupCLI URPC getsettings -d DEV@SETUP_CLI -f C:\example.urs
SetupCLI URPC exit
```

After connecting the device using IP address, the device name DEV@SETUP_CLI is used to identify this device in 'getsettings' command.

Example of a batch file using a device IP address to retrieve a settings file when RADIUS authentication is required:

```
SetupCLI URPC start
SetupCLI URPC adddevice -I 192.168.140.113 -S 113 -P 502
SetupCLI URPC login -d DEV@SETUP_CLI -a %1 -w %2 -A radius
SetupCLI URPC getsettings -d DEV@SETUP_CLI -f "example file.urs"
SetupCLI URPC logout -d DEV@SETUP_CLI
SetupCLI URPC exit
```

DEV@SETUP_CLI has to be used as the device name in the commands followed by the 'adddevice' command.

C

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Appendix D: Miscellaneous

This chapter provides the warranty and revision history.

D.1 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 Terms and Conditions at

https://www.gegridsolutions.com/multilin/warranty.htm

For products shipped before 1 October 2013, the standard 24-month warranty applies.

D.2 Revision history

The tables outline the releases and revision history of this document.

Table D-1: Revision history (English)

Manual P/N	C70 revision	Release date	ECO
1601-9015-P1	5.2x	23 October 2006	URX-230
1601-9015-P2	5.2x	24 January 2007	URX-232
1601-9015-R1	5.4x	26 June 2007	URX-242
1601-9015-R2	5.4x	31 August 2007	URX-246
1601-9015-R3	5.4x	17 October 2007	URX-251
1601-9015-S1	5.5x	7 December 2007	URX-253
1601-9015-S2	5.5x	22 February 2008	URX-258
1601-9015-S3	5.5x	12 March 2008	URX-260
1601-9015-T1	5.6x	27 June 2008	08-0390
1601-9015-U1	5.7x	29 May 2009	09-0938
1601-9015-U2	5.7x	30 September 2009	09-1165
1601-9015-V1	5.8x	29 May 2010	09-1457
1601-9015-V2	5.8x	04 January 2011	11-2237
1601-9015-W1	5.9x	12 January 2011	11-2227
1601-9015-X1	6.0x	21 December 2011	11-2840

Manual P/N	C70 revision	Release date	ECO
1601-9015-X2	6.0x	5 April 2012	12-3254
1601-9015-Y1	7.0x	30 September 2012	12-3529
1601-9015-Y2	7.0x	11 November 2012	12-3601
1601-9015-Z1	7.1x	30 March 2013	13-0126
1601-9015-AA1	7.2x	1 August 2013	13-0401
1601-9015-AB1	7.3x	7 November 2014	14-1408
1601-9015-AB2	7.3x	1 September 2015	15-2215
1601-9015-AB3	7.3x	1 March 2021	21-6255

Table D-2: Major changes for C70 manual version AB3 (English)

Page	Description
---	Updated document throughout, including branding from GE Digital Energy to GE Grid Solutions
---	Deleted EAC logo from title page and deleted EAC certification from Approvals specifications because document not translated into Russian
---	Added redundant power supply to Order Codes and Control Power sections
2-	Updated Dropout Level specification for several elements, changing percent range to a number
2-	Deleted end-of-manufacturing modules 2G from order code tables
2-8	Added order codes for Inter-relay communication modules in U column for horizontal unit
3-	Updated Typical Wiring Diagram at CPU module, CPU Module Communications Wiring figure, and Options for IRIG-B Connection figure
5-138	Added Phase TOC I2t FlexLogic operands to the FlexLogic operand table for C70
5-162	Added I2t content to Phase TOC settings section and added logic diagram specific to C70
B-	Updated RADIUS chapter
C-	Added Command Line Interface appendix

Table D-3: Major changes for C70 manual version AB2 (English)

Page	Description
---	Updated document throughout, including numbers of elements and FlexLogic operands table
---	Added EAC compliance information throughout, including logo on title page, rear panel, added specifications, added life expectancy and decommissioning, added sections on Repairs, Storage, and Disposal
---	Updated several figures for consistency
2-15	Added UR Signal Processing section
5-	Updated IEC 61850 content
A-	Updated FlexAnalog table

Table D-4: Major changes for C70 manual version AB1 (English)

Page	Description
---	Updated document throughout and put into new template. Major revision.
---	Updated references to digital inputs/outputs to contact inputs/outputs for consistency
---	Added content for advanced IEC 61850, for example in the Settings and Actual Values chapters
2-	Updated Order Codes and Specifications
5-28	Added RS232 Baud Rate setting to Serial Ports section. Baud rate is now configurable, with two options.
5-32	Added Far-End Fault Indication (FEFI) section
5-56	Deleted Ethernet Global Data (EGD) settings, which do not apply to the C70
9-2	Added Software Upgrade section to the Maintenance chapter
---	Moved communications appendices B through F to new UR Series Communications Guide for UR 7.3x AB1

Page	Description
C-1	Updated product warranty from 24 months to 10 years

D

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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
AWG	American Wire Gauge
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
CID	Configured IED Description
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/Check
CRT, CRNT	Current
CSA	Canadian Standards Association
CT	Current Transformer
CVT	Capacitive Voltage Transformer
D/A	Digital to Analog
DC (dc)	Direct Current
DCE	Data Communications Equipment
DCS	Distributed Control System
DD	Disturbance Detector
DFLT	Default
DGNST	Diagnostics
DIFF	Differential
DIR	Directional
DISCREP	Discrepancy
DIST	Distance
DMD	Demand
DNP	Distributed Network Protocol
DPO	Dropout
DPS	Double-Point Status
DSP	Digital Signal Processor
DST	Daylight Savings Time
dt	Rate of Change
DTT	Direct Transfer Trip
DUTT	Direct Under-reaching Transfer Trip
EGD	Ethernet Global Data
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
GSU	Generator Step-Up
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
HV	High Voltage
HYB	Hybrid
Hz	Hertz
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
LV	Low Voltage
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
PP	Power Profile
PRESS	Pressure
PRI	Primary
PRP	Parallel Redundancy Protocol
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
SA	Security Association
SAT	CT Saturation
SBO	Select Before Operate
SCADA	Supervisory Control and Data Acquisition
SCC	Serial Communication Controller
SCL	Substation Configuration Language
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
WGS	World Geodetic System
WRT	With Respect To
X	Reactance
XDUCER	Transducer
XFMR	Transformer
Z	Impedance, Zone

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