GE Energy Services

Auto-Sectionalizing Firmware
Product Description, Information and Specification

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Introduction

Purpose of this Document

The purpose of this document is to fully describe the features, functions and performance of the auto-sectionalizing firmware. The document should be used by GE Energy Services staff and customers to specify, design and test systems which employ this firmware.

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Product Background

The auto-sectionalizing firmware is a member of the DART and SCD product firmware family. This firmware, which uses a fault detector developed and patented by the S&C Electric Company and implemented by GE Energy Services, was created from an early version of DART firmware for satisfying the needs of the LILCO Feeder Re-Configuration Program.

The auto-sectionalizing firmware was introduced to LILCO in 1993 and, as of the latest publication of this document, is in use at over 850 LILCO pole-top locations. As of year-end 1997, this firmware has prevented 763,784 LILCO customer outages[1] and has increased LILCO's SAIFI[2] by approximately four months. LILCO has received a patent for this auto-sectionalizing firmware and, in recognition of its contribution to the utility market place, received the most valuable product award at DA/DSM '96. In 1996, GE Energy Services and LILCO signed a joint marketing agreement, which gives GE Energy Services an exclusive license to market the auto-sectionalizing software.

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[1] The New York State Public Service Commission defines an outage as a loss of power for at least a five minute period.

[2] System Average Interruption Frequency Index.

Chapter 1: Product Information

1.1 Features of the Auto-Sectionalizing Firmware

The auto-sectionalizing firmware features the following:

- Automatic sectionalizing - operation of a control point when a load side overcurrent is followed by a sustained loss of voltage and current. This feature turns a motorized switch into a sectionalize.
- External battery test - external battery test control and battery health pseudo status points for determining the "life" of the switch control's battery.
- Automatic calculation of sensor correction factors - choose from standard PT/CT, Square-D LSCV-110-122 or Fisher Pierce 1301 sensors. Enter the nominal and actual values, conductor diameter and conductor geometry (as applicable for the type of sensor chosen) and the configuration system automatically calculates the sensor correction factor.
- Loss of voltage, over voltage and high current pseudo status points for detecting swells, sags and other distribution system events.
- Unsolicited message tries limit - after the switch sectionalizing controller has attempted to send an unsolicited message and failed a consecutive number of times, the sending of unsolicited messages is terminated. Unsolicited messages are then enabled upon the next poll from the host. This feature conserves communications bandwidth.
- Peak load storage and reporting - stores the maximum hourly peak load and the maximum 72 hour peak load. Values are reported to the host on demand. These peak loads are used by the auto-restoration firmware to qualify the ability to restore load.
- Neutral fault reporting enable/disable - allows the user to disable the neutral fault alarm for feeders that are inadequately balanced or employ single phase switching. This feature conserves communication bandwidth and prevents system operator confusion.

- Current threshold for phase angle reporting - if current drops below this threshold, the phase angles are reported as zero. This feature is used to prevent misinterpretation that arises from sensor non-linearities.
- Automatic analog reporting - when unsolicited report by exception is enabled, all analog points are reported upon a loss of voltage, over voltage or high current. This feature can be used to automatically update operator displays upon a switch operation.
- Configurable current direction qualification - If current direction changes state for longer than the configured number of cycles, the direction pseudo point for the appropriate phase will change state.

1.2 Compatibility of the Auto-Sectionalizing Firmware

1.2.1 Hardware Compatibility

1.2.1.1 Switch Sectionalizing Controllers

Switch sectionalizing controllers currently supported are the DART and the SCD96. Contact the factory for other possible options.

1.2.1.1.1 DART

The auto-sectionalizing firmware is supported on the following vintages (and greater) of the WESDAC DART:

512-0001-22, 512-0002-23, 512-0003-20, 512-0004-19, 512-0005-04, 512-0006-04, 512-0007-04, 512-0008-04

DART's with older vintages must be upgraded to the above vintages or greater.

1.2.1.1.2 SCD96

The auto-sectionalizing firmware is supported in SCD9600 and SCD9650 models. The SCD96 product line does not however support DC inputs, the Square-D and Fisher-Pierce sensor models mentioned previously and multiple feeder monitoring. Functions related to the external battery test, automatic calculation of Square-D and Fisher-Pierce line post sensor correction factors and multiple feeder monitoring are therefore not usable.

1.2.1.2 Voltage and Current Monitoring Configurations

The auto-sectionalizing feature requires at least one voltage and three current inputs per feeder to operate correctly.

1.2.2 Software Compatibility

1.2.2.1 DART

The DNP, DSP and configuration system must be upgraded to auto-sectionalizing versions.

The point mapping between this firmware and other firmware differs. The host's configuration will require re-mapping to ensure compatibility.

1.2.2.2 SCD96

The DNP, DSP and configuration system must be upgraded to auto-sectionalizing versions.

The point mapping between this firmware and other firmware differs. The host's configuration will require re-mapping to ensure compatibility. Consult the configuration system user's guide for the points list.

1.2.2.3 D20/CPM

The use of DNP data link 3.02 or greater is recommended. Firmware that does not incorporate this version must be re-integrated to include this version.

1.2.3 Documentation

GE Energy Services will make available a configuration guide specific to this firmware. Configuration guide documentation should therefore be upgraded.

1.2.4 Utility Environment Compatibility

The purpose of this firmware is to enhance and improve day-to-day operational management of utilities' electric distribution systems. This firmware should not be used for protection purposes. Utilities wishing to use this firmware should fully understand how the features and functions described herein are implemented. It is the utility's responsibility to determine firmware limitations that may surface in particular applications.

1.3 Ordering Auto-Sectionalizing Firmware

To order the auto-sectionalizing firmware, specify the part numbers for the DNP chip, DSP chip and configuration system. GE Energy Services can also provide a sample switch sectionalizing controller configuration to get you started. Contact the factory for the latest part numbers.

Chapter 2: Product Description

The auto-sectionalizing firmware includes the following features.

2.1 Peak Load Storage and Reporting

The firmware records the peak load storage using two circular buffers and two analog points. One circular buffer and analog point is used for the one hour maximum and the other circular buffer and analog point is used for the 72 hour maximum. The peak load storage algorithm is implemented as follows:

The switch sectionalizing controller samples RMS current magnitude every minute. The largest magnitude between the three phases on the feeder is stored in a 60 minute circular buffer. The largest value in the buffer is used to update the peak hourly analog point. Once the 60 minute buffer is full, the oldest value in the buffer is overwritten with the new value. If the overwritten value is the current peak hourly value, then the entire buffer is searched for a new peak hourly value.

Each new peak hourly value overwrites the value at the current buffer position in a second 72 hour circular buffer. Each hour, the position in the 72 hour buffer is incremented. The largest value in the buffer is used to update the peak 72 hour analog point. When the buffer is full, the oldest value in the buffer is overwritten with the next peak hourly value. If the overwritten value is the current 72 hour peak value, then the entire buffer is searched for a new 72 hour peak value.

☞**NOTE:** Events which have been qualified as overcurrents are not placed in the buffers.

2.2 Automatic Sectionalizing

2.2.1 Functionality

After the switch sectionalizing controller detects an overcurrent event followed by a loss of voltage and current (deduced as breaker operation) followed by a sustained loss of voltage and current (deduced as breaker pre-lockout[3]) on any phase of a feeder, control relay number 1 is operated for feeder 1 and control relay number for feeder 2 if the following three conditions are satisfied:

1. The other two phases are not in the normal state and not qualifying a fault or recovery. The other two phases must be in powered down state or also in the breaker pre-lockout state.
2. A backfeed condition is not present on any phase. This prevents sectionalizing on a line-side overcurrent event.
3. Auto-sectionalizing is enabled.

One latching pseudo control point is used to enable and disable auto-sectionalizing on a per feeder basis.

A pseudo status point indicates whether the sectionalizing feature is enabled or disabled.

If a backfeed has been detected, auto-sectionalizing is disabled until all three phases have returned to the normal state. The auto-sectionalizing relay will operate once on a fault that sequences to the pre-lockout state. The last phase to pass through the pre-lockout state will cause the auto-sectionalizing relay to operate. This is guaranteed by condition 1 above.

A pseudo status is generated when the auto-sectionalizing relay operates. The pseudo status is cleared when all three phases of the feeder have entered the normal state, idle state or the No I or V state (in any combination). The configuration system provides a means to enable COS and/or SOE on this status point.

The auto-sectionalizing feature operates for one or two feeders configured for either “forward faults with backfeed” (typically used for radial distribution systems) or “forward and reverse faults without backfeed” (typically used for closed loop distribution systems). Regardless of the configured fault detector mode, auto-sectionalizing will operate when the actual backfeed deviation angle is less than the configured backfeed deviation angle. However, if the backfeed deviation angle is configured to 180 degrees, auto-sectionalizing will work for both upstream and downstream faults. For example, assume the user configures the backfeed deviation angle to 120 degrees. If the phase shift between the pre-fault current and fault current is between 0 and 120 degrees, then the auto-sectionalize will operate.

[3] Breaker pre-lockout is defined as the breaker open period before the breaker locks out.

2.2.2 Typical Application

The figure below describes the basic topology of a typical distribution circuit. A typical installation of the switch sectionalizing controller and line-sensing devices is shown at S1. Faults are indicated by "**X**".

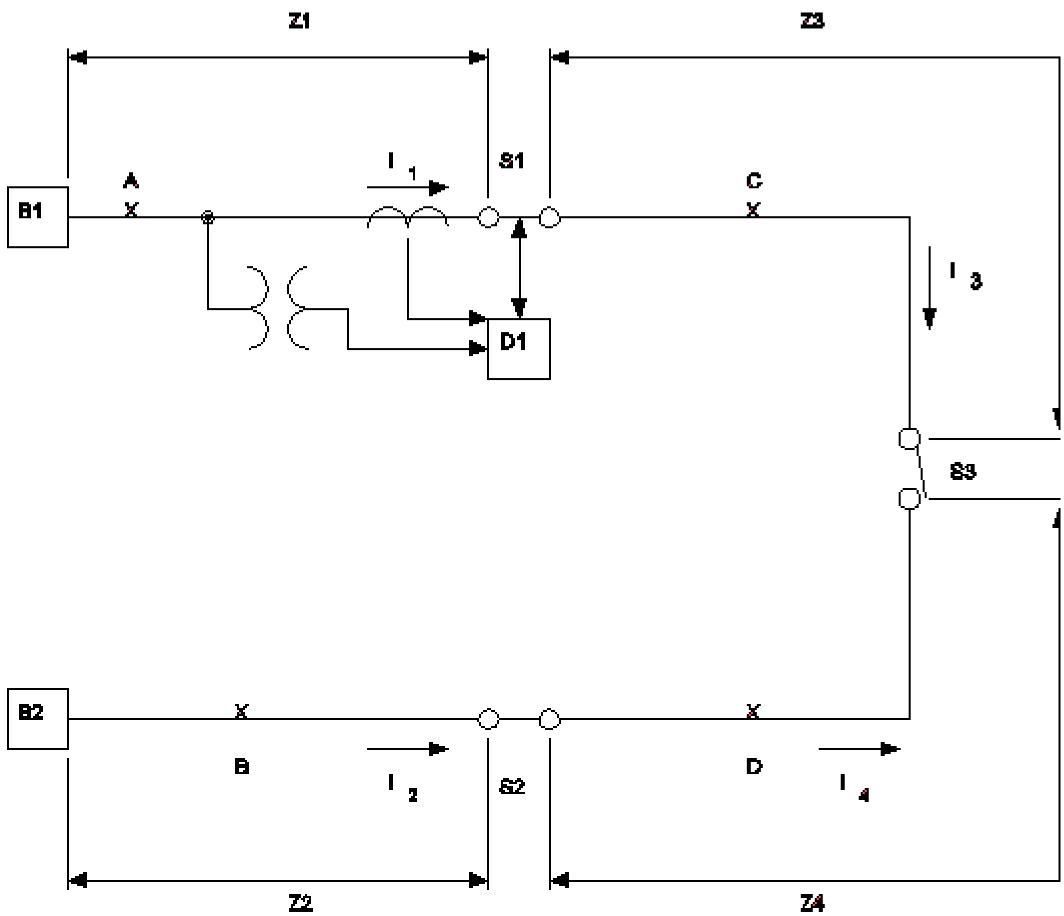

Figure 1 Basic Topology of a Typical Distribution Circuit

B1 and B2 represent three phase reclosing breakers that are each controlled by three lines and one ground overcurrent relay. S1 and S2 are normally closed sectionalizing switches and S3 is a normally open midpoint switch. Each switch is monitored and controlled by a switch sectionalizing controller. Not shown are manual disconnect switches along the length of the circuit that are used for maintenance operations.

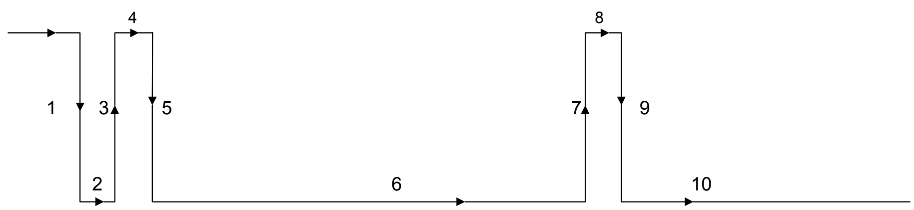

Figure 2 Breaker Operating Profile

The following figure illustrates a typical breaker's operating profile that has been configured as shown in the table below:

Parameter	Setting
Fault magnitude pick-up	960 Amps
Number of instantaneous trips	1
Number of delayed recloses	1
Reclose time delay	30 seconds
Relay reset period	60 seconds

Table 1 Breaker's Relay Settings

Breaker operation for a sustained overcurrent fault that exceeds the pick up setting of the line overcurrent relay is as follows. The steps below relate to the numbers in the diagram above:

1. Once the line current exceeds 960A, the line overcurrent relay will trip the breaker according to a time-to-open characteristic curve (for example, at 960A (the line fault pick up setting) the relay "starts" to pick up, at 2880A the relay trips the breaker in 0.84 seconds and at 4800A the relay trips the breaker in 0.3 seconds),
2. the breaker will then remain open for a period of 5 to 20 cycles,
3. and then instantaneously close. This is called the first reclose attempt,
4. the breaker will then remain closed for a period of time that is a function of the level of the fault current (see point 1 above). This is called the first close duration,
5. following this initial reclose period, the breaker will trip for the second time,

6. and remain open for 30 seconds (pre-lockout),
7. then, it will reclose for the last time,
8. and will then remain closed for a period of time that is equal to the time of the first close duration (same as 4 above),
9. following this second reclose attempt the breaker will trip for the third time,
10. and finally lock out the circuit.

For the breaker to lock out, the three trip operations have to occur within a 60 second period. After a total of 60 seconds from the first trip operation (1), the breaker will reset and the reclosing cycle will start from the beginning.

In this scheme, the switch sectionalizing controller is configured to auto-sectionalize following the first reclose attempt. This will of course minimize the number of customers experiencing the outage by maintaining service to the loads between the breaker and the first sectionalizing switch.

2.2.3 Fault Detector Operation

Let's examine how the auto-sectionalizing firmware's fault detector behaves in each of the operating regions of the breaker for an overcurrent fault (refer to the previous figure):

1. The line current starts to rise. Once the current reaches a pre-configured level for a pre-configured period of time, the switch sectionalizing controller issues an overcurrent alarm. The line current continues to rise until it exceeds the line fault pick up setting of the line overcurrent relay. At this point the breaker trips and causes a loss of three phase line voltage and current,
2. the switch sectionalizing controller immediately detects the loss of voltage and current. The breaker remains open for a period of 5 to 20 cycles. Within this 5 to 20 cycle time, the switch sectionalizing controller recognizes that the breaker has opened and it issues a breaker operation alarm,
3. the breaker then closes,
4. and remains closed for a period of time that is a function of the level of the fault current (typically 5 seconds or less),
5. following this initial reclose period, the breaker will trip for the second time,
6. and remain open for 30 seconds. The switch sectionalizing controller now issues an auto-sectionalizing command and two alarms. The first alarm is a breaker pre-lockout alarm. At the same time, the switch sectionalizing controller issues an auto-sectionalizing alarm to indicate that an open command has been issued to the overhead switch. The switch sectionalizing controller will also detect a loss of voltage and current, 7. the breaker will then reclose for the last time,
8. and will remain closed. The switch sectionalizing controller will now return to the normal state.

The above is graphically summarized in the fault detector's state machine, which is illustrated in the following figure.

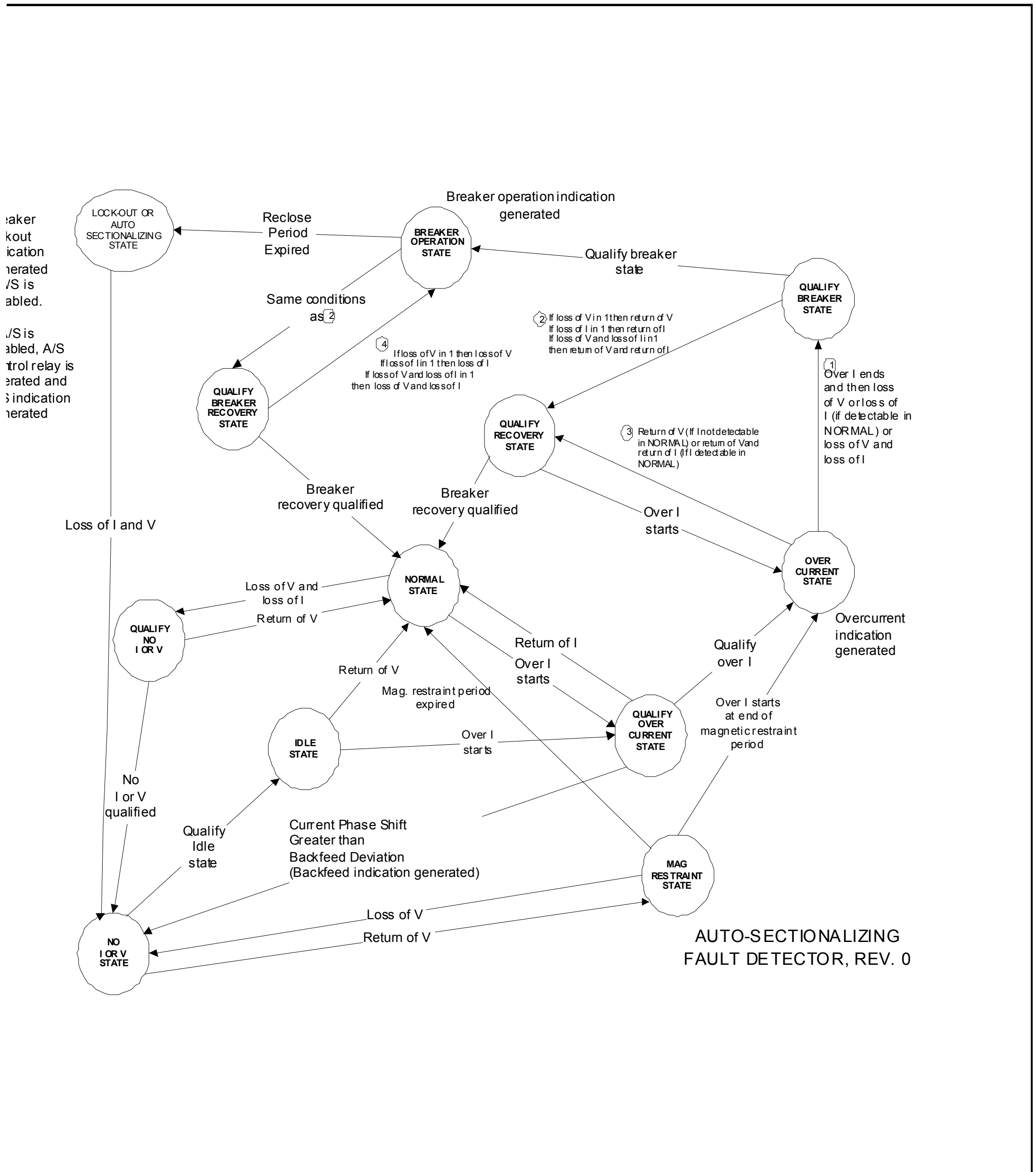

Figure 3 Fault Detector's State Machine

2.2.4 User Interface

The user configures the sectionalizing switch controller's fault detector using the following parameters:

Magnitude Threshold	Qualification Period	Other
Over I Starts	Qualify Over I	COS on Fault Events (enable/disable)
Over I Ends	Qualify Over I Recovery	SOE on Fault events (enable/disable)
Return of I	Qualify No I or V	
Loss of I	Qualify Breaker State	
Return of V	Reclose Period	
Loss of V	Qualify Breaker Recovery	
Neutral Fault Starts	Magnetic Restraint	
Backfeed Deviation	Qualify Idle State	
	Qualify Neutral Fault	
	Qualify Direction	

Table 2 User Interface Settings for Fault Detector

2.2.5 Performance

The algorithm takes into account pre and post fault current magnitude, pre and post fault current phase shift and the presence or absence of voltage. The algorithm does not examine voltage fault angles or line impedance. End users are encouraged to evaluate the performance of this implementation for their specific fault scenarios and feeder topologies.

2.3 Loss of Voltage Pseudo Status Point

The switch sectionalizing controller monitors the RMS voltage magnitude on each phase of the feeder. A pseudo status point per phase is generated when the voltage magnitude drops below a configurable threshold and a configurable number of cycles. The configuration system provides a means to configure the loss of voltage threshold, loss of voltage qualifying period and the ability to enable COS and/or SOE on a feeder basis. This pseudo status point operates independently from the fault detector.

2.4 High Voltage Pseudo Status Point

The switch sectionalizing controller monitors the RMS voltage magnitude on each phase of the feeder. A pseudo status point per phase is generated when the voltage magnitude rises above a configurable threshold and a configurable number of cycles. The configuration system provides a means to configure the high voltage threshold, high voltage qualifying period and the ability to enable COS and/or SOE on a feeder basis. This pseudo status point operates independently from the fault detector.

2.5 High Current Pseudo Status Point

The switch sectionalizing controller monitors the RMS current magnitude on each phase of the feeder. A pseudo status point per phase is generated when the current magnitude rises above a configurable threshold and a configurable number of cycles. The configuration system provides a means to configure the high current threshold, high current qualifying period and the ability to enable COS and/or SOE on a feeder basis. This pseudo status point operates independently from the fault detector.

2.6 Unsolicited Reporting Retry Limit

After the switch sectionalizing controller has attempted to send an unsolicited message and failed to receive an acknowledgement a consecutive number of configurable times, the sending of unsolicited messages is terminated. Events that occur following the termination, reset the retry counter and enable unsolicited messages again. When any of the pseudo status points change, all the analog values are included in the next unsolicited message.

2.7 Sensor Correction Factors

In addition to standard PTs and CTs, the configuration system provides a means to input phase angle and magnitude correction factors for Square-D and Fisher-Pierce sensors.

2.7.1 Square D LSCV-110-122

The nominal ratio, conductor diameter and phase angle data is entered on a per phase basis.

2.7.1.1 Specifics of Magnitude Correction

The configuration system automatically calculates the actual turns ratio based on the conductor diameter and nominal ratio the user enters. The configuration system then automatically calculates the magnitude correction factor. The actual turns ratio is based on the following formula supplied by the Square-D company for 60Hz operation:

Actual turns ratio = (Conductor diameter X 17.52) + 77.81

2.7.2 Fisher-Pierce 1301 Current Only Sensors

The nominal ratio, conductor diameter, conductor geometry and phase angle data is entered on a per phase basis.

2.7.2.1 Specifics of Magnitude Correction

The configuration system automatically calculates the actual turns ratio based on the conductor diameter and nominal ratio the user enters. The configuration system then automatically calculates the magnitude correction factor. The actual turns ratio is based on the following formula supplied by Fisher-Pierce for 60Hz operation:

Actual turns ratio = (Conductor diameter X 13.48) + 52.85

The user can also enter an additional correction factor for conductor geometry. The correction factors for various geometries are published in the Fisher-Pierce literature.

2.8 External Battery Test

Control point six is used to start the test. The control remains energized for the duration of the test. This control relay is used to connect an external load across the power source to be tested. Once the test has started, it continues for a configurable period of time or until the battery voltage drops below a configurable threshold. A pseudo status point reports the battery test in progress and a pseudo status point reports a low voltage condition when the battery voltage drops below the configured threshold.

The external battery test control relay has low priority. The battery test will be cancelled and the battery test control relay will open if any other control relay operation is requested by a DNP3 message or a message from the fault detector requesting that the sectionalizing relay be operated.

The configuration system provides a means to configure:

- - the test duration. The duration is configurable from 0 to 30 seconds.
- - the low voltage threshold. The threshold is configurable from 0 to 60 volts.
- - COS and/or SOE on the low voltage and the test in progress pseudo status points.

2.9 Difference Between Standard and Auto-Sectionalizing Firmware

The auto-sectionalizing firmware includes all of the standard DNP chip and standard configuration system functionality with the exception of:

- Unsolicited analogs for class data reporting - the standard chip allows the user to configure thresholds and deadbands for line quantities. Changes are reported following a class scan.
- Fault detector limits - the standard configuration system incorporates minimum and maximum values for the fault detector limits. The auto-sectionalizing configuration system allows a wider range of values for the fault detector settings.
- Three feeder monitoring - the standard chip can monitor one, two or three feeders. The auto-sectionalizing chip can monitor one or two feeders.
- Energy accumulators - the standard chip allows the user to view these in DARTMAINT. The auto-sectionalizing chip does not.

2.10 Product Documentation

Product Description, Information & Specification & Configuration User's Guide

Quantity of product documentation is defined on a per contract basis. Documentation for additional contract deliverables is arranged on a per contract basis.