SEL-311M Relay

Line Current Differential, Protection, and Automation System

Instruction Manual

20100122

SCHWEITZER ENGINEERING LABORATORIES, INC.

⚠CAUTION

Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

⚠ATTENTION

Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.

⚠CAUTION

There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.

⚠ATTENTION

Il y a un danger d'explosion si la pile électrique n'est pas correctement remplacée. Utiliser exclusivement Ray-O-Vac® No. BR2335 ou un équivalent recommandé par le fabricant. Se débarrasser des piles usagées suivant les instructions du fabricant.

⚠DANGER

Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.

⚠DANGER

Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.

⚠DANGER

Contact with instrument terminals can cause electrical shock that can result in injury or death.

⚠DANGER

Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessuers ou la mort.

⚠WARNING

Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.

⚠AVERTISSEMENT

L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.

⚠WARNING

Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

⚠AVERTISSEMENT

Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.

⚠WARNING

This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

⚠AVERTISSEMENT

Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.

PM311M-01

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Preface

Manual Overview

The SEL-311M Relay Instruction Manual describes common aspects of line differential relay application and use. It includes the necessary information to install, set, test, and operate the relay and more detailed information about settings and commands.

An overview of each manual section and topics follows:

Preface. Describes the manual organization and conventions used to present information.

Section 1: Introduction and Specifications. Introduces SEL-311M features, options, and accessories. In addition, this section summarizes relay functions and applications, and it lists relay specifications, type tests, and ratings.

Section 2: Installation. Describes mounting and wiring the SEL-311M, application and communications connections, and the operation of circuit board jumpers. *Figure 2.2* shows the SEL-311M front and rear panels.

Section 3: Protection Functions. Describes the operation of line current differential elements, the function of various relay protection elements, describes how the relay processes these elements, and gives detailed specifics on protection scheme logic.

Section 4: Trip, Close, and Target Logic. Describes the operation of the following:

- Line current differential high-speed trip logic
- Backup protection trip logic
- Switch-Onto-Fault trip logic
- Communications-assisted trip logic
- Close logic
- Other close conditions (e.g., manual close initiation via serial port or optoisolated inputs)
- Front-panel target LEDs

Section 5: SELogic Control Equation Programming. Explains the operation of the following:

- Optoisolated inputs **IN101–IN106**
- Output contacts **OUT101–OUT107**, **ALARM**, and **OUT201–OUT206**
- Local control switches (local bit outputs LB1–LB16)
- Remote control switches (remote bit outputs RB1–RB16)
- Latch control switches (latch bit outputs LT1–LT16)
- Multiple setting groups (six available)

- Programmable timers (timer outputs SV1T–SV16T)
- Rotating default displays and display points

Section 6: Metering and Monitoring. Describes the operation of the following:

- Line current differential and local (backup) metering
- Demand and maximum/minimum metering
- Energy metering
- Breaker monitor
- Station dc monitor

Section 7: Settings. Explains how to enter settings and also contains the following setting reference information:

- Time-overcurrent curves (5 US and 5 IEC curves)
- Relay Word bit table and definitions (Relay Word bits are used in SELOGIC® control equation settings)
- Settings Sheets for general relay, SELOGIC control equation, global, SER, text label, and serial port settings
  - The Settings Sheets can be photocopied and filled out to set the SEL-311M.
  - Note that these sheets correspond to the serial port **SET** commands listed in *Table 7.1*.

Section 8: Communications. Describes the following:

- 87L communications interfaces, channel monitors, and associated settings
- Serial port connector pinout/terminal functions
- Communications cables
- Communications protocol
- Serial port commands

  See *SHO Command (Show/View Settings) on page 8.33* for a list of the SEL-311M factory default relay settings.

Section 9: Front-Panel Operations. Describes the following:

- Pushbuttons and correspondence to serial port commands
- Local control switches (local bit outputs LB1–LB16)
- Rotating default displays and display points

Section 10: Analyzing Events. Describes the following:

- Standard 15- and 30-cycle event reports for line current differential and backup protection
- Event summaries
- Sequential events recorder (SER) report

Section 11: Testing and Troubleshooting. Describes the following:

- General testing philosophy, methods, and tools
- Alpha plane 87L element test procedures

- ➤ Event Playback test procedure

  See *PLA Command (Event Playback) on page 8.48* for using the event playback function.

- ➤ Relay self-tests and troubleshooting
- ➤ 87L channel troubleshooting
- ➤ Commissioning

Appendix A: Firmware and Manual Versions. Lists the current relay firmware version and details differences between the current and previous versions. Provides a record of changes made to the manual since the initial release.

Appendix B: Firmware Upgrade Instructions. Describes the procedure to update the firmware stored in flash memory.

Appendix C: SEL Communications Processors. Describes how SEL communications processors and PC software use SEL protocols optimized for performance and reliability.

Appendix D: MIRRORED BITS Communications. Describes how SEL protective relays and other devices can directly exchange information quickly, securely, and with minimal cost.

SEL-311M Relay Command Summary. Briefly describes the serial port commands that are fully described in *Section 8: Communications*.

Conventions

Typographic Conventions

There are two ways to communicate with the SEL-311M:

- ➤ Using a command line interface on a PC terminal emulation window, such as Microsoft® HyperTerminal.
- ➤ Using the front-panel menus and pushbuttons.

The instructions in this manual indicate these options with specific font and formatting attributes. The following table lists these conventions:

Example	Description
STATUS	Commands typed at a command line interface on a PC.
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
{CLOSE}	Relay front-panel pushbuttons.
ENABLE	Relay front- or rear-panel labels.
MAIN > METER	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.

Examples

This instruction manual uses several example illustrations and instructions to explain how to effectively operate the SEL-311M. These examples are for demonstration purposes only; the firmware identification information or settings values included in these examples may not necessarily match those in the current version of your SEL-311M.

Safety Information

This manual uses three kinds of hazard statements, formatted as follows:

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, may result in minor or moderate injury or equipment damage.

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

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

Section 1
Introduction and Specifications

Overview

This instruction manual covers the SEL-311M, a digital line current differential relay with integrated communications interfaces. In addition to line current differential protection, the SEL-311M contains directional and nondirectional overcurrent protection, directional power protection, under- and overvoltage protection, and frequency protection.

The SEL-311M implements line current differential protection using communications interfaces, a processor, and contact outputs separate from those used for backup protection and control. A failure in the line current differential hardware does not impact backup protection.

This section includes the following overviews of the SEL-311M:

- SEL-311M Relay Models
- Applications
- AC/DC Connections
- Communications Ports
- Communications Connections
- Relay Specifications

SEL-311M Relay Models

The SEL-311M has the following standard features:

- Screw-terminal blocks
- Wye-connected voltage inputs
- 8 standard output contacts and 6 fast, high-current interrupting output contacts
- 6 optoisolated contact inputs
- 1 EIA-485 port
- 3 EIA-232 ports
- 2 fiber-optic ports for differential protection (the second can be used as a hot standby channel)
- IRIG-B time synchronization

Select among the following ordering options:

- ➤ Horizontal or rack mount
- ➤ 1 A or 5 A phase current transformers
- ➤ 125/250 V, 48/125 V, or 24/48 V power supply
- ➤ Six control input voltage selections

Applications

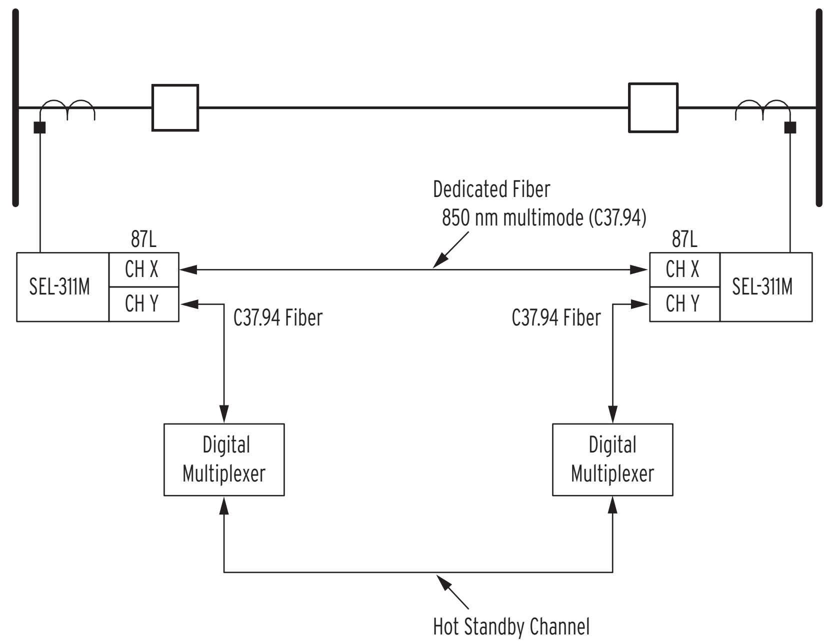


Figure 1.1 Typical Two-Terminal Application With Hot Standby Channel

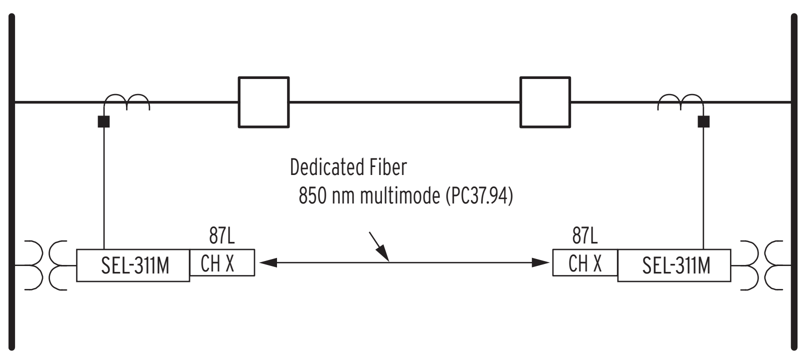


Figure 1.2 Typical Two-Terminal Application With Voltage Inputs

AC/DC Connections

Figure 1.3 and *Figure 1.4* show general connection points. See *Specifications on page 1.6* and *Section 2: Installation* for more information on hardware and connections.

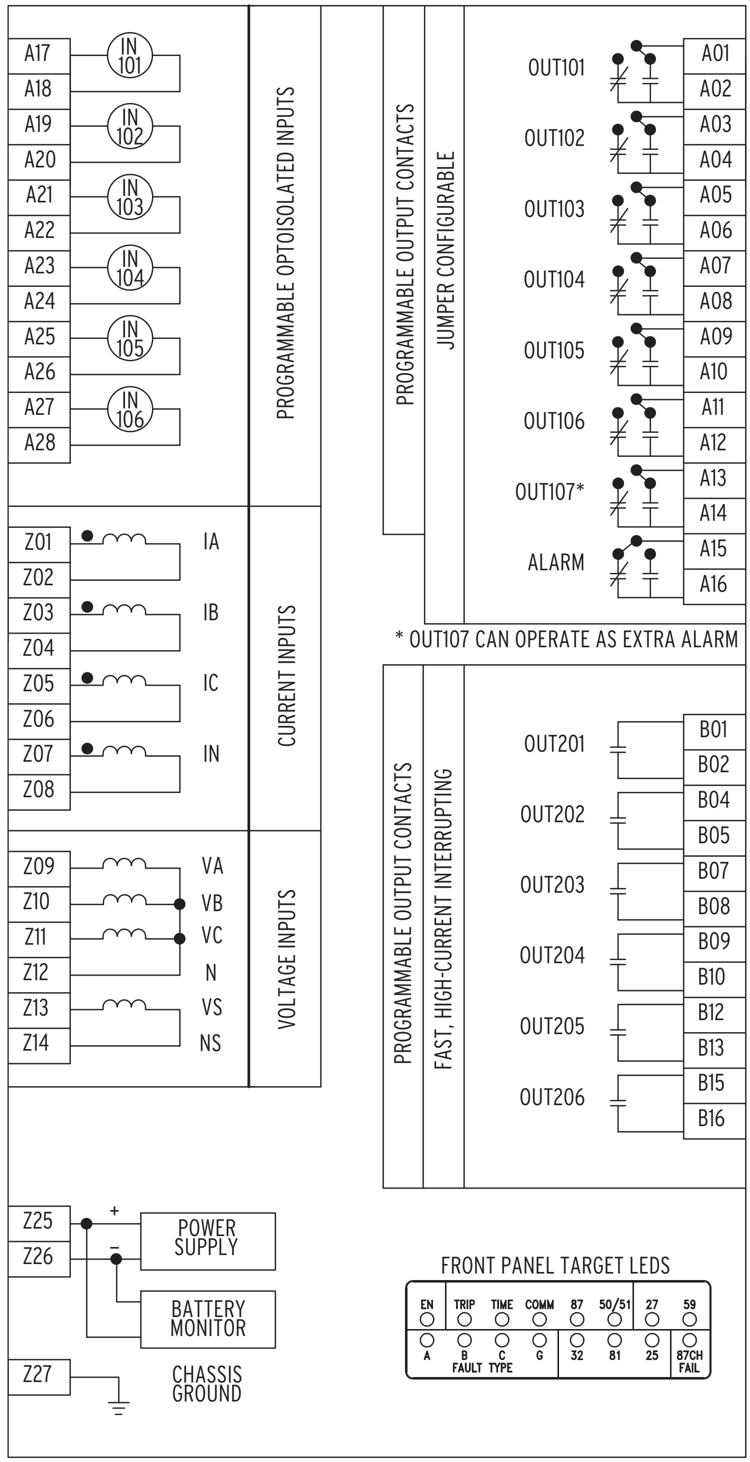
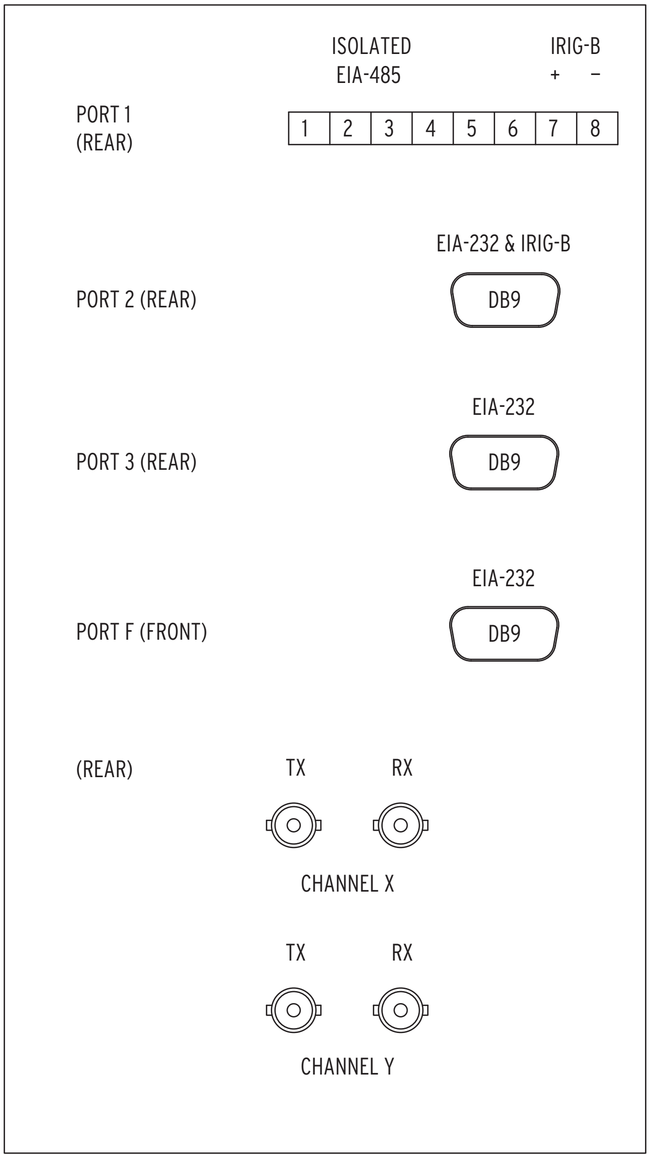


Figure 1.3 SEL-311M Relay Inputs and Outputs



Typical line current differential communications interface.

Figure 1.4 SEL-311M Relay Communications Interfaces

Communications Connections

See *Port Connector and Communications Cables on page 8.9* for more communications connection information.

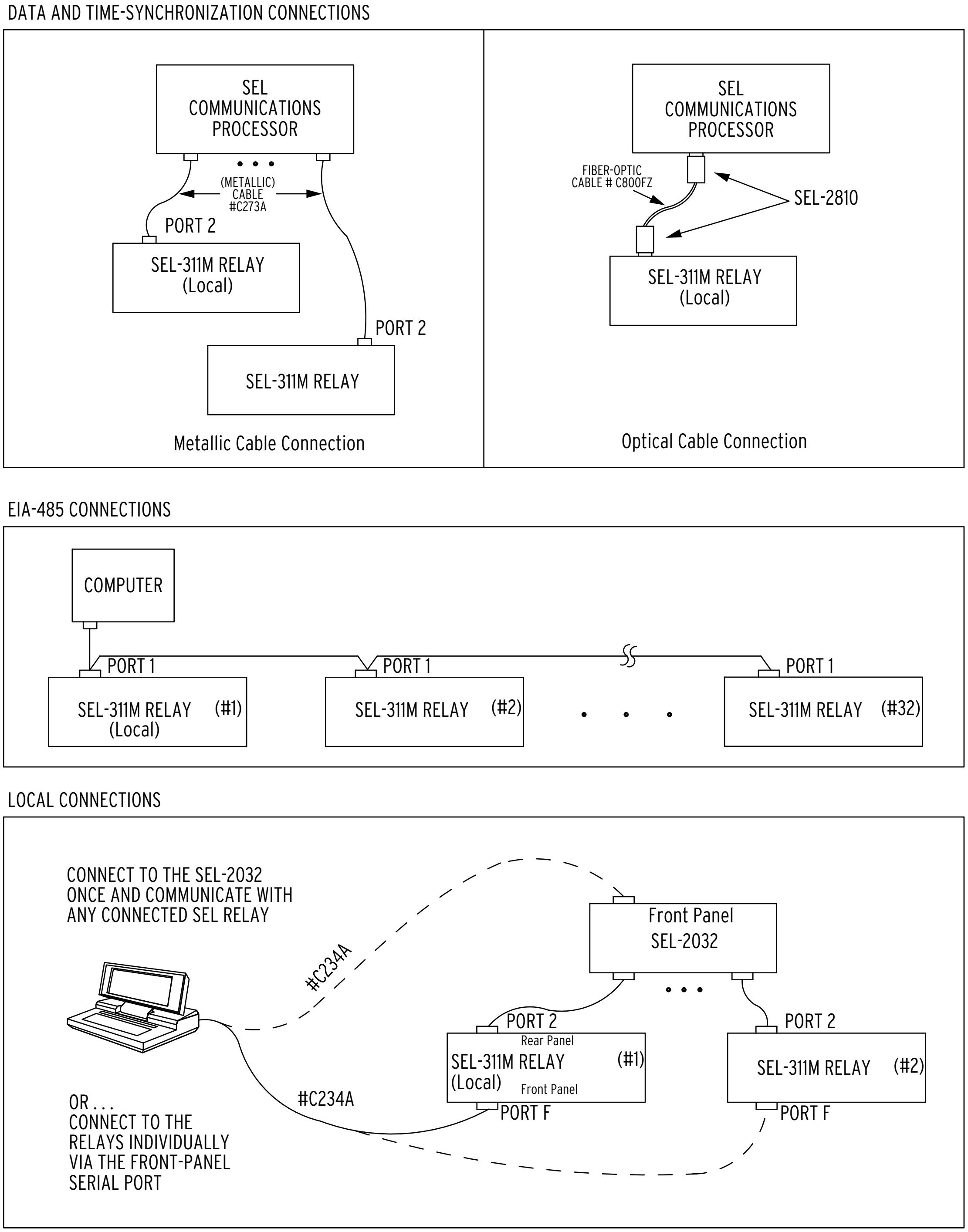


Figure 1.5 SEL-311M Relay Communications Connections Examples

Specifications

General

Terminal Connections

Rear Screw-Terminal Tightening Torque

Minimum:	0.9 Nm (8-in-lb)
Maximum:	1.4 Nm (12-in-lb)

Terminals or stranded copper wire. Ring terminals are recommended.
Minimum temperature rating of 105°C.

AC Phase Current Input (IA, IB, IC)

Nominal:	5 A
Continuous:	15 A, linear to 100 A symmetrical
1 Second Thermal:	500 A for 1 second 1250 A for 1 cycle
Burden:	0.27 VA at 5 A 2.51 VA at 15 A
Nominal:	1 A
Continuous:	3 A, linear to 20 A symmetrical
1 Second Thermal:	100 A for 1 second 250 A for 1 cycle
Burden:	0.13 VA at 1 A 1.31 VA at 3 A

AC Neutral Channel (IN)

Nominal:	0.2 A
Continuous:	15 A, linear to 5.5 A symmetrical
1 Second Thermal:	500 A for 1 second 1250 A for 1 cycle
Burden:	0.002 VA at 0.2 A 1.28 VA at 15 A

AC Voltage Inputs

Nominal:	120 V_{L-N} three-phase four-wire connection.
Continuous:	300 V_{L-N} (connect any voltage up to 300 Vac).
Measurement Range:	600 Vac for 10 seconds.
Burden:	0.03 VA at 67 V 0.06 VA at 120 V 0.8 VA at 300 V

Power Supply

Input Voltage:	
Rated:	125/250 Vdc or Vac
Range:	85–350 Vdc or 85–264 Vac
Rated:	48/125 Vdc or 125 Vac
Range:	38–200 Vdc or 85–140 Vac
Rated:	24/48 Vdc
Range:	18–60 Vdc polarity dependent
Power Consumption:	< 25 W

Control Outputs

Standard (OUT101–107, ALARM)

Make:	30 A
Carry:	10 A for 50 ms
1 Second Rating:	50 A for one second
MOV Protection (maximum voltage):	270 Vac, 360 Vdc, 40 J
Pickup/Dropout Time:	<5 ms typical

Break Capacity (10,000 operations):

48 Vdc	0.50 A	L/R = 40 ms
125 Vdc	0.30 A	L/R = 40 ms
250 Vdc	0.20 A	L/R = 40 ms

Cyclic Capacity (2.5 cycle/second):

48 Vdc	0.50 A	L/R = 40 ms
125 Vdc	0.30 A	L/R = 40 ms
250 Vdc	0.20 A	L/R = 40 ms

Note: Make per IEEE C37.90-1989; Breaking and Cyclic Capacity per IEC 60255-23:1994.

Hybrid (High-Current Interrupting; OUT201–206)

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
MOV Protection (maximum voltage):	330 Vdc, 130 J
Pickup/Dropout Time:	< 10 µs typical

Break Capacity (10,000 operations):

48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Cyclic Capacity (4 interruptions/second, followed by 2 minutes idle for thermal dissipation):

48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Optoisolated Inputs

When Used With DC Control Signals

250 Vdc:	Pickup 200–300 Vdc; dropout 150 Vdc
220 Vdc:	Pickup 176–264 Vdc; dropout 132 Vdc
125 Vdc:	Pickup 105–150 Vdc; dropout 75 Vdc
110 Vdc:	Pickup 88–132 Vdc; dropout 66 Vdc
48 Vdc:	Pickup 38.4–60 Vdc; dropout 28.8 Vdc
24 Vdc:	Pickup 15–30 Vdc

When Used With AC Control Signals

250 Vdc:	Pickup 170.6–300.0 Vac; dropout 106 Vac
220 Vdc:	Pickup 150.3–264.0 Vac; dropout 93.2 Vac
125 Vdc:	Pickup 89.6–150.0 Vac; dropout 53 Vac
110 Vdc:	Pickup 75.1–132.0 Vac; dropout 46.6 Vac
48 Vdc:	Pickup 32.8–60.0 Vac; dropout 20.3 Vac
24 Vdc:	Pickup 12.8–30.0 Vac

AC mode is selectable for each input via Global settings IN101D–IN106D. AC input recognition delay from time of switching: 0.75 cycles maximum pickup; 1.25 cycles maximum dropout.

Note: 24, 48, 125, 220, and 250 Vdc optoisolated inputs draw approximately 5 mA of current; 110 Vdc inputs draw approximately 8 mA of current. All current ratings are at nominal input voltages.

Frequency and Rotation

System Frequency:	50 or 60 Hz
Phase Rotation:	ABC or ACB (settable)
Frequency Tracking:	40.1–65 Hz (VA or VS required)

Serial Communications Ports

EIA-232:	1 Front, 2 Rear
Baud Rate:	300–38400 bps
EIA-485:	1 Rear, 2100 Vdc isolation
Baud Rate:	300–19200 bps

Differential Communications Ports

Fiber Optics—ST Connector

850 nm multimode, C37.94:

	50 µm	62.5 µm
Tx Power:	–23 dBm	–19 dBm
Rx Min. Sensitivity:	–32 dBm	–32 dBm
Rx Max. Sensitivity:	–11 dBm	–11 dBm
System Gain:	9 dB	13 dB

Time-Code Input

Relay accepts demodulated IRIG-B time-code input at Port 1 or 2. Relay time is synchronized to within ±5 ms of time-source input. Current differential protection does not require external time source.

Dimensions

Rack-Mount Chassis

132.6 mm H x 482.6 mm W x 223.5 mm D
(5.22 in. H x 19.00 in. W x 8.80 in. D)

Panel-Mount Chassis

168.9 mm H x 502.9 mm W x 223.5 mm D
(6.65 in. H x 19.80 in. W x 8.80 in. D)

Operating Temperature

–40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20°C.

Weight

3U Rack Unit: 7.24 kilograms (16 pounds)

Type Tests

Environmental Tests

Cold:	IEC 60068-2-1:1993, Test Ad; Normal operating status at –40°C for 16 hours
Damp Heat, Cyclic:	IEC 60068-2-30:1980, Test Db; Normal operating status at 55°C, 6 cycles, 95% humidity
Dry Heat:	IEC 60068-2-2:1993, Test Bd; Normal operating status at +85°C for 16 hours
Object Penetration:	IEC 60529:1992, IP30

Dielectric Strength and Impulse Tests

Dielectric Strength:	IEC 60255-5:2000 IEEE C37.90-1989 2500 Vac for 10 seconds on analog inputs; 3100 Vdc for 10 seconds on power supply, optoisolated inputs, and output contacts.
Impulse:	IEC 60255-5:2000, 0.5 J, 5000 V
Laser Safety:	IEC 60825-1:1993 21 CFR 1040.10 ANSI Z136.1-1993 ANSI Z136.2-1988, eye-safe Class 1 laser product.

Electrostatic Discharge Test

ESD:	IEC 60255-22-2:1996, Severity Level 4 (8000 V contact, 15000 V air)

Electromagnetic Compatibility Immunity

Fast Transient Disturbance:	IEC 60255-22-4:2002 4 kV at 2.5 kHz IEC 61000-4-4:1995 4 kV at 2.5 kHz (4000 V on power supply, 2000 V on inputs and outputs)
Radiated Radio Frequency:	IEC 60255-22-3:2000, 10 V/m IEEE C37.90.2-1995, 35 V/m
Surge Withstand:	IEEE C37.90.1-2002, 3000 V oscillatory, 5000 V transient
1 MHz Burst Disturbance:	IEC 60255-22-1:1988, Severity Level 3 (2500 V common and 1000 V differential mode)

Vibration and Shock Tests

Vibration:	IEC 60255-21-1:1995, Class 1; IEC 60255-21-2:1995, Class 1; IEC 60255-21-3:1993, Class 2.

Certifications

ISO: Relay designed and manufactured using ISO 9001 certified quality program.

Processing Specifications

AC Voltage and Current Inputs

16 samples per power system cycle, 3 dB low-pass filter cut-off frequency of 560 Hz.

Digital Filtering

One-cycle full cosine after low-pass analog filtering. Net filtering (analog plus digital) rejects dc and harmonics.

Current Differential Processing

16 times per power system cycle for line current differential protection and tripping logic.

Backup Protection and Control Processing

4 times per power system cycle

Relay Elements

Line Current Differential (87L)Elements

87L Enable Levels (Difference or Total Current)

Phase Setting Range:	OFF, 0.20 to 2.00 A, 0.01 A steps
Accuracy:	±3% ±0.01 I_{NOM}

Restraint Characteristics

Outer Radius

Radius Range:	2 to 8 in steps of 0.1 (unitless).
Angle Range:	90–270° in steps of 1°
Accuracy:	±5% of radius setting ±3° of angle setting
Operate Time (for bolted fault):	See operate time curves in *Figure 3.7*.

Refer to *Line Current Differential Elements on page 3.2* for the definition of terms and terminology listed above.

Difference Current Alarm Setting

Setting Range:	OFF, 0.1 to 2.0 A, 0.1 A steps
Accuracy:	±3% of ±0.01 I_{NOM}

Ground Current Differential (87W) Element

Minimum Sensitivity Threshold:	0.005–5.000, 0.001 A steps
Forward Ground Directional Element:	± 900,000 ohm, 0.01 ohm steps
Source Adjustment Angle:	0–90°, 1° steps

Substation Battery Voltage Monitor Specifications

Pickup Range:	20–300 Vdc, 1 Vdc steps
Pickup Accuracy:	±5% ±2 Vdc of setting

Timer Specifications

Programmable Timer Pickup:	0.00–999,999.00 cycles, 0.25-cycle steps (programmable timers)
Other Timers:	0.00–16,000.00 cycles, 0.25-cycle steps (other various timers)
Pickup/Dropout Accuracy for All Timers:	±0.25 cycle and ±0.1% of setting

Undervoltage and Overvoltage Elements

Pickup Range:	OFF, 2.00–300.00 V, 0.01 V steps (various elements) OFF, 2.00–520.00 V, 0.01 V steps (phase-to-phase elements) OFF, 2.00–200.00 V, 0.01 V steps (negative-sequence elements)
Steady-State Pickup Accuracy:	±2 V and ±5% of setting
Transient Overreach	< 5% of pickup

Instantaneous/Definite-Time Overcurrent Elements

Pickup Range:	OFF, 0.25–100.00 A, 0.01 A steps (5 A nominal) OFF, 0.05–20.00 A, 0.01 A steps (1 A nominal) OFF, 0.005–5.00 A, 0.001 A steps (0.2 A nominal)
Steady-State Pickup Accuracy:	±0.05 A and ±3% of setting (5 A nominal) ±0.01 A and ±3% of setting (1 A nominal) ±0.001 A and ±3% of setting (0.2 A nominal)
Transient Overreach:	< 5% of pickup
Time Delay:	0.00–16,000.00 cycles, 0.25-cycle steps
Timer Accuracy:	±0.25 cycle and ±0.1% of setting
Max. Operating Time:	See pickup and reset time curves in *Figure 3.15* and *Figure 3.16*.

Time-Overcurrent Elements

Pickup Range:	OFF, 0.50–16.00 A, 0.01 A steps (5 A nominal) OFF, 0.10–3.20 A, 0.01 A steps (1 A nominal) OFF, 0.005–0.640 A, 0.001 A steps (0.2 A nominal)
Steady-State pickup Accuracy:	±0.05 A and ±3% of setting (5 A nominal) ±0.01 A and ±3% of setting (1 A nominal) ±0.001 A and ±3% of setting (0.2 A nominal)
Time Dial Range:	0.50–15.00, 0.01 steps (US) 0.05–1.00, 0.01 steps (IEC)
Curve Timing Accuracy:	±1.50 cycles and ±4% of curve time for current between 2 and 30 multiples of pickup.

Synchronism-Check Elements

Slip Frequency Pickup Range:	0.005–0.500 Hz, 0.001 Hz steps
Slip Frequency Pickup Accuracy:	±0.003 Hz
Phase Angle Range:	0–80°, 1° steps
Phase Angle Accuracy:	±4°

Definite-Time Overfrequency or Underfrequency (81) Elements

Pickup Range:	41.00–65.00 Hz, 0.01 Hz steps
Pickup Time:	32 ms at 60 Hz (max)
Time Delays:	2.00–16,000.00 cycles, 0.25-cycle steps
Maximum Definite-Time Delay Accuracy:	±0.25 cycles, ±1% of setting at 60 Hz
Steady-State plus Transient Overshoot:	±0.01 Hz
Supervisory 27:	25.0–300.0 V, ±5%, ±0.2 V

Metering Accuracy

Voltages

V_A, V_B, V_C, V_S:	±2.5% ±1 V (20.0–300.0 V)

Currents

I_A, I_B, I_C, I_N (Local):	±0.2% ±0.08 mA (0.005–5 A; 0.2 A nominal) ±1% ±0.2 mA (0.1–5.0 A; 1 A nominal) ±1% ±1.0 mA (0.5–10 A; 5 A nominal)
I_A, I_B, I_C, I_N, $3I_2$, $3I_0$, I_1 (Differential):	±5%
I_A, I_B, I_C, I_N, $3I_2$, $3I_0$, I_1 (Total):	±5%

Section 2
Installation

Overview

The first steps in applying the SEL-311M Relay are installing and connecting the relay. This section describes common installation features and particular installation requirements for the physical configurations of the SEL-311M. The SEL-311M comes with 6 inputs and 14 outputs, 6 of which are high-speed, high-current outputs. To install and connect the relay safely and effectively, you must be familiar with relay configuration features, options, and relay jumper configuration. You should plan relay placement, cable connection, and relay communication carefully.

Consider the following when installing the SEL-311M:

- General configuration attributes
  - Relay size
  - Front-panel templates
  - Rear panels
  - Connector types
  - Current and voltage inputs
  - Control inputs
  - Control outputs
  - Time inputs
  - Communications interfaces
  - Battery-backed clock
  - Main, password, and circuit breaker jumpers
- Relay placement
  - Physical location
- Connection
  - Rear-panel layout
  - Rear-panel symbols
  - Screw terminal connectors
  - Grounding
  - Power connections
  - Monitor connections (dc battery)
  - Current and voltage connections
  - Input/output connections
  - Time input connections
  - Communications ports connections

- Replacing the lithium battery
- AC/DC connection diagrams

  This section contains a drawing of typical ac and dc connections to the SEL-311M (*SEL-311M AC/DC Connection Diagram for Various Applications on page 2.7*). Use the drawing as a starting point for planning your particular relay application.

It is very important to limit access to the SEL-311M settings and control functions by using passwords. For information on relay access levels and passwords, see *Section 8: Communications*.

Relay Mounting

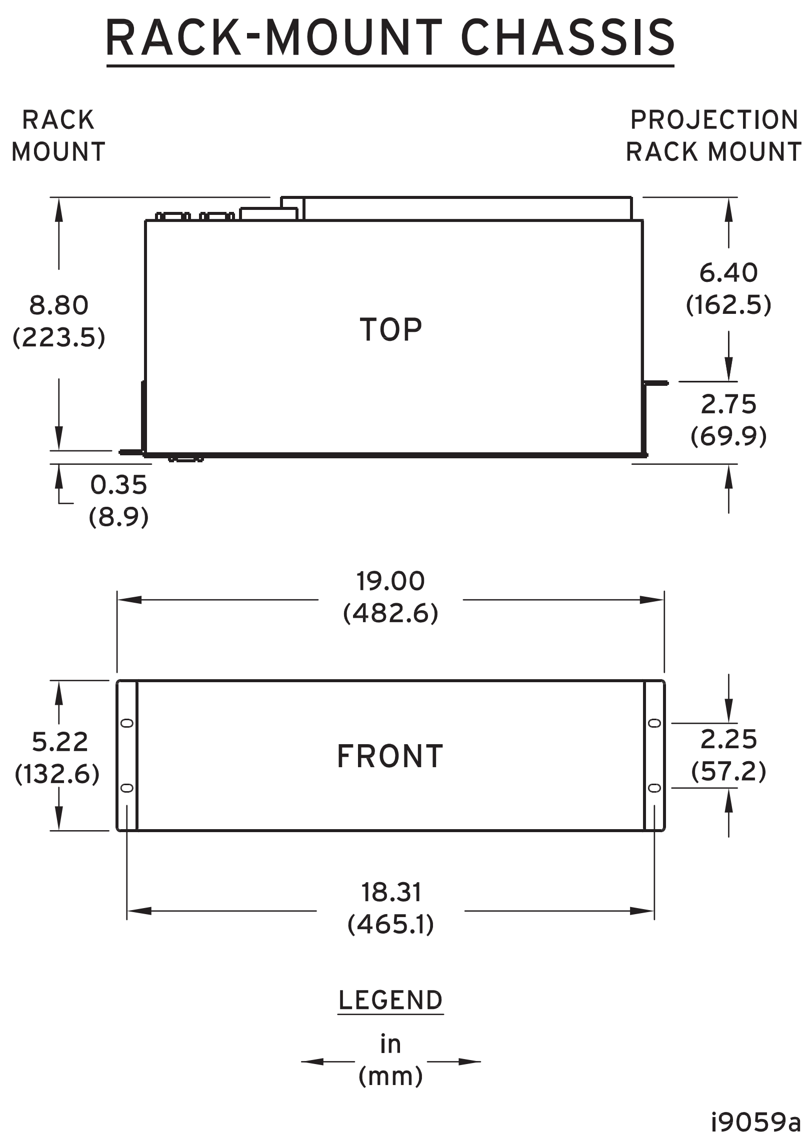


Figure 2.1 SEL-311M Relay Dimensions and Rack-Mount Cutout

Figure 2.1 provides the relay dimensions and the rack-mount cutout. Refer to *Figure 2.2* for example front- and rear-panels drawings.

Front- and Rear-Panel Diagrams

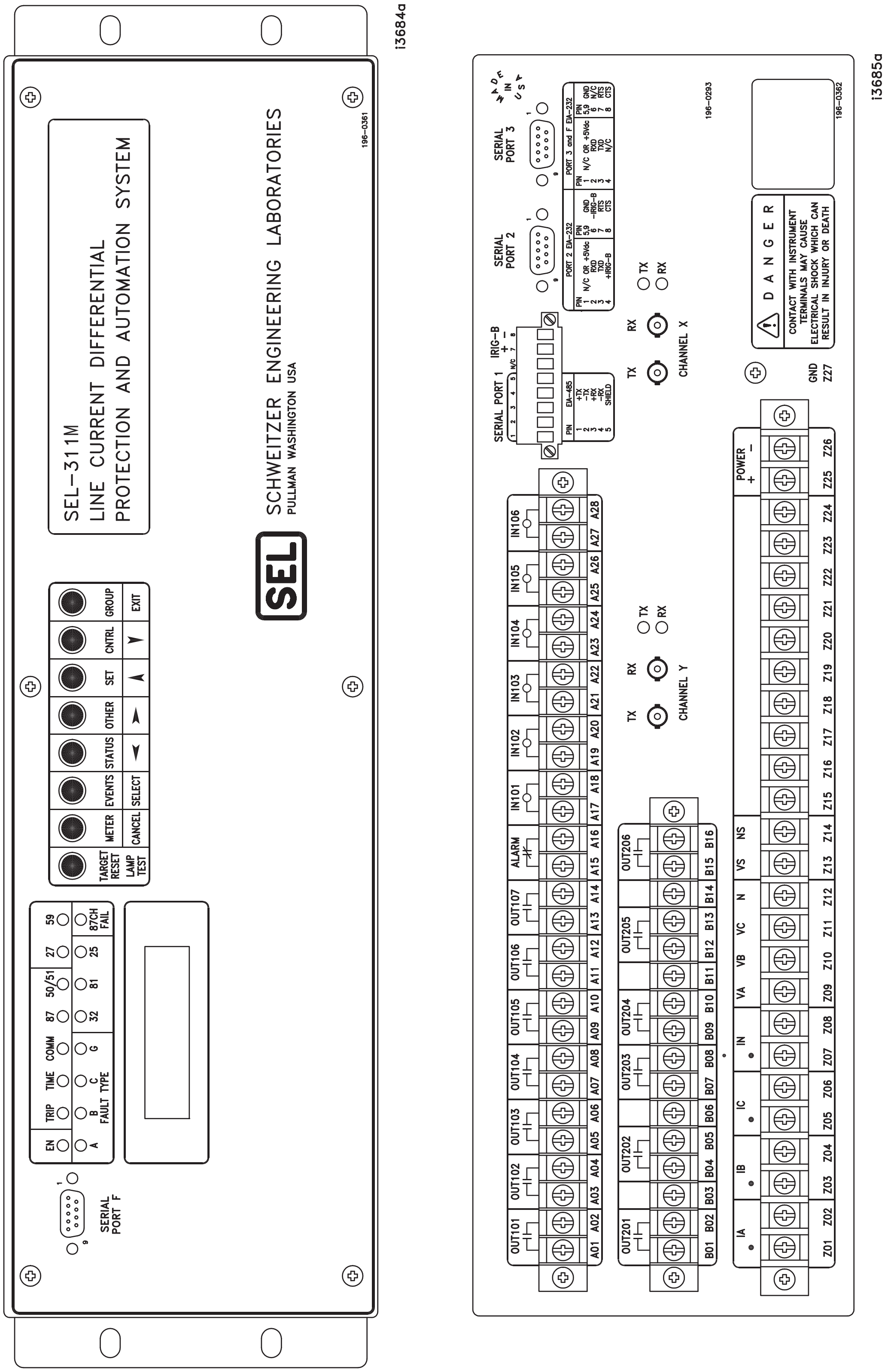


Figure 2.2 SEL-311M Relay Horizontal Rack-Mount Front-Panel and Typical Rear-Panel Drawings

Making Rear-Panel Connections

Refer to *Figure 2.4* for a wiring example of a typical application.

Tools: Phillips or slotted-tip screwdriver

Parts: All screw terminals are size #6-32. Locking screws can be requested from the factory.

Ground the relay chassis at terminal Z27.

Power Supply

Connect control voltage to the POWER terminals. Note the polarity indicators on terminals Z25(+) and Z26(−). Control power passes through these terminals to a fuse and to the switching power supply. The control power circuitry is isolated from the relay chassis ground.

Refer to *Section 1: Introduction and Specifications* for power supply ratings. The relay power supply rating is listed on the serial number sticker on the relay rear panel.

Output Contacts

All SEL-311M relays have six fast, high current interrupting output contacts (OUT201–OUT206) and eight standard output contacts (OUT101–OUT107, ALARM). Refer to *Specifications on page 1.6* for output contact ratings. Refer to *Figure 2.2* for output contact locations.

Use both types of contacts to switch either ac or dc loads.

Optoisolated Inputs

The optoisolated inputs in the SEL-311M (IN101–IN106) are not polarity dependent and are located on the main board. Refer to *Specifications on page 1.6* for optoisolated input ratings.

Refer to the serial number sticker on the relay rear panel for the optoisolated input voltage rating.

Current Transformer Inputs

Note the polarity dots above terminals Z01, Z03, Z05, and Z07. Refer to *Figure 2.4* for a typical CT wiring example.

Refer to the serial number sticker on the relay rear panel for the nominal current ratings (5 A or 1 A) for the phase (IA, IB, IC) and 0.2 A for the neutral (IN) current inputs.

Potential Transformer Inputs (Optional Connections)

Note the signal labels (VA, VB, VC, N, VS, NS) on terminals Z09–Z14. *Figure 1.3* shows the internal connection for terminals VA, VB, VC, and N. Note also that VS/NS is a separate single-phase voltage input.

Wye-Connected Voltages

Any of the voltage inputs (i.e., VA-N, VB-N, VC-N, or VS-NS) can be connected to voltages up to 300 V rms continuous. *Figure 2.4* shows an example of wye-connected voltages. System frequency for under- and overfrequency elements is determined from the voltage connected to terminals VA-N if voltage is present on the relay. Otherwise system frequency is determined from the VS-NS channel if the associated breaker is closed.

Serial Ports (1, 2, 3, and F)

The SEL-311M contains the following multifunction communications ports.

Serial Port 1 on all the SEL-311M models is an EIA-485 port (4-wire). The Serial Port 1 plug-in connector accepts wire size AWG 24 to 12. Strip the wires 8 mm (0.31 in) and install with a small slotted-tip screwdriver. The Serial Port 1 connector has extra positions for IRIG-B time-code signal input (see *Table 8.1*; also see the following discussion on IRIG-B time code input).

Serial Ports F, 2, and 3 are EIA-232 ports and accept 9-pin D-subminiature male connectors. Port 2 on all the SEL-311M models includes the IRIG-B time-code signal input (see *Table 8.1*; also see the following discussion on IRIG-B time-code input).

All serial ports are independent—you can communicate to any combination simultaneously.

The pin definitions for all the ports are given on the relay rear panel and are detailed in *Table 8.2*–*Table 8.4* in *Section 8: Communications*.

NOTE: Devices not manufactured by SEL are listed in Table 2.1 for the convenience of our customers. SEL does not specifically endorse or recommend such products, nor does SEL guarantee proper operation of those products, or the correctness of connections, over which SEL has no control.

Refer to *Table 2.1* for a list of cables available from SEL for various EIA-232 communications applications. Refer to *Section 8: Communications* for detailed cable diagrams for selected cables.

For example, to connect any EIA-232 port to the 9-pin male connector on a laptop computer, order cable number C234A and specify the length needed (standard length is eight feet). To connect the SEL-311M Port 2 to an SEL communications processor (SEL-2032, SEL-2030, or SEL-2020) that supplies the communication link and the IRIG-B time synchronization signal, order cable number C273A. For connecting devices at distances over 100 feet, SEL offers fiber-optic transceivers. The SEL-2800 family of transceivers provides fiber-optic links between devices for electrical isolation and long-distance signal transmission. See *Application Guide AG2001-06: Communication Cable Application Guideline*, or contact SEL for further information on these products.

Table 2.1 EIA-232 Communications Cables to Connect the SEL-311M to Other Devices (Sheet 1 of 2)

SEL-311M EIA-232 Serial Ports	Connect to Device (gender refers to the device)	SEL Cable No.
all EIA-232 ports	PC, 25-Pin Male (DTE)	C227A
all EIA-232 ports	Laptop PC, 9-Pin Male (DTE)	C234A
all EIA-232 ports	SEL-2032, SEL-2030, or SEL-2020 without IRIG-B	C272A
2	SEL-2032, SEL-2030, or SEL-2020 with IRIG-B	C273A
2[a] 3[a]	StarComm Modem, 5 Vdc Powered	C220*
all EIA-232 ports	Standard Modem, 25-Pin Female (DCE)	C222
all EIA-232 ports	SEL-2100	C272A

Table 2.1 EIA-232 Communications Cables to Connect the SEL-311M to Other Devices (Sheet 2 of 2)

SEL-311M EIA-232 Serial Ports	Connect to Device (gender refers to the device)	SEL Cable No.
2	SEL-2100 with IRIG	C273A
2 3	SEL-2505	SEL-2800

[a] A corresponding main board jumper must be installed to power the StarComm Modem with +5 Vdc (0.5 A limit) from the SEL-311M. See Figure 2.5 and Table 2.5.

IRIG-B Time-Code Input

The SEL-311M accepts a demodulated IRIG-B time signal to synchronize the relay internal clock with some external source. The line current differential protection does NOT rely upon IRIG-B time synchronization.

A demodulated IRIG-B time code can be input into Serial Port 2 on any of the SEL-311M models (see *Table 8.4*) by connecting Serial Port 2 of the SEL-311M to an SEL communications processor (SEL-2032, SEL-2030, or SEL-2020) with Cable C273A, or by using an SEL-2810 Fiber-Optic Transceiver.

A demodulated IRIG-B time code can also be input into the connector for Serial Port 1 (see *Table 8.3*). If demodulated IRIG-B time code is input into this connector, it should not be input into Serial Port 2 and vice versa.

Line Current Differential Communications Channel Interfaces

Order the SEL-311M with up to two line current differential interfaces. Each interface is factory configured as IEEE Standard C37.94 compliant multimode fiber. When the SEL-311M arrives, the channels are configured per your ordering options.

Figure 2.3 depicts the signal names, pinout and direction at the SEL-311M. The electrical 87L channel interface options on the SEL-311M are isolated from the chassis to at least 1500 V rms. To maintain that isolation, and to avoid ground loops, ground all cable shields only at the communications equipment.

See *Section 8: Communications* for channel interface configuration settings, and for channel monitor settings.

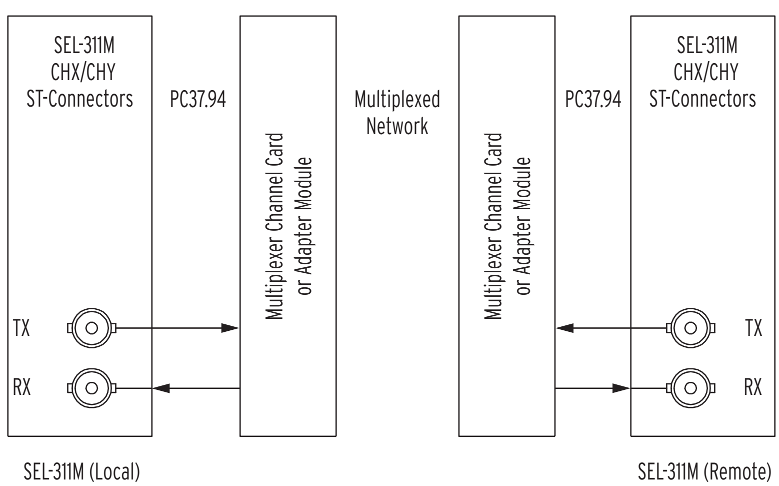


Figure 2.3 IEEE Standard C37.94 Fiber-to-Multiplexer Interface

SEL-311M AC/DC Connection Diagram for Various Applications

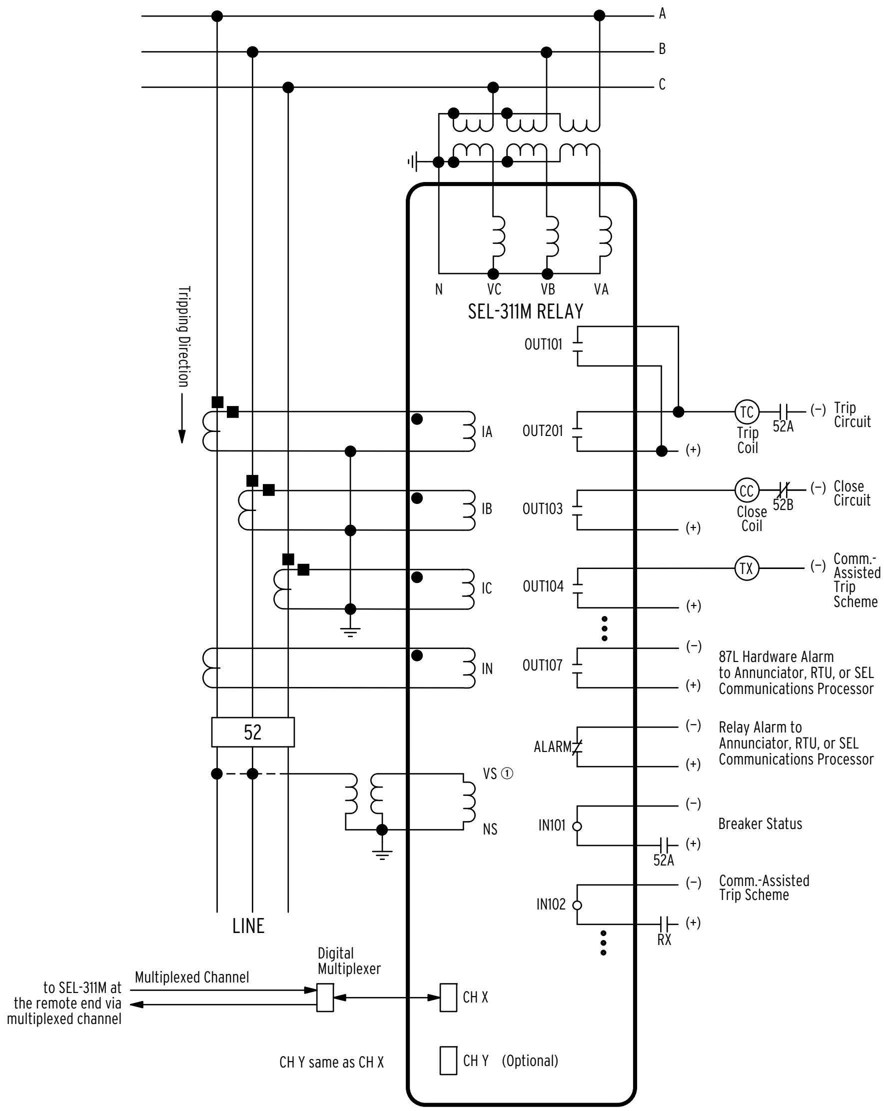


Figure 2.4 SEL-311M Provides Line Current Differential, Backup Overcurrent Protection for a Transmission Line

① Voltage Channel VS is used in voltage and synchronism check elements and voltage metering.

Circuit Board Connections

Accessing the Relay Circuit Boards

⚠CAUTION
The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.

⚠DANGER
Contact with instrument terminals can cause electrical shock that can result in injury or death.

To change circuit board jumpers or replace the clock battery, refer to *Figure 2.5* and take the following steps:

Step 1. De-energize the relay.

Step 2. Remove any cables connected to serial ports or line current differential interfaces on the front and rear panels.

Step 3. Remove the EIA-485 connector.

Step 4. Loosen the six front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 5. Each circuit board corresponds to a row of rear-panel terminal blocks or connectors and is affixed to a drawout tray.

Step 6. Disconnect circuit board cables as necessary.

Removal of the differential board requires removal of the main board first.

a. Ribbon cables can be removed by pushing the extraction ears away from the connector.

b. The 6-conductor power cable can be removed by grasping the power connector wires and pulling away from the circuit board.

Step 7. Grasp the drawout assembly of the board and pull the assembly from the relay chassis.

Step 8. Locate the jumper(s) or battery to be changed (refer to *Figure 2.5*).

Step 9. Make the desired changes.

Note that the output contact jumpers are soldered in place.

Step 10. When finished, slide the drawout assembly into the relay chassis.

Step 11. Reconnect the cables removed in *Step 6*.

Step 12. Replace the relay front-panel cover.

Step 13. Replace any cables previously connected to serial ports or line current differential interfaces.

Step 14. Reenergize the relay.

Step 15. Verify that the **ENABLE** LED illuminates.

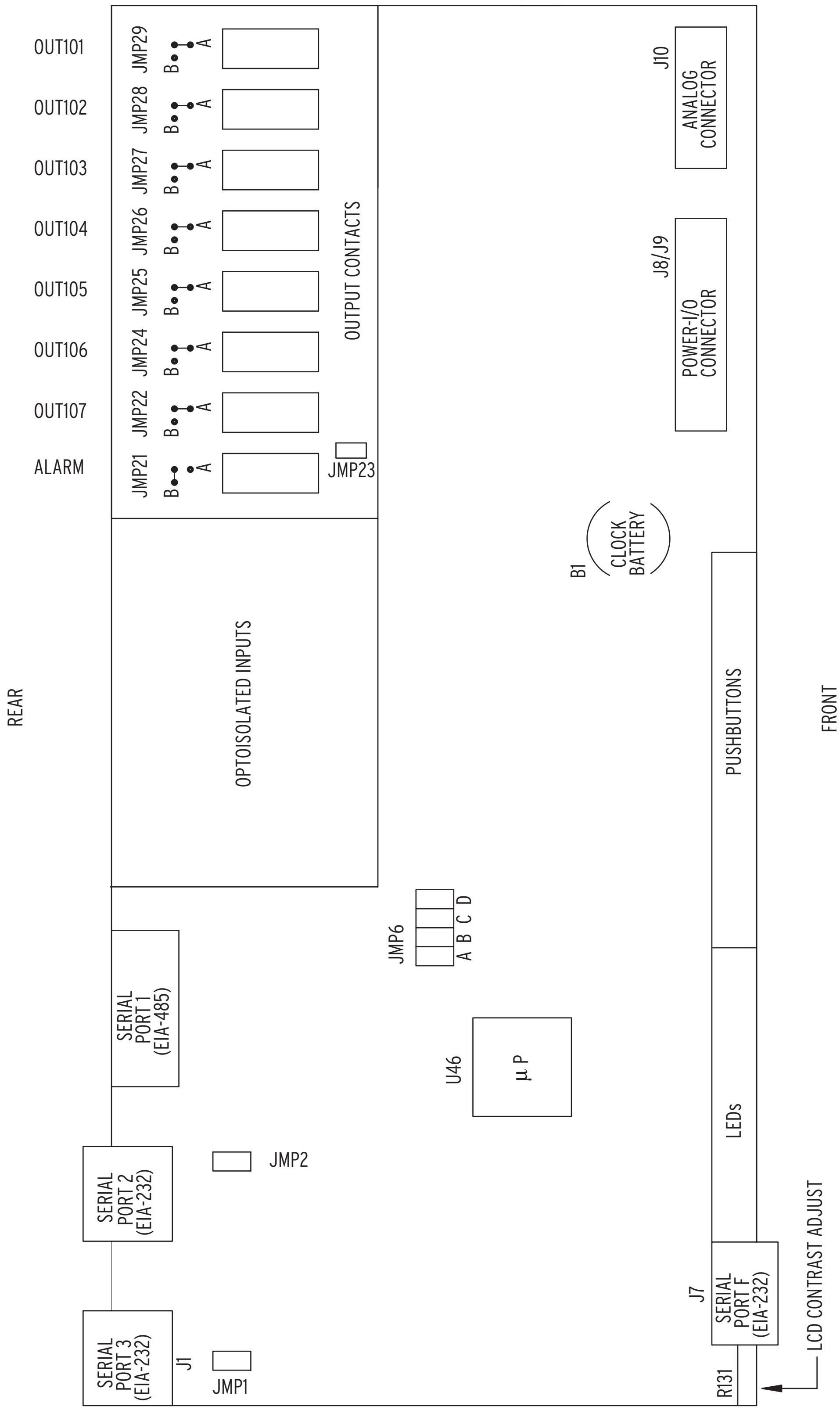


Figure 2.5 Jumper, Connector, and Major Component Locations on the SEL-311M Main Board

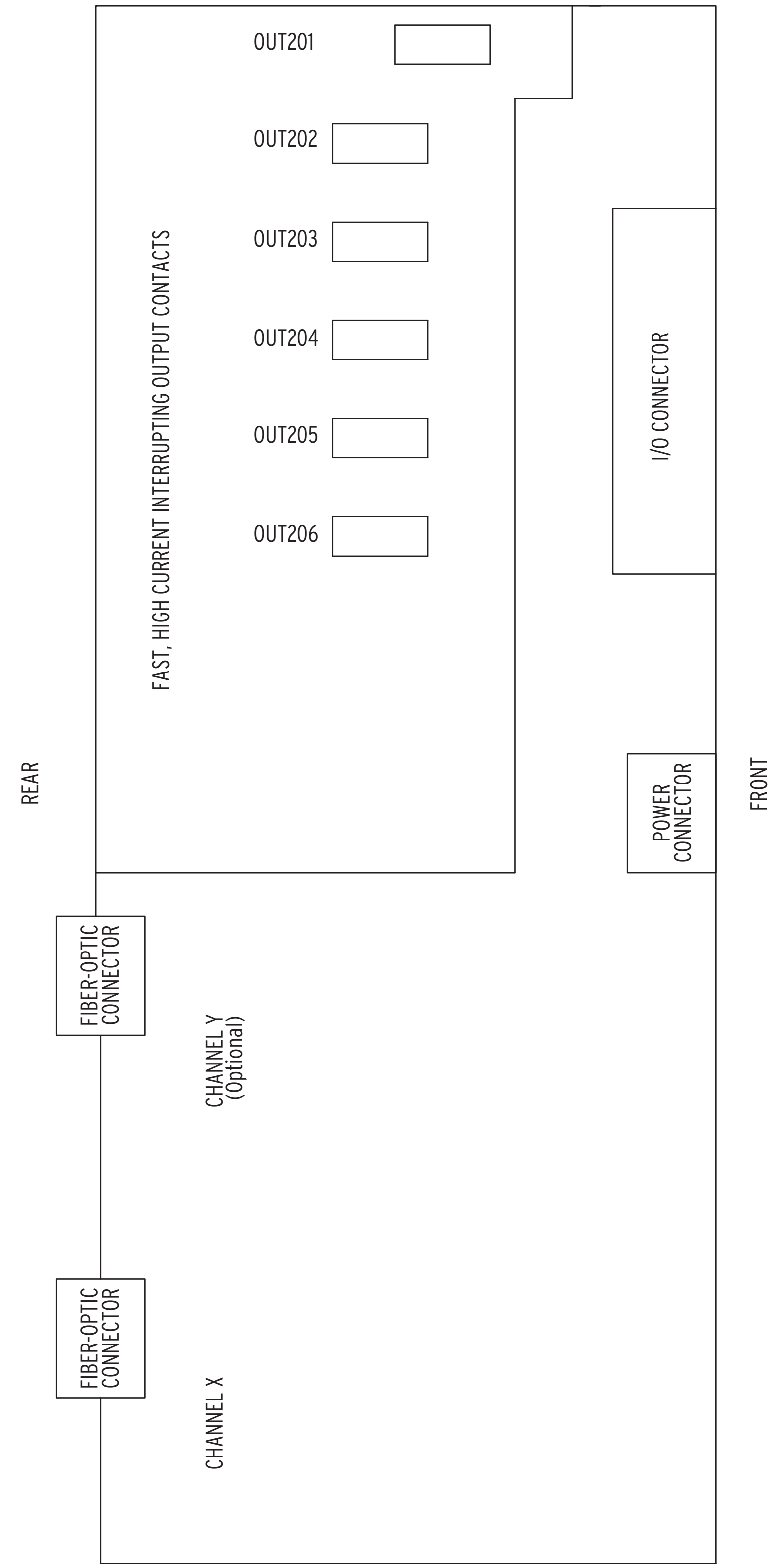


Figure 2.6 Connector and Major Component Locations on the SEL-311M Differential I/O Board

Output Contact Jumpers

Table 2.2 shows the correspondence between output contact jumpers and the output contacts they control. The referenced figures show the exact location and correspondence. With a jumper in the A position, the corresponding output contact is an "a" type output contact. An "a" type output contact is closed when the associated SELOGIC® control equation is asserted, and open when the associated SELOGIC control equation is deasserted. With a jumper in the B position, the corresponding output contact is a "b" type output contact. A "b" type output contact is closed when the associated SELOGIC control equation is deasserted, and open when the associated SELOGIC control equation is asserted. These jumpers are soldered in place.

In *Figure 2.5*, note that the **ALARM** output contact is a "b" type output contact and the other output contacts are all "a" type output contacts. This is how these jumpers are configured in a standard relay shipment. Refer to *Figure 5.13* and *Figure 5.14* for examples of output contact operation for different output contact types.

The fast, high-current interrupting contacts **OUT201–OUT206** are all "a" type contacts and cannot be configured as "b" type contacts.

Table 2.2 Output Contact Jumpers and Corresponding Output Contacts

SEL-311M Model Number	Output Contact Jumpers	Corresponding Output Contacts	Reference Figure
All Models	JMP21–JMP29 (but not JMP23)	ALARM–OUT101	*Figure 2.5*

"Extra Alarm" Output Contact Control Jumper

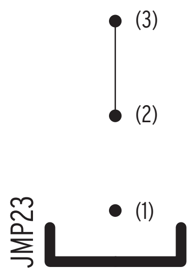
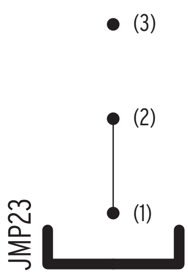
All the SEL-311M relays have a dedicated alarm output contact labeled **ALARM** (see *Figure 2.2*). Often more than one alarm output contact is needed for such applications as local or remote annunciation, backup schemes, etc.

Convert the output contact adjacent to the dedicated **ALARM** output contact to operate as an "extra alarm" output contact by moving jumper JMP23 on the main board (see *Table 2.3*).

With the jumper in one position, the output contact operates regularly. With the jumper in the other position, the output contact is driven by the same signal that operates the dedicated **ALARM** output contact (see *Table 2.3*).

Do not convert **OUT107** to an "extra alarm" if it is used as a line current differential hardware alarm. When configured as an "extra alarm," **OUT107** no longer responds to SELOGIC control equation OUT107 = 87HWAL.

Table 2.3 Move Jumper JMP23 to Select Extra Alarm

Position	Output Contact OUT107 Operation
	Output contact **OUT107** is operated by Relay Word bit OUT107. Jumper JMP23 comes in this position in a standard relay shipment (see *Figure 5.14*). Place jumper JMP23 as shown and set SELOGIC control equation OUT107 = 87HWAL to obtain an alarm upon loss of the 87L Hardware.
	"Extra Alarm" output contact is operated by alarm logic/circuitry. Relay Word bit OUT107 does not have any effect on output contact **OUT107** when jumper JMP23 is in this position (see *Figure 5.14*). If you place jumper JMP23 in position 1–2, loss of the 87L board will not result in an alarm via OUT107 = 87HWAL.

If an output contact is operating as an "extra alarm" (driven by the same signal that operates the dedicated **ALARM** output contact), it will be in the opposite state of the dedicated **ALARM** output contact in a standard relay shipment. In a standard relay shipment, the dedicated **ALARM** output contact comes as a "b" type output contact and all the other output contacts (including the "extra alarm") come as "a" type output contacts.

The output contact type for output contacts **OUT101–OUT107** can be changed (see *Output Contact Jumpers on page 2.10*). Thus, the dedicated **ALARM** output contact and the "extra alarm" output contact can be configured as the same output contact type if desired (e.g., both can be configured as "b" type output contacts).

Password and Breaker Jumpers

Table 2.4 Password and Breaker Jumper Operation

Jumper	Jumper Position	Function
Password JMP6-A	ON (in place)	Disable password protection[a] for serial ports and front panel.
	OFF (removed/not in place)	Enable password protection[a] for serial ports and front panel. Passwords are enabled in a standard relay shipment.
Breaker JMP6-B	ON (in place)	Enable serial port commands **OPEN**, **CLOSE**, and **PULSE**[b].
	OFF (removed/not in place)	Disable serial port commands **OPEN**, **CLOSE**, and **PULSE**[b]. These commands are disabled in a standard relay shipment.

[a] View or set the passwords with the **PASSWORD** command (see Section 8: Communications).
[b] The **OPEN**, **CLOSE**, and **PULSE** commands are used primarily to assert output contacts for circuit breaker control or testing purposes (see Section 8: Communications).

Note that JMP6 in *Figure 2.5* has multiple jumpers A–D. Jumpers A and B are used (see *Table 2.4*). Since jumpers C and D are not used, the positions (ON or OFF) of jumpers C and D are of no consequence.

EIA-232 Multifunction Serial Port Voltage Jumpers

The jumpers listed in *Table 2.5* connect or disconnect +5 Vdc to Pin 1 on the corresponding EIA-232 serial ports. The +5 Vdc is rated at 0.5 A maximum for each port. See *Table 8.2* in *Section 8: Communications* for EIA-232 serial port pin functions.

In a standard relay shipment, the jumpers are “OFF” (removed/not in place) so that the +5 Vdc is not connected to Pin 1 on the corresponding EIA-232 serial ports. Put the jumpers “ON” (in place) so that the +5 Vdc is connected to Pin 1 on the corresponding EIA-232 serial ports.

Table 2.5 EIA-232 Serial Port Voltage Jumper Positions for Standard Relay Shipments

SEL-311M Model Number	EIA-232 Serial Port 2 (rear panel)	EIA-232 Serial Port 3 (rear panel)	Reference Figure
All Models	JMP2 = OFF	JMP1 = OFF	*Figure 2.5*

Condition of Acceptability for North American Product Safety Compliance

To meet product safety compliance for end-use applications in North America, use an external fused rated 3 A or less in-line with the +5 Vdc source on Pin 1. SEL fiber-optic transceivers include a fuse that meets this requirement.

Clock Battery

⚠CAUTION

There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer’s instructions.

Refer to *Figure 2.5* for clock battery B1 location. This lithium battery powers the relay clock (date and time) if the external power source is lost or removed. The battery is a 3 V lithium coin cell, Ray-O-Vac No. BR2335 or equivalent. At room temperature (25°C), the battery will nominally operate for 10 years with power removed from the relay.

If external power is lost or disconnected, the battery powers the clock. When the relay is powered from an external source, the battery only experiences a low self-discharge rate. Thus, battery life can extend well beyond the nominal 10 years because the battery rarely has to discharge after the relay is installed. The battery cannot be recharged.

If the relay does not maintain the date and time after power loss, replace the battery.

Step 1. Follow the instructions in *Accessing the Relay Circuit Boards on page 2.8* to remove the relay main board.

Step 2. Remove the battery from beneath the clip.

Step 3. Install a new one.

The positive side (+) of the battery faces up.

Step 4. Reassemble the relay as described in *Accessing the Relay Circuit Boards*.

Step 5. Set the relay date and time via serial communications port or front panel (see *Section 8: Communications* or *Section 9: Front-Panel Operations*).

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Section 3

Protection Functions

Overview

The SEL-311M Relay includes both current- and voltage-based protection elements. Loss or absence of potential does not affect current-based elements such as line current differential and overcurrent protection. This section describes operational theory and settings guidelines for key elements shown in *Figure 3.1*.

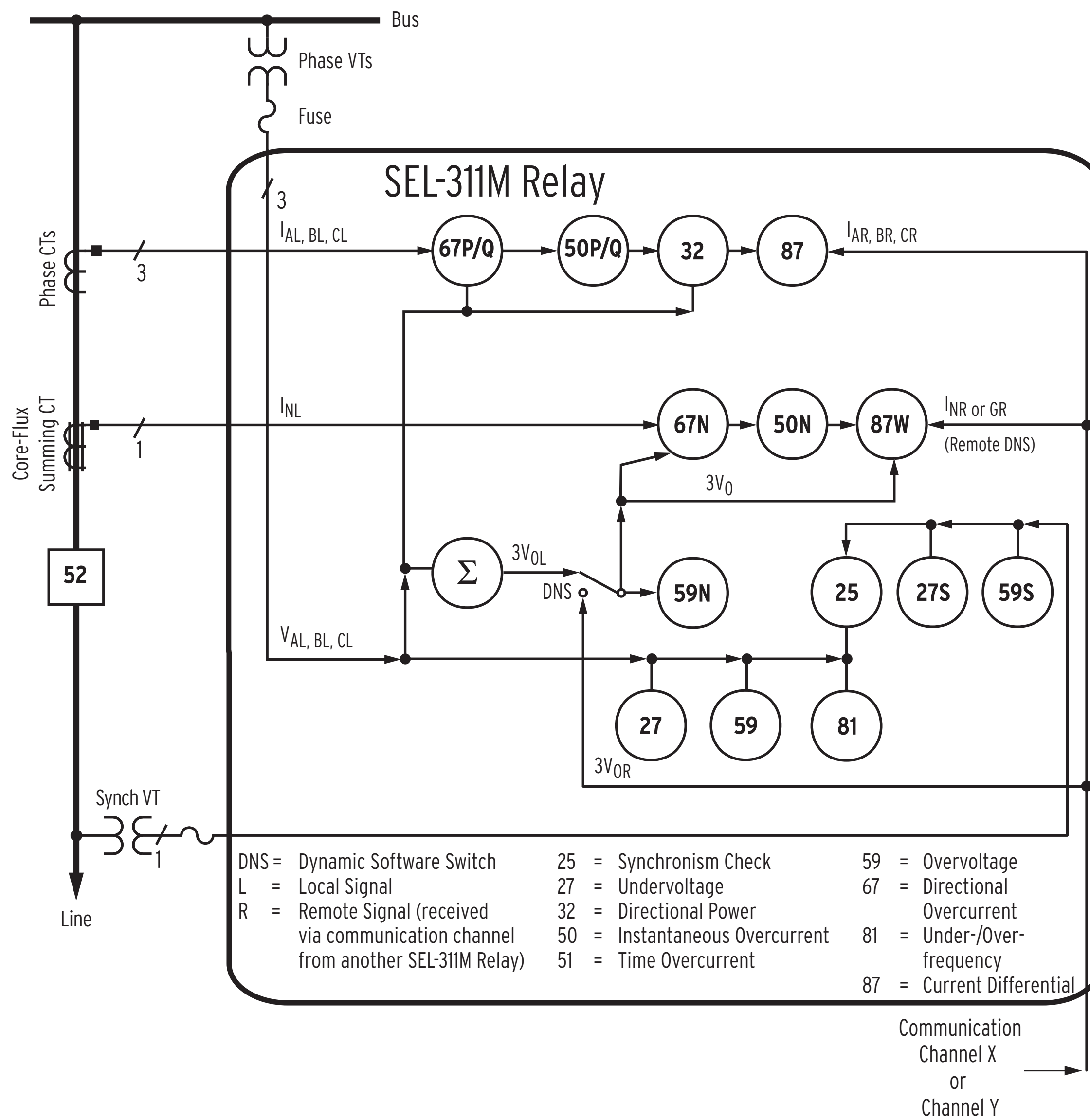


Figure 3.1 Functional Diagram

Line Current Differential Elements

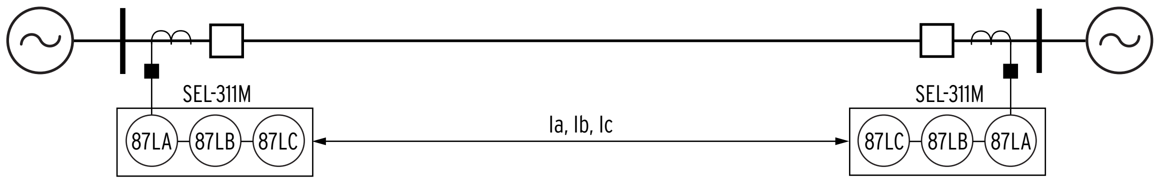


Figure 3.2 SEL-311M Line Current Differential Elements

The SEL-311M Relay contains three line current differential elements—one for each phase.

This section familiarizes you with the operating principles of the line current differential elements in the SEL-311M and introduces a setting philosophy that gives secure, fast, sensitive, and dependable operation. For most two-terminal applications, the 87L settings need not be changed from the factory defaults.

The SEL-311M exchanges time-synchronized Ia, Ib, and Ic samples between two line terminals. Current differential elements 87LA, 87LB, and 87LC in each relay compare Ia, Ib, and Ic from each line terminal. All relays perform identical line current differential calculations in a peer-to-peer architecture to avoid transfer trip delays.

This section describes settings considerations for the differential elements. Phase differential elements 87LA, 87LB, and 87LC reliably detect phase faults.

Theory of Operation (Patented)

Figure 3.3 and *Figure 3.4* help explain how the phase differential elements operate for a two-terminal line. *Figure 3.3* shows the alpha plane, which represents the phasor or complex ratio of remote (IR) to local (IL) currents. There is a separate alpha plane for every current.

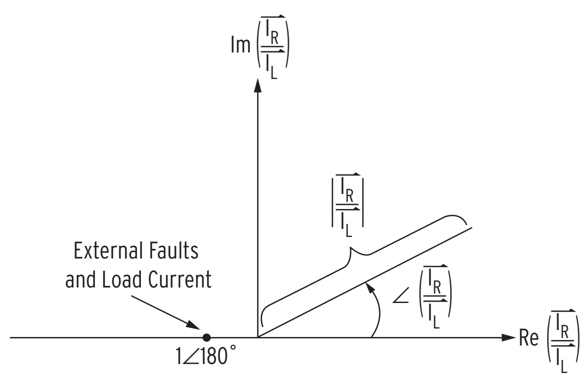


Figure 3.3 Alpha Plane Represents Complex Ratio of Remote-to-Local Currents

Arbitrarily assign current flowing into the protected line to have zero angle, and current flowing out of the protected line to have angle 180 degrees. Five amps of load current flowing from the local to the remote relay produces an A-phase current of 5∠0° at the local relay and 5∠180° at the remote relay. The ratio of remote to local current is:

$$\frac{\overrightarrow{I_{AR}}}{\overrightarrow{I_{AL}}} = \frac{5\angle 180°}{5\angle 0°} = 1\angle 180°$$

$$\frac{\overrightarrow{I_{BR}}}{\overrightarrow{I_{BL}}} = \frac{5\angle 60°}{5\angle -120°} = 1\angle 180°$$

$$\frac{\overrightarrow{I_{CR}}}{\overrightarrow{I_{CL}}} = \frac{5\angle -60°}{5\angle 120°} = 1\angle 180°$$

Equation 3.1

On the A-phase alpha plane, this plots one unit to the left of the origin, as shown in *Figure 3.3*. The other two phases also reside at $1\angle 180°$ on their respective alpha planes.

In fact, all through-load current plots at $1\angle 180°$ regardless of magnitude and regardless of angle with respect to the system voltages. Likewise, an external fault has equal and opposite current at the two line ends, and so external faults also plot at $1\angle 180°$.

The SEL-311M surrounds the point $1\angle 180°$ on the alpha plane with a restraint region, as shown in *Figure 3.4*. The relay trips when the alpha plane ratio travels outside the restraint region, and the differential current is above a settable threshold. The relay restrains when the alpha plane ratio calculation remains inside the restraint region, or when there is insufficient differential current.

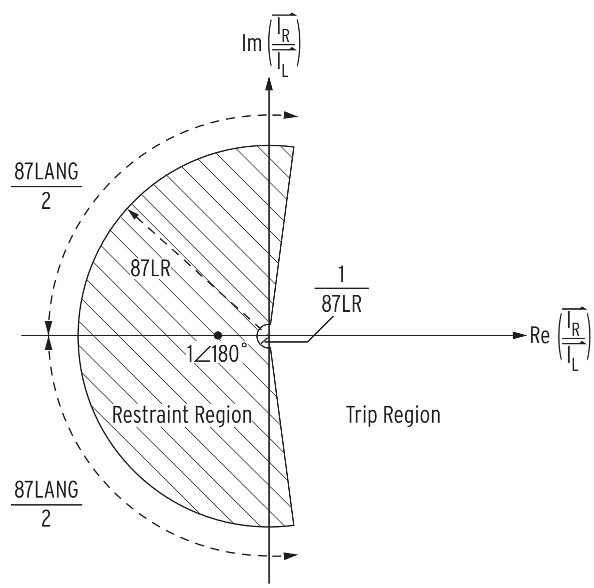


Figure 3.4 SEL-311M Restraint Region Surrounds External Faults

The shape of the restraint region is described by two settings, as shown in *Figure 3.4*. Setting 87LANG determines the angular extent of the restraint region. Setting 87LR determines the outer radius of the restraint region. The inner radius is the reciprocal of 87LR. Setting 87LPP supervises trips generated by the phase current differential elements 87LA, 87LB, and 87LC. If the A-phase current ratio travels outside the restraint characteristic, and the A-phase differential current exceeds setting 87LPP, then element 87LA asserts, indicating an internal fault.

Traditional line current differential relays, phase comparison relays, and charge comparison relays can also be represented as a restraint region on the alpha plane. See the technical paper “The Effect of Multiprinciple Line Protection on Dependability and Security” by Jeff Roberts, Demetrios Tziouvaras, et al. to see how other alpha plane restraint regions compare to the restraint region of the SEL-311M. In every case, the SEL-311M gives significant improvement in security, sensitivity, speed, dependability, or all four.

Current Transformer Requirements

The SEL-311M is very tolerant of CT saturation. The equation below relates the maximum permissible CT burden that avoids CT saturation.

$$Z_B < \frac{V_S}{I_F\left(\frac{X}{R} + 1\right)}$$

Equation 3.2

where:

Z_B = the burden impedance in ohms
V_s = the voltage class of the CT
I_F = the fault current in secondary amps
X/R = the power system reactance to resistance ratio for the fault of interest

If the CT burden is exactly Z_B as expressed above, then a fully offset fault current of magnitude I_F that decays as indicated by the system X/R ratio will bring the CT to the brink of saturation.

In two terminal applications, the SEL-311M requires current transformers that meet both of the following criteria.

1. The CT cannot saturate at less than $I_F = 15$ amps secondary for a relay with five amp current transformers, or $I_F = 3$ amps secondary for a relay with one amp current transformers.
2. The CT burden cannot exceed:

$$\frac{7.5V_S}{I_F\left(\frac{X}{R} + 1\right)}$$

Equation 3.3

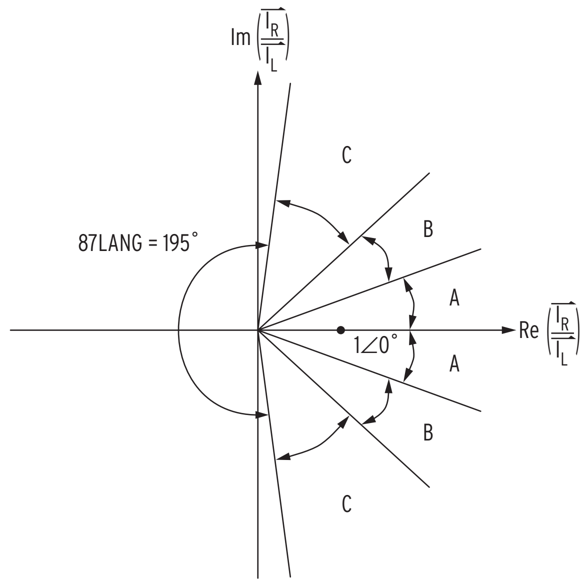
In other words, when set per the recommendations set forth in the following sections, the SEL-311M will operate and restrain properly if the CT does not saturate at less than 3 per unit nominal current, and the CT burden is less than 7.5 times the burden that just causes the CT to saturate.

Setting the Restraint Region and Supervision Elements

This section discusses setting the restraint region and differential overcurrent supervision elements to protect a two-terminal line. Set the phase differential elements 87LA, 87LB, and 87LC to reliably detect internal phase faults.

Set Phase Differential Elements 87LA, 87LB, and 87LC to Detect Internal Phase Faults

Refer to *Figure 3.5*. Consider a three-phase fault at midline on a homogenous system with no load flow. For this example, the remote and local currents are equal in magnitude and phase. The vector ratio of remote to local currents is $1\angle 0°$. This plots one unit to the right of the origin, as shown in *Figure 3.5*. If the system is nonhomogeneous, then the line-end current angles differ, and hence the angle of the current ratio is not zero. If the source impedance angles differ by 10 degrees, and there is an angular difference of 10 degrees between the sources, then the angle between remote and local currents can approach 20 degrees. *Example Calculations for 87L Settings on page 3.82* gives a more thorough discussion of the effects of source angle and source impedance angle.



A: 20° shift caused by source angle and source impedance angle.
B: 21.6° shift caused by 2 ms channel assymetry.
C: 40° shift caused by CT saturation.

Figure 3.5 Alpha Plane Angle Setting 87LANG Is Based on Maximum Alpha Plane Angle for an External Fault

If the internal fault is not at midline, or if the sources do not have equal strength, the alpha plane ratio moves away from 1∠0° to the right or left. In the limit, either the remote or the local current approaches zero during weak-infeed.

If the remote current approaches zero, the ratio moves toward the origin from the right half-plane. If the local current approaches zero, the ratio moves toward the far right end of the right half-plane.

Therefore, for an internal three-phase fault the phase current ratio lies in the right hand plane within ±20 degrees of the positive real axis as shown in *Figure 3.5* for the source and impedance angles assumed above.

Now consider a data alignment error caused by unequal delays in transmit and receive channels. In a unidirectional SONET ring with 20 nodes, the transmit and receive times might be different by 2 ms, assuming adjacent nodes in one direction and 19 intervening nodes in the other direction (an extreme case). The SEL-311M estimates the one-way channel delay as half the round trip delay. In this situation, the round trip delay is about 2 ms (100 µs one way, 2 ms the other way, for a total round trip of about 2 ms).

In this extreme case both SEL-311M relays estimate a one-way channel delay of 1 ms, and each relay uses local currents measured 1 ms earlier to align the local data with the received remote data. Thus, both relays have a 1 ms data alignment error (one relay leading, the other lagging). This causes the angle of the alpha plane ratio to be in error by about 22 degrees on a 60 Hz system. In one relay, the error is positive (counterclockwise on the alpha plane); in the other relay the error is negative (clockwise on the alpha plane).

Depending on the angular shift at a particular relay, this error could add to or subtract from the angles caused by the system non-homogeneity and load angle discussed above. Assume the angles add, as a worst case. For an internal fault, the alpha plane angle could be as much as ±(20 + 22) = ±42 degrees.

Next consider CT saturation. As shown in *Figure 3.6*, a severely saturated CT might temporarily cause the fundamental component of the secondary current to lead the primary current by as much as 40 degrees. Considering CT saturation, system non-homogeneity, load angle, and asymmetrical channel delay, the alpha plane angle for phase currents could be as much as ±(40 + 22 + 20) = ±82 degrees for an internal three-phase fault.

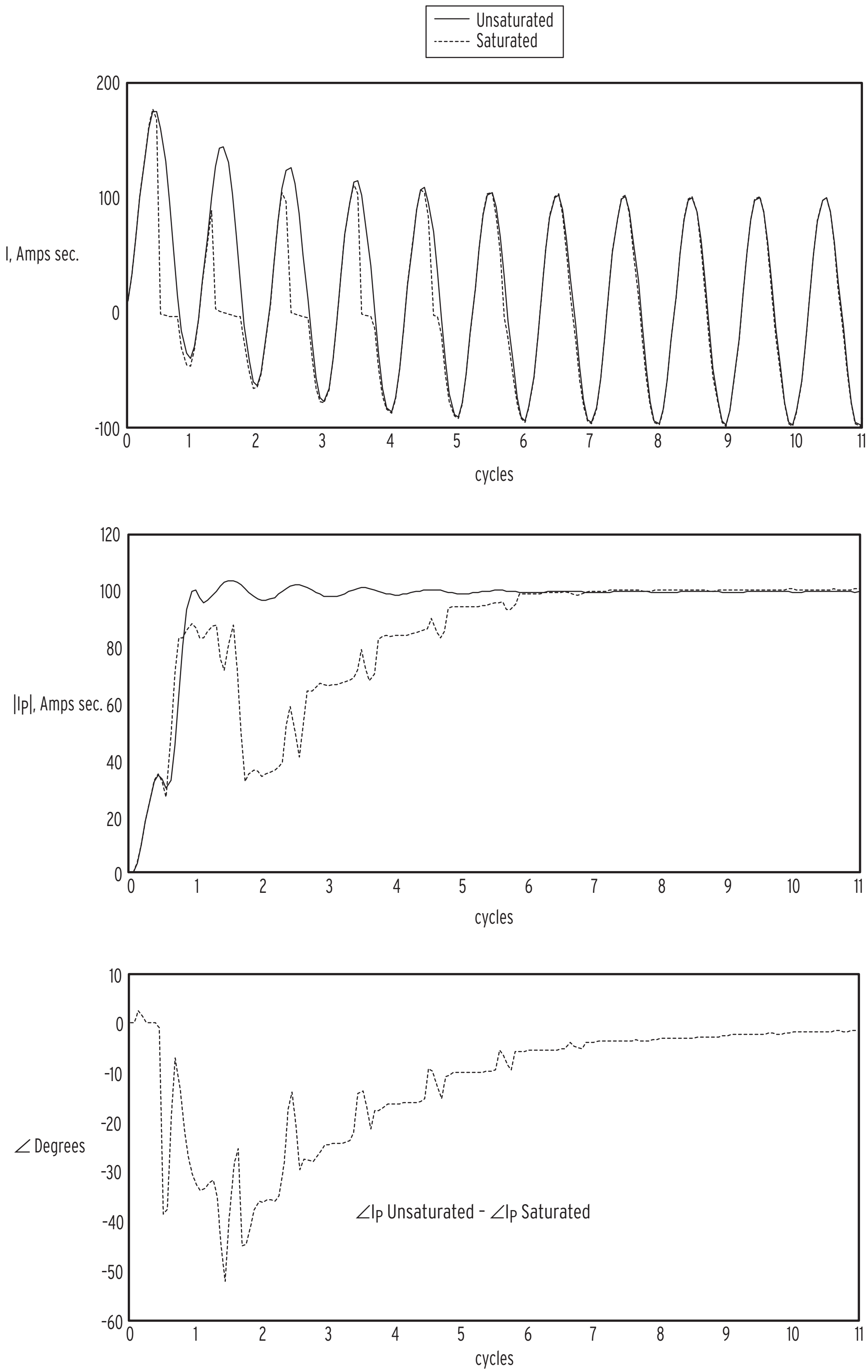


Figure 3.6 CT Saturation Causes Angle Lead and Reduction in Magnitude

Another possible source of phase angle error might be line-charging current. However, since we are discussing internal three-phase faults, line-charging current is not a source of significant error. See *Example Calculations for 87L Settings on page 3.82* for a more thorough discussion of line charging current.

From this discussion, it is apparent that given combinations of asymmetrical channel delay, system non-homogeneity and load angle, and CT saturation, an internal three-phase fault should lie within about 82 degrees of the positive real axis. For the example power system considered, conditions that cause points to lie outside that region can safely be considered non-internal faults (external faults, load current, etc.). We shall see that the SEL-311M handles all of these conditions easily, even if all conditions exist simultaneously.

Phase 87L Settings and Alpha Plane Settings

Three settings control operation of the phase 87L elements. Refer to *Figure 3.4*.

- ➤ 87LANG (the angular extent of the restraint region)
- ➤ 87LR [the outer radius of the restraint region (the inner radius is the reciprocal of 87LR)]
- ➤ 87LPP (the differential current which supervises tripping when the alpha plane ratio lies outside the restraint region)

Settings 87LANG and 87LR are common for all differential elements. There are not separate restraint region settings for each type of element.

Phase fault protection places the highest constraints on setting 87LANG, because of source angle considerations. Set 87LANG as described above, considering maximum load angle, system nonhomogeneity, asymmetrical channel delay, and CT saturation. For this example, set 87LANG to 360 – (82 • 2) = 196 degrees. The factory default setting is 195 degrees. Even if your installation cannot experience these conditions, consider leaving 87LANG = 195 degrees. Extensive testing at SEL demonstrates that this setting provides a good balance of security and dependability.

Setting 87LR defines the outer radius of the restraint region, and the reciprocal of 87LR defines the inner radius of the restraint region. Set 87LR to exclude from the restraint region all internal phase faults, including those with zero-infeed. An 87LR setting of 6 gives an outside radius of 6 and an inside radius of 1/6. This comfortably excludes zero-infeed conditions from the restraint region.

Set 87LPP to reliably detect all internal three-phase faults. Setting 87LPP must be set above line charging current. Set 87LPP above maximum expected load current to prevent misoperation when a ganged set of CT test switches is left shorted at one line end. The factory default setting for 87LPP is 1.2 times nominal secondary current (1.2 A for a 1 A relay) and probably does not need to be changed except for special conditions.

The settings defined above are factory default. They are also the settings used to produce the operate speed curves shown in *Figure 3.7* (using high-speed output contacts).

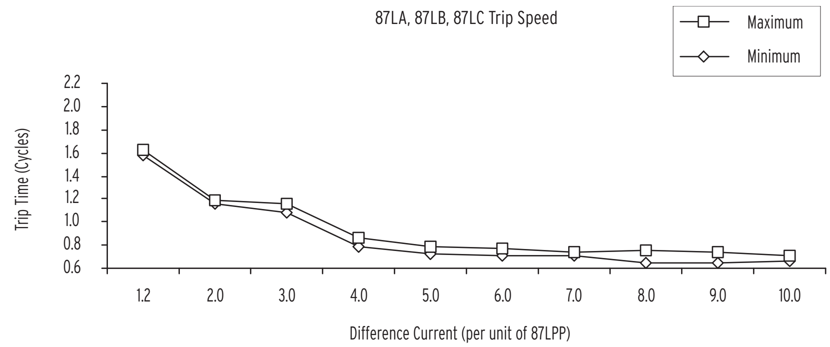


Figure 3.7 Phase 87L Element Trip Speeds for Symmetrical Fault Currents With 87LANG = 195 and 87LR = 6 Using a Direct Fiber Connection

Factory Settings Give Excellent Security During External Faults

In summary, the 87L element settings derived above give excellent speed, sensitivity, and dependability for internal faults of all types on the example power system considered. Recall that the alpha plane ratio ideally lies at $1\angle180°$ for external faults. The restraint regions defined by the settings derived above surround $1\angle180°$ and must include possible sources of error. To check these settings for security during external faults, consider all possible sources of ratio and angle error on the alpha plane during an external fault.

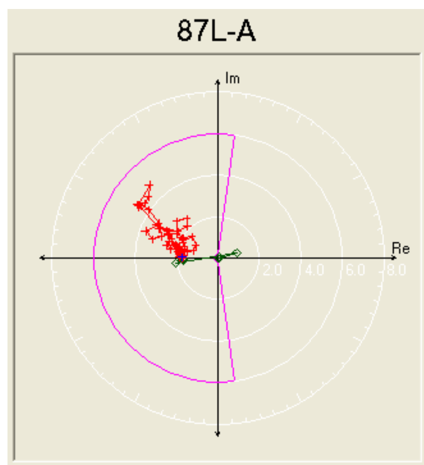


Figure 3.8 Alpha Plane Plot for an External Fault With CT Saturation at One Terminal

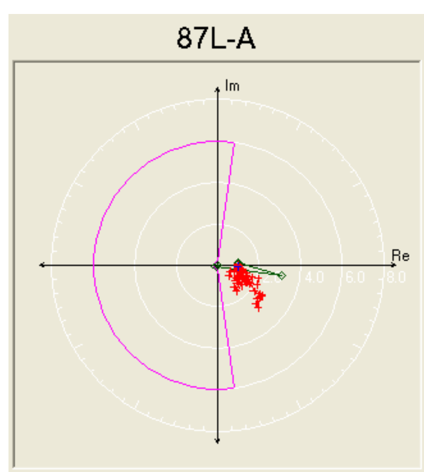


Figure 3.9 Alpha Plane Plot for an Internal Fault With CT Saturation at One Terminal

Figure 3.9 shows the alpha plane plot generated by applying the waveforms shown in *Figure 3.6* as an internal fault. Notice that the locus does not encroach on the restraint characteristic for this internal fault.

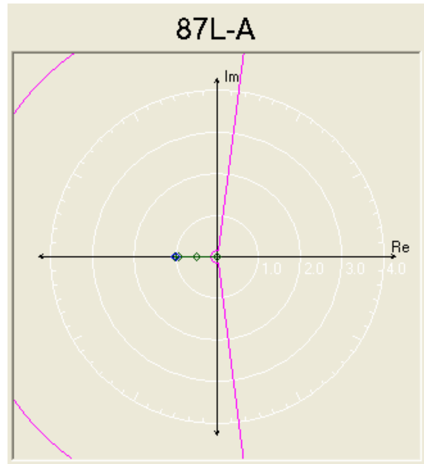


Figure 3.10 Alpha Plane Plot for an External Fault With No CT Saturation

Figure 3.10 shows the alpha plane plot for an external fault without CT saturation. Notice that the locus is tightly grouped around 1∠180°.

Settings Related to 87L Elements

The remainder of this section discusses all settings related to the 87L elements. Most settings need not be calculated, only selected to match system topology and protection practices. Use the **SET** command to access these settings.

CTR

Setting range: 1–6000

Select CTR to match the local CT ratio. For example, for a local CT ratio of 600:5, set CTR = 120. Differential current in each relay is referenced to the CTR setting. The differential current used by 87L elements in both relays in *Figure 3.11* is secondary current referenced to the relay CTR setting. If setting 87LPP = 1.2 in both relays, the phase differential elements assert for internal faults that produce more than 1.2 • 120 = 144 A phase differential current. Event reports and meter displays report primary values (current, voltage, power, and energy).

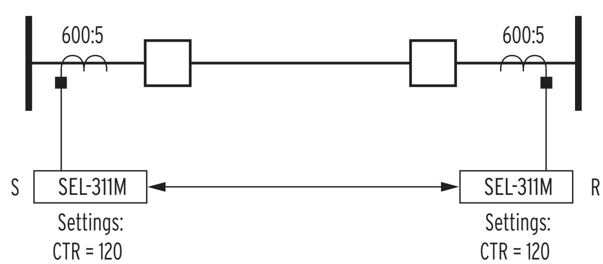


Figure 3.11 SEL-311M Relays Applied With the Same CT Ratios

E87L

Setting range: 2, N

This setting selects the number of terminals in the 87L protection zone (2). For example, in a configuration such as shown in *Figure 3.11*, set E87L = 2 in Relay S and Relay R. Set E87L = N to disable line current differential protection. Setting E87L = N also disables all 87L communications circuits.

87LPP

Setting Range:

OFF, 0.2–2 A secondary (1 A nominal phase current inputs, IA, IB, IC)
OFF, 1.0–10 A secondary (5 A nominal phase current inputs, IA, IB, IC)

The phase line current differential elements 87LA, 87LB, and 87LC restrain when the phase differential current is less than 87LPP. Set 87LPP to detect three-phase faults as described above. The setting is in secondary amps, referenced to the CTR setting. For example, assume E87L = 2 and CTR = 400. If setting 87LPP = 1.2 A in both relays, the phase 87L elements assert for all internal faults that produce more than 1.2 • 400 = 480 A of phase differential current.

CTALRM

Setting range:

0.1–2 A secondary	(1 A nominal phase current inputs, IA, IB, IC)
0.5–10 A secondary	(5 A nominal phase current inputs, IA, IB, IC)

Relay Word bit CTAA asserts when A-phase differential current exceeds setting CTALRM. Similarly, CTBA and CTCA assert when B-phase or C-phase differential current exceeds setting CTARLM. Use these bits to detect and alarm for excessive steady-state phase differential current, such as might be caused when the CTs at one terminal are shorted. This setting is in secondary amps, referenced to the CTR setting.

87LR

Setting range: 2.0–8 (unitless)

This setting controls the outer and inner radii of the restraint region, as shown in *Figure 3.4*. Unless special circumstances warrant, set 87LR = 6 (the factory default).

87LANG

Setting range: 90–270 degrees

This setting controls the angular extension of the restraint region, as shown in *Figure 3.4*. Unless special circumstances warrant, set 87LANG = 195 (the factory default).

Table 3.1 Differential Element Settings and Specifications

Setting Description	Setting	Setting Range
Minimum differential current Enable Level Settings		
Phase 87L:	87LPP	OFF, 0.2–2.0 A, sec. (1 A nominal) OFF, 1.0–10 A, sec. (5 A nominal)
Accuracy:		±3% ±0.01 I_{NOM}
Ph. Diff. Current Alarm Pickup:	CTALRM	0.1–2 A, sec. (1 A nominal) 0.5–10 A, sec. (5 A nominal)
Accuracy:		±3% ±0.01 I_{NOM}
Restraint Region Characteristic Settings		
Outer Radius:	87LR	2.0–8.0
Angle:	87LANG	90–270, degrees
Accuracy:		±5% of radius setting ±3° of angle setting

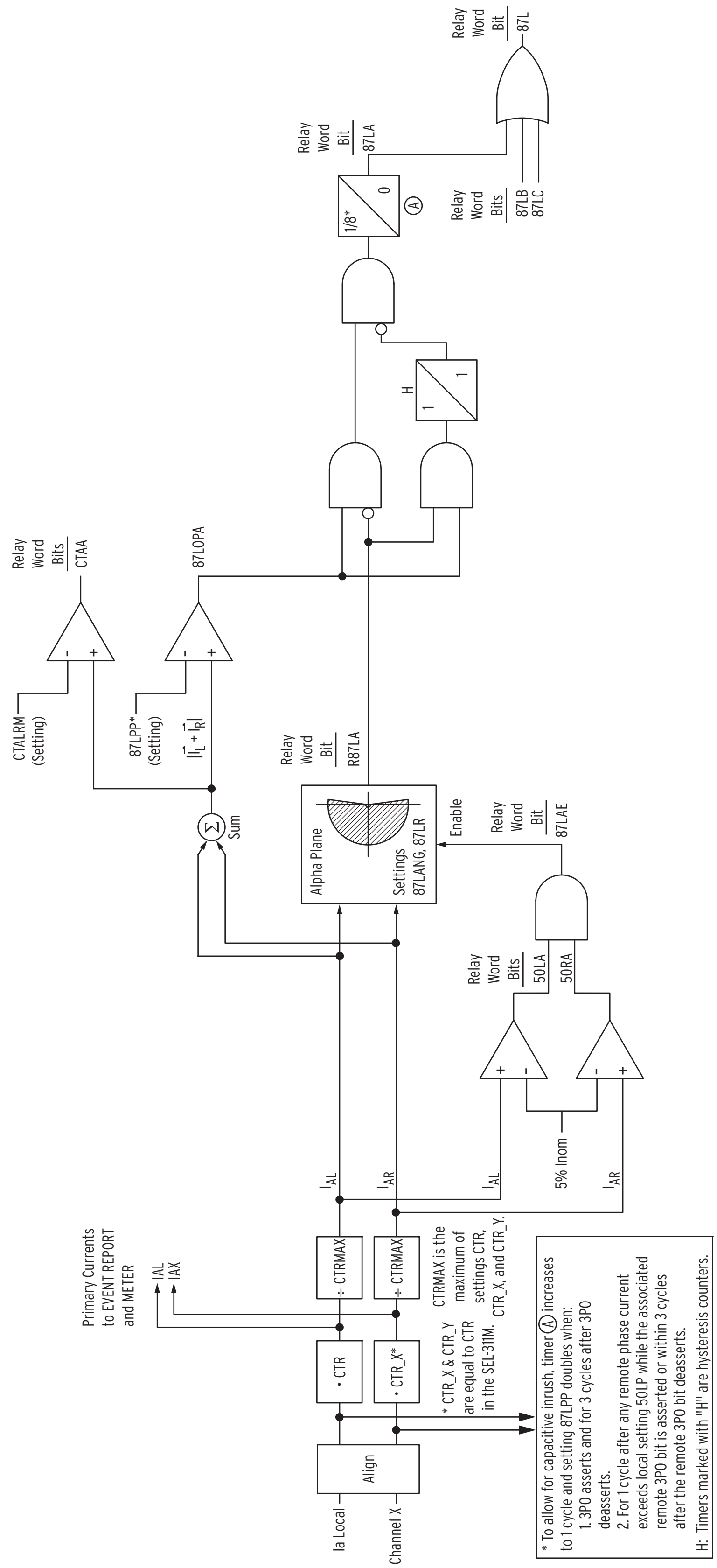


Figure 3.12 Phase Differential Element 87LA Processing for Channel X; B and C Phases and Channel Y Are Similarly Processed

Ground Differential Element

The SEL-311M Relay includes a ground differential element. The ground differential element (87W) is the primary means to detect phase-to-ground faults on an ungrounded or high-impedance grounded system when communications between the relays is available. See *Ground Differential Element Theory of Operation (Patented) on page 3.86* to become familiar with the operating principles of the ground differential elements in the SEL-311M Relay and the setting philosophy.

The ground differential logic operates as shown in *Figure 3.13*.

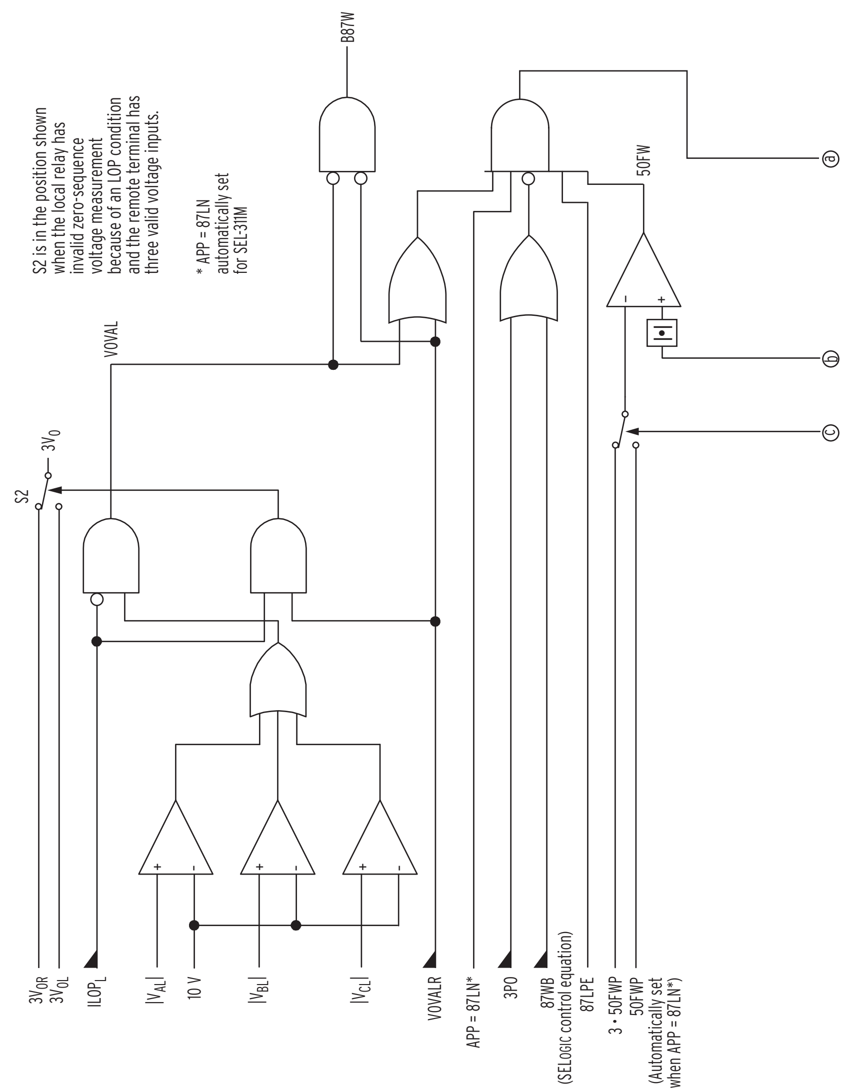


Figure 3.13 Ground Directional Element Logic for Ungrounded and High-Resistance Grounded Systems (87W)

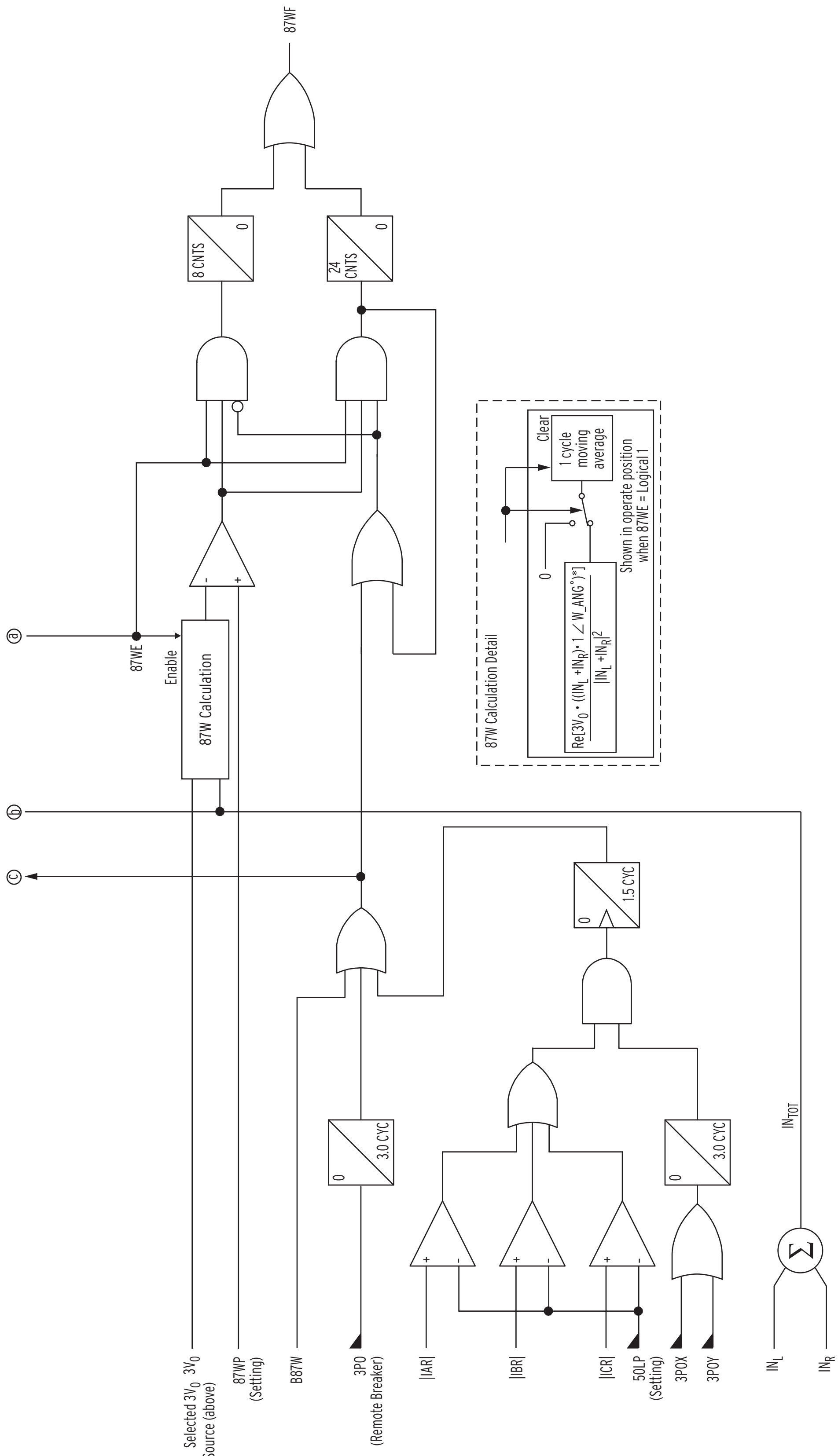


Figure 3.13 Ground Directional Element Logic for Ungrounded and High-Resistance Grounded Systems (87W) (Continued**)**

The following are 87W logic inputs.

> **NOTE:** These settings should remain at their factor default values except for special applications.

$3V_{0L}$	Zero-sequence voltage as calculated by local relay from the measured phase voltage inputs identified as V_A, V_B, and V_C. The calculation for the local 3V0 phasor is $(V_A + V_B + V_C)$. This same phasor is available for transmittal to the remote terminal relay via the communication channel.
$3V_{0R}$	Zero-sequence voltage (3V0) as calculated by remote relay and received by the local relay via the communication link.
$\|I_{AR}\|$	Remote Terminal A-Phase current magnitude
$\|I_{BR}\|$	Remote Terminal B-Phase current magnitude
$\|I_{CR}\|$	Remote Terminal C-Phase current magnitude
$\|V_{AL}\|$	Local Terminal A-Phase voltage magnitude
$\|V_{BL}\|$	Local Terminal B-Phase voltage magnitude
$\|V_{CL}\|$	Local Terminal C-Phase voltage magnitude
IN_L	Local Terminal IN current
IN_R	Remote Terminal IN current
IN_{TOT}	Total Terminal IN current $(IN_{TOT} = IN_L + IN_R)$
3PO	Three-pole open condition as determined by each relay independently. Each relay declares its breaker open if the 52A input is de-energized and the relay determines that each phase current below the 50LP threshold.
3POX	3PO received from Channel X (i.e., the remote relay 3PO indication)
3POY	3PO received from Channel Y
87WB	SELOGIC control equation variable
50FWP	Minimum sensitivity threshold(s)
87WP	Forward Ground Directional Element Threshold for ungrounded systems
W_ANG	Source adjustment angle

Ground Differential Element Settings

87WB—Ground Differential Element Block

SELOGIC setting 87WB can be set with elements listed in *Table 7.5* subject to the constraints of the SELOGIC control equations. Asserting this element blocks both the 87WF element enable calculation and resets the security timer(s) preventing the 87WF element from asserting. The factory default is 0 (OFF).

50FWP—Minimum Sensitivity Threshold

Setting range: 0.005–5 A in 0.001 A steps.

50FWP is used to supervise the ground differential element 87W by requiring a minimum zero-sequence current magnitude $|I_0|$.

For setting 50FW = 0.005, the zero-sequence current magnitude $|I_0|$ has to be greater than 5 mA secondary in order for the 87W element to assert.

87WP—Forward Ground Directional Element Threshold for Ungrounded Systems

Setting range: -900,000–0 Ω in 0.01 Ω steps.

W_ANG—Source ADJUSTMENT ANGLE

Setting range: -90°to +90° in 1° increments.

Instantaneous/Definite-Time Overcurrent Elements

Phase Instantaneous/ Definite-Time Overcurrent Elements

Four levels of phase instantaneous/definite-time overcurrent elements are available. The different levels are enabled with the E50P enable setting, as shown in *Figure 3.14*.

Element 672S in *Figure 4.12* is used in directional comparison blocking schemes (see *Directional Comparison Blocking Logic on page 4.21*).

Settings Ranges

Setting range for pickup settings 50P1P through 50P4P:

OFF, 0.05–20.00 A secondary (1 A nominal phase current inputs, IA, IB, IC)
OFF, 0.25–100.00 A secondary (5 A nominal phase current inputs, IA, IB, IC)

Setting range for definite-time settings 67P1D through 67P4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Setting range for definite-time setting 67SD (used in the DCB logic):

0.00–60.00 cycles, in 0.25-cycle steps

Accuracy

Pickup:	±0.01 A secondary and ±3% of setting (1 A nominal phase current inputs, IA, IB, IC)
	±0.05 A secondary and ±3% of setting (5 A nominal phase current inputs, IA, IB, IC)
Timer:	±0.25 cycles and ±0.1% of setting
Transient Overreach:	±5% of setting

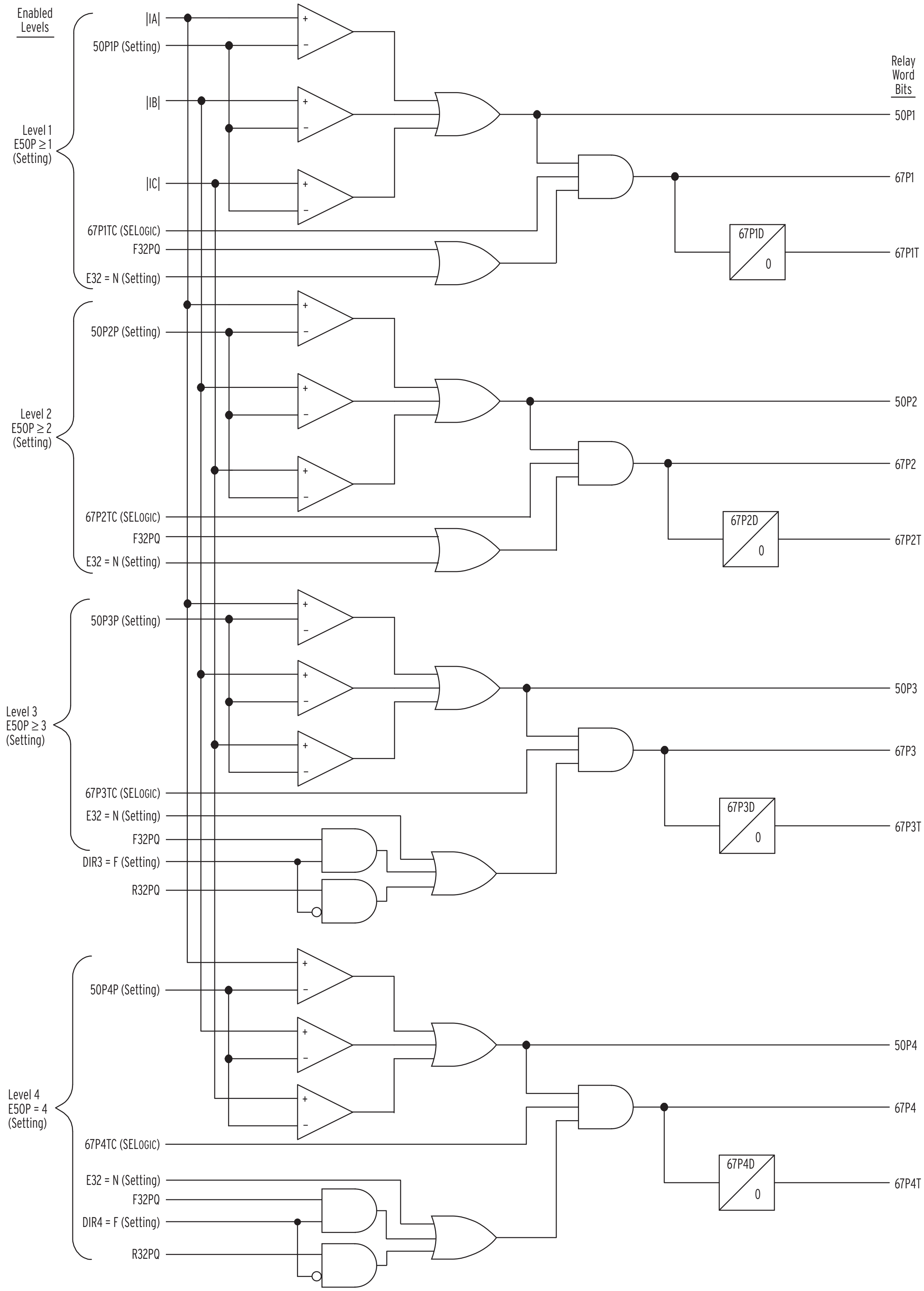


Figure 3.14 Levels 1 through 4 Phase Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

Pickup Operation

The phase instantaneous/definite-time overcurrent element logic begins with *Figure 3.14*. The pickup settings for each level (50P1P through 50P4P) are compared to the magnitudes of the individual phase currents I_A, I_B, and I_C. The logic outputs in *Figure 3.14* are Relay Word bits and operate as follows (Level 1 example shown):

50P1 = 1 (logical 1), if $|I_A|$, $|I_B|$, or $|I_C|$ > pickup setting 50P1P

Ideally, set 50P1P > 50P2P > 50P3P > 50P4P so that instantaneous overcurrent elements 67P1 through 67P4 will display in an organized fashion in event reports (see *Figure 3.14* and *Table 10.4*).

Directional Control Option

Level 3 and Level 4 in *Figure 3.14* have corresponding directional control options. See *Directional Control Settings on page 3.72* for more information on this optional directional control. If the directional control enable setting E32 is set:

E32 = **N**

then directional control is defeated, and the directional control of Level 3 and Level 4 phase instantaneous/definite-time overcurrent element levels in *Figure 3.14* are defeated. Then only the corresponding SELOGIC® control equation torque control settings have to be considered in the control of the phase instantaneous/definite-time overcurrent elements.

For example, consider the Level 3 phase instantaneous/definite-time overcurrent elements 67P3/67P3T in *Figure 3.14*. If the directional control enable setting E32 is set:

E32 = **N**

then the directional control is defeated. Then only the corresponding SELOGIC control equation torque control setting 67P3TC has to be considered in the control of the phase instantaneous/definite-time overcurrent elements 67P3/67P3T.

Torque Control

Levels 1 through 4 in *Figure 3.14* have corresponding SELOGIC control equation torque control settings 67P1TC through 67P4TC. SELOGIC control equation torque control settings cannot be set directly to logical 0. The following are torque control setting examples for Level 1 phase instantaneous/definite-time overcurrent elements 67P1/67P1T.

67P3TC = **1** Setting 67P3TC set directly to logical 1:

If directional control enable setting E32 =N, then phase instantaneous /definite-time overcurrent elements 67P3/67P3T are enabled and nondirectional.

Note: All overcurrent element SELOGIC control equation torque control settings are set directly to logical 1 (e.g., 67P1TC = 1) for the factory default settings. See *SHO Command (Show/View Settings) on page 8.33* for a list of the factory default settings.

67P1TC = **IN105** Input IN105 deasserted (67P1TC = IN105 = logical 0):

Then phase instantaneous/definite-time overcurrent elements 67P1/67P1T are defeated and nonoperational.

Input IN105 asserted (67P1TC = IN105 = logical 1):

The phase instantaneous/ /definite-time overcurrent elements 67P1/67P1T are enabled and nondirectional.

Sometimes SELOGIC control equation torque control settings are set to provide directional control.

Pickup and Reset Time Curves

Figure 3.15 and *Figure 3.16* show pickup and reset time curves applicable to all nondirectional instantaneous overcurrent elements in the SEL-311M Relay (60 Hz or 50 Hz relays). These times do not include output contact operating time and, thus, are accurate for determining element operation time for use in internal SELOGIC control equations. Output contact pickup/dropout time is approximately 4 ms (0.25 cycle for a 60 Hz relay; 0.20 cycle for a 50 Hz relay).

If instantaneous overcurrent elements are made directional, the pickup time curve in *Figure 3.15* is adjusted as follows:

multiples of pickup setting ≤ 4: add 0.25 cycle

multiples of pickup setting > 4: add 0.50 cycle

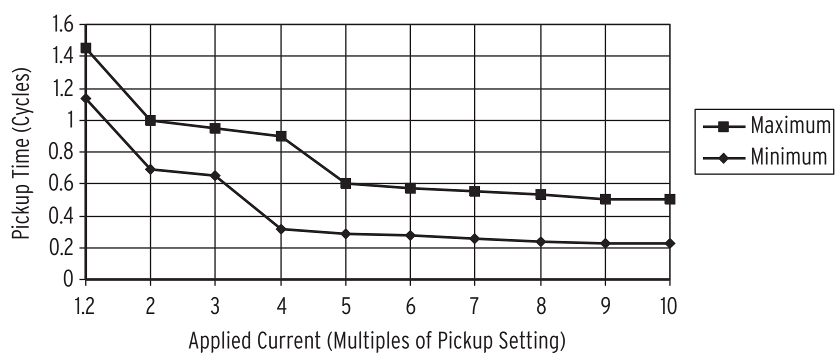


Figure 3.15 SEL-311M Nondirectional Instantaneous Overcurrent Element Pickup Time Curve

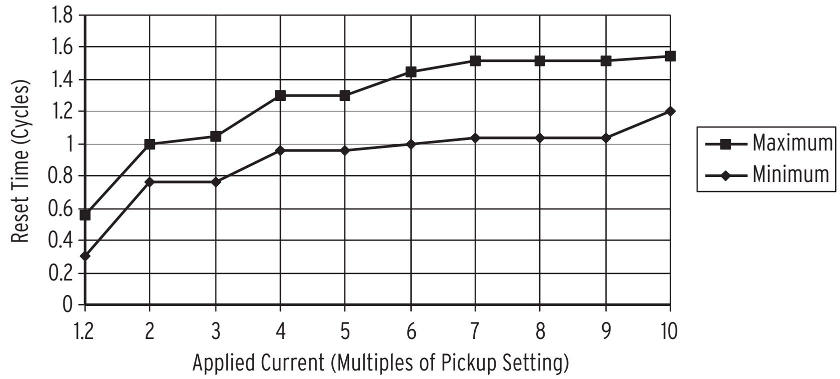


Figure 3.16 SEL-311M Nondirectional Instantaneous Overcurrent Element Reset Time Curve

Neutral Ground Instantaneous/ Definite-Time Overcurrent Elements

Four levels of neutral ground instantaneous/definite-time overcurrent elements are available. The different levels are enabled with the E50NG enable setting, as shown in *Figure 3.17*.

To understand the operation of *Figure 3.17*, follow the explanation given for *Figure 3.14* in the preceding subsection *Phase Instantaneous/Definite-Time Overcurrent Elements on page 3.17*, substituting current I_N (channel IN current) for phase currents and substituting like settings and Relay Word bits.

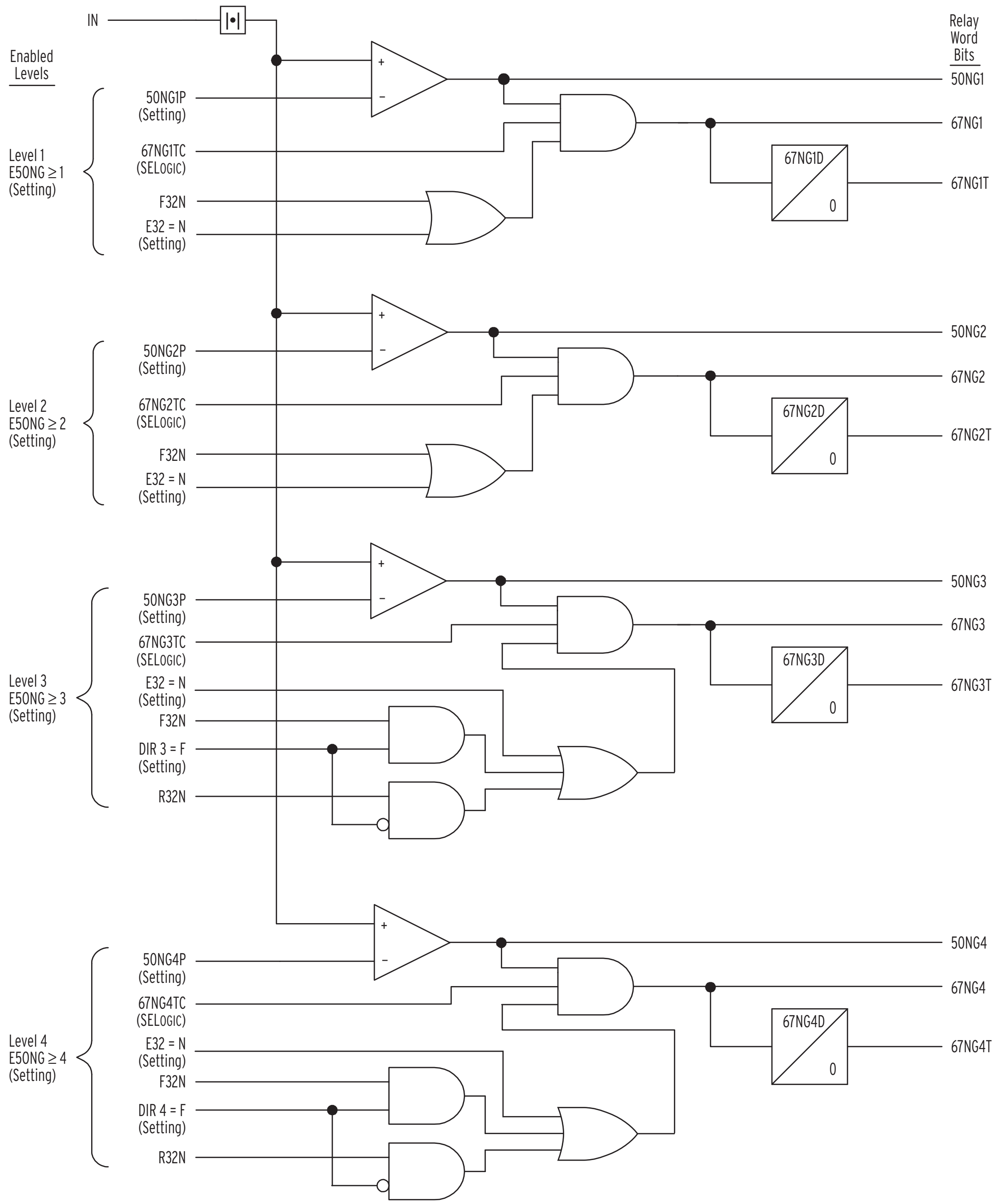


Figure 3.17 Levels 1 Through 4 Neutral Ground Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

Settings Ranges

Setting range for pickup settings 50NG1P through 50NG4P:

OFF, 0.005–5.00 A secondary (0.2 A nominal neutral current input, IN)

Setting range for definite-time settings 67N1D through 67N4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Setting range for definite-time setting 67N2SD (used in DCB logic):

0.00–60.00 cycles, in 0.25-cycle steps

Accuracy

Pickup: ±0.001 A secondary and ±3% of setting
(0.2 A nominal neutral current input, IN)

Timer: ±0.25 cycles and ±0.1% of setting

Transient Overreach: ±5% of setting

Pickup and Reset Time Curves

See *Figure 3.15* and *Figure 3.16*.

Negative-Sequence Instantaneous/ Definite-Time Overcurrent Elements

IMPORTANT: See *Setting Negative-Sequence Overcurrent Elements on page 3.80* for information on setting negative-sequence overcurrent elements.

Four levels of negative-sequence instantaneous/definite-time overcurrent elements are available. The different levels are enabled with the E50Q enable setting, as shown in *Figure 3.18*.

To understand the operation of *Figure 3.18*, follow the explanation given for *Figure 3.14* in the preceding subsection *Phase Instantaneous/Definite-Time Overcurrent Elements on page 3.17*, substituting negative-sequence current $3I_2$ [$3I_2 = I_A + a^2 \bullet I_B + a \bullet I_C$ (ABC rotation), $3I_2 = I_A + a^2 \bullet I_C + a \bullet I_B$ (ACB rotation), where $a = 1\angle120°$ and $a^2 = 1\angle{-120°}$] for phase currents and substituting like settings and Relay Word bits.

Settings Ranges

Setting range for pickup settings 50Q1P through 50Q4P:

OFF, 0.05–20.00 A secondary (1 A nominal phase current inputs, IA, IB, IC

OFF, 0.25–100.00 A secondary (5 A nominal phase current inputs, IA, IB, IC)

Setting range for definite-time settings 67Q1D through 67Q4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Accuracy

Pickup: ±0.01 A secondary and ±3% of setting
(1 A nominal phase current inputs, IA, IB, IC)

±0.05 A secondary and ±3% of setting
(5 A nominal phase current inputs, IA, IB, IC)

Timer: ±0.25 cycles and ±0.1% of setting

Transient Overreach: ±5% of setting

Pickup and Reset Time Curves

See *Figure 3.15* and *Figure 3.16*.

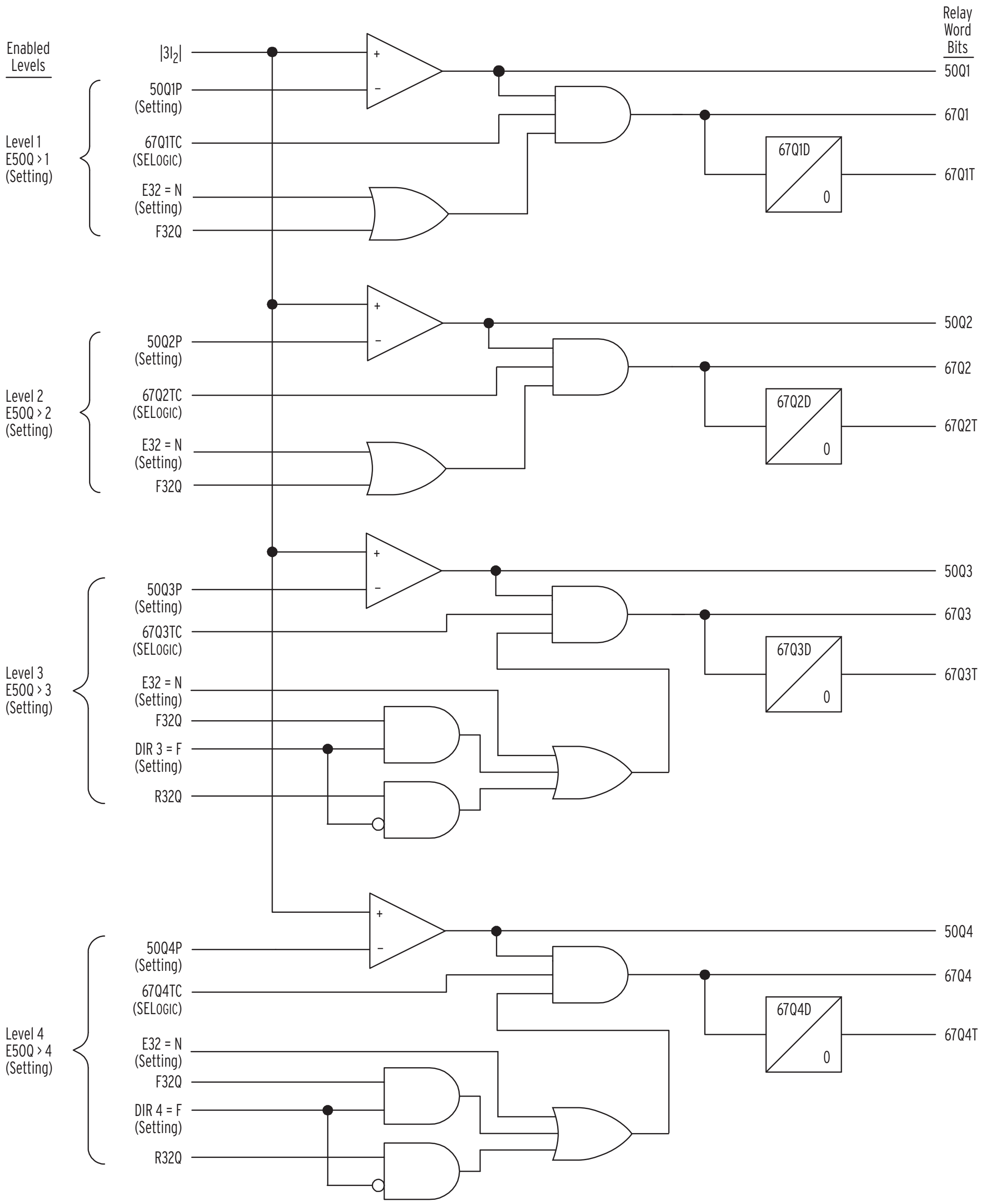


Figure 3.18 Levels 1 Through 4 Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

Time-Overcurrent Elements

Phase Time-Overcurrent Elements

One phase time-overcurrent element is available. Setting E51P enables or disables the phase time-overcurrent element.

The following describes the 51PT element operation.

Settings Ranges (51PT Element Example)

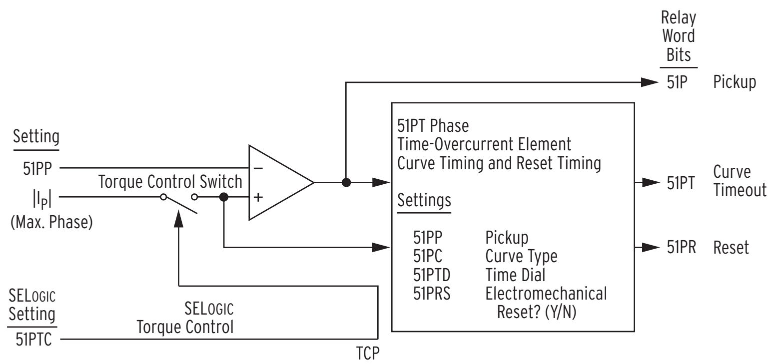
Besides the settings involved with the Torque Control Switch operation in *Figure 3.19*, the 51PT phase time-overcurrent element has the following settings:

Table 3.2 Phase Time-Overcurrent Elements (Maximum Phase) Settings

Setting	Definition	Range
51PP	pickup	OFF, 0.10–3.20 A secondary (1 A nominal phase current inputs, IA, IB, IC) OFF, 0.50–16.00 A secondary (5 A nominal phase current inputs, IA, IB, IC)
51PC	curve type	U1–U5 (US curves), C1–C5 (IEC curves)—see *Figure 7.1–Figure 7.10*
51PTD	time dial	0.50–15.00 (US curves), 0.05–1.00 (IEC curves)—see *Figure 7.1–Figure 7.10*
51PRS	electromechanical reset timing	Y, N
51PTC	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table 7.5* or set directly to logical 1 (= 1)[a]

[a] SELOGIC control equation torque control setting (e.g., 51PTC) cannot be set directly to logical 0.

See *Section 7: Settings* for additional time-overcurrent element setting information.



Logic Point TCP Controls the Torque Control Switch

TCP State	Torque Control Switch Position	Setting 51PRS =	Reset Timing
Logical 1	Closed	Y	Electromechanical
Logical 0	Open	N	1 Cycle

Figure 3.19 Phase Time-Overcurrent Element 51PT (With Directional Control Option)

Accuracy

Pickup: ±0.01 A secondary and ±3% of setting
(1 A nominal phase current inputs, IA, IB, IC)

±0.05 A secondary and ±3% of setting
(5 A nominal phase current inputs, IA, IB, IC)

Curve Timing: ±1.50 cycles and ±4% of curve time for currents between (and including) 2 and 30 multiples of pickup

Logic Outputs (51PT Element Example)

The resultant logic outputs in *Figure 3.19* are the following Relay Word bits:

Table 3.3 Phase Time-Overcurrent Element (Maximum Phase) Logic Outputs

Relay Word Bit	Definition/Indication	Application
51P	Maximum phase current, I_P, is greater than phase time-overcurrent element pickup setting 51PP.	Element pickup testing or other control applications.
51PT	Phase time-overcurrent element is timed out on its curve.	Tripping and other control applications.
51PR	Phase time-overcurrent element is fully reset.	Element reset testing or other control applications.

Torque Control Switch Operation (51PT Element Example)

Torque Control Switch Closed

The pickup comparator in *Figure 3.19* compares the pickup setting (51PP) to the maximum phase current, $|I_P|$, if the Torque Control Switch is closed. $|I_P|$ is also routed to the curve timing/reset timing functions. The Relay Word bits logic outputs operate as follows with the Torque Control Switch closed:

51P = 1 (logical 1), if $|I_P|$ > pickup setting 51PP and the phase time-overcurrent element is timing or is timed out on its curve
= 0 (logical 0), if $|I_P| \leq$ pickup setting 51PP

51PT = 1 (logical 1), if $|I_P|$ > pickup setting 51PP and the phase time-overcurrent element is timed out on its curve
= 0 (logical 0), if $|I_P|$ > pickup setting 51PP and the phase time-overcurrent element is timing, but not yet timed out on its curve
= 0 (logical 0), if $|I_P| \leq$ pickup setting 51PP

51PR = 1 (logical 1), if $|I_P| \leq$ pickup setting 51PP and the phase time-overcurrent element is fully reset
= 0 (logical 0), if $|I_P| \leq$ pickup setting 51PP and the phase time-overcurrent element is timing to reset (not yet fully reset)
= 0 (logical 0), if $|I_P|$ > pickup setting 51PP and the phase time-overcurrent element is timing or is timed out on its curve

Torque Control Switch Open

If the Torque Control Switch in *Figure 3.19* is open, maximum phase current, $|I_P|$, cannot get through to the pickup comparator (setting 51PP) and the curve timing/reset timing functions. For example, suppose that the Torque Control Switch is closed, $|I_P|$ is:

$|I_P|$ > pickup setting 51PP

and the phase time-overcurrent element is timing or is timed out on its curve. If the Torque Control Switch is then opened, $|I_P|$ effectively appears as a magnitude of zero (0) to the pickup comparator:

$|I_P|$ = 0 A (effective) < pickup setting 51PP

resulting in Relay Word bit 51P deasserting to logical 0. $|I_P|$ also effectively appears as a magnitude of zero (0) to the curve timing/reset timing functions, resulting in Relay Word bit 51PT also deasserting to logical 0. The phase time-overcurrent element then starts to time to reset. Relay Word bit 51PR asserts to logical 1 when the phase time-overcurrent element is fully reset.

Control of Logic Point TCP

Refer to *Figure 3.19*.

The Torque Control Switch is controlled by logic point TCP. Logic point TCP is controlled by SELOGIC control equation torque control setting 51PTC.

If logic point TCP = logical 1, the Torque Control Switch is closed and maximum phase current, $|I_P|$, is routed to the pickup comparator (setting 51PP) and the curve timing/reset timing functions.

If logic point TCP = logical 0, the Torque Control Switch is open and maximum phase current, $|I_P|$, cannot get through to the pickup comparator and the curve timing/reset timing functions. The maximum phase current, $|I_P|$, effectively appears as a magnitude of zero (0) to the pickup comparator and the curve timing/reset timing function.

Torque Control

Refer to *Figure 3.19*.

SELOGIC control equation torque control settings (e.g., 51PTC) cannot be set directly to logical 0. The following are setting examples of SELOGIC control equation torque control setting 51PTC for phase time-overcurrent element 51PT.

51PTC = **1** Setting 51PTC set directly to logical 1:

The logic point TCP = logical 1 and, thus, the Torque Control Switch closes and phase time-overcurrent element 51PT is enabled and nondirectional.

Note: All overcurrent element SELOGIC control equation torque control settings are set directly to logical 1 (e.g., 51PTC = 1) for the factory default settings. See *SHO Command (Show/View Settings) on page 8.33* for a list of the factory default settings.

51PTC = **IN105** Input IN105 deasserted (51PTC = IN105 = logical 0):

Then logic point TCP = logical 0 and, thus, the Torque Control Switch opens and phase time-overcurrent element 51PT is defeated and nonoperational.

Input IN105 asserted (51PTC = IN105 = logical 1):

The Torque Control Switch closes and phase time-overcurrent element 51PT is enabled and nondirectional.

Sometimes SELOGIC control equation torque control settings are set to provide directional control.

Reset Timing Details (51PT Element Example)

Refer to *Figure 3.19*.

Any time current $|I_P|$ goes above pickup setting 51PP and the phase time-overcurrent element starts timing, Relay Word bit 51PR (reset indication) = logical 0. If the phase time-overcurrent element times out on its curve, Relay Word bit 51PT (curve time-out indication) = logical 1.

Setting 51PRS = Y

If electromechanical reset timing setting 51PRS = Y, the phase time-overcurrent element reset timing emulates electromechanical reset timing. If maximum phase current, $|I_P|$, goes above pickup setting 51PP (element is timing or already timed out) and then current $|I_P|$ goes below 51PP, the element starts to time to reset, emulating electromechanical reset timing. Relay Word bit 51PR (resetting indication) = logical 1 when the element is fully reset.

Setting 51PRS = N

If reset timing setting 51PRS = N, element 51PT reset timing is a 1-cycle dropout. If current $|I_P|$ goes above pickup setting 51PP (element is timing or already timed out) and then current $|I_P|$ goes below pickup setting 51PP, there is a 1-cycle delay before the element fully resets. Relay word bit 51PR (reset indication) = logical 1 when the element is fully reset.

Neutral Ground Time-Overcurrent Elements

To understand the operation of *Figure 3.20*, follow the explanation given for *Figure 3.19* in the preceding subsection *Phase Time-Overcurrent Elements on page 3.25*, substituting current I_N (channel IN) for maximum phase current I_P and substituting like settings and Relay Word bits.

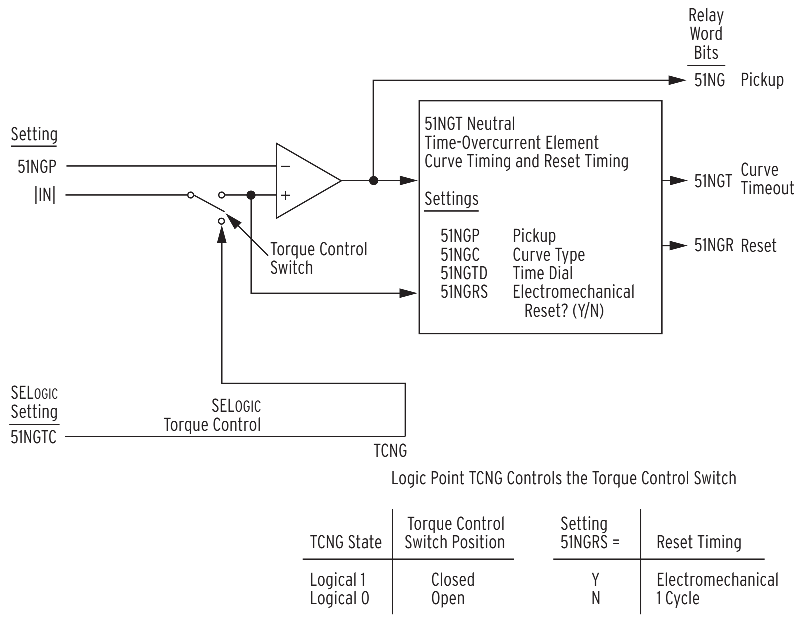


Figure 3.20 Neutral Ground Time-Overcurrent Element 51NGT (With Directional Control Option)

Settings Ranges

Table 3.4 Neutral Ground Time-Overcurrent Element Settings

Setting	Definition	Range
51NGP	pickup	OFF, 0.005–0.640 A secondary (0.2 A nominal neutral current input, IN)
51NGC	curve type	U1–U5 (US curves), C1–C5 (IEC curves)—see *Figure 7.1–Figure 7.10*
51NGTD	time dial (has no multiplying effect on constant time adder or minimum response time)	0.50–15.00 (US curves), 0.05–1.00 (IEC curves)—see *Figure 7.1–Figure 7.10*
51NGRS	electromechanical reset timing	Y, N
51NGTC	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table 7.5* or set directly to logical 1 (= 1)[a]

[a] SELOGIC control equation torque control setting (e.g., 51NGTC) cannot be set directly to logical 0.

See *Section 7: Settings* for additional time-overcurrent element setting information.

Accuracy

Pickup: ±0.001 A secondary and ±3% of setting
(0.2 A nominal neutral current input, IN)

Curve Timing: ±1.50 cycles and ±4% of curve time for currents between (and including) 2 and 30 multiples of pickup.

Negative-Sequence Time-Overcurrent Element

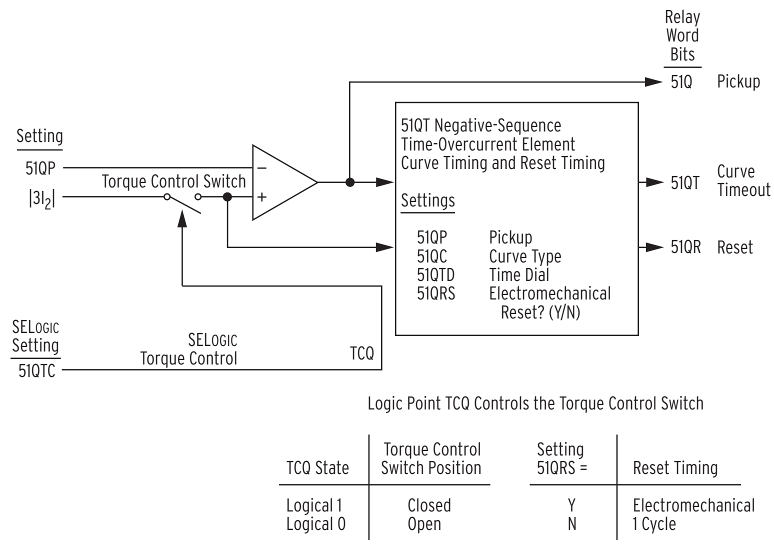


Figure 3.21 Negative-Sequence Time-Overcurrent Element 51QT (With Directional Control Option)

IMPORTANT: See *Setting Negative-Sequence Overcurrent Elements on page 3.80* for information on setting negative-sequence overcurrent elements.

To understand the operation of *Figure 3.21*, follow the explanation given for *Figure 3.19* in the preceding subsection *Phase Time-Overcurrent Elements on page 3.25*, substituting negative-sequence current $3I_2$ [$3I_2 = I_A + a^2 \cdot I_B + a \cdot I_C$ (ABC rotation), $3I_2 = I_A + a^2 \cdot I_C + a \cdot I_B$ (ACB rotation), where $a = 1 \angle 120°$ and $a^2 = 1 \angle -120°$] for maximum phase current $|I_P|$ and like settings and Relay Word bits.

Settings Ranges

Table 3.5 Negative-Sequence Time-Overcurrent Element Settings

Setting	Definition	Range
51QP	pickup	OFF, 0.10–3.20 A secondary (1 A nominal phase current inputs, IA, IB, IC) OFF, 0.50–16.00 A secondary (5 A nominal phase current inputs, IA, IB, IC)
51QC	curve type	U1–U5 (US curves), C1–C5 (IEC curves)—see *Figure 7.1–Figure 7.10*
51QTD	time dial (has no multiplying effect on constant time adder or minimum response time)	0.50–15.00 (US curves), 0.05–1.00 (IEC curves)—see *Figure 7.1–Figure 7.10*
51QRS	electromechanical reset timing	Y, N
51QTC	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table 7.5* or set directly to logical 1 (= 1)[a]

[a] SELOGIC control equation torque control setting (e.g., 51QTC) cannot be set directly to logical 0.

See *Section 7: Settings* for additional time-overcurrent element setting information.

Accuracy

Pickup: ±0.01 A secondary and ±3% of setting (1 A nominal phase current inputs, IA, IB, IC)

±0.05 A secondary and ±3% of setting (5 A nominal phase current inputs, IA, IB, IC)

Curve Timing: ±1.50 cycles and ±4% of curve time for currents between (and including) 2 and 30 multiples of pickup.

Voltage Elements

Four levels of voltage elements are available. The different levels are enabled with setting EVOLT (as shown in *Figure 3.22* and *Figure 3.23*).

Voltage Values

The voltage elements operate off of various voltage values shown in *Table 3.6*.

Table 3.6 Voltage Values Used by Voltage Elements

Voltage	Description
V_A	A-phase voltage, from SEL-311M rear-panel voltage input **VA**
V_B	B-phase voltage, from SEL-311M rear-panel voltage input **VB**
V_C	C-phase voltage, from SEL-311M rear-panel voltage input **VC**
V_{AB}	Phase-to-phase voltage
V_{BC}	Phase-to-phase voltage
V_{CA}	Phase-to-phase voltage
$3V_{0L}$	Zero-sequence voltage, local ($3V_0 = V_A + V_B + V_C$)
V_2	Negative-sequence voltage
V_1	Positive-sequence voltage
V_S	Synchronism voltage, from SEL-311M rear-panel voltage input **VS**

Voltage Element Settings

Table 3.7 lists available voltage elements and the corresponding voltage inputs and settings ranges for the SEL-311M Relay (also refer to *Figure 1.3*).

NOTE: Voltage element pickup settings should not be set near zero, because they can assert or deassert due to noise when no signal is applied. SEL recommends a minimum setting of 2.00 V.

Table 3.7 Voltage Elements Settings and Settings Ranges (Wye-Connected PTs) (Sheet 1 of 3)

Voltage Element (Relay Word Bits)	Operating Voltage	Pickup Setting/Range	See Figure
27A1	V_A	27P1P 2.00–300.00 V secondary (300 V voltage inputs)	*Figure 3.22*
27B1	V_B		
27C1	V_C		
3P27 = 27A1 * 27B1 * 27C1			
27A2	V_A	27P2P 2.00–300.00 V secondary (300 V voltage inputs)	
27B2	V_B		
27C2	V_C		
27A3	V_A	27P3P 2.00–300.00 V secondary (300 V voltage inputs)	
27B3	V_B		
27C3	V_C		
27A4	V_A	27P4P 2.00–300.00 V secondary (300 V voltage inputs)	
27B4	V_B		
27C4	V_C		
27S1	V_S	27S1P 2.00–900.00 V secondary (300 V voltage inputs)	
27S2	V_S	27S2P 2.00–900.00 V secondary (300 V voltage inputs)	
27S3	V_S	27S3P 2.00–900.00 V secondary (300 V voltage inputs)	
27S4	V_S	27S4P 2.00–900.00 V secondary (300 V voltage inputs)	
59A1	V_A	59P1P 2.00–300.00 V secondary (300 V voltage inputs)	
59B1	V_B		
59C1	V_C		
3P59 = 59A1 * 59B1 * 59C1			
59A2	V_A	59P2P 2.00–300.00 V secondary (300 V voltage inputs)	
59B2	V_B		
59C2	V_C		
59A3	V_A	59P3P 2.00–300.00 V secondary (300 V voltage inputs)	
59B3	V_B		
59C3	V_C		
59A4	V_A	59P4P 2.00–300.00 V secondary (300 V voltage inputs)	
59B4	V_B		
59C4	V_C		

Table 3.7 Voltage Elements Settings and Settings Ranges (Wye-Connected PTs) (Sheet 2 of 3)

Voltage Element (Relay Word Bits)	Operating Voltage	Pickup Setting/Range	See Figure
59S1	V_S	59S1P 2.00–300.00 V secondary (300 V voltage inputs)	
59S2	V_S	59S2P 2.00–300.00 V secondary (300 V voltage inputs)	
59S3	V_S	59S3P 2.00–300.00 V secondary (300 V voltage inputs)	
59S4	V_S	59S4P 2.00–300.00 V secondary (300 V voltage inputs)	
27AB	V_A	27PP1P 2.00–520.00 V secondary (300 V voltage inputs)	*Figure 3.23*
27BC	V_B		
27CA	V_C		
27AB2	V_A	27PP2P 2.00–520.00 V secondary (300 V voltage inputs)	
27BC2	V_B		
27CA2	V_C		
27AB3	V_A	27PP3P 2.00–520.00 V secondary (300 V voltage inputs)	
27BC3	V_B		
27CA3	V_C		
27AB4	V_A	27PP4P 2.00–520.00 V secondary (300 V voltage inputs)	
27BC4	V_B		
27CA4	V_C		
59AB1	V_A	59PP1P 2.00–520.00 V secondary (300 V voltage inputs)	
59BC1	V_B		
59CA1	V_C		
59AB2	V_A	59PP2P 2.00–520.00 V secondary (300 V voltage inputs)	
59BC2	V_B		
59CA2	V_C		
59AB3	V_A	59PP3P 2.00–520.00 V secondary (300 V voltage inputs)	
59BC3	V_B		
59CA3	V_C		
59AB4	V_A	59PP4P 2.00–520.00 V secondary (300 V voltage inputs)	
59BC4	V_B		
59CA4	V_C		
59N1	Local $3V_0$	59N1P 2.00–900.00 V secondary (300 V voltage inputs)	
59N2	Local $3V_0$	59N2P 2.00–900.00 V secondary (300 V voltage inputs)	

Table 3.7 Voltage Elements Settings and Settings Ranges (Wye-Connected PTs) (Sheet 3 of 3)

Voltage Element (Relay Word Bits)	Operating Voltage	Pickup Setting/Range	See Figure
59N3	Local $3V_0$	59N3P 2.00–900.00 V secondary (300 V voltage inputs)	
59N4	Local $3V_0$	59N4P 2.00–900.00 V secondary (300 V voltage inputs)	
59Q1	V_2	59Q1P 2.00–300.00 V secondary (300 V voltage inputs)	
59Q2	V_2	59Q2P 2.00–300.00 V secondary (300 V voltage inputs)	
59Q3	V_2	59Q3P 2.00–300.00 V secondary (300 V voltage inputs)	
59Q4	V_2	59Q4P 2.00–300.00 V secondary (300 V voltage inputs)	
59V1	V_1	59V1P 2.00–300.00 V secondary (300 V voltage inputs)	

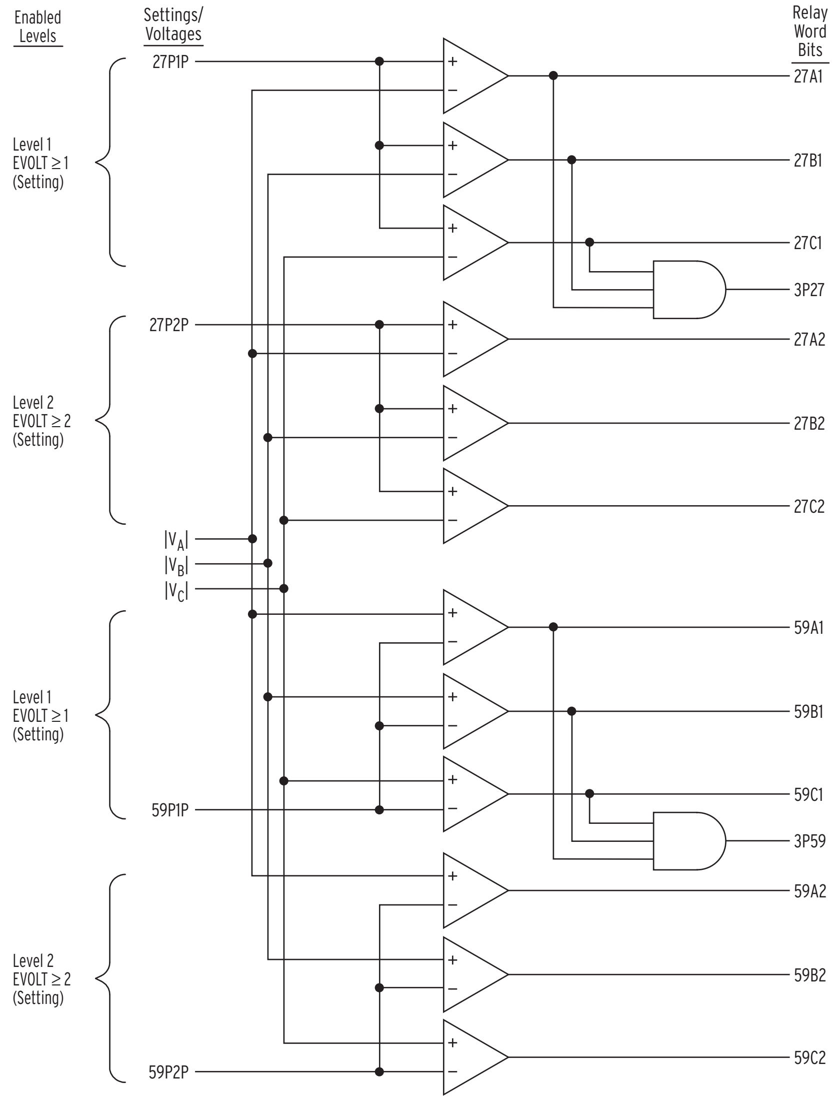


Figure 3.22 Single-Phase and Three-Phase Voltage Elements

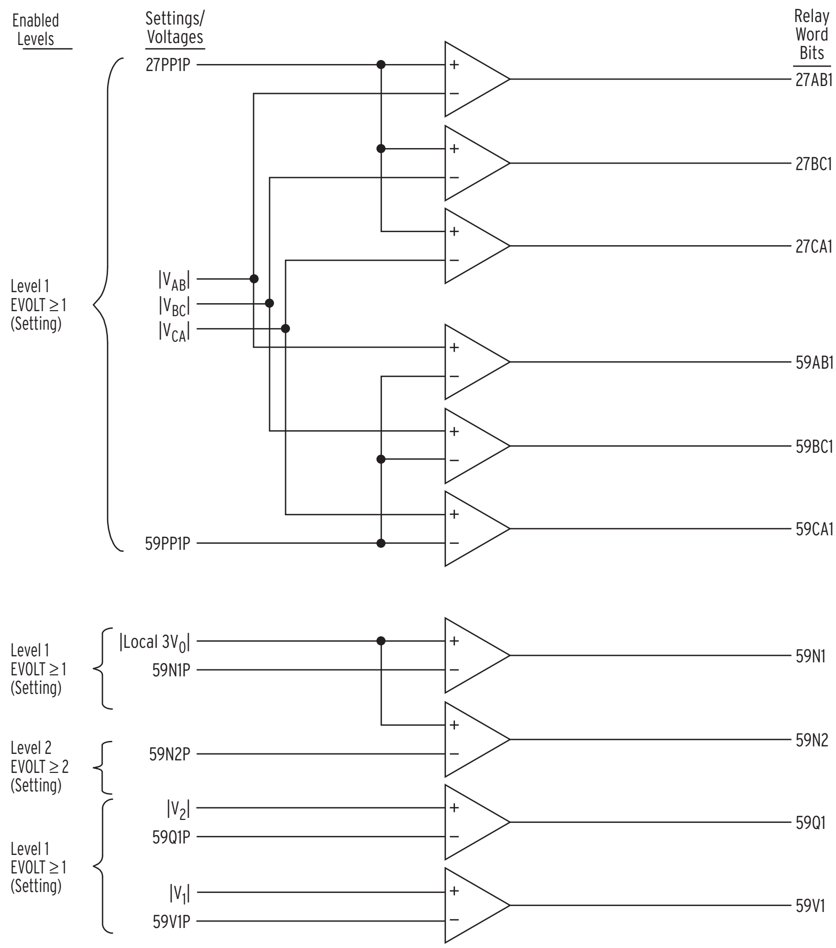


Figure 3.23 Phase-to-Phase and Sequence Voltage Elements

The other levels of the voltage elements operate similarly to those shown in *Figure 3.22* and *Figure 3.23*. To understand the operation of the other levels, substitute like settings and Relay Word bits.

Accuracy

Pickup: ±2 V and ±5% of setting

Transient Overreach: ±5% of setting (300 V voltage inputs)

Voltage Element Operation

Note that the voltage elements in *Table 3.7*, *Figure 3.22*, and *Figure 3.23* are a combination of "undervoltage" (Device 27) and "overvoltage" (Device 59) type elements. Undervoltage elements (Device 27) assert when the operating voltage goes below the corresponding pickup setting. Overvoltage elements (Device 59) assert when the operating voltage goes above the corresponding pickup setting.

Undervoltage Element Operation Example

Refer to *Figure 3.22* (top of the figure).

Pickup setting 27P1P is compared to the magnitudes of the individual phase voltages $|V_A|$, $|V_B|$, and $|V_C|$. The logic outputs in *Figure 3.22* are the following Relay Word bits:

27A1 = 1 (logical 1), if $|V_A|$ < pickup setting 27P1P
= 0 (logical 0), if $|V_A| \geq$ pickup setting 27P1P

27B1 = 1 (logical 1), if $|V_B|$ < pickup setting 27P1P
= 0 (logical 0), if $|V_B| \geq$ pickup setting 27P1P

27C1 = 1 (logical 1), if $|V_C|$ < pickup setting 27P1P
= 0 (logical 0), if $|V_C| \geq$ pickup setting 27P1P

3P27 = 1 (logical 1), if all three Relay Word bits 27A1, 27B1, and 27C1 are asserted (27A1 = 1, 27B1 = 1, and 27C1 = 1)
= 0 (logical 0), if at least one of the Relay Word bits 27A1, 27B1, or 27C1 is deasserted (e.g., 27A1 = 0)

Overvoltage Element Operation Example

Refer to *Figure 3.22* (bottom of the figure).

Pickup setting 59P1P is compared to the magnitudes of the individual phase voltages $|V_A|$, $|V_B|$, and $|V_C|$. The logic outputs in *Figure 3.22* are the following Relay Word bits:

59A1 = 1 (logical 1), if $|V_A|$ > pickup setting 59P1P
= 0 (logical 0), if $|V_A| \leq$ pickup setting 59P1P

59B1 = 1 (logical 1), if $|V_B|$ > pickup setting 59P1P
= 0 (logical 0), if $|V_B| \leq$ pickup setting 59P1P

59C1 = 1 (logical 1), if $|V_C|$ > pickup setting 59P1P
= 0 (logical 0), if $|V_C| \leq$ pickup setting 59P1P

3P59 = 1 (logical 1), if all three Relay Word bits 59A1, 59B1, and 59C1 are asserted (59A1 = 1, 59B1 = 1, and 59C1 = 1)
= 0 (logical 0), if at least one of the Relay Word bits 59A1, 59B1, or 59C1 is deasserted (e.g., 59A1 = 0)

Voltage Elements Used in POTT Logic

Refer to *Figure 3.22*. Note that voltage elements 27AB, 27BC, 27CA, and 59N1 are also used in the weak-infeed portion of the POTT logic, if the weak-infeed logic is enabled (see *Figure 4.7*).

If the weak-infeed portion of the POTT logic is enabled (setting EWFC = Y) and these voltage elements are used in the logic, they can still be used in other applications (if the settings are applicable). If the weak-infeed portion of the POTT logic is not enabled, these voltage elements can be used in any desired application.

Synchronism Check Elements

Enable the two single-phase synchronism check elements by making the enable setting:

E25 = **Y**

Figure 2.5 in *Section 2: Installation* shows an example where synchronism check can be applied. Synchronism check voltage input VS is connected to one side of the circuit breaker, on any desired phase. The other synchronizing phase (VA, VB, VC, voltage inputs) on the other side of the circuit breaker is setting-selected.

The two synchronism check elements use the same voltage window (to assure healthy voltage) and slip frequency settings (see *Figure 3.24*). They have separate angle settings (see *Figure 3.25*).

If the voltages are static (voltages not slipping with respect to one another) or setting TCLOSD = 0.00, the two synchronism check elements operate as shown in the top of *Figure 3.25*. The angle settings are checked for synchronism check closing.

If the voltages are not static (voltages slipping with respect to one another), the two synchronism check elements operate as shown in the bottom of *Figure 3.25*. The angle difference is compensated by breaker close time, and the breaker is ideally closed at a zero degree phase angle difference, to minimize system shock.

These synchronism check elements are explained in detail in the following text.

Sometimes synchronism check voltage V_S cannot be in phase with voltage V_A, V_B, V_C. This happens in applications where voltage input VS is connected

- Phase-to-phase when using a wye-connected relay.
- Beyond a delta-wye transformer.

For such applications requiring V_S to be at a constant phase angle difference from any of the possible synchronizing voltages (V_A, V_B, or V_C), an angle setting is made with the SYNCP setting (see *Table 3.8* and the SYNCP setting discussion that follows).

Synchronism Check Elements Settings

Table 3.8 Synchronism Check Elements Settings and Settings Ranges (Sheet 1 of 2)

Setting	Definition	Range
25VLO	low voltage threshold for "healthy voltage" window	0.0–300.0 V secondary (300 V voltage inputs)
25VHI	high voltage threshold for "healthy voltage" window	0.0–300.0 V secondary (300 V voltage inputs)
25SF	maximum slip frequency	0.005–0.500 Hz
25ANG1	synchronism check element 25A1 maximum angle	0°–80°
25ANG2	synchronism check element 25A2 maximum angle	0°–80°

Table 3.8 Synchronism Check Elements Settings and Settings Ranges (Sheet 2 of 2)

Setting	Definition	Range
SYNCP	synchronizing phase or the number of degrees that synchronism check voltage V_S constantly lags voltage V_A (wye-connected voltages) or V_{AB} (delta-connected voltages)	VA, VB, or VC VAB, VBC, or VCA 0°–330°, in 30° steps
TCLOSD	breaker close time for angle compensation	0.00–60.00 cycles
BSYNCH	SELOGIC control equation block synchronism check setting	Relay Word bits referenced in *Table 7.5*

Setting SYNCP

The angle setting choices (0, 30, …, 300, or 330 degrees) for setting SYNCP are referenced to V_A, and they indicate how many degrees V_S constantly lags V_A. In any synchronism check application, voltage input VA-N always has to be connected to determine system frequency on one side of the circuit breaker (to determine the slip between V_S and V_A). V_A always has to meet the "healthy voltage" criteria (settings 25VHI and 25VLO—see *Figure 3.24*). Thus, for situations where V_S cannot be in phase with V_A, V_B, or V_C, it is most straightforward to have the angle setting choices (0, 30, …, 300, or 330 degrees) referenced to V_A.

Note on setting SYNCP = 0:

> Settings SYNCP = 0 and SYNCP = VA are effectively the same (voltage V_S is directly synchronism checked with voltage V_A; V_S does not lag V_A). The relay will display the setting entered (SYNCP = VA or SYNCP = 0).

Figure 2.5 shows a relay wired with wye-connected phase PTs, and an A-phase-to-B-phase connected VS input. With ABC rotation, the correct SYNCP setting for this example is 30 degrees.

See the Application Guide entitled *Compensate for Constant Phase Angle Difference in Synchronism Check with the SEL-351 Relay Family* for more information on setting SYNCP with an angle setting.

Accuracy

Voltage Pickup:	±2 V and ±5% of setting (300 V voltage inputs)
Voltage Transient Overreach:	±5% of setting
Slip Pickup:	0.003 Hz
Angle Pickup:	±4°

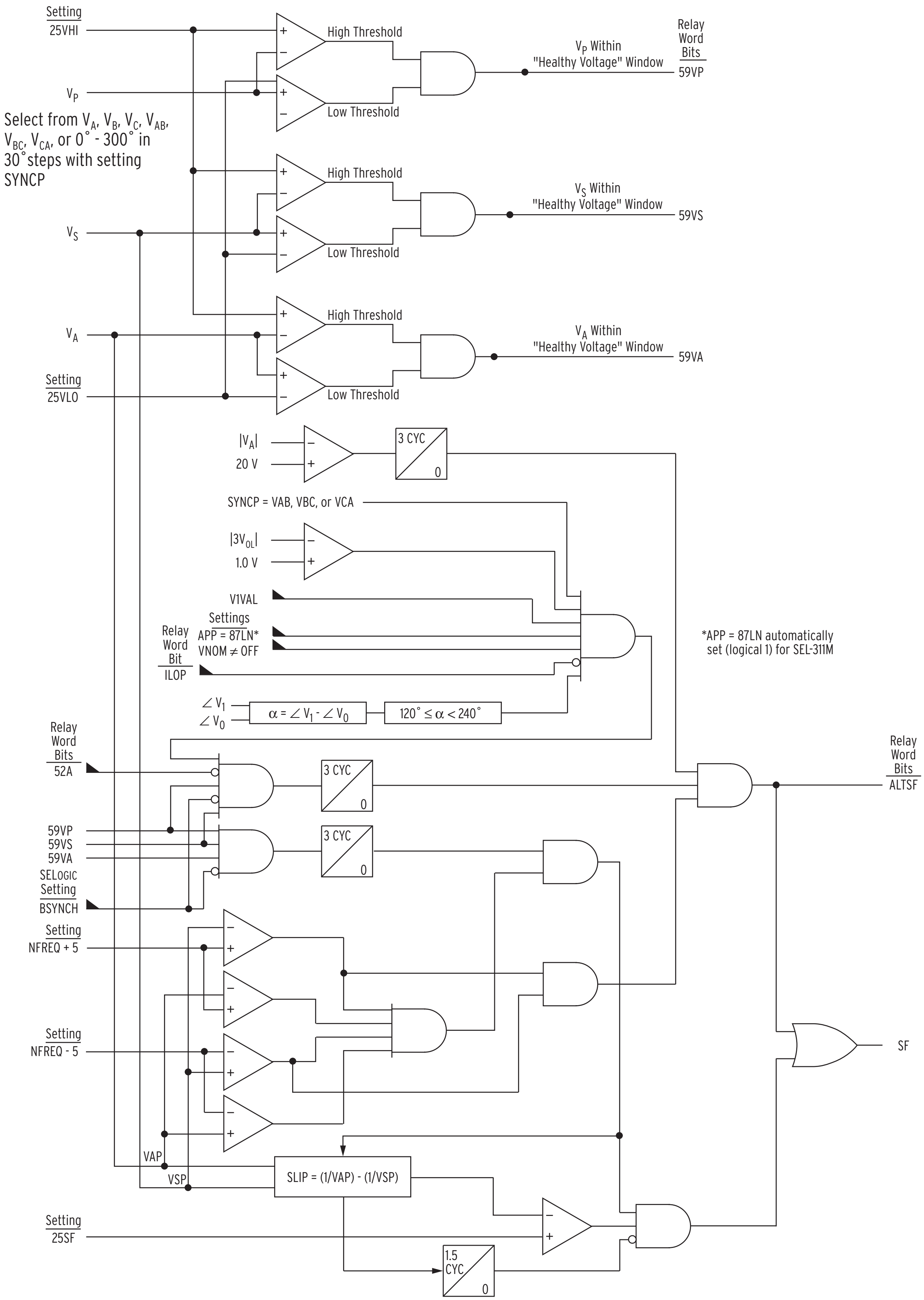


Figure 3.24 Synchronism Check Voltage Window and Slip Frequency Elements

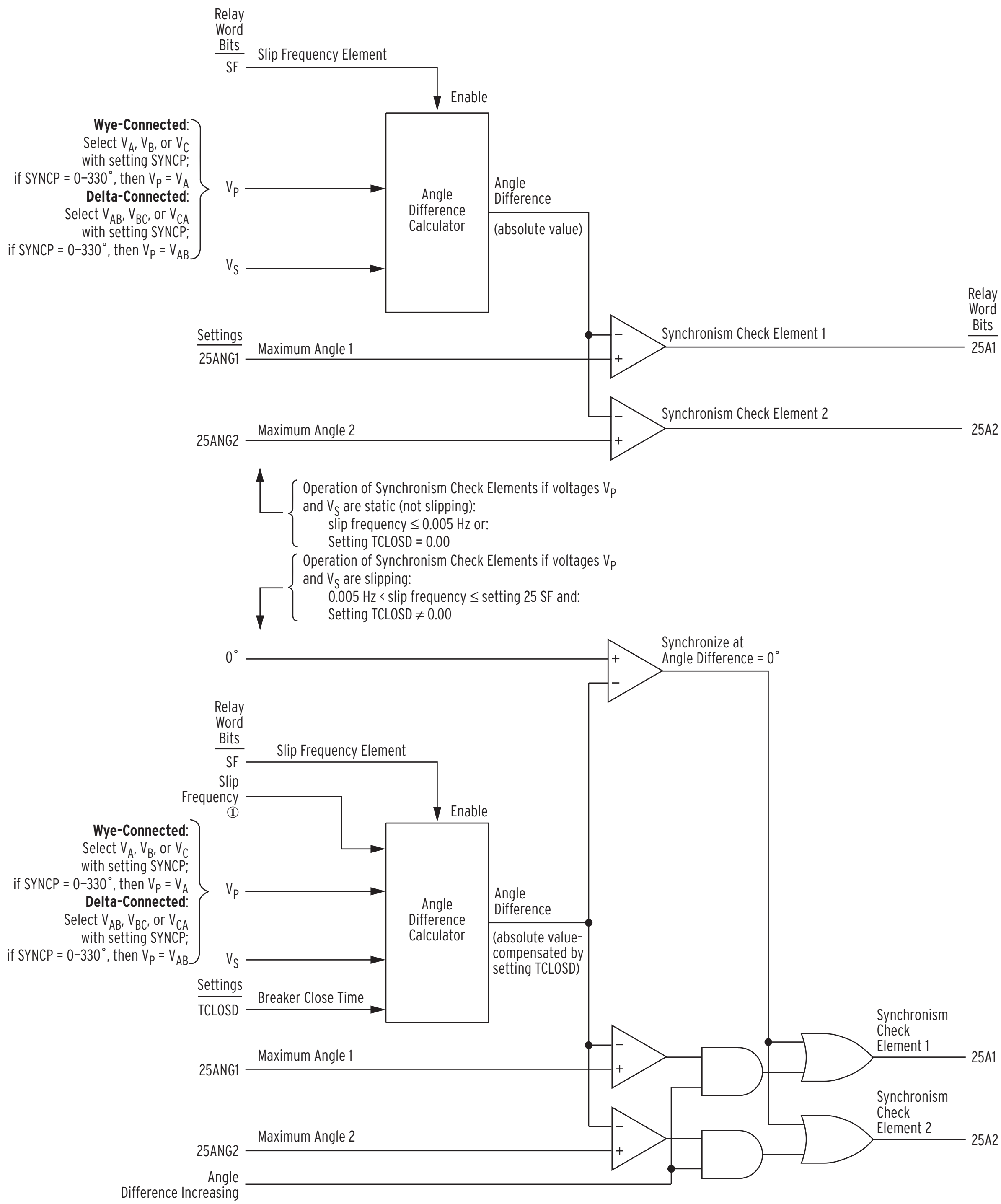


Figure 3.25 Synchronism Check Elements

① From Figure 3.24.

Synchronism Check Elements Voltage Inputs

The two synchronism check elements are single-phase elements, with single-phase voltage inputs V_P and V_S used for both elements:

V_P Phase input voltage (V_A, V_B, V_C, V_{AB}, V_{BC}, or V_{CA}), designated by setting SYNCP (e.g., if SYNCP = VB, then $V_P = V_B$)

V_S Synchronism check voltage, from SEL-311M rear-panel voltage input VS

For example, if V_P is designated as voltage V_{BC} (setting SYNCP = VBC), then rear-panel voltage input VS-NS is connected to BC phase-to-phase on the other side of the circuit breaker. The voltage across terminals VB-VC is synchronism checked with the voltage across terminals VS-NS (see *Figure 2.5*).

System Frequencies Determined from Voltages V_A and V_S

The SEL-311M determines the system frequencies on both sides of the circuit breaker to determine slip frequency. Voltage V_S determines the frequency on one side. Voltage V_A (for wye-connected voltage inputs) determines the frequency on the other side. Thus, voltage terminals VA-N have to be connected, even if another voltage (e.g., voltage V_B for wye) is to be synchronized with voltage V_S. If voltage V_A is lost and the circuit breaker is closed, the relay uses voltage V_S to frequency track. Examples of cases where input V_A is lost are continued operation of a high-impedance or ungrounded system with a sustained A-phase-to-ground fault or a blown/missing A-phase PT fuse.

In most applications, all three voltage inputs V_A, V_B, and V_C are connected to the three-phase power system and no additional connection concerns are needed for voltage connection VA-N. The presumption is that the frequency determined for A-phase is also valid for B- and C-phase in a three-phase power system.

However, for example, if voltage V_B is to be synchronized with voltage V_S and plans were to connect only voltage terminals VB-N and VS-NS then voltage terminals VA-N will also have to be connected for frequency determination. If desired, voltage terminals VA-N can be connected in parallel with voltage terminals VB-N (or voltage terminals VB-VA connected in parallel with voltage terminals VB-VC for delta; connect voltage terminal VA to VC). In such a nonstandard parallel connection, remember that voltage terminals VA-N are monitoring Phase B. This understanding helps prevent confusion when observing metering and event report information or voltage element operation.

Another possible solution to this example for wye-connected relays (synchronism check voltage input VS-NS connected to V_B) is to make setting SYNCP = 120 (the number of degrees that synchronism check voltage V_S constantly lags voltage V_A) and connect voltage input VA-N to V_A. Voltage inputs VB and VC do not have to be connected.

System Rotation Can Affect Setting SYNCP

The solution in the preceding paragraph:

- Voltage input VA connected to Phase A
- Voltage input VS connected to Phase B
- Setting SYNCP = 120 degrees (V_S constantly lags V_A by 120°)

presumes ABC system rotation. If voltage input connections are the same, but system rotation is ACB, then setting SYNCP = 240 degrees (V_S constantly lags V_A by 240°). See the SEL Application Guide titled *Compensate for Constant Phase Angle Difference in Synchronism Check with the SEL-351 Relay Family* for more information on setting SYNCP with an angle setting.

Synchronism Check Elements Operation

Refer to *Figure 3.24* and *Figure 3.25*.

Voltage Window

Refer to *Figure 3.24*.

Single-phase voltage inputs $|V_P|$ and $|V_S|$ are compared to a voltage window, to verify that the voltages are "healthy" and lie within settable voltage limits 25VLO and 25VHI. If both voltages are within the voltage window, the following Relay Word bits assert:

59VP indicates that voltage $|V_P|$ is within voltage window setting limits 25VLO and 25VHI

59VS indicates that voltage $|V_S|$ is within voltage window setting limits 25VLO and 25VHI

As discussed previously, voltage V_A determines the frequency on the voltage V_P side of the circuit breaker. Voltage V_A is also run through voltage limits 25VLO and 25VHI to ensure "healthy voltage" for frequency determination, with corresponding Relay Word bit output 59VA. As discussed earlier, if voltage V_A is not present the synchronism check bypasses the slip frequency calculation and the relay uses the angular difference calculation only to close the breaker.

Other Uses for Voltage Window Elements

If voltage limits 25VLO and 25VHI are applicable to other control schemes, Relay Word bits 59VP, 59VS, and 59VA can be used in other logic at the same time they are used in the synchronism check logic.

If synchronism check is not being used, Relay Word bits 59VP, 59VS, and 59VA can still be used in other logic, with voltage limit settings 25VLO and 25VHI set as desired. Enable the synchronism check logic (setting E25 = Y) and make settings 25VLO and 25VHI. Apply Relay Word bits 59VP, 59VS, and 59VA in the desired logic scheme, using SELOGIC control equations. Even though synchronism check logic is enabled, the synchronism check logic outputs (Relay Word bits SF, 25A1, and 25A2) do not need to be used.

Block Synchronism Check Conditions

Refer to *Figure 3.24*.

The synchronism check element slip frequency calculator runs if both voltages V_P and V_S are healthy (59VP and 59VS asserted to logical 1) and the SELOGIC control equation setting BSYNCH (Block Synchronism Check) is deasserted (= logical 0). Setting BSYNCH is most commonly set to block synchronism check operation when the circuit breaker is closed (synchronism check is only needed when the circuit breaker is open):

BSYNCH = **52A**

In addition, synchronism check operation can be blocked when the relay is tripping:

BSYNCH = ... **+ TRIP**

Slip Frequency Calculator

Refer to *Figure 3.24*.

The synchronism check element Slip Frequency Calculator in *Figure 3.24* runs if voltages V_P, V_S, and V_A are healthy (59VP, 59VS, and 59VA asserted to logical 1) and the SELOGIC control equation setting BSYNCH (Block Synchronism Check) is deasserted (= logical 0). The Slip Frequency Calculator output is:

Slip Frequency = $f_P - f_S$ (in units of Hz = slip cycles/second)

f_P = frequency of voltage V_P (in units of Hz = cycles/second)

[determined from V_A (or V_{AB} for delta)]

f_S = frequency of voltage V_S (in units of Hz = cycles/second)

A complete slip cycle is one single 360-degree revolution of one voltage (e.g., V_S) by another voltage (e.g., V_P). Both voltages are thought of as revolving phasor-wise, so the “slipping” of V_S past V_P is the relative revolving of V_S past V_P.

For example, in *Figure 3.24*, if voltage V_P has a frequency of 59.95 Hz and voltage V_S has a frequency of 60.05 Hz, the difference between them is the slip frequency:

Slip Frequency = 59.95 Hz – 60.05 Hz = –0.10 Hz = –0.10 slip cyc/sec

The slip frequency in this example is negative, indicating that voltage V_S is not “slipping” behind voltage V_P, but in fact “slipping” ahead of voltage V_P. In a time period of one second, the angular distance between voltage V_P and voltage V_S changes by 0.10 slip cycles, which translates into:

0.10 slip cycles/second • (360°/slip cycle) • 1 second = 36°

Thus, in a time period of one second, the angular distance between voltage V_P and voltage V_S changes by 36 degrees.

The absolute value of the Slip Frequency output is run through a comparator and if the slip frequency is less than the maximum slip frequency setting, 25SF, Relay Word bit SF asserts to logical 1.

Angle Difference Calculator

The synchronism check element Angle Difference Calculator in *Figure 3.25* runs if the slip frequency is less than the maximum slip frequency setting 25SF (Relay Word bit SF is asserted).

Voltages V_P and V_S are “Static”

Refer to top of *Figure 3.25*.

If the slip frequency is less than or equal to 0.005 Hz, the Angle Difference Calculator does not take into account breaker close time—it presumes voltages V_P and V_S are “static” (not “slipping” with respect to one another). This would usually be the case for an open breaker with voltages V_P and V_S

that are paralleled via some other electric path in the power system. The Angle Difference Calculator calculates the angle difference between voltages V_P and V_S:

$$\text{Angle Difference} = |(\angle V_P - \angle V_S)|$$

For example, if SYNCP = 90 (indicating V_S constantly lags $V_P = V_A$ by 90 degrees), but V_S actually lags V_A by 100 angular degrees on the power system at a given instant, the Angle Difference Calculator automatically accounts for the 90 degrees and:

$$\text{Angle Difference} = |(\angle V_P - \angle V_S)| = 10°$$

Also, if breaker close time setting TCLOSD = 0.00, the Angle Difference Calculator does not take into account breaker close time, even if the voltages V_P and V_S are "slipping" with respect to one another. Thus, synchronism check elements 25A1 or 25A2 assert to logical 1 if the Angle Difference is less than corresponding maximum angle setting 25ANG1 or 25ANG2.

Voltages V_P and V_S are "Slipping"

Refer to bottom of *Figure 3.25*.

If the slip frequency is greater than 0.005 Hz and breaker close time setting TCLOSD ≠ 0.00, the Angle Difference Calculator takes the breaker close time into account with breaker close time setting TCLOSD (set in cycles; see *Figure 3.26*). The Angle Difference Calculator calculates the Angle Difference between voltages V_P and V_S, compensated with the breaker close time:

$$\text{Angle Difference} = \left|(\angle V_P - \angle V_S) + \left[(f_P - f_S) \bullet \text{TCLOSD} \bullet \left(\frac{1\text{ second}}{60\text{ cycles}}\right) \bullet \left(\frac{360°}{\text{slip cycle}}\right)\right]\right|$$

Angle Difference Example (Voltages V_p and V_s are "Slipping")

Refer to bottom of *Figure 3.25*.

For example, if the breaker close time is ten cycles, set TCLOSD = 10. Presume the slip frequency is the example slip frequency calculated previously. The Angle Difference Calculator calculates the angle difference between voltages V_P and V_S, compensated with the breaker close time:

$$\text{Angle Difference} = \left|(\angle V_P - \angle V_S) + \left[(f_P - f_S) \bullet \text{TCLOSD} \bullet \left(\frac{1\text{ second}}{60\text{ cycles}}\right) \bullet \left(\frac{360°}{\text{slip cycle}}\right)\right]\right|$$

Intermediate calculations:

$(f_P - f_S)$ = (59.95 Hz – 60.05 Hz) = –0.10 Hz = –0.10 slip cycles/second

TCLOSD • (1 second/60 cycles) = 10 cycles • (1 second/60 cycles)
= 0.167 second

Resulting in:

$$\begin{aligned}\text{Angle Difference} &= \left|(\angle V_P - \angle V_S) + \left[(f_P - f_S) \bullet \text{ TCLOSD} \bullet \right.\right.\\ &\qquad \left.\left.\left(\frac{1 \text{ second}}{60 \text{ cycles}}\right) \bullet \left(\frac{360°}{\text{slip cycle}}\right)\right]\right| \\ &= \left|(\angle V_P - \angle V_S) + [-0.10 \bullet 0.167 \bullet 360°]\right| \\ &= \left|(\angle V_P - \angle V_S) - 6°\right|\end{aligned}$$

NOTE: The angle compensation in Figure 3.26 appears much greater than six degrees. Figure 3.26 is for general illustrative purposes only.

During the breaker close time (TCLOSD), the voltage angle difference between voltages V_P and V_S changes by six degrees. This six degree angle compensation is applied to voltage V_S, resulting in derived voltage V_S*, as shown in *Figure 3.26*.

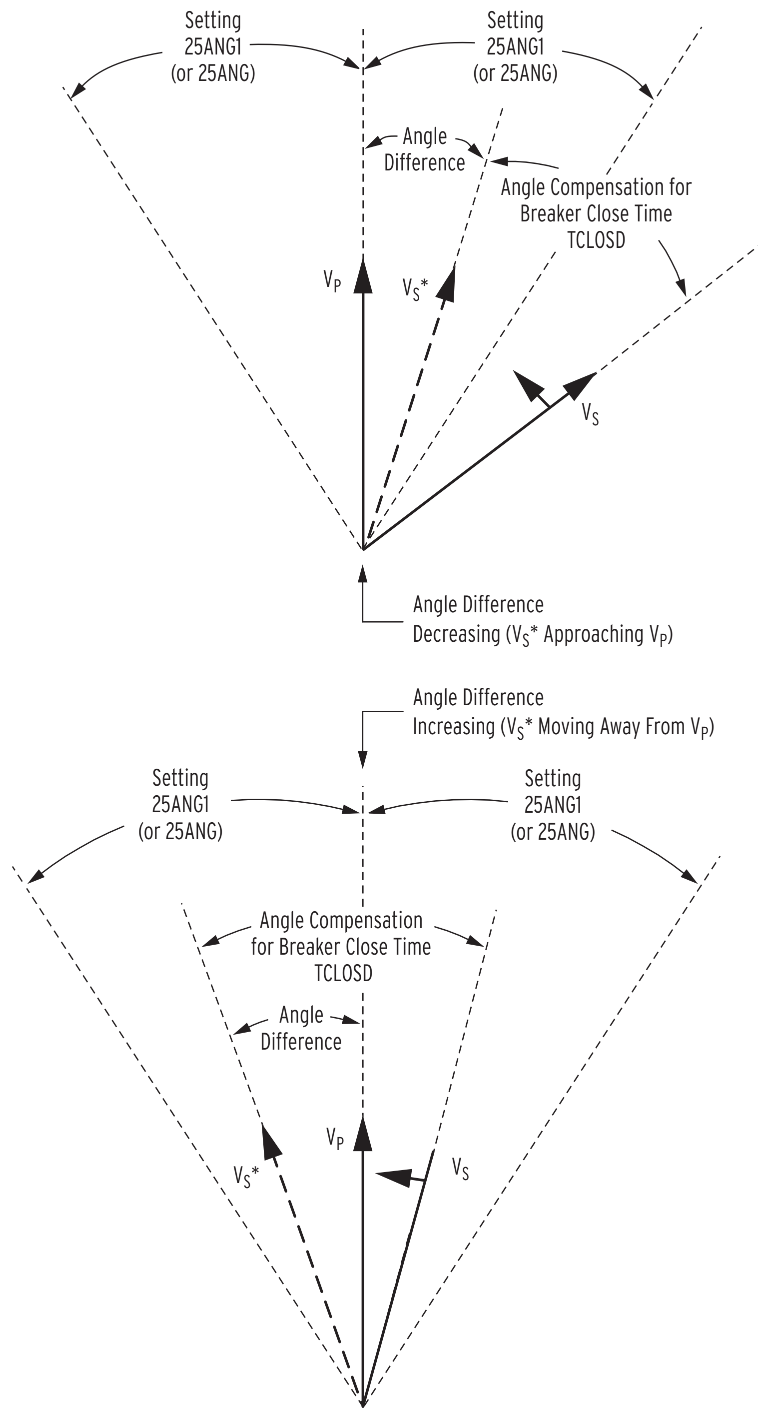


Figure 3.26 Angle Difference Between V_P and V_S Compensated by Breaker Close Time (V_P Shown as Reference in This Example)

The top of *Figure 3.26* shows the Angle Difference **decreasing**—V_S* is approaching V_P. Ideally, circuit breaker closing is initiated when V_S* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in phase with V_P, minimizing system shock.

The bottom of *Figure 3.26* shows the Angle Difference **increasing**—V_S* is moving away from V_P. Ideally, circuit breaker closing is initiated when V_S* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in phase with V_P. But in this case,

V_S* has already moved past V_P. In order to initiate circuit breaker closing when V_S* is in phase with V_P (Angle Difference = 0 degrees), V_S* has to slip around another revolution, relative to V_P.

Synchronism Check Element Outputs

Synchronism check element outputs (Relay Word bits 25A1 and 25A2 in *Figure 3.25*) assert to logical 1 for the conditions explained in the following text.

Voltages V_P and V_S are "Static" or Setting TCLOSD = 0.00

Refer to top of *Figure 3.25*.

If V_P and V_S are "static" (not "slipping" with respect to one another), the Angle Difference between them remains constant—it is not possible to close the circuit breaker at an ideal zero degree phase angle difference. Thus, synchronism check elements 25A1 or 25A2 assert to logical 1 if the Angle Difference is less than corresponding maximum angle setting 25ANG1 or 25ANG2.

Also, if breaker close time setting (TCLOSD = 0.00), the Angle Difference Calculator does not take into account breaker close time, even if the voltages V_P and V_S are "slipping" with respect to one another. Thus, synchronism check elements 25A1 or 25A2 assert to logical 1 if the Angle Difference is less than corresponding maximum angle setting 25ANG1 or 25ANG2.

Voltages V_P and V_S are "Slipping" and Setting TCLOSD ≠ 0.00

Refer to bottom of *Figure 3.25*. If V_P and V_S are "slipping" with respect to one another and breaker close time setting ≠ 0.00, the Angle Difference (compensated by breaker close time TCLOSD) changes through time. Synchronism check element 25A1 or 25A2 asserts to logical 1 for any one of the following three scenarios.

1. The top of *Figure 3.26* shows the Angle Difference **decreasing**—V_S* is approaching V_P. When V_S* is in phase with V_P (Angle Difference = 0 degrees), synchronism check elements 25A1 and 25A2 assert to logical 1.

2. The bottom of *Figure 3.26* shows the Angle Difference **increasing**—V_S* is moving away from V_P. V_S* was in phase with V_P (Angle Difference = 0 degrees), but has now moved past V_P. If the Angle Difference is **increasing**, but the Angle Difference is still less than maximum angle settings 25ANG1 or 25ANG2, then corresponding synchronism check elements 25A1 or 25A2 assert to logical 1.

   In this scenario of the Angle Difference increasing, but still being less than maximum angle settings 25ANG1 or 25ANG2, the operation of corresponding synchronism check elements 25A1 and 25A2 becomes **less restrictive**. Synchronism check breaker closing does not have to wait for voltage V_S* to slip around again in phase with V_P (Angle Difference = 0 degrees). There might not be enough time to wait for this to happen. Thus, the "Angle Difference = 0 degrees" restriction is eased for this scenario.

Synchronism Check Applications for Manual Closing

Refer to *Figure 4.14*.

Set 25ANG2 = 25° and use the resultant synchronism check element in manual close logic to supervise manual closing (e.g., assert IN106 to initiate manual close), e.g.,

CL = **IN106 * (25A2 + ...)**

In this example, the angular difference across the circuit breaker can be up to 25 degrees for a manual close.

Frequency Elements

Six frequency elements are available. Enable the desired number of frequency elements with the E81 enable setting:

E81 = **N** (none), **1** through **6**

as shown in *Figure 3.29*. Frequency is determined from the voltage connected to voltage terminals VA-N. If VA-N voltage drops below 20 V and the breaker is closed (determined by 52A), the relay uses VS to frequency track.

Frequency Element Settings

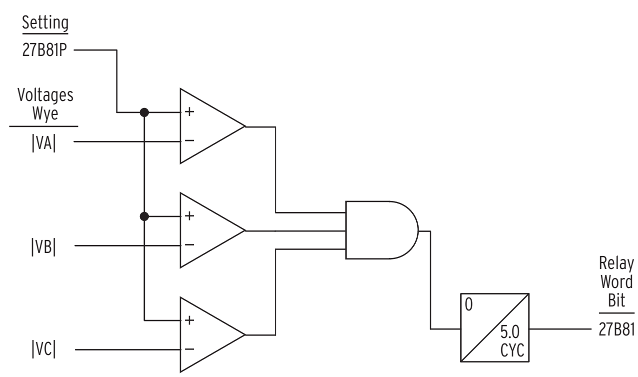


Figure 3.27 Undervoltage Block for Frequency Elements (Group Setting VNOM ≠ OFF)

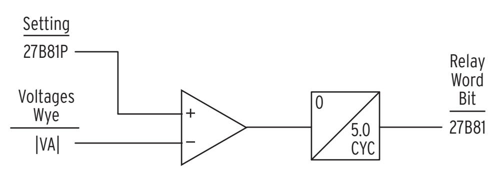


Figure 3.28 Undervoltage Block for Frequency Elements (Group Setting VNOM = OFF)

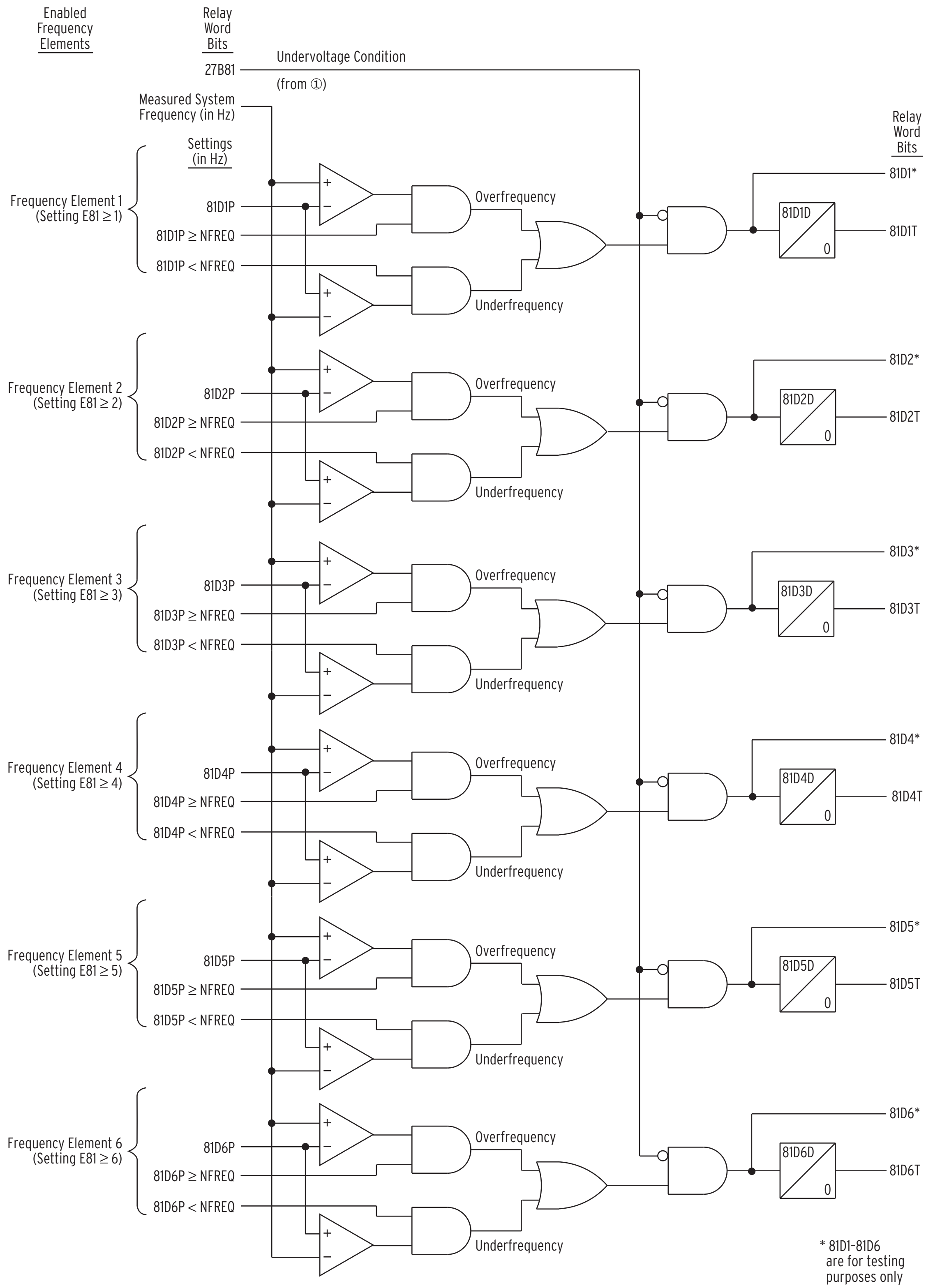


Figure 3.29 Levels 1 Through 6 Frequency Elements

① Figure 3.27 or Figure 3.28.

Table 3.9 Frequency Elements Settings and Settings Ranges

Setting	Definition	Range
27B81P	undervoltage frequency element block	25.00–300.00 V secondary (300 V voltage inputs)
81D1P	frequency element 1 pickup	40.10–65.00 Hz
81D1D	frequency element 1 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D2P	frequency element 2 pickup	40.10–65.00 Hz
81D2D	frequency element 2 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D3P	frequency element 3 pickup	40.10–65.00 Hz
81D3D	frequency element 3 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D4P	frequency element 4 pickup	40.10–65.00 Hz
81D4D	frequency element 4 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D5P	frequency element 5 pickup	40.10–65.00 Hz
81D5D	frequency element 5 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D6P	frequency element 6 pickup	40.10–65.00 Hz
81D6D	frequency element 6 time delay	2.00–16000.00 cycles, in 0.25-cycle steps

Accuracy

Pickup: ±0.01 Hz

Timer: ±0.25 cycles and ±0.1% of setting

Create Over- and Underfrequency Elements

Refer to *Figure 3.29*.

Note that pickup settings 81D1P through 81D6P are compared to setting NFREQ. NFREQ is the nominal frequency setting (a global setting), set to 50 or 60 Hz.

Overfrequency Element

For example, make settings:

NFREQ = 60 Hz	(nominal system frequency is 60 Hz)
E81 ≥ 1	(enable frequency element 1)
81D1P = 61.25 Hz	(frequency element 1 pickup)
81D1D = 2.0	(frequency element 1 time delay)

With these settings: 81D1P ≥ NFREQ

the overfrequency part of frequency element 1 logic is enabled. 81D1T operates as an overfrequency element. 81D1 is used in **testing only**.

Underfrequency Element

For example, make settings:

NFREQ = 60 Hz	(nominal system frequency is 60 Hz)
E81 ≥ 2	(enable frequency element 2)
81D2P = 59.65 Hz	(frequency element 2 pickup)
81D1D = 2.0	(frequency element 1 time delay)

With these settings: 81D2P < NFREQ

the underfrequency part of frequency element 2 logic is enabled. 81D2 and 81D2T operate as underfrequency elements. 81D2 is used in testing only.

Frequency Element Operation

Refer to *Figure 3.29*.

Overfrequency Element Operation

With the previous overfrequency element example settings, if system frequency is less than or equal to 61.25 Hz (81D1P = 61.25 Hz), frequency element 1 outputs:

81D1	= logical 0	(instantaneous element)
81D1T	= logical 0	(time delayed element)

If system frequency is greater than 61.25 Hz (81D1P = 61.25 Hz), frequency element 1 outputs:

81D1	= logical 1	(instantaneous element)
81D2T	= logical 1	(time delayed element)

Relay Word bit 81D1T asserts to logical 1 only after time delay 81D1D.

Underfrequency Element Operation

With the previous underfrequency element example settings, if system frequency is less than or equal to 59.65 Hz (81D2P = 59.65 Hz), frequency element 2 outputs:

81D2	= logical 1	(instantaneous element)
81D2T	= logical 1	(time delayed element)

Relay Word bit 81D2T asserts to logical 1 only after time delay 81D2D.

If system frequency is greater than 59.65 Hz (81D2P = 59.65 Hz), frequency element 2 outputs:

81D2	= logical 0	(instantaneous element)
81D2T	= logical 0	(time delayed element)

Frequency Element Voltage Control

Refer to *Figure 3.27*, *Figure 3.28*, and *Figure 3.29*.

Note that all six frequency elements are controlled by the same undervoltage element (Relay Word bit 27B81). For example, when group setting VNOM ≠ OFF, Relay Word bit 27B81 asserts to logical 1 and blocks the frequency element operation if all three voltages (V_A, V_B, or V_C) go below voltage pickup 27B81P. This control prevents erroneous frequency element operation following fault inception.

However, if group setting VNOM = OFF, Relay Word bit 27B81 is only affected by the voltage applied to the VA-N terminals.

Other Uses for Undervoltage Element 27B81

If voltage pickup setting 27B81P is applicable to other control schemes, Relay Word bit 27B81 can be used in other logic at the same time it is used in the frequency element logic.

If frequency elements are not being used, Relay Word bit 27B81 can still be used in other logic, with voltage setting 27B81P set as desired. Enable the frequency elements (setting E81 ≥ 1) and make setting 27B81P. Apply Relay Word bit 27B81 in the desired logic scheme, using SELOGIC control equations. Even though frequency elements are enabled, the frequency element outputs (Relay Word bits 81D1T through 81D6T) do not have to be used.

Frequency Element Uses

The instantaneous frequency elements (81D1 through 81D6) are used in testing only.

The time-delayed frequency elements (81D1T through 81D6T) are used for underfrequency load shedding, frequency restoration, and other schemes.

Power Elements

Four independent power elements are available. The group setting EPWR setting determines how many power elements are enabled:

EPWR = **N** (none), **1**, **2**, **3**, **4**

Each enabled power element can be set to detect real power or reactive power. With SELOGIC control equations, the power elements provide a wide variety of protection and control applications. Typical applications are:

- Overpower and/or underpower protection/control
- Reverse power protection/control

Power Elements Settings

Table 3.10 Power Element Settings and Setting Ranges (EPWR = 1, 2, 3, or 4)

Settings	Definition	Range
PWR1P, PWR2P, PWR3P, PWR4P	Power element pickup	OFF, 0.4–2600.00, single-phase (1 A nominal phase current inputs, IA, IB, IC) OFF, 2.00–13000.00 WATTS (5 A nominal phase current inputs, IA, IB, IC)
PWR1T, PWR2T, PWR3T, PWR4T	Power element type	+WATTS, –WATTS, +VARS, –VARS
PWR1D, PWR2D, PWR3D, PWR4D	Power element time delay	0.00–16000 cycles, in 0.25-cycle steps

The power element type settings are made in reference to the load convention:

+WATTS: positive or forward real power
–WATTS: negative or reverse real power
+VARS: positive or forward reactive power (lagging)
–VARS: negative or reverse reactive power (leading)

Power Element Time Delay Setting Considerations

The four power element time delay settings (PWR1D–PWR4D) can be set to have no intentional delay for testing purposes. For protection applications involving the power element Relay Word bits, SEL recommends a minimum time delay setting of 5.00 cycles for general applications. The classical power calculation is a product of voltage and current, to determine the real and reactive power quantities. During a system disturbance, because of the high sensitivity of the power elements, the changing system phase angles and/or frequency shifts may cause transient errors in the power calculation.

Using Power Elements in the Relay Trip Equation

The power elements are not supervised by any relay elements other than the minimum voltage and current level checks shown in *Figure 3.30*. If the protection application requires overcurrent protection in addition to the power elements, there may be a race condition, during a fault, between the overcurrent element(s) and the power element(s) if the power element(s) are still receiving sufficient operating quantities. In some protection schemes this may jeopardize coordination. One method of accommodating this is to increase the power element time delay settings. Another method is to supervise the power element Relay Word bit(s) with the overcurrent element pickup. For example, if the application requires that the relay trip the attached circuit breaker when a forward power flow threshold is exceeded, and a phase definite-time overcurrent element is also in the relay trip equation, extra security can be achieved with these SELOGIC control equation settings:

TR = **... + ... + SV1T + 67P1T SV1 = PWR1 * !67P1**

And group settings:

E50P = **1**

ESV = **1**

EPWR = **1**

50P1P = **5.00 A**

67P1D = **10.00 cycles**

SV1PU = **1.00 cycle**

SV1DO = **0.00 cycles**

PWR1P = **360.00**

PWR1T = **+WATTS**

PWR1D = **5.00 cycles**

During a fault that can pickup both the power element and the overcurrent element, these settings will ensure that the definite-time overcurrent element (67P1T) will trip the relay for the fault, even if the PWR1D setting is set to a smaller time delay than the 67P1D setting. Relay Word bit PWR1 is ANDed with Relay Word bit NOT(67P1), which effectively blocks PWR1 when 67P1 is asserted. The SELOGIC variable timer SV1T is employed in this example to avoid another race condition that could occur if the fault were cleared by another device before the definite-time element time-out, which could potentially deassert 67P1 a few quarter-cycles before PWR1 deasserts. Without this timer, an incorrect trip operation may occur.

See *Instantaneous/Definite-Time Overcurrent Elements on page 3.17* in this section, and *Variables/Timers on page 5.7* for details on the operation of these functions and their settings.

Accuracy

Single-Phase Power Elements (EPWR = 1, 2, 3, or 4)

Pickup: ±0.005 A • (voltage secondary) and ±5% of setting at unity power (for PWR*n*T = +WATTS or –WATTS) or power factor = 0 (for PWR*n*T = +VARS or –VARS)(1 A nominal phase current inputs, IA, IB, IC)

±0.025 A • (voltage secondary) and ±5% of setting at unity power (for PWR*n*T = +WATTS or –WATTS) or power factor = 0 (for PWR*n*T = +VARS or –VARS)(5 A nominal phase current inputs, IA, IB, IC)

Timer: ±0.25 cycles and ±0.1% of setting

Single-Phase Power Element Calculations

The numeric method used in the single-phase power elements uses line-to-neutral voltage and phase current quantities. Each phase is calculated separately, with the resulting power quantities subject to the minimum voltage and current tests shown in the lower half of *Figure 3.30*.

Three-Phase Power Elements

The three-phase power elements (3PWR1–3PWR4) assert when all three associated single-phase power elements assert.

For example, 3PWR1 asserts when Relay Word bits PWRA1, PWRB1, and PWRC1 all assert. See *Figure 3.30* for the logic that asserts PWR*n*1 (where *n* = A, B, or C).

Power Elements Logic Operation

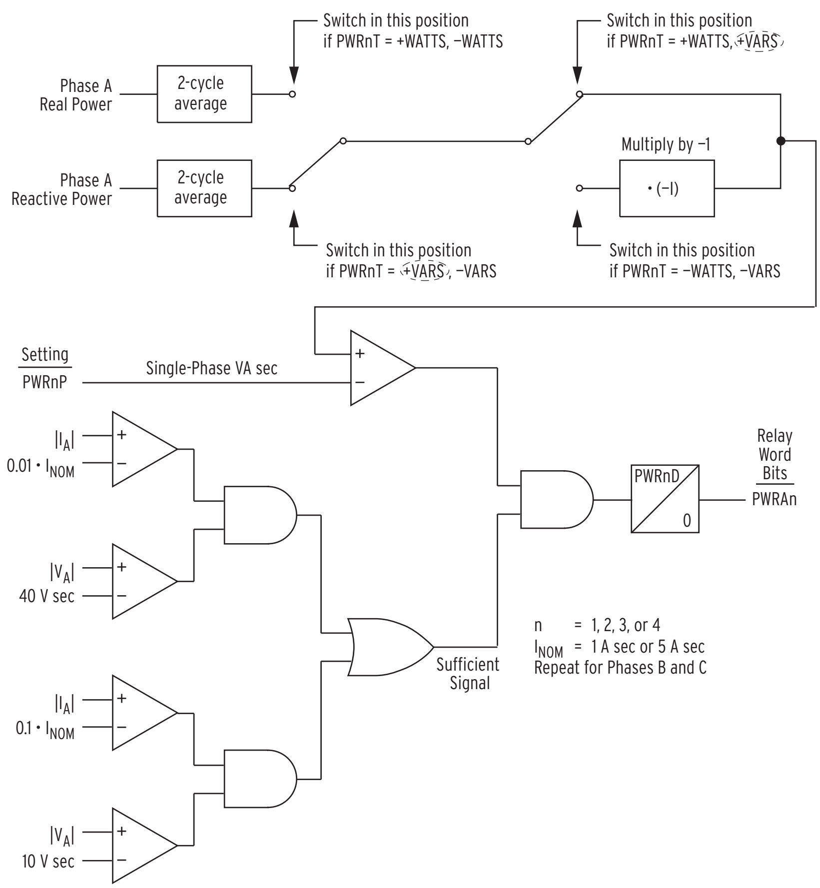


Figure 3.30 Single-Phase Power Elements Logic (+VARS Example Shown)

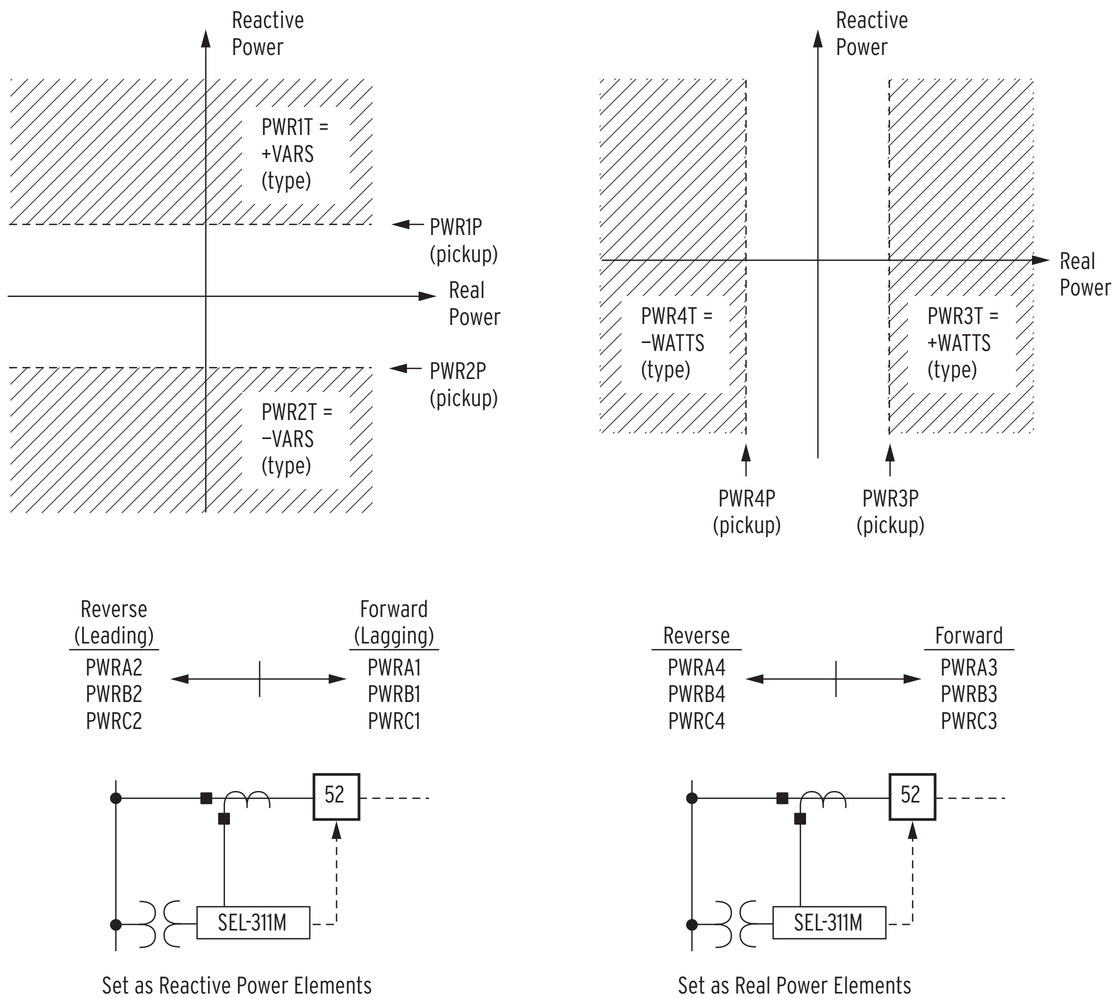


Figure 3.31 Power Elements Operation in the Real/Reactive Power Plane

In *Figure 3.30*, an example is shown with setting PWR*n*T = +VARS. This corresponds to the settings PWR1P (pickup) and PWR1T (type) in *Figure 3.31*.

In *Figure 3.31*, if the Phase A reactive power level is above pickup setting PWR*n*P, Relay Word bit PWRA*n* asserts (PWRA*n* = logical 1) after time delay setting PWR*n*D (*n* = 1 through 4), subject to the “sufficient signal” conditions.

In *Figure 3.31*, if all three-phase (A, B, and C) reactive power levels are above setting PWR*n*P, Relay Word bits PWRA*n*, PWRB*n*, and PWRC*n* assert and cause 3PWR*n* to assert.

The “sufficient signal” conditions in *Figure 3.31* require at least 1 percent nominal current if the corresponding phase voltage is greater than 40 V secondary. If the voltage is between 10 and 40 V secondary, at least 10 percent nominal current is required.

Pickup setting PWR*n*P is always a positive number value (see *Table 3.10*). Thus, if –WATTS or –VARS are chosen with setting PWR*n*T, the corresponding real or reactive power values have to be multiplied by –1 so that element PWRA*n* asserts for negative real or reactive power.

Loss-of-Potential Logic

The loss-of-potential (LOP) logic operates as shown in *Figure 3.32*.

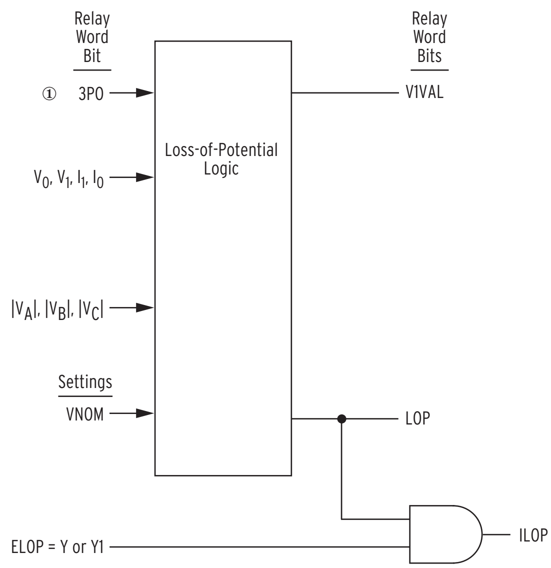


Figure 3.32 Loss-of-Potential Logic

① From Figure 4.4.

Inputs into the LOP logic are described in *Table 3.11*:

Table 3.11 LOP Logic Inputs

Input	Description
3PO	Three-pole open condition (indicates circuit breaker open condition; see *Figure 4.4*).
V_1	Positive-sequence voltage (V secondary).
I_1	Positive-sequence current (A secondary).
V_0	Zero-sequence voltage (V secondary).
VNOM	PT nominal voltage setting (line-to-neutral secondary).
I_0	Zero-sequence current (A secondary).
$\|V_A\|$	Voltage channel VA voltage (V secondary).
$\|V_B\|$	Voltage channel VB voltage (V secondary).
$\|V_C\|$	Voltage channel VC voltage (V secondary).

The circuit breaker has to be closed (Relay Word bit 3PO = logical 0) for the LOP logic to operate.

Loss-of-potential is declared (Relay Word bit LOP = logical 1) when a 10 percent or larger drop in V_1 is detected, with no corresponding change in I_1. If the LOP condition persists for 60 cycles, it latches in.

LOP resets (Relay Word bit LOP = logical 0) when V_1 returns above 75 percent of setting VNOM (Relay Word bit V1VAL also asserts), magnitudes of V_A, V_B, and V_C are greater than 40 percent of setting VNOM, and V_0 is less than 7.8 percent of setting VNOM.

The loss-of-potential enable setting, ELOP, does not enable or disable the LOP logic. It just routes the LOP Relay Word bit to different logic, as shown in *Figure 3.32* and explained in the remainder of this subsection.

Setting VNOM = OFF

If setting VNOM = OFF, the loss-of-potential logic is disabled (Relay Word bits LOP and V1VAL are forced to logical 0), and setting ELOP can only be set to "N." See *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings on page 7.36* for more details on the VNOM setting.

Setting ELOP = Y or Y1

If setting ELOP = Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts to logical 1), all internal enables are disabled (see *Figure 3.35*, *Figure 3.37*, and *Figure 3.38*). The loss-of-potential condition makes the voltage-polarized directional elements (which are controlled by these internal enables) unreliable. Thus, they are disabled. The overcurrent elements controlled by these voltage-polarized directional elements are disabled also (unless overridden by conditions explained in the following Setting ELOP = Y discussion).

In *Figure 4.7*, if setting ELOP = Y1 and LOP asserts, keying and echo keying in the permissive overreaching transfer trip (POTT) logic are blocked.

Setting ELOP = Y

NOTE: When LOP is asserted and setting ELOP = Y1, the relay will not force an enable of the ground elements that are set direction-forward when Relay Word bit 3V0 is asserted (= logical 1) and the zero-sequence voltage-polarized ground directional element enable (32NE) is asserted. Refer to Potential Transformer Ratios and PT Nominal Secondary Voltage Settings on page 7.36.

Additionally, if setting ELOP = Y and a loss-of-potential condition occurs (Relay Word bit LOP asserts to logical 1), overcurrent elements set direction forward are enabled (see *Figure 3.37*). These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

As detailed previously, voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements controlled by these voltage-based directional elements are also disabled. However, this disable condition is overridden for the overcurrent elements set direction forward if setting ELOP = Y.

Setting ELOP = N

If setting ELOP = N, the loss-of-potential logic still operates (Relay Word bit LOP asserts to logical 1 for a loss-of-potential condition) but does not disable any voltage-based directional elements (as occurs with ELOP = Y or Y1) or enable overcurrent elements set direction forward (as occurs with ELOP = Y).

Load-Encroachment Logic

The load-encroachment logic (see *Figure 3.33*) and settings are enabled/disabled with setting ELOAD (= Y or N). (If group setting VNOM = OFF, then ELOAD can only be set to "N." See *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings on page 7.36* for more details on the VNOM setting.)

The load-encroachment feature allows phase overcurrent elements to be set without regard for load levels. This is especially helpful in bus overcurrent applications. A bus relay sees the cumulative currents of all the feeders but still has to provide overcurrent backup protection for all these feeders. If the phase elements in the bus relay are set to provide adequate backup, they often are set close to maximum bus load current levels. This runs the risk of tripping on bus load current. The load-encroachment feature prevents this from happening as shown in the example that follows in this subsection.

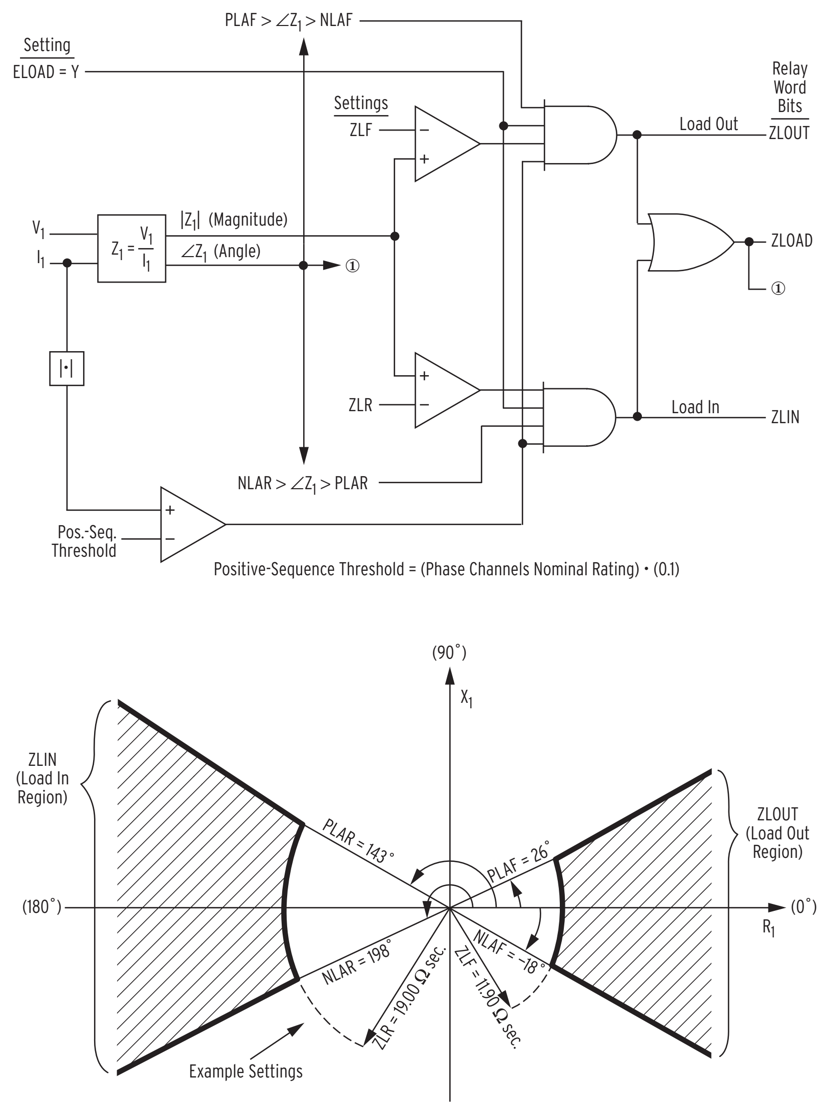


Figure 3.33 Load-Encroachment Logic

① To Figure 3.38

Note that a positive-sequence impedance calculation (Z_1) is made in the load-encroachment logic in *Figure 3.33*. Load is largely a balanced condition, so apparent positive-sequence impedance is a good load measure. The load-encroachment logic operates only if the positive-sequence current (I_1) is greater than the Positive-Sequence Threshold defined in *Figure 3.33*. For a balanced load condition, I_1 = phase current magnitude.

Forward load (load flowing out) lies within the hatched region labeled ZLOUT. Relay Word bit ZLOUT asserts to logical 1 when the load lies within this hatched region.

Reverse load (load flowing in) lies within the hatched region labeled ZLIN. Relay Word bit ZLIN asserts to logical 1 when the load lies within this hatched region.

Relay Word bit ZLOAD is the OR-combination of ZLOUT and ZLIN:

ZLOAD = ZLOUT + ZLIN

Settings Ranges

Refer to *Figure 3.33*.

Table 3.12 Load-Encroachment Settings Ranges

Setting	Description and Range
ZLF	Forward Minimum Load Impedance—corresponding to maximum load flowing out
ZLR	Reverse Minimum Load Impedance—corresponding to maximum load flowing in 0.25–320.00 Ω secondary (1 A nominal phase current inputs, IA, IB, IC; 300 V voltage inputs) 0.05–64.00 Ω secondary (5 A nominal phase current inputs, IA, IB, IC)
PLAF	Maximum Positive Load Angle Forward (–90° to +90°)
NLAF	Maximum Negative Load Angle Forward (–90° to +90°)
PLAR	Maximum Positive Load Angle Reverse (+90° to +270°)
NLAR	Maximum Negative Load Angle Reverse (+90° to +270°)

Load-Encroachment Setting Example

Example system conditions:

Nominal Line-Line Voltage:	230 kV
Maximum Forward Load:	800 MVA
Maximum Reverse Load:	500 MVA
Power Factor (Forward Load):	0.90 lag to 0.95 lead
Power Factor (Reverse Load):	0.80 lag to 0.95 lead
CT ratio:	2000/5 = 400
PT ratio:	134000/67 = 2000

The PTs are connected line-to-neutral.

Convert Maximum Loads to Equivalent Secondary Impedances

Start with maximum forward load:

$$800\ \text{MVA} \bullet (1/3) = 267\ \text{MVA per phase}$$
$$230\ \text{kV} \bullet (1/\sqrt{3}) = 132.8\ \text{kV line-to-neutral}$$
$$267\ \text{MVA} \bullet (1/132.8\ \text{kV}) \bullet (1000\ \text{kV/MV}) = 2010\ \text{A primary}$$
$$\begin{aligned} 2010\ \text{A primary} \bullet (1/\text{CT ratio}) &= 2010\ \text{A primary} \bullet (1\ \text{A secondary}/400\ \text{A primary}) \\ &= 5.03\ \text{A secondary} \end{aligned}$$
$$132.8\ \text{kV} \bullet (1000\ \text{V/kV}) = 132800\ \text{V primary}$$
$$\begin{aligned} 132800\ \text{V primary} \bullet (1/\text{PT ratio}) &= 132800\ \text{V primary} \bullet (1\ \text{V secondary}/2000\ \text{V primary}) \\ &= 66.4\ \text{V secondary} \end{aligned}$$

Now, calculate the equivalent secondary impedance:

$$\frac{66.4\ \text{V secondary}}{5.03\ \text{A secondary}} = 13.2\ \Omega\ \text{secondary}$$

This secondary value can be calculated more expediently with the following equation:

$$\frac{(\text{line-line voltage in kV})^2 \bullet \text{CT ratio}}{\text{3-phase load in MVA} \bullet \text{PT ratio}}$$

Again, for the maximum forward load:

$$\frac{230^2 \bullet 400}{800 \bullet 2000} = 13.2\ \Omega\ \text{secondary}$$

To provide a margin for setting ZLF, multiply by a factor of 0.9:

$$\begin{aligned} \text{ZLF} &= 13.2\ \Omega\ \text{secondary} \bullet 0.9 \\ &= 11.90\ \Omega\ \text{secondary} \end{aligned}$$

For the maximum reverse load:

$$\frac{230^2 \bullet 400}{500 \bullet 2000} = 21.1\ \Omega\ \text{secondary}$$

Again, to provide a margin for setting ZLR:

$$\begin{aligned} \text{ZLR} &= 21.1\ \text{secondary} \bullet 0.9 \\ &= 19.00\ \Omega\ \text{secondary} \end{aligned}$$

Convert Power Factors to Equivalent Load Angles

The power factor (forward load) can vary from 0.90 lag to 0.95 lead.

Setting PLAF = $\cos^{-1}(0.90) = 26°$

Setting NLAF = $\cos^{-1}(0.95) = -18°$

The power factor (reverse load) can vary from 0.80 lag to 0.95 lead.

Setting PLAR = $180^{\circ} - \cos^{-1}(0.80) = 180^{\circ} - 37^{\circ} = 143^{\circ}$

Setting NLAR = $180^{\circ} + \cos^{-1}(0.95) = 180^{\circ} + 18^{\circ} = 198^{\circ}$

Apply Load-Encroachment Logic to a Nondirectional Phase Time-Overcurrent

Again, from *Figure 3.33*:

ZLOAD = ZLOUT + ZLIN

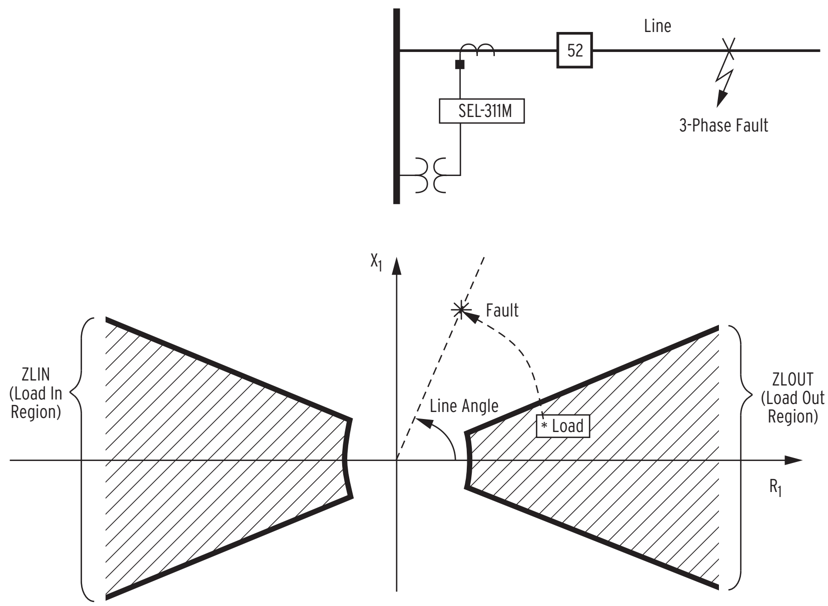


Figure 3.34 Migration of Apparent Positive-Sequence Impedance for a Fault Condition

Refer to *Figure 3.34*. In a load condition, the apparent positive-sequence impedance is within the ZLOUT area, resulting in:

$$\begin{aligned} \text{ZLOAD} &= \text{ZLOUT} + \text{ZLIN} \\ &= \text{logical } 1 + \text{ZLIN} \\ &= \text{logical } 1 \end{aligned}$$

If a fault occurs, the apparent positive-sequence impedance moves outside the ZLOUT area (and stays outside the ZLIN area, too), resulting in:

$$\begin{aligned} \text{ZLOAD} &= \text{ZLOUT} + \text{ZLIN} \\ &= \text{logical } 0 + \text{logical } 0 \\ &= \text{logical } 0 \end{aligned}$$

Refer to *Figure 3.19*. To prevent phase time-overcurrent element 51PT from operating for high load conditions, make the following SELOGIC® control equation torque control setting:

$$\text{51PTC} = \text{F32PQ} + \text{R32PQ} + \text{50P4}$$

In this setting example, phase instantaneous element 50P4 is set above any maximum load current level: if 50P4 picks up, there is assuredly a fault. For faults below the pickup level of 50P4, the forward and reverse directional elements (F32PQ and R32PQ) include load encroachment supervision for the positive-sequence elements. To create a directional time-overcurrent element, use either the forward or the reverse element as desired.

The load encroachment calculation is not valid for negative-sequence faults (phase-to-phase), and using the ZLOAD bit directly in torque control equations is not recommended. During phase-to-phase faults or phase-to-ground faults, or in a loss-of-potential condition, ZLOAD may assert or deassert inappropriately. Embedded logic driving the F32PQ and R32PQ bits handles these conditions correctly.

Use the SEL-321 Relay Application Guide for the SEL-311M Relay

The load-encroachment logic and settings in the SEL-311M are the same as those in the SEL-321. Refer to *Application Guide 93-10 (SEL-321 Relay Load-Encroachment Function Setting Guidelines)* for applying the load-encroachment logic in the SEL-311M. Note that *Application Guide AG93-10* discusses applying the load-encroachment feature to phase distance elements in the SEL-321. The SEL-311M does not have phase distance elements, but the principles and settings example are still applicable to the SEL-311M.

Directional Control for Ground Overcurrent Elements

The directional control for overcurrent elements is enabled by making directional control enable setting E32. Setting E32 and other directional control settings are described in the following subsection *Directional Control Settings on page 3.72*.

The zero-sequence voltage-polarized directional element (ungrounded/high-impedance grounded system) is available to control the ground overcurrent elements.

Internal Enables

Note that *Figure 3.35* has extra internal enable 32QE, which is used in the directional element logic that controls negative-sequence and phase overcurrent elements (see *Figure 3.38*).

Additionally, note that if enable setting ELOP = Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts), the internal enable is disabled (see *Figure 3.35*).

The settings involved with the internal enables are explained in *Directional Control Settings on page 3.72*.

Directional Elements

Refer to *Figure 3.35* and *Figure 3.36*.

Directional Element Routing

The directional element outputs are routed to the forward (Relay Word bit F32N) and reverse (Relay Word bit R32N) logic points.

Loss-of-Potential

Note that if the following are true ...

- Enable setting ELOP = Y,
- And a loss-of-potential condition occurs (Relay Word bit LOP asserts),

... then the forward logic point (Relay Word bit F32N in *Figure 3.36*) asserts to logical 1, thus enabling neutral ground (*Figure 3.17*) overcurrent elements that are set direction forward (with settings DIR3 = F, DIR4 = F, etc.). These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

As detailed previously in *Internal Enables on page 3.63*, all of the voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements controlled by these voltage-based directional elements are also disabled. However, this disable condition is overridden for these overcurrent elements set direction forward if setting ELOP = Y.

Refer to *Figure 3.32 on page 3.57* and accompanying text for more information on loss-of-potential.

Direction Forward/ Reverse Logic

The forward (Relay Word bit F32N in *Figure 3.36*) and reverse (Relay Word bit R32N in *Figure 3.36*) logic points are routed to the different levels of overcurrent protection by the level direction settings DIR3 and DIR4. Levels 1 and 2 are fixed forward (see *Figure 3.17*)

In most communications-assisted trip schemes, the levels are set as follows (see *Figure 3.17*):

Level 1 overcurrent elements fixed forward

Level 2 overcurrent elements fixed forward

Level 3 overcurrent elements are direction reverse (DIR3 = R)

See the beginning of *Directional Control Settings on page 3.72* for discussion of the operation of level direction settings DIR3 and DIR4 when the directional control enable setting E32 is set to E32 = N.

In some applications, level direction settings DIR3 and DIR4 are not flexible enough in assigning the desired direction for certain overcurrent elements. Subsection *Directional Control Provided by Torque Control Settings on page 3.79* describes how to avoid this limitation for special cases.

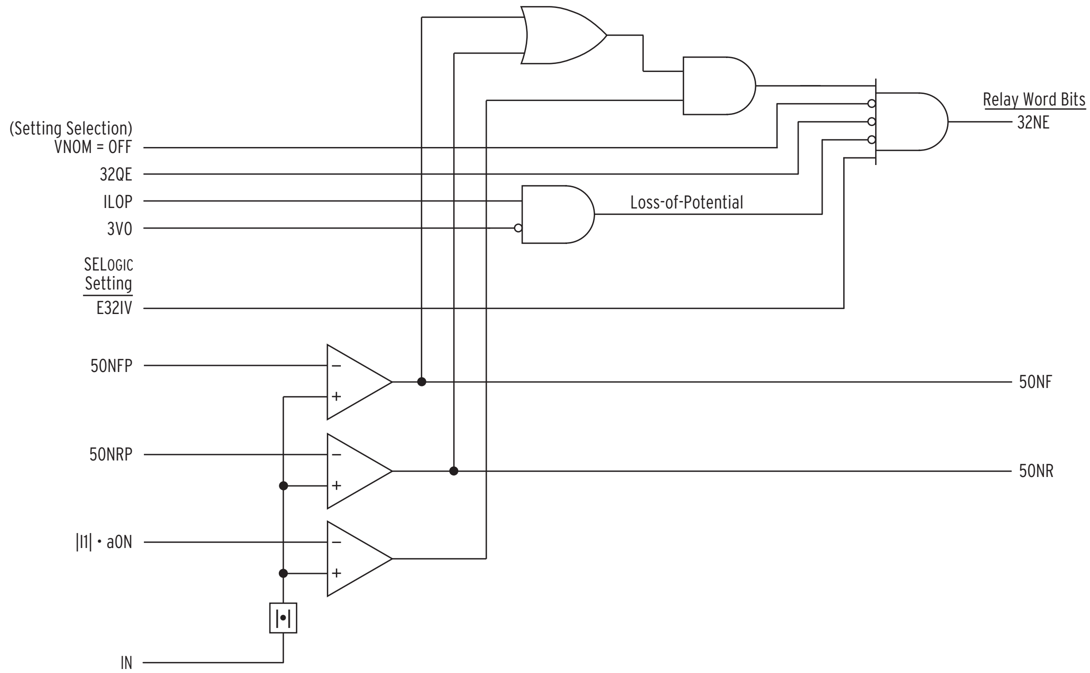
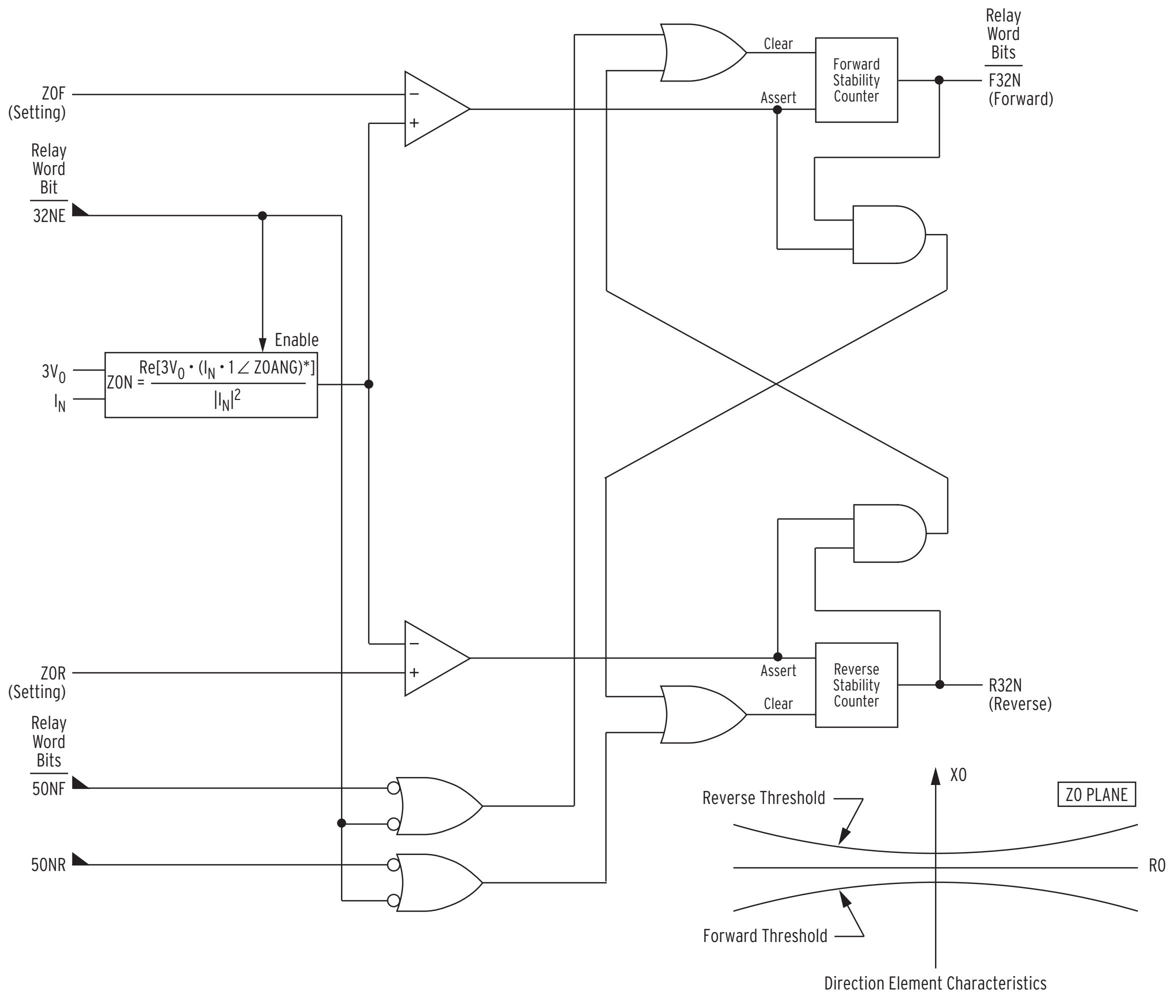


Figure 3.35 Internal Enable (32NE) Logic for Zero-Sequence Voltage-Polarized Directional Elements (Ungrounded/High-Impedance Grounded Systems)

Refer to *Ungrounded/High-Impedance Grounded System Considerations for Setting E32IV on page 3.79* for setting ideas for SELOGIC setting E32IV.



Forward Threshold:

If Z0F Setting ≤ 0, Forward Threshold = $0.75 \cdot Z0F - 0.25 \cdot \left|\frac{3V_0}{I_N}\right|$

If Z0F Setting > 0, Forward Threshold = $1.25 \cdot Z0F - 0.25 \cdot \left|\frac{3V_0}{I_N}\right|$

Reverse Threshold:

If Z0R Setting ≥ 0, Reverse Threshold = $0.75 \cdot Z0R + 0.25 \cdot \left|\frac{3V_0}{I_N}\right|$

If Z0F Setting < 0, Reverse Threshold = $1.25 \cdot Z0R + 0.25 \cdot \left|\frac{3V_0}{I_N}\right|$

Figure 3.36 Zero-Sequence Voltage-Polarized Directional Element (Ungrounded/High-Impedance Grounded Systems)

Directional Control for Negative-Sequence and Positive-Sequence Overcurrent Elements

The directional control for overcurrent elements is enabled by making directional control enable setting E32. Setting E32 and other directional control settings are described in *Directional Control Settings on page 3.72*.

The negative-sequence voltage-polarized directional element controls the negative-sequence overcurrent elements. Negative-sequence voltage-polarized and positive-sequence voltage-polarized directional elements control the phase overcurrent elements.

If three-phase voltage signals are not available, make the group setting VNOM = OFF. This prevents the negative-sequence voltage-polarized and positive-sequence voltage-polarized elements from operating on false voltage quantities. This shut-down logic is shown in the center portion of *Figure 3.38*. See *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings on page 7.36* for a complete list of changes caused by setting VNOM = OFF.

The negative-sequence voltage-polarized directional element has priority over the positive-sequence voltage-polarized directional elements in controlling the phase overcurrent elements. The negative-sequence voltage-polarized directional element operates for unbalanced faults, while the positive-sequence voltage-polarized directional element operates for three-phase faults.

Internal Enables

Refer to *Figure 3.38*.

The internal enable 32QE corresponds to the negative-sequence voltage-polarized directional element.

The settings involved with internal enable 32QE (e.g., setting a2) are explained in *Directional Control Settings on page 3.72*.

Directional Elements

Refer to *Figure 3.37* and *Figure 3.38*.

If enable setting ELOP = Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts), the negative-sequence voltage-polarized and positive-sequence voltage-polarized directional elements are disabled (see *Figure 3.38*).

Refer to *Figure 3.32* and accompanying text for more information on loss-of-potential.

Note in *Figure 3.38* and *Figure 3.39* that the assertion of internal enable 32QE (for the negative-sequence voltage-polarized directional element) disables the positive-sequence voltage-polarized directional element. The negative-sequence voltage-polarized directional element has priority over the positive-sequence voltage-polarized directional elements in controlling the phase overcurrent elements. The negative-sequence voltage-polarized directional element operates for unbalanced faults, while the positive-sequence voltage-polarized directional element operates for three-phase faults.

Note also in *Figure 3.38* that the assertion of ZLOAD disables the positive-sequence voltage-polarized directional element. ZLOAD asserts when the relay is operating in a user-defined load region (see *Figure 3.33*).

Directional Element Routing

Refer to *Figure 3.39*.

The directional element outputs are routed to the forward (Relay Word bits F32Q and F32P) and reverse (Relay Word bits R32Q and R32P) logic points.

Loss-of-Potential

Note if both of the following are true:

- Enable setting ELOP = Y,
- A loss-of-potential condition occurs (Relay Word bit LOP asserts),

then the forward logic points (Relay Word bits F32Q and F32P) assert to logical 1, thus enabling the negative-sequence and phase overcurrent elements that are set direction forward (with settings DIR3 = F, DIR4 = F, etc.). These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

As detailed previously, voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements controlled by these voltage-based directional elements are also disabled. But this disable condition is overridden for the overcurrent elements set direction forward if setting ELOP = Y.

Refer to *Figure 3.32* and accompanying text for more information on loss-of-potential.

Direction Forward/ Reverse Logic

Refer to *Figure 3.14*, and *Figure 3.18*.

The forward (Relay Word bits F32Q and F32P) and reverse (Relay Word bits R32Q and R32P) logic points are routed to the different levels of overcurrent protection by the level direction settings DIR3 and DIR4. Levels 1 and 2 are fixed forward (see *Figure 4.5*).

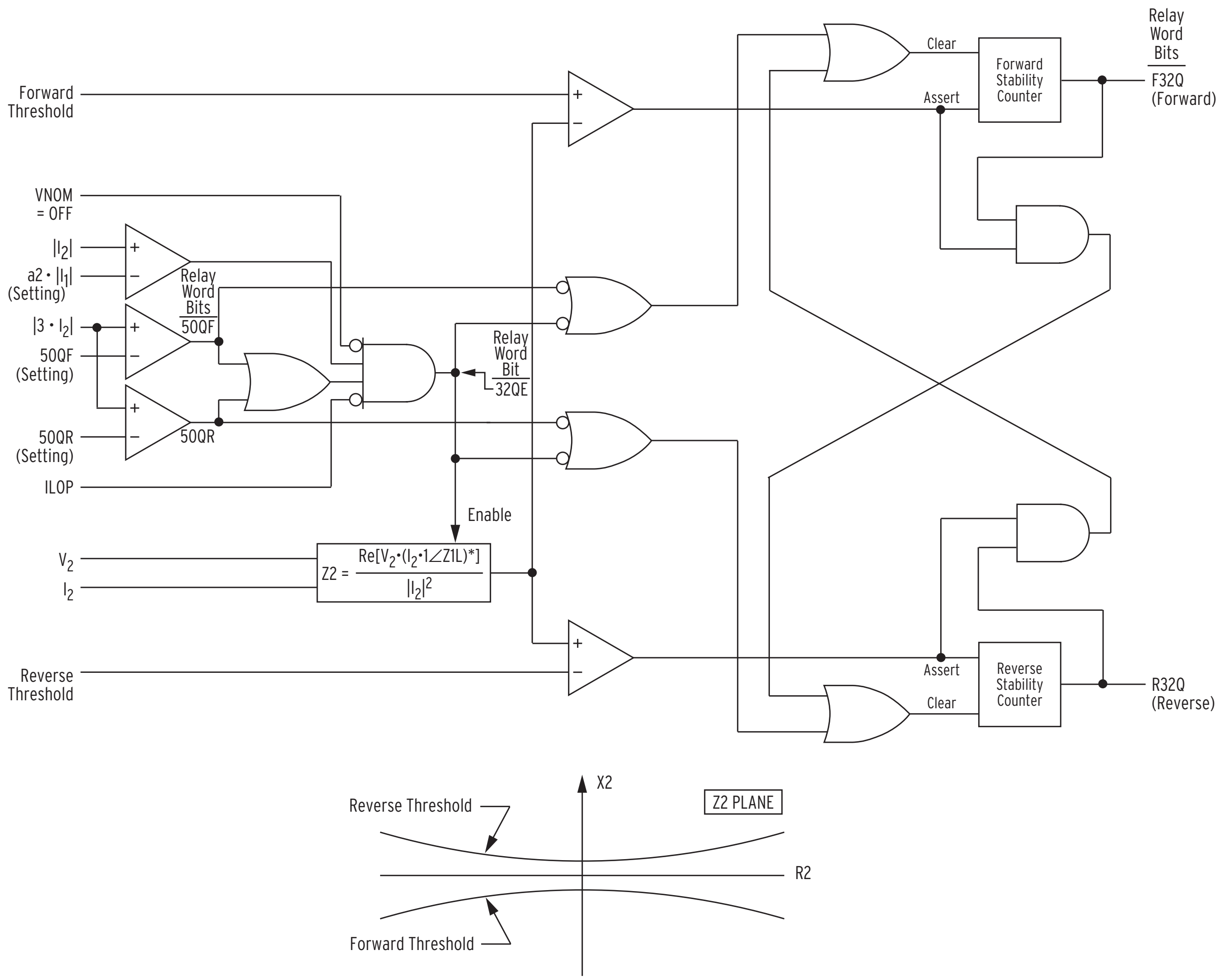
In most communications-assisted trip schemes, the levels are set as follows (see *Figure 5.4*):

Level 1 overcurrent elements fixed forward
Level 2 overcurrent elements fixed forward
Level 3 overcurrent elements set direction reverse (DIR3 = R)

If group setting VNOM = OFF, then the directional control outputs in *Figure 3.37* and *Figure 3.38* assert to logical 1. This effectively makes the phase and negative-sequence elements nondirectional.

See *Directional Control Settings on page 3.72* for a discussion of the operation of level direction settings DIR3 and DIR4 when the directional control enable setting E32 is set to E32 = N.

In some applications, level direction settings DIR3 and DIR4 are not flexible enough in assigning the desired direction for certain overcurrent elements. *Directional Control Provided by Torque Control Settings on page 3.79* describes how to avoid this limitation for special cases.



Direction Element Characteristics

Forward Threshold:

If Z2F Setting $\leq$ 0, Forward Threshold = $0.75 \cdot Z2F - 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

If Z2F Setting $>$ 0, Forward Threshold = $1.25 \cdot Z2F - 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

Reverse Threshold:

If Z2R Setting $\geq$ 0, Reverse Threshold = $0.75 \cdot Z2R + 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

If Z2F Setting $<$ 0, Reverse Threshold = $1.25 \cdot Z2R + 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

Note: $1\angle Z1L$ = One Ohm at the positive-sequence line angle

Figure 3.37 Negative-Sequence Voltage-Polarized Directional Element for Negative-Sequence and Phase Overcurrent Elements

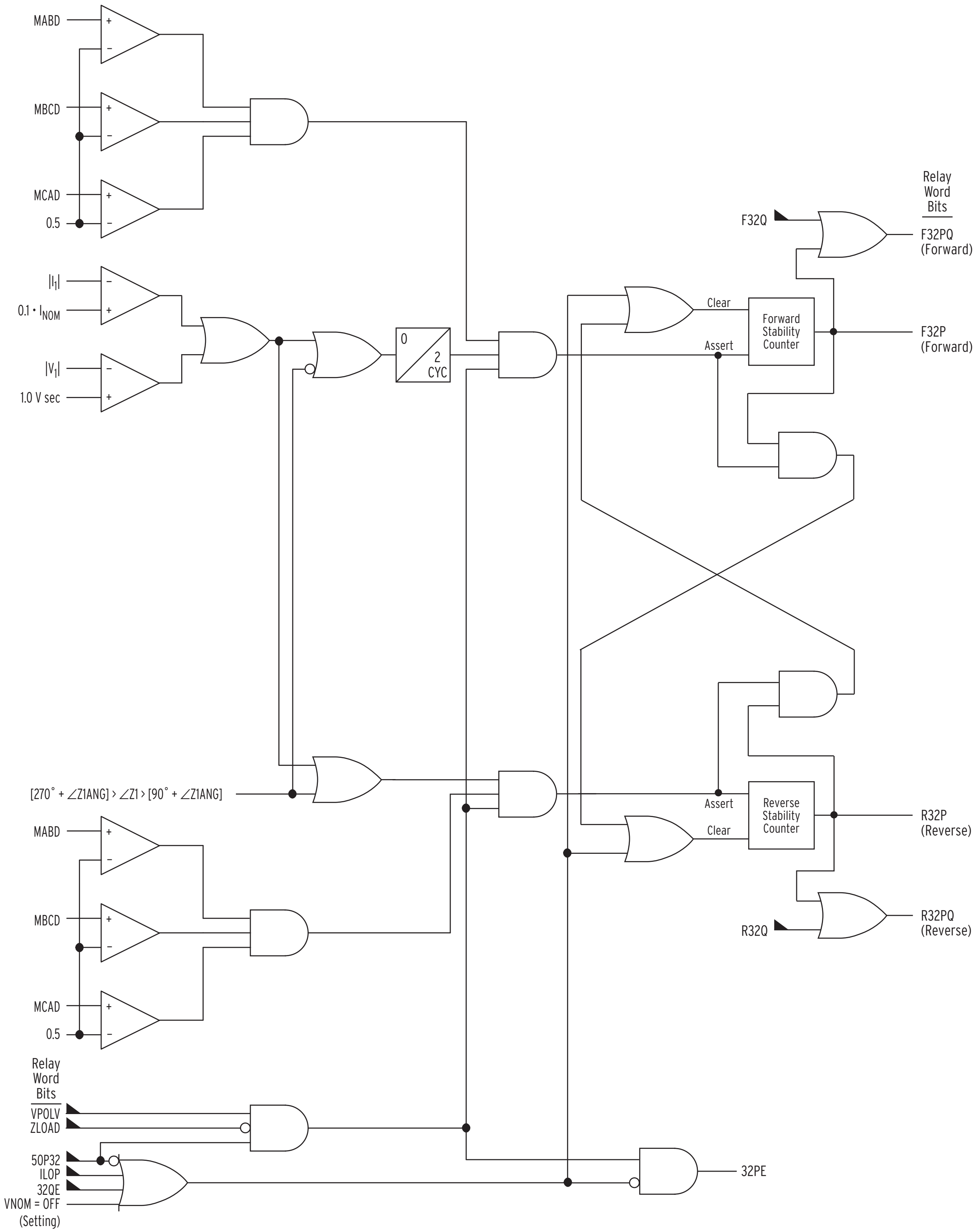


Figure 3.38 Positive-Sequence Voltage-Polarized Phase Directional Element Logic

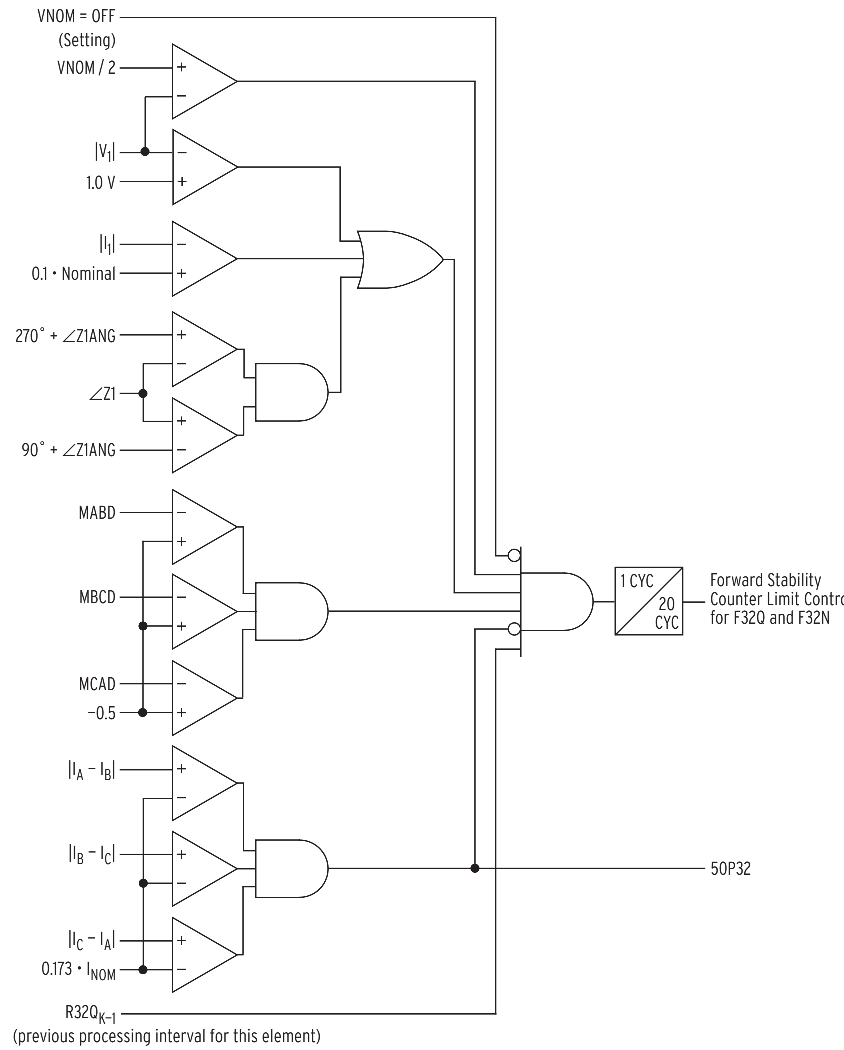


Figure 3.39 Forward Counter Control Logic for F32Q and F32N Directional Elements

where:

MABD = $\mathrm{Re}[(1\angle Z1ANG \cdot IAB) \cdot VAB1_{mem}{}^*]$

MACD = $\mathrm{Re}[(1\angle Z1ANG \cdot IBC) \cdot VAC1_{mem}{}^*]$

MCAD = $\mathrm{Re}[(1\angle Z1ANG \cdot ICA) \cdot VCA1_{mem}{}^*]$

Z1ANG = Relay setting. Replica line angle in degrees.

IAB = IA–IB phasor

IBC = IB–IC phasor

ICA = IC–IA phasor

$VAB1_{mem}$ = $VA1_{mem}–VB1_{mem}$

$VBC1_{mem}$ = $VB1_{mem}–VC1_{mem}$

$VCA1_{mem}$ = $VC1_{mem}–VA1_{mem}$

$VA1_{mem}$ = Positive-sequence memory voltage referenced to A-phase voltage.

Directional Control Settings

The directional control for overcurrent elements is enabled by making directional control enable setting E32. Setting E32 has setting choices:

Y	Enable directional control
N	Disable directional control
AUTO	Enable directional control and set many of the directional element settings automatically

If directional control enable setting E32 = N, directional control is disabled and no directional control settings are made. All level direction settings are set internally as:

Level 1	Fixed forward direction
Level 2	Fixed forward direction
DIR3	(no directional control for Level 3 overcurrent elements)
DIR4	(no directional control for Level 4 overcurrent elements)

Settings Made Automatically

If the directional control enable setting E32 is set:

E32 = **AUTO**

then the following directional control settings are calculated and set automatically:

Z2F, Z2R, 50QFP, 50QRP, a2, a0N, Z0F, and Z0R

Once these settings are calculated automatically, they can only be modified if the user goes back and changes the directional control enable setting to E32 = Y.

The remaining directional control settings are not set automatically if setting E32 = AUTO. They have to be set, whether setting E32 = AUTO or Y. These settings are:

DIR3, DIR4, 50NFP, 50NRP, and E32IV (E32IV is a SELOGIC setting)

All these settings are explained in detail in the remainder of this subsection.

Not all these directional control settings (set automatically or by the user) are used in every application. The following are particular directional control settings that are hidden/not made for particular conditions:

Settings

Levels 1 and 2 overcurrent element directions are fixed forward.

DIR3—Level 3 Overcurrent Element Direction Setting

DIR4—Level 4 Overcurrent Element Direction Setting

Setting Range:

F = Direction Forward

R = Direction Reverse

Table 3.13 shows the overcurrent elements that are controlled by each level direction setting. Note in *Table 3.13* that all the time-overcurrent elements (51_T elements) are controlled by the 1 level direction setting. *Figure 3.48*, *Figure 3.49*, *Figure 3.54*, and *Figure 3.55* show the logic implementation of the control listed in *Table 3.13*.

Table 3.13 Overcurrent Elements Controlled by Level Direction Settings 1 Through DIR4 (Corresponding Overcurrent Element Figure Numbers in Parentheses)

Level Direction Settings	Phase	Ground	Negative-Sequence
Forward	67P1 (*Figure 3.14*) 67P1T (*Figure 3.14*)	67NG1 (*Figure 3.17*) 67NG1T (*Figure 3.17*)	67Q1 (*Figure 3.18*) 67Q1T (*Figure 3.18*)
Forward	67P2 (*Figure 3.14*) 67P2T (*Figure 3.14*)	67NG2 (*Figure 3.17*) 67NG2T (*Figure 3.17*)	67Q2 (*Figure 3.18*) 67Q2T (*Figure 3.18*)
DIR3	67P3 (*Figure 3.14*) 67P3T (*Figure 3.14*)	67NG3 (*Figure 3.17*) 67NG3T (*Figure 3.17*)	67Q3 (*Figure 3.18*) 67Q3T (*Figure 3.18*)
DIR4	67P4 (*Figure 3.14*) 67P4T (*Figure 3.14*)	67NG4 (*Figure 3.17*) 67NG4T (*Figure 3.17*)	67Q4 (*Figure 3.18*) 67Q4T (*Figure 3.18*)

In most communications-assisted trip schemes, the levels are set as follows (see *Figure 5.4*):

Level 1 overcurrent elements fixed forward

Level 2 overcurrent elements fixed forward

Level 3 overcurrent elements set direction reverse (DIR3 = R)

In some applications, level direction settings are not flexible enough in assigning the desired direction for certain overcurrent elements. Subsection *Directional Control Provided by Torque Control Settings on page 3.79* describes how to avoid this limitation for special cases.

Z2F—Forward Directional Z2 Threshold

Z2R—Reverse Directional Z2 Threshold

Setting Range:

–320.00 to 320.00 Ω secondary (300 V voltage inputs, VA, VB, VC; 1 A nominal phase current inputs, IA, IB, IC)

–64.00 to 64.00 Ω secondary (300 V voltage inputs, VA, VB, VC; 5 A nominal phase current inputs, IA, IB, IC)

Z2F and Z2R are used to calculate the Forward and Reverse Thresholds, respectively, for the negative-sequence voltage-polarized directional elements (see *Figure 3.37*).

If enable setting E32 = Y, settings Z2F and Z2R (negative-sequence impedance values) are calculated by the user and entered by the user, but setting Z2R must be greater in value than setting Z2F by 0.1 Ω secondary (1 A nominal phase currents).

Z2F and Z2R Set Automatically

If enable setting E32 = AUTO, settings Z2F and Z2R (negative-sequence impedance values) are calculated automatically, using the positive-sequence line impedance magnitude setting Z1MAG as follows:

Z2F = Z1MAG/2 (Ω secondary)
Z2R = Z1MAG/2 + z (Ω secondary; z listed in below)

NOTE: If the above calculation of Z2F and Z2R exceeds the setting range, the quantity is set to the upper limit of the setting range.

Table 3.14 Z2F and Z2R Automatic Settings

Relay Configuration	z (Ω secondary)
1 A nominal current, 300 V voltage inputs	0.1 Ω
5 A nominal current, 300 V voltage inputs	0.02 Ω

Figure 3.40 and *Figure 3.41* and supporting text concern the zero-sequence impedance network, relay polarity, and the derivation of settings Z0F and Z0R. The same general approach outlined for deriving settings Z0F and Z0R can also be applied to deriving settings Z2F and Z2R in the negative-sequence impedance network, though the preceding method of automatically making settings Z2F and Z2R usually suffices.

50QFP—Forward Directional Negative-Sequence Current Pickup

50QRP—Reverse Directional Negative-Sequence Current Pickup

Setting Range:

0.05–1.00 A secondary (1 A nominal phase current inputs, IA, IB, IC)
0.25–5.00 A secondary (5 A nominal phase current inputs, IA, IB, IC)

The 50QFP setting ($3I_2$ current value) is the pickup for the forward fault detector 50QF of the negative-sequence voltage-polarized directional elements (see *Figure 3.37*). Ideally, the setting is above normal load unbalance and below the lowest expected negative-sequence current magnitude for unbalanced forward faults.

The 50QRP setting ($3I_2$ current value) is the pickup for the reverse fault detector 50QR of the negative-sequence voltage-polarized directional elements (see *Figure 3.37*). Ideally, the setting is above normal load unbalance and below the lowest expected negative-sequence current magnitude for unbalanced reverse faults.

50QFP and 50QRP Set Automatically

If enable setting E32 = AUTO, settings 50QFP and 50QRP are set automatically at:

50QFP = 0.10 A secondary (1 A nominal phase current inputs, IA, IB, IC)
= 0.50 A secondary (5 A nominal phase current inputs, IA, IB, IC)

50QRP = 0.05 A secondary (1 A nominal phase current inputs, IA, IB, IC)
= 0.25 A secondary (5 A nominal phase current inputs, IA, IB, IC)

a2—Positive-Sequence Current Restraint Factor, I_2/I_1

Setting Range:

0.02–0.50 (unitless)

Refer to *Figure 3.38*.

The a2 factor increases the security of the negative-sequence voltage-polarized directional elements. It keeps the elements from operating for negative-sequence current (system unbalance), which circulates due to line asymmetries, CT saturation during three-phase faults, etc.

a2 Set Automatically

If enable setting E32 = AUTO, setting a2 is set automatically at:

a2 = 0.1

For setting a2 = 0.1, the negative-sequence current (I_2) magnitude has to be greater than 1/10 of the positive-sequence current (I_1) magnitude in order for the negative-sequence voltage-polarized directional elements to be enabled ($|I_2| > 0.1 \bullet |I_1|$).

Z0F—Forward Directional Z0 Threshold

Z0R—Reverse Directional Z0 Threshold

Setting Range:

–320.00 to 320.00 Ω secondary (300 V voltage inputs, VA, VB, VC; 0.2 A nominal neutral current input, IN)

Z0F and Z0R are used to calculate the Forward and Reverse Thresholds, respectively, for the zero-sequence voltage-polarized directional elements (see *Figure 3.36*).

If enable setting E32 = Y, settings Z0F and Z0R (zero-sequence impedance values) are calculated by the user and entered by the user, but setting Z0R must be greater in value than setting Z0F by 0.1 Ω secondary.

Z0F and Z0R Set Automatically

If enable setting E32 = AUTO, settings Z0F and Z0R (zero-sequence impedance values) are calculated automatically as follows:

NOTE: If the calculation of Z0F and Z0R exceeds the setting range, the quantity is set to the upper limit of the setting range.

Z0F = 0 (Ω secondary)
Z0R = 0.1 (Ω secondary)

Deriving Z0F and Z0R Settings

Figure 3.40 shows the voltage and current polarity for an SEL-311M in a zero-sequence impedance network (the same approach can be instructive for negative-sequence impedance analysis, too). For a forward fault, the SEL-311M effectively sees the sequence impedance behind it as:

$$Z_M = V_0/(-I_0) = -(V_0/I_0)$$

$$V_0/I_0 = -Z_M \text{ (forward fault)}$$

For a reverse fault, the SEL-311M effectively sees the sequence impedance in front of it:

$$Z_N = V_0/I_0$$

$$V_0/I_0 = Z_N \text{ (reverse fault)}$$

If the system in *Figure 3.40* were a solidly-grounded system (mostly inductive; presume uniform system angle), the impedance plot (in the R + jX plane) would appear as in *Figure 3.41*. In a high-impedance-grounded shipboard system, the system's zero-sequence impedances are mostly capacitive, and the impedance plot (in the R + jX plane) appears as in *Figure 3.42*a, with Z0F and Z0R settings as in *Figure 3.42*b.

The zero-sequence line angle (∠Z0) noted in *Figure 3.42a* —a negative angle between -90° and 0°—is the same angle found in *Figure 3.36* (in the equation box with the Enable line).

The preceding method of automatically making settings Z0F and Z0R (where Z0R > Z0F) usually suffices—*Figure 3.40*, *Figure 3.41*, and *Figure 3.42* provide a theoretic background.

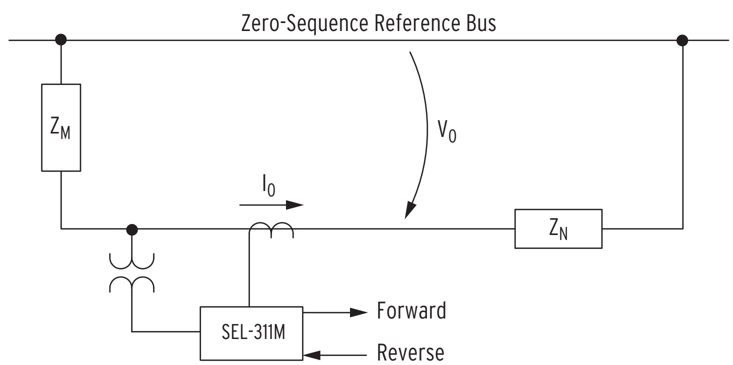


Figure 3.40 Zero-Sequence Impedance Network and Relay Polarity

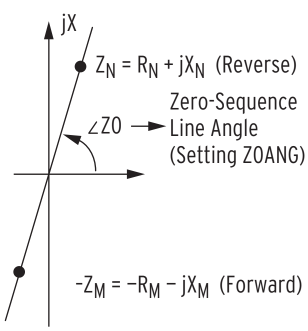


Figure 3.41 Zero-Sequence Impedance Plot for Solidly-Grounded, Mostly Inductive System

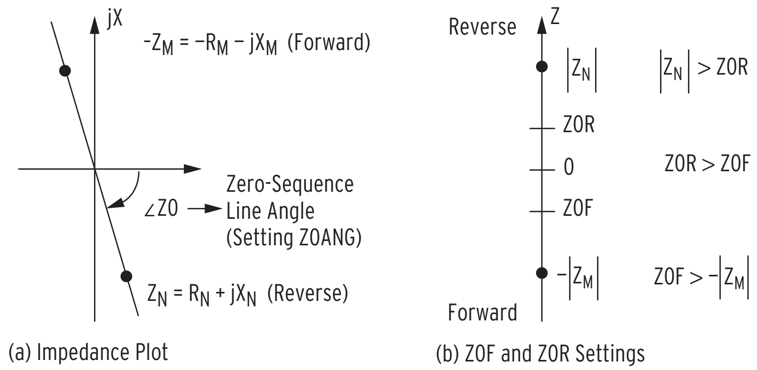


Figure 3.42 Zero-Sequence Impedance Plot for High-Impedance-Grounded, Mostly Capacitive System

50NFP—Forward Directional Neutral Ground Current Pickup

50NRP—Reverse Directional Neutral Ground Current Pickup

Setting Range:

0.005–5.00 A secondary (0.2 A nominal neutral channel input, IN)

The 50NFP setting (I_N current value) is the pickup for the forward fault detector 50NF of the zero-sequence voltage-polarized directional elements: low-impedance or ungrounded/high-impedance grounded (see *Figure 3.35*). Ideally, this setting is above normal load unbalance and below the lowest expected zero-sequence current magnitude for unbalanced forward faults.

The 50NRP setting (I_N current value) is the pickup for the reverse fault detector 50NR of the zero-sequence voltage-polarized directional elements: low-impedance or ungrounded/high-impedance grounded (see *Figure 3.35*). Ideally, this setting is above normal load/system unbalance and below the lowest expected zero-sequence current magnitude for unbalanced reverse faults.

a0N—Positive-Sequence Current Restraint Factor, I_N/I_1

Setting Range:

0.001–0.500 (unitless)	(1 A nominal phase current inputs, IA, IB, IC)
0.0002–0.100 (unitless)	(5 A nominal phase current inputs, IA, IB, IC)

Refer to *Figure 3.35*. The following comparison is made as part of internal enable 32NE (for low-impedance grounded and ungrounded/high-impedance grounded systems):

$$|I_N| > a0N \bullet |I_1|$$

I_N is the secondary current measured by neutral channel IN. I_1 is the positive-sequence secondary current derived from the phase current channels IA, IB, and IC. Presumably, channel IN is connected in such a manner that it sees the system zero-sequence current (e.g., channel IN is connected to a core-balance CT through which the three phase conductors pass; in such a connection, channel IN sees $3I_0$ zero-sequence current, $I_N = 3I_0$).

If a core-balance current transformer is connected to neutral channel IN, it most likely has a different ratio, compared to the current transformers connected to the phase current channels IA, IB, and IC (CT ratio settings CTRN and CTR, respectively).

From a primary system study, load profile values, or metering values, derive a0N as follows:

a0N = $(3I_0$ pri./I_1 pri.) • (CTR/CTRN)
$3I_0$ pri. = standing system unbalance current (zero-sequence; A primary)
I_1 pri. = maximum load current (positive-sequence; A primary)

Adjust the final setting value of a0N from the above derived value of a0N, depending on your security philosophy, etc.

The a0N factor increases the security of the zero-sequence voltage-polarized directional elements: low-impedance grounded or ungrounded/high-impedance grounded. It keeps the elements from operating for zero-sequence current (system unbalance), which circulates due to line asymmetries, etc.

a0 Set Automatically

If enable setting E32 = AUTO, setting a0 is set automatically at:

a0 = 0.001 (1 A nominal phase current inputs, IA, IB, IC)
= 0.0002 (5 A nominal phase current inputs, IA, IB, IC)

For setting a0 = 0.001, the neutral current (I_N) magnitude has to be greater than 1/1000 of the positive-sequence current (I_1) magnitude in order for the zero-sequence voltage-polarized directional elements to be enabled ($|I_N| > 0.001 \cdot |I_1|$).

E32IV—SELOGIC Control Equation Enable

Refer to *Figure 3.35*.

SELOGIC control equation setting E32IV must be asserted to logical 1 to enable the zero-sequence voltage-polarized and channel IN current-polarized directional elements for directional control of neutral ground overcurrent elements.

For most applications, set E32IV directly to logical 1:

E32IV = **1** (numeral 1)

For situations where zero-sequence source isolation can occur (e.g., by opening a circuit breaker) and result in possible mutual coupling problems for the zero-sequence voltage-polarized and channel IN current-polarized directional elements, SELOGIC control equation setting E32IV should be deasserted to logical 0. In this example, connect a circuit breaker auxiliary contact from the isolating circuit breaker to the SEL-311M:

E32IV = **IN106** 52a connected to optoisolated input IN106)

Almost any desired control can be set in SELOGIC control equation setting E32IV.

Ungrounded/High-Impedance Grounded System Considerations for Setting E32IV

On ungrounded/high-impedance grounded systems, phase-to-phase or unbalanced three-phase faults can cause the ungrounded/high-impedance grounded element to operate on false quantities. To prevent this situation, SELOGIC setting E32IV may be used as follows:

E32IV = **V1VAL * !32QE**

The V1VAL Relay Word bit (see *Figure 3.32*) deasserts during a three-phase fault, and the 32QE Relay Word bit (see *Figure 3.38*) asserts during a phase-to-phase fault. If either one of these occur, the E32IV setting evaluates to logical 0, and the ungrounded/high-impedance grounded directional element is blocked (see *Figure 3.35*).

When a switch or breaker closes, the poles can close sequentially (not at the same time), creating a momentary current unbalance condition. To avoid any possible operation of the ungrounded/ high-impedance grounded element for this momentary current unbalance condition, set 3PO (three-pole open condition; see *Figure 4.4*) in SELOGIC setting E32IV as follows:

E32IV = **... + !3PO** (= … + NOT[3PO])

The 3PO dropout time (setting 3POD) provides the extended blocking (3PO = logical 1; !3PO = logical 0) for this momentary current unbalance condition.

Directional Control Provided by Torque Control Settings

For most applications, the level direction settings 1 through DIR4 are used to set overcurrent elements direction forward, reverse, or nondirectional. *Table 3.13* shows the overcurrent elements that are controlled by each level direction setting. Note in *Table 3.13* that all the time-overcurrent elements (51_T elements) are controlled by the 1 level direction setting.

In most communications-assisted trip schemes, the levels are set as follows (see *Figure 4.5*):

Level 1 overcurrent elements fixed forward

Level 2 overcurrent elements fixed forward

Level 3 overcurrent elements set direction reverse (DIR3 = R)

Suppose that the Level 4 overcurrent elements should be set as follows:

67P4	direction forward
67NG4	direction reverse
51PT	direction forward

To accomplish this, the DIR4 setting is turned off, and the corresponding SELOGIC control equation torque control settings for the above overcurrent elements are used to make the elements directional (forward or reverse) or nondirectional. The required settings are:

DIR4 = **N**	(turned off)
67P4TC = **F32P**	(direction forward; see *Figure 3.4*)
67NG4TC = **R32N**	(direction reverse; see *Figure 3.11*)
51PTC = **F32P**	(direction forward; see *Figure 3.15*)

This is just one example of using SELOGIC control equation torque control settings to make overcurrent elements directional (forward or reverse) or nondirectional. This example shows only Level 4 overcurrent elements (controlled by level direction setting DIR4). The same setting principles apply to the other levels as well. Many variations are possible.

Setting Negative-Sequence Overcurrent Elements

Setting Negative-Sequence Definite-Time Overcurrent Elements

Negative-sequence instantaneous overcurrent elements 50Q1–50Q4 and 67Q1–67Q4 should not be set to trip directly. This is because negative-sequence current can transiently appear when a circuit breaker is closed and balanced load current suddenly appears.

To avoid tripping for this transient condition, use negative-sequence definite-time overcurrent elements 67Q1T–67Q4T with at least 1.5 cycles of time delay (transient condition lasts less than 1.5 cycles). For example, make time delay setting:

67Q1D = **1.50**

for negative-sequence definite-time overcurrent element 67Q1T. Refer to *Figure 3.18* for more information on negative-sequence instantaneous and definite-time overcurrent elements.

NOTE: You must be an IEEE member to access this document.

Read A. F. Elneweihi, E. O. Schweitzer, M. W. Feltis, "Negative-Sequence Overcurrent Element Application and Coordination in Distribution Protection," available at http://ieeexplore.ieee.org/xpi/tocresult.jsp?isNumber=6449&Page=1 for guidelines on coordinating negative-sequence definite-time overcurrent elements. The coordination example described in this paper uses time-overcurrent elements, but the same principles can be applied to definite-time overcurrent elements.

Setting Negative-Sequence Time-Overcurrent Elements

Negative-sequence time-overcurrent element 51QT should not be set to trip directly when it is set with a low time-dial setting 51QTD, that results in curve times below 3 cycles (see curves in *Figure 7.1*–*Figure 7.10*). This is because negative-sequence current can transiently appear when a circuit breaker is closed and balanced load current suddenly appears. Refer to *Figure 3.21* for more information on negative-sequence time-overcurrent element 51QT.

To avoid having negative-sequence time-overcurrent element 51QT with such low time dial settings trip for this transient negative-sequence current condition, make settings similar to the following:

SV6PU = **1.50 cycles** (minimum response time; transient condition lasts less than 1.5 cycles)

SV6 = **51Q** (run pickup of negative-sequence time-overcurrent element 51QT through SELOGIC control equation variable timer SV6)

TR = **... + 51QT * SV6T + ...** (trip conditions; SV6T is the output of the SELOGIC control equation variable timer SV6)

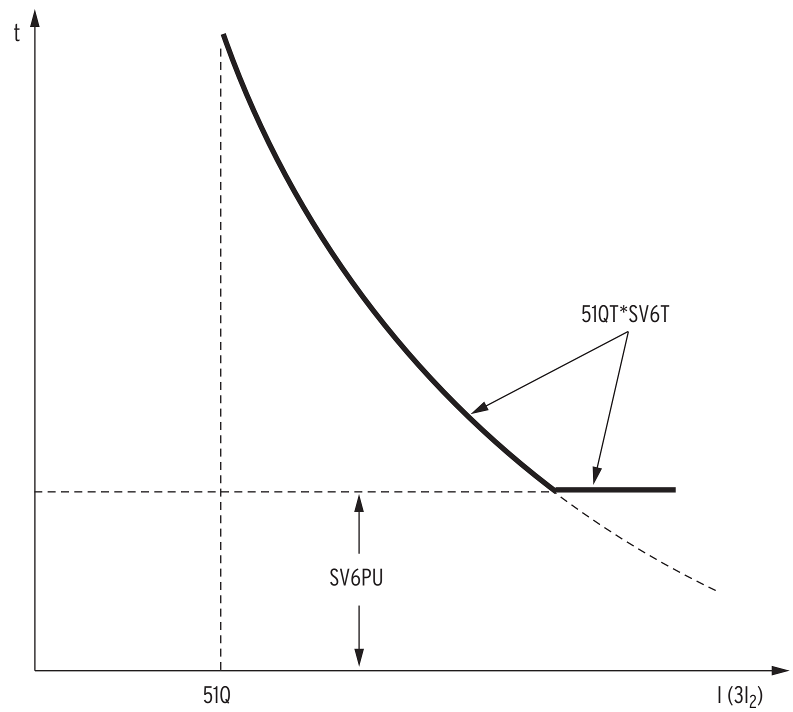


Figure 3.43 Minimum Response Time Added to a Negative Sequence Time-Overcurrent Element 51QT

Other Negative-Sequence Overcurrent Element References

A. F. Elneweihi, E. O. Schweitzer, M. W. Feltis, "Negative-Sequence Overcurrent Element Application and Coordination in Distribution Protection," IEEE Transactions on Power Delivery, Volume 8, Number 3, July 1993, pp. 915–924.

This IEEE paper is the source of the coordination guidelines and example given in this section. The paper also contains analyses of system unbalances and faults and the negative-sequence current generated by such conditions.

Edmund O. Schweitzer, III, Mark W. Feltis, Ahmed F. Elneweihi, "Improved Sensitivity and Security for Distribution Bus and Feeder Relays," http://www.selinc.com/techpprs/6042.pdf.

Appendix I of this paper contains information similar to the first paper in this listing about negative-sequence overcurrent element coordination.

A. F. Elneweihi, "Useful Applications for Negative-Sequence Overcurrent Relaying," 22nd Annual Western Protective Relay Conference, Spokane, Washington, October 24–26, 1995.

This conference paper gives many good application examples for negative-sequence overcurrent elements. The focus is on the transmission system, where negative-sequence overcurrent elements provide better sensitivity than zero-sequence overcurrent elements in detecting some single-line-to-ground faults.

Example Calculations for 87L Settings

87LANG Setting Considerations

This section describes calculations useful in determining the optimal alpha plane angle setting: 87LANG. The alpha plane characteristic angle is adjustable from 90° to 270°. Remember that while a larger angle setting does permit greater security for out-of-section faults, making 87LANG too large affects the dependability for internal faults.

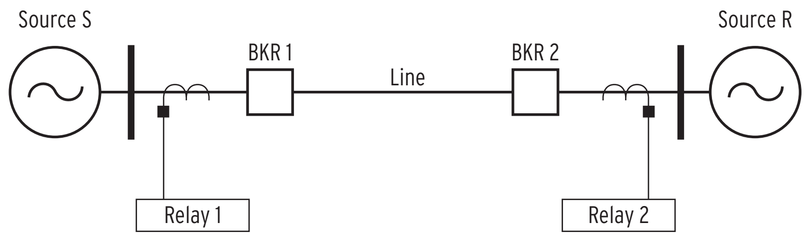


Figure 3.44 Example System Single Line

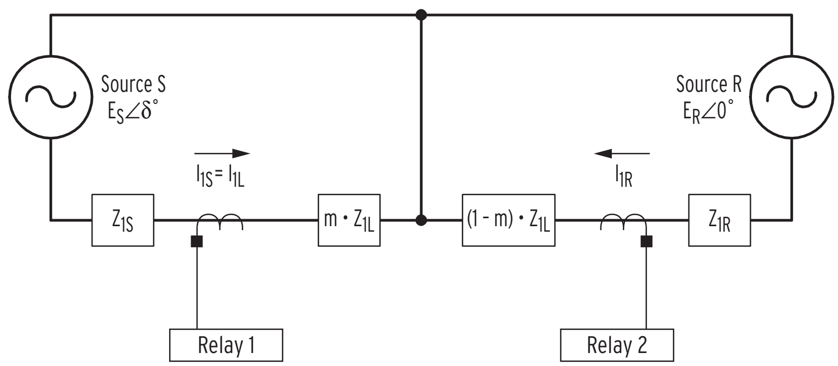


Figure 3.45 Sequence Connection Diagram for an Internal Three-Phase Fault

Z_{1S} = Source S Positive-Sequence Impedance

Z_{1R} = Source R Positive-Sequence Impedance

Z_{1L} = Line Positive-Sequence Impedance

m = Per-unit distance from Breaker 1 (BKR 1)

I_{1S} = Positive-Sequence current measured by Relay 1 (local relay current, I_{1L}, for our example)

I_{1R} = Positive-Sequence current measured by Relay 2 (remote relay current, I_{1R}, for our example)

Figure 3.45 shows the positive-sequence connection diagram for an internal three-phase fault shown in *Figure 3.44*. If I_{1S} and I_{1R} are equal in magnitude and phase, then $I_{AR} / I_{AL} = 1\angle 0°$. For this to occur given a fault placed at $m = 0.5$, the system twist angle (δ) must be zero, and Sources S and R must have equal strength (where m = per-unit distance from Bus S). How do source impedances, δ, and fault location m affect I_{AR} / I_{AL}?

Calculating I_{AR}/I_{AL} for Phase Faults

We can use positive-sequence currents from each line terminal to evaluate three-phase faults (see *Equation 3.4* and *Equation 3.5*). *Equation 3.6* shows the ratio of remote to local positive-sequence currents. Note that $I_{1R} / I_{1L} = I_{AR} / I_{AL}$ for balanced faults.

$$I_{1S} = \frac{E_S\angle\delta°}{Z_{1S} + mZ_{1L}} \qquad \textbf{Equation 3.4}$$

$$I_{1R} = \frac{E_R \angle 0°}{Z_{1R} + (1 - m) \bullet Z_{1L}} \quad \textbf{Equation 3.5}$$

$$\frac{I_{1R}}{I_{1S}} = \frac{I_{AR}}{I_{AL}} = \frac{E_R \angle 0°}{E_S \angle \delta°} \bullet \frac{[Z_{1S} + m \bullet Z_{1L}]}{[Z_{1R} + (1 - m) \bullet Z_{1L}]} \quad \textbf{Equation 3.6}$$

From *Equation 3.6*, we conclude the following:

3. If the system is homogeneous (i.e., $\angle Z_{1S} = \angle Z_{1L} = \angle Z_{1R}$), then $\angle(I_{1R} / I_{1S})$ is zero when $\delta = 0°$. In our default settings, we assumed $\delta = 10°$. Given the following system:
   - ➢ System Voltage: 230 kV_{LL}
   - ➢ Line Length: 10 miles
   - ➢ Line Impedance: 0.8 Ω/mi (8.0 Ω primary total)
   - ➢ Source S and R Impedance: ½ Z_{LINE}
   - ➢ Current Transformer Ratio: 1200/5 (240:1)

   Increasing δ greater than 10° causes the secondary line current to exceed 6 A. In actual practice, we expect the source impedances to be much lower. From this we conclude that 10° is a reasonable maximum value for δ.

4. If the system is nonhomogeneous, this too can create an angle difference between I_{1R} and I_{1S}. The extent of the angle difference depends in part on the fault location. For example, if Source R and the Line have the same angle and $\angle Z_{1S}$ is 10° less than $\angle Z_{1R}$, a fault at $m = 0$ creates a 10° difference between the remote and local currents. Moving the fault location to $m = 1$ creates a 3.3° difference between the phase currents. As a worst case study, the nonhomogeneous angle difference can add with the angle difference caused by $\delta = 10°$. If the $\angle Z_{1S}$ is 10° greater than $\angle Z_{1R}$ for the fault at $m = 0$, the nonhomogeneous system angle and system load angle errors cancel: I_{AR} and I_{AL} are then in-phase.

Calculating I_{2R}/I_{2L} for Ground Faults

Equation 3.7 and *Equation 3.8* show the local terminal negative-sequence currents as a function of total negative-sequence current (I_{2T}). *Equation 3.9* shows the ratio of remote to local negative-sequence currents shown in *Figure 3.46*. Note *Equation 3.9* differs from *Equation 3.6* only by the ratio of local and remote source voltages. This means that the negative-sequence ratio is not affected by load flow magnitude. Because the phase, negative- and zero-sequence 87L elements all use 87LANG to establish the restraint characteristic angle, the limiting case is that set by the phase differential elements. Any increase in alpha plane coverage caused by ($E_R \angle 0° / E_S \angle \delta°$) serves to increase the security of the 87L2 and 87LG elements without sacrificing sensitivity.

$$I_{2S} = I_{2T} \bullet \frac{[(1 - m) \bullet Z_{2L} + Z_{2R}]}{[Z_{2S} + Z_{2L} + Z_{2R}]} \quad \textbf{Equation 3.7}$$

$$I_{2R} = I_{2T} \bullet \frac{[m \bullet Z_{2L} + Z_{2S}]}{[Z_{2S} + Z_{2L} + Z_{2R}]} \quad \textbf{Equation 3.8}$$

$$\frac{I_{2R}}{I_{2S}} = \frac{[Z_{1S} + m \bullet Z_{1L}]}{[Z_{1R} + (1 - m) \bullet Z_{1L}]}$$ **Equation 3.9**

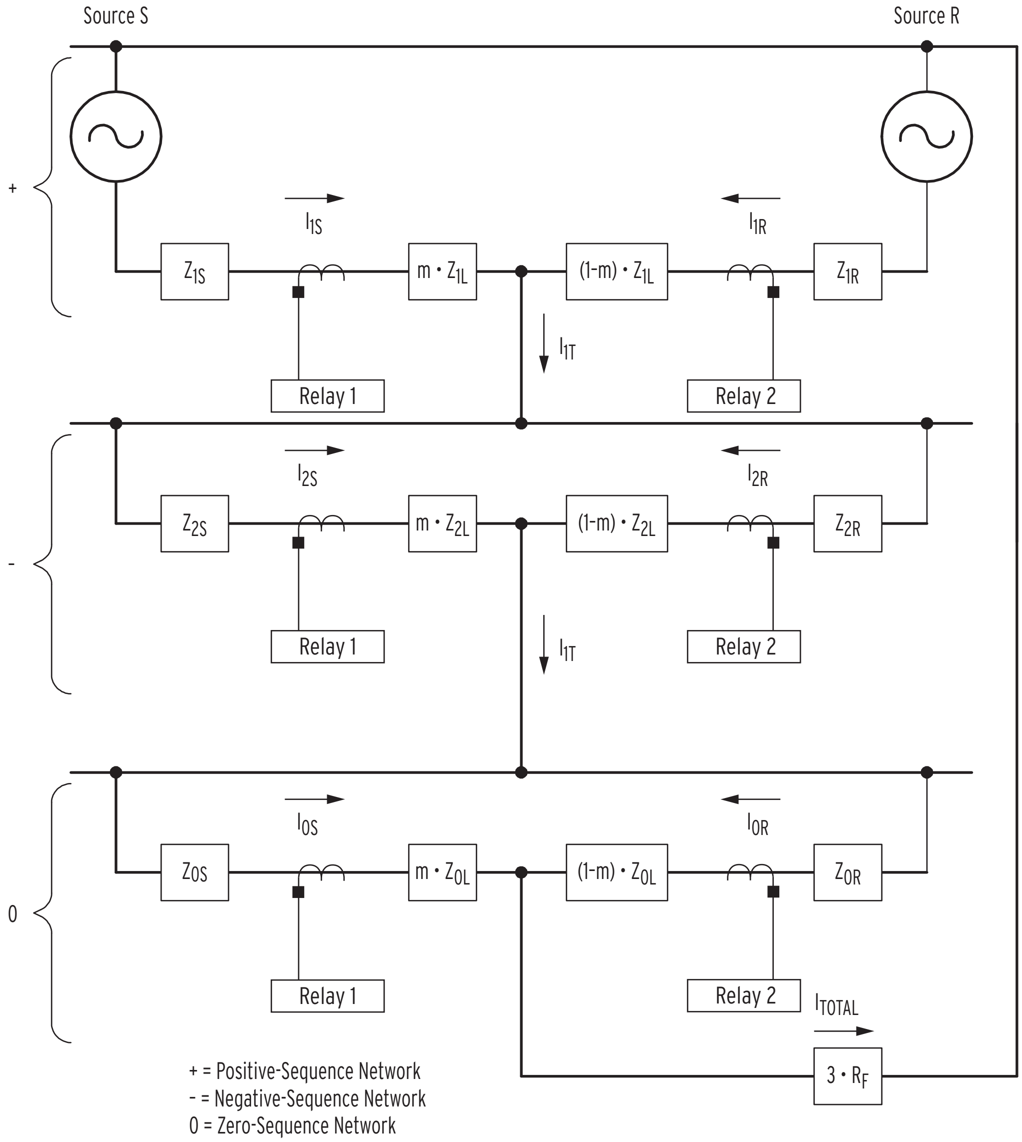


Figure 3.46 Sequence Connection Diagram for an A-Phase Ground Fault

Summary

System nonhomogeneity and non-zero load angle can add to create a 20° angular difference between I_{AR} and I_{AL}. Continuing with our worst-case scenario for setting 87LANG, we must consider the additional sources of angle errors from CT saturation (40°) and communication channel asymmetry (22.5°). The sum of these worst-case errors, and assuming that they all occur simultaneously, is 82.5°. Given this analysis, set 87LANG = 195°.

Line Charging Current Calculation Examples

EXAMPLE 3.1 500 kV OH Transmission Line: 100 Miles of Single 1113 MCM Conductor

$$I = 2 \bullet \pi \bullet f \bullet C \bullet V_{L-N} \text{ [A per-phase, per mile]} \quad \textbf{Equation 3.10}$$

$$C = \frac{0.0388}{\log_{10}(D_{EQ}/r)} l \text{ [}\mu\text{F]} \quad \textbf{Equation 3.11}$$

where:

D_{EQ}[a] = Equivalent spacing between three conductors: $[D_{EQ} = (D_{AB} \bullet D_{BC} \bullet D_{CA})^{1/3}]$ (ft)

r = Conductor radius (ft) (1113 MCM ACSR, 0.6465 in = 0.0539 ft)

l = Conductor length (miles) (100 miles)

C = Shunt capacitance (*Equation 3.11*: 0.01265 µF/mi • 100 mi = 1.265 µF)

f = system frequency (60 Hz)

$V_{L\text{-}N}$ = system phase-neutral voltage (500 / √3 kV)

@ V = 500 kV / √3, $I_{1CHARGING}$ = 137.6 A primary for a line length = 100 miles

@ V = 2886 V, $I_{2CHARGING}$ = 1.37 A primary for the same line length, with 1% unbalance

[a] Assuming a conductor spacing of 50 ft between the conductors of a horizontal line configuration (D_{EQ} = 63 ft).

If the current transformer ratio for this 500 kV application is 400:1 (2000/5), the phase charging currents are 0.334 A secondary, and the negative-sequence charging current ($3I_2$) is 0.01A secondary. Make setting 87L2P = 0.5 for excellent security and sensitivity.

For weak systems, consider the maximum voltage unbalance that can be caused by an external unbalanced fault. This can be significantly higher than the one percent voltage unbalance assumed above, and can cause the charging current unbalance to approach the phase charging current.

EXAMPLE 3.2 15 kV Underground Cable: 5 Miles

$$C = \frac{0.0169 \bullet n \bullet k}{G} l \text{ [}\mu\text{F]} \quad \textbf{Equation 3.12}$$

where:

C = cable capacitance (see *Equation 3.12*, 0.2345 • (5.28) • (5 mi) = 6.19 µF)

n = number of conductors (3)

k = cable dielectric constant (3.7)

$V_{L\text{-}N}$ = system phase-neutral voltage (15 / √3 kV)

G = cable geometric factor (shaped differs from circular, etc. Our example assumes a G = 0.8)

l = cable length in 1,000s of feet (5 mi • 5.28 kft/mi)

@ V = 8.66 kV, $I_{1CHARGING}$ = 60.6 A primary for a 15-mile long cable

@ V = 86.6 V, $I_{2CHARGING}$ = 0.60 A primary for the same cable length

If the current transformer ratio for this 15 kV application is 60:1 (300/5), the phase charging current is 1 A secondary, and the negative-sequence charging current ($3I_2$) is 0.03 A secondary. Again, make setting 87L2P = 0.5 A for excellent security and sensitivity.

As with the overhead line example, also consider the maximum voltage unbalance caused by an external unbalanced fault. This voltage unbalance can cause considerable charging current unbalance, up to the phase charging current.

Ground Fault Resistance Coverage With 87L2P = 0.5 A

In both examples, setting 87L2P = 0.5 A secondary allows ground fault resistance coverage up to:

$$R_F = \frac{66.4\,V}{0.5\,A} = 132.8\ \Omega \text{ secondary}$$

Equation 3.13

Equation 3.13 assumes load current less than 1/3 of nominal secondary current. See *Figure 3.9* for ground fault resistance coverage with more load current.

Ground Differential Element Theory of Operation (Patented)

To assist with understanding the operation of the 87W element, we first discuss ungrounded or isolated neutral power systems.

The main goals of system grounding are to minimize equipment voltage and thermal stresses, provide personnel safety, reduce communication system interference, and give assistance in rapid detection and elimination of ground faults.

Operating a power system ungrounded restricts ground fault current magnitudes and achieves most of the goals listed above with the exception of minimized voltage stress. The drawback of an ungrounded power system is that it also creates ground fault detection (protection) sensitivity problems. Ferroresonance could be a problem in ungrounded systems if there is sufficient system capacitance such that this capacitance matches the connected system inductance.

In an ungrounded system (see *Figure 3.47*) the neutral has no intentional connection to ground. The system is connected to ground through the line to ground capacitances (C_{AG}, C_{BG} and C_{CG}). Single line to ground faults shift the system neutral voltage but leave the phase to phase voltage triangle intact. Thus, if all the loads are connected phase-phase, the loads do not suffer from a reduced voltage and can continue operation during single-phase-to-ground faults.

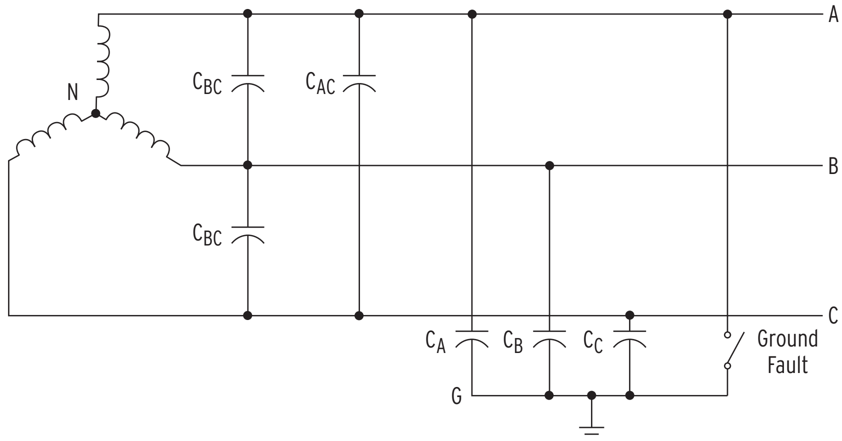


Figure 3.47 Isolated Neutral System Single-Line Diagram

For these systems, the major factors that limit ground fault current are the zero sequence line to ground impedance and fault resistance. Because the voltage triangle is relatively undisturbed, these systems can remain operational during sustained, low-magnitude faults until the fault is either cleared or a second fault on another phase develops.

Zero-sequence or three-phase voltage relays can detect ground faults in ungrounded systems. However, this method of fault detection is not selective because all relays across a system measure virtually the same zero-sequence voltage for a single-phase-to-ground fault. Locating and isolating the fault requires sequential disconnection of the feeders and then determining that the zero-sequence voltage returned to its prefault value.

SEL has developed two elements used in these protection schemes to detect ground faults in ungrounded systems. Specifically, these elements are a ground directional element, 32N, used as a stand-alone element (i.e., a communication channel is not required) for backup protection and as a keying element in a directional comparison scheme, and a line differential zero-sequence element referred to as 87W. These elements, and associated protection schemes, achieve very high sensitivity (the ability to detect ground faults with high magnitudes of fault resistance), selectivity (the ability to determine the faulted line section) and high-speed operation. *Figure 3.48* shows an overview diagram of the protection system for a power line feeder line application. This system is comprised of protective relays at each line end. Each relay interfaces to two communications channels (labeled "Communications Channel 1" and "Communications Channel 2"). The purpose of each communication channel is different. Communications Channel 1 communicates a minimal amount of information necessary for a directional comparison scheme. Communications Channel 2 supports the differential scheme. The directional comparison scheme utilizes the differential scheme communication channel.

The advantage of having two communications channels each supporting different tripping schemes are:

1. Maximum reliability: the likelihood of a fault going undetected by both protection schemes is extremely remote.
2. Dual communication channels with divergent routing minimize the likelihood of a single event interrupting protection system communications between the relays.

These advantages represent state of the art technology typical of power system protection systems serving critical applications.

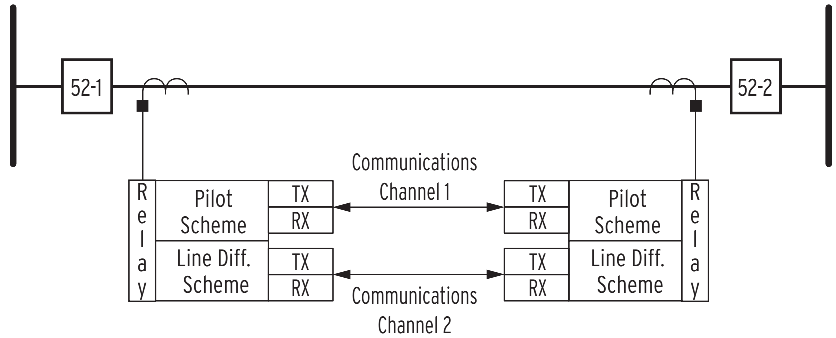


Figure 3.48 Line Protection Diagram

Ungrounded Radial Distribution System Analysis

In this section the steady-state behavior of ungrounded systems is analyzed in both the phase and the symmetrical component domains.

Three-Phase Analysis

Figure 3.49 shows a simplified representation of a three-phase ungrounded power distribution system. The relay location defines the protected line. All the other distribution lines are lumped in an equivalent line representing the remainder of the distribution system. For simplification of the steady-state analysis, we assume ideal sources operating at nominal frequency, no load, and disregard line series impedances (resistance and reactance). Zero-sequence components are used to determined fault conditions. Therefore load may be disregarded on the basis that all loads are connected phase-to-phase so they do not generate any zero-sequence unbalance current. These assumptions introduce no significant error in the results but greatly simplify the calculations.

In *Figure 3.49*, C_{AL}, C_{BL}, and C_{CL} represent the phase-to-ground capacitances of the protected line, and C_{AS}, C_{BS}, and C_{CS} are the phase-to-ground capacitances of the remaining network. The phase-to-phase capacitances (C_{AB}, C_{BC}, and C_{CA}) are not represented in *Figure 3.49* because they do not contribute to the residual current, and so they are irrelevant to this analysis.

The circuit of *Figure 3.49* yields:

$$\overrightarrow{I_{AL}} + \overrightarrow{I_{BL}} + \overrightarrow{I_{CL}} + \overrightarrow{I_{AS}} + \overrightarrow{I_{BS}} + \overrightarrow{I_{CS}} = 0 \quad \textbf{Equation 3.14}$$

The relay element measures the residual current $3I_{0L}$ of the protected line. From *Equation 3.14*:

$$\overrightarrow{3I_{0L}} = \overrightarrow{I_{AL}} + \overrightarrow{I_{BL}} + \overrightarrow{I_{CL}} = -(\overrightarrow{I_{AS}} + \overrightarrow{I_{BS}} + \overrightarrow{I_{CS}}) \quad \textbf{Equation 3.15}$$

Closing Switch S_F represents a forward solid A-phase fault in the system of *Figure 3.49*. In this case the fault current I_F equals I_{AL}:

$$I_F = \overrightarrow{I_{AL}} = -(\overrightarrow{I_{BL}} + \overrightarrow{I_{CL}} + \overrightarrow{I_{AS}} + \overrightarrow{I_{BS}} + \overrightarrow{I_{CS}}) \quad \textbf{Equation 3.16}$$

Equation 3.16 shows that the residual current measured by the relay is actually the residual current supplied by the remainder of the system. Further, *Equation 3.16* shows that if the protected line were the only feeder connected to the bus, the residual current measured by the relay would equal zero (i.e., $3I_0 = I_{AL} - (I_{BL} + I_{CL}) = 0$). In this case a ground fault is detected with only a zero-sequence overvoltage element.

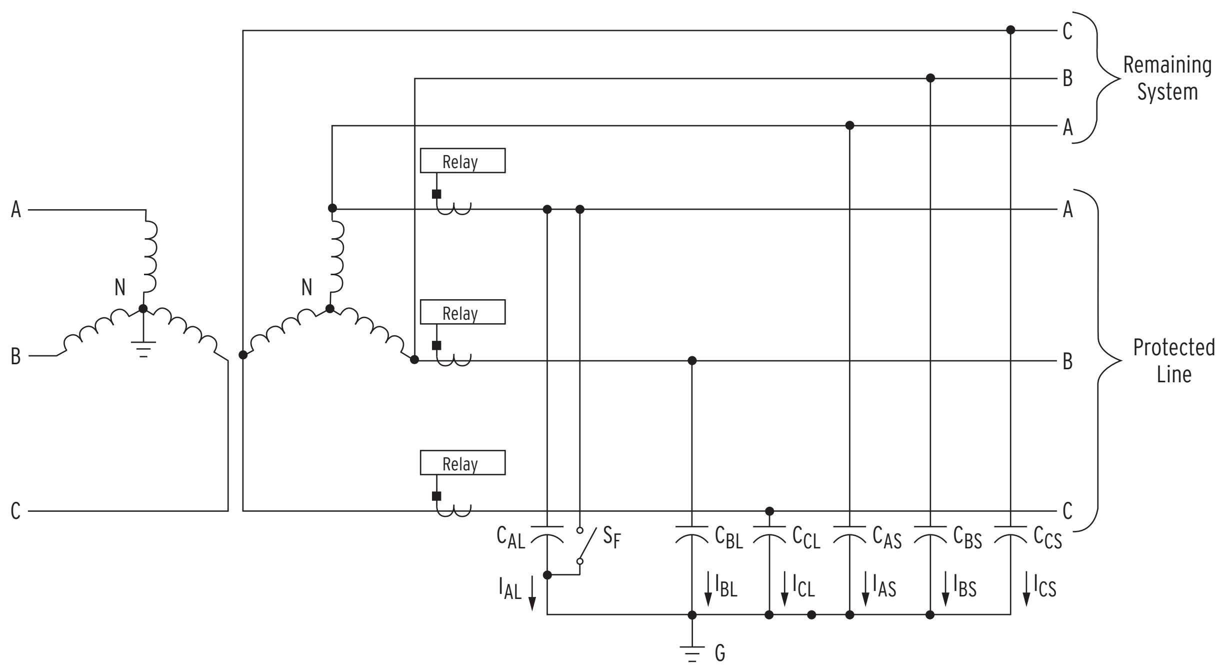


Figure 3.49 Three-Phase Simplified Representation of an Ungrounded Network

In a symmetrical unfaulted system the residual current for the protected line is zero ($3I_{0L} = 0$) and the system neutral N is at ground potential ($V_{NG} = 0$) (see *Figure 3.50* a). Natural system asymmetry produces some neutral current and shifts the system neutral from the ideal ground potential of $V_{NG} = 0$ but is not critical to the discussion and is therefore ignored.

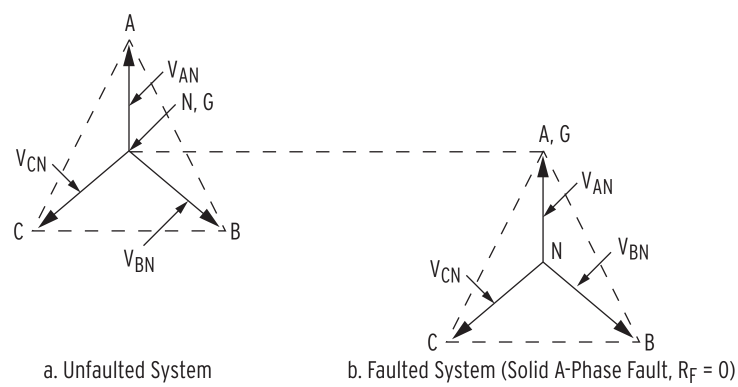


Figure 3.50 Voltage Phasor Diagrams for the System in Figure 3.49

For a solid A-to-ground fault ($R_F = 0$), the faulted phase and ground potential are equal (see *Figure 3.50* b). The phase-to-ground voltage of the two remaining unfaulted phases equals the phase-to-phase voltage ($V_{BG} = V_{BA}$, $V_{CG} = V_{CA}$) and the neutral to ground voltage equals the negative of the source phase-to-neutral voltage corresponding to the faulted phase ($V_{NG} = -V_{AN}$).

Symmetrical Component Analysis

The phase-domain analysis provides an exact representation of the ungrounded system, which is valid even for asymmetrical systems. However, ground fault detection methods are typically based on zero-sequence quantities, so it is also important to outline a symmetrical-component-domain analysis of ungrounded systems operating in steady state.

The zero-sequence impedance of an ungrounded system is very large. Because the zero-sequence impedance is much larger than the positive- and negative-sequence impedances they may be ignored without significant loss of accuracy when evaluating single line-to-ground faults. *Figure 3.51* shows an approximate zero-sequence representation of the forward ground fault in the system depicted in *Figure 3.49* (Switch S_F closed). *Figure 3.52* shows an approximate zero-sequence representation of the reverse ground fault in the system depicted in *Figure 3.49*. Assume that the system is symmetrical ($C_{AL} = C_{BL} = C_{CL} = C_L$, $C_{AS} = C_{BS} = C_{CS} = C_S$) and that the Thevenin prefault voltage, at the fault point, is equal to the nominal (phase-to-neutral) system voltage (V_{NOM}).

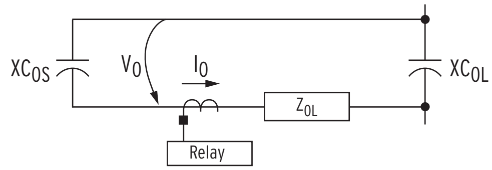


Figure 3.51 Zero-Sequence Network for the Forward Ground Fault in Figure 3.49

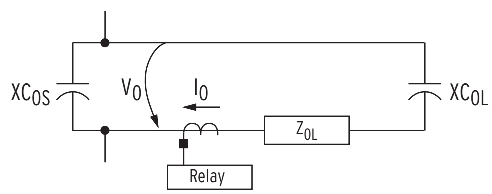


Figure 3.52 Zero-Sequence Network for the Reverse Ground Fault in Figure 3.49

In *Figure 3.51* the relay measures V_0 across and the current through XC_{0S}, where XC_{0S} is the zero-sequence impedance. In *Figure 3.52* the relay measures V_0 across and the current through the series combination of (Z_{0L} + XC_{0L}), where Z_{0L} is the zero sequence line impedance and XC_{0L} is the distributed line-ground capacitance reactance of the protected line. Thus, the relay measures $-XC_{0S}$ for forward faults and ($Z_{0L} + XC_{0L}$) for reverse faults. For most power system conditions Z_{0L} is much less than XC_{0L} and can be ignored.

Figure 3.53 a shows the phasor diagram for forward and reverse faults in the system shown in *Figure 3.49*. *Figure 3.53* b shows a patented directional element characteristic for ungrounded systems. The function of a directional element is to determine forward and reverse conditions, i.e., differentiate $-XC_{0S}$ from XC_{0L}. The 87W element does this with a threshold set between these two impedance values. If the measured impedance is below the threshold (and all of the supervisory conditionals are met), the fault is declared forward.

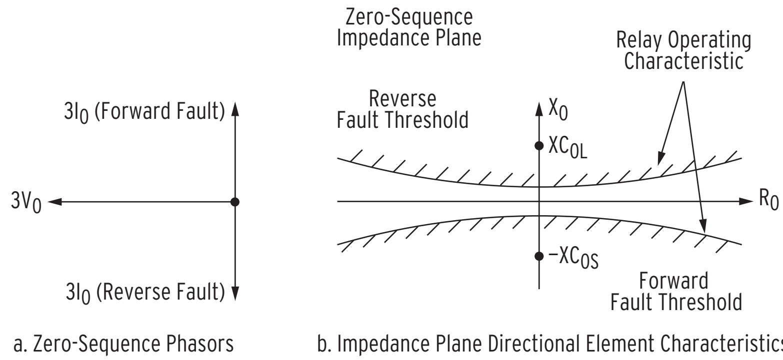


Figure 3.53 Ground Directional Element Characteristics (Patent Pending)

The relay uses Equation 5 to calculate zero-sequence impedance.

$$z0T = \frac{Re[3V_0 \bullet ((I_{NL} + I_{NR}) \bullet 1\angle W\_ANG°)^*]}{|I_{NL} + I_{NR}|^2} \quad \textbf{Equation 3.17}$$

where:

$3V_0$ = Summation of phase voltages ($V_A + V_B + V_C$)

I_{NL} = Zero-seq. current supplied by core-flux summing current transformer local to the relay location

I_{NR} = Zero-seq. current measured by the remote relay. This zero-sequence current is also supplied to the relay by a core-flux summing current transformer local to the remote relay location.

Re = Real operator

* = Complex conjugate

Figure 3.54 and *Figure 3.55* show the relationship between $3V_0$ and $3I_0$ for forward and reverse faults. Negative Z_0T indicates a forward fault as shown in *Figure 3.51*. Positive Z_0T indicates a reverse fault as shown in *Figure 3.52*.

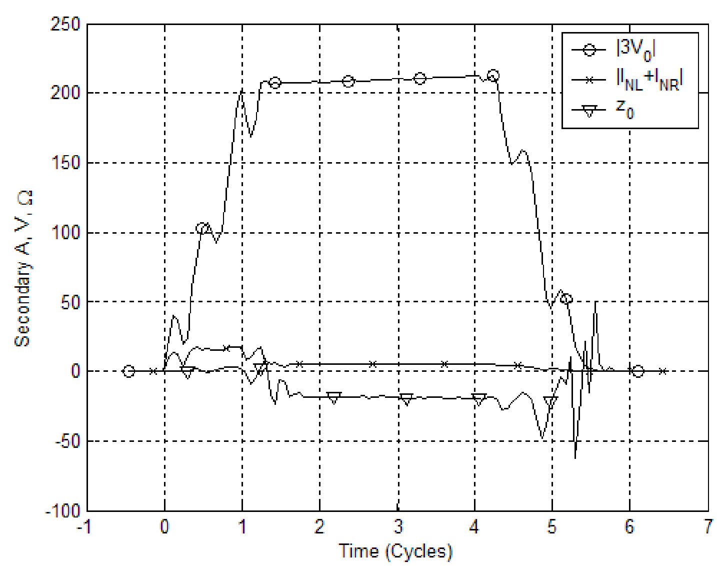


Figure 3.54 Fault Decision for an In-Section A-Ground Fault

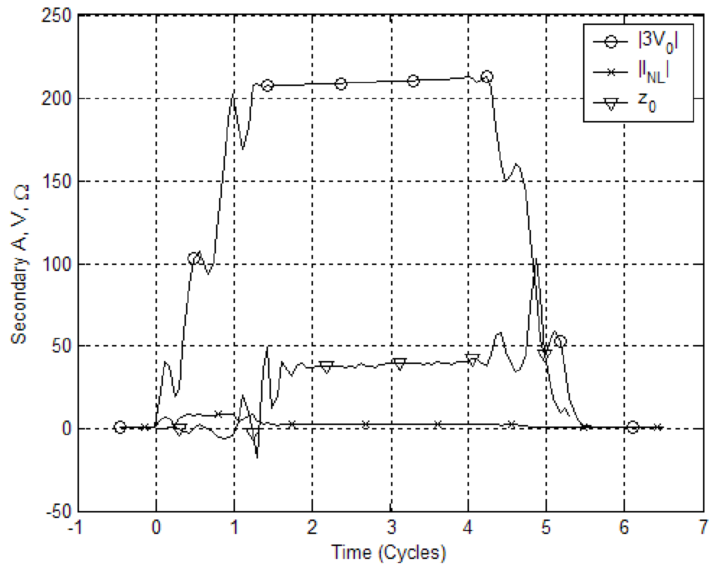


Figure 3.55 Single-Ended Fault Decision for an Out-of-Section A-Ground Fault in the Reverse Direction

Section 4

Trip, Close, and Target Logic

Overview

The SEL-311M Relay trip logic combines trip decisions from several sources into a single Relay Word bit, useful for controlling trip contacts. The relay also contains line current differential high-speed tripping logic, which bypasses the normal trip logic and directly controls trip contacts. This high-speed trip logic results in 87L trip times up to 3/4 cycle faster than available using SELOGIC® control equations.

The SEL-311M Relay close logic describes the final logic that controls the close output contact (e.g., OUT103 = CLOSE). This output contact closes the circuit breaker for other close conditions (e.g., manual close initiation via serial port or optoisolated inputs).

If the SEL-311M Relay is to close the circuit breaker for other close conditions (e.g., manual close initiation via serial port or optoisolated inputs), then this subsection is the only subsection that needs to be read in this section (particularly the description of SELOGIC control equation setting CL).

Line Current Differential Trips

High-Speed 87L Tripping

For the fastest 87L protection, set EHST—a six-bit mask—to select the desired high-speed trip contacts. No additional trip logic settings are required for line current differential protection. Relay Word bit TRIP87 asserts when line current differential algorithms detect an internal fault, as shown in *Figure 4.1*. As shown in *Figure 4.2*, TRIP87 directly controls high-speed outputs OUT201–OUT206 when their corresponding EHST bits are set. For example, when EHST = 000011, TRIP87 directly controls high-speed outputs OUT201 and OUT202. These high-speed outputs close in less than 10 µs, are trip rated, and interrupt dc trip current, so tripping auxiliary relays are often not required. Use this method to achieve the trip times shown in *Figure 3.7*.

When high-speed tripping is enabled, Relay Word bit TRIP87 is also routed to the backup protection tripping logic in *Figure 4.3*. This triggers event reports and the target logic when a high-speed 87L trip occurs.

87L Tripping Via SELOGIC

To qualify 87L protection using a SELOGIC control equation, make setting EHST = 000000. This disables direct control of high-speed outputs OUT201–OUT206. Place Relay Word bit TRIP87 directly in SELOGIC control equation TR, supervised by the appropriate relay elements and conditions. Place Relay Word bit TRIP in the SELOGIC control equation for high-speed outputs OUT201–OUT206, and/or in the SELOGIC control equations for conventional outputs OUT101–OUT107. Add 3/4 cycle to the trip times shown in *Figure 3.7* when using 87L protection qualified by SELOGIC control equations. See *Backup Protection Trips on page 4.3* for more information about Relay Word bit TRIP.

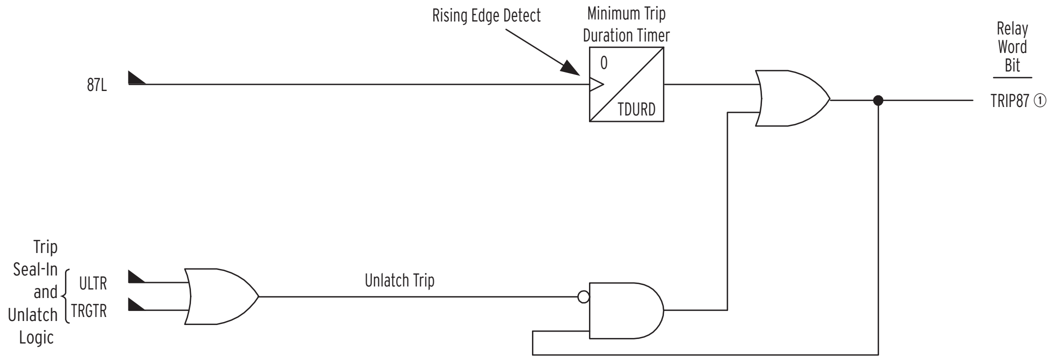


Figure 4.1 Line Current Differential Trip Logic

① To Figure 4.3

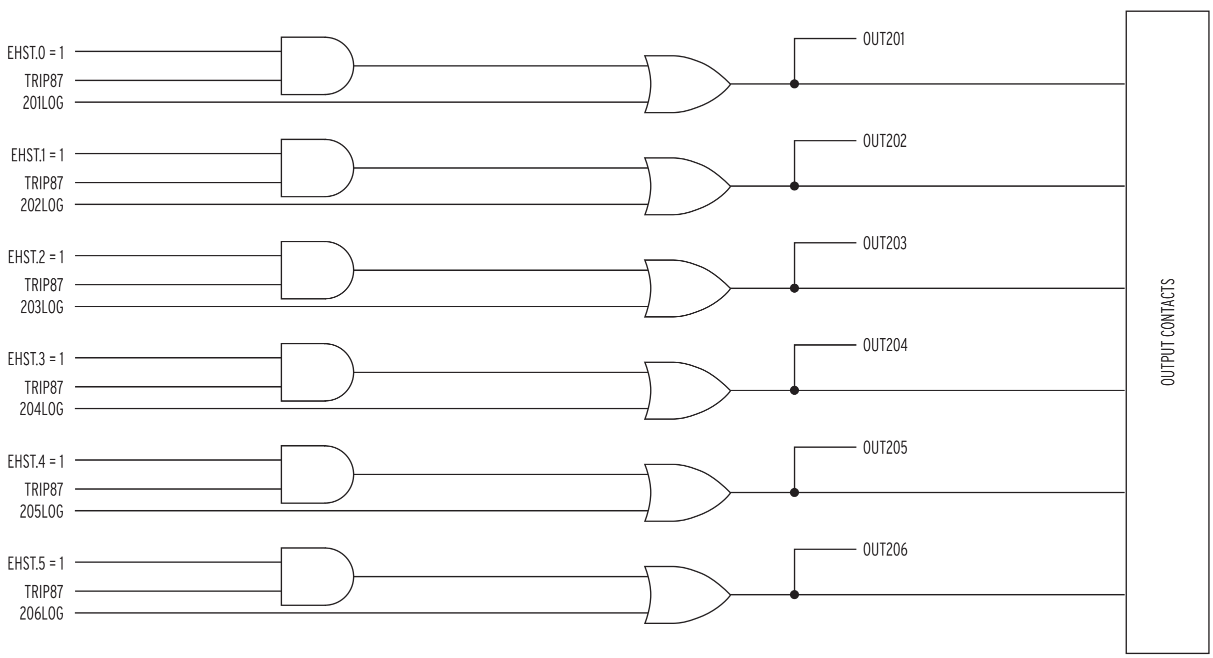


Figure 4.2 High-Speed Output Logic

Backup Protection Trips

The trip logic in *Figure 4.3* provides flexible tripping with SELOGIC control equation settings:

TRCOMM Communications-Assisted Trip Conditions.

Setting TRCOMM is supervised by communications-assisted trip logic. See *Communications-Assisted Trip Logic (General Overview) on page 4.11* for more information on communications-assisted tripping.

DTT Direct Transfer Trip Conditions.

Note in *Figure 4.3* that setting DTT is unsupervised. Any element that asserts in setting DTT will cause Relay Word bit TRIP to assert to logical 1.

Although setting TR is also unsupervised, setting DTT is provided separately from setting TR for target LED purposes. (**COMM** target LED on the front panel illuminates when DTT asserts to logical 1; see *COMM Target LED on page 4.29*).

Typical settings for DTT are:

DTT = **IN106** or DTT = **RMB1A**

where input **IN106** is connected to the output of direct transfer trip communications equipment or receive MIRRORED BIT™ RMB1A is asserted by the transfer trip condition in a remote SEL relay.

Setting DTT is also used for Direct Underreaching Transfer Trip (DUTT) schemes.

TRSOTF Switch-Onto-Fault Trip Conditions.

Setting TRSOTF is supervised by the switch-onto-fault condition SOTFE. See *Switch-Onto-Fault Trip Logic on page 4.8* for more information on switch-onto-fault logic.

TR Other Trip Conditions.

Setting TR is the SELOGIC control equation trip setting most often used if tripping does not involve communications-assisted trip logic (settings TRCOMM and DTT), switch-onto-fault (setting TRSOTF) trip logic, or 87L trip logic (use high-speed tripping via setting EHST).

Note in *Figure 4.3* that SELOGIC control equation trip setting TR is unsupervised. Any element that asserts in SELOGIC control equation setting TR will cause Relay Word bit TRIP to assert to logical 1.

ULTR Unlatch Trip Conditions.

TDURD Minimum Trip Duration Time.

This timer establishes the minimum time duration for which the TRIP Relay Word bit asserts. The settable range for this timer is 4–16,000 cycles.

More than one trip setting (or all four trip settings TRCOMM, DTT, TRSOTF, and TR) can be set.

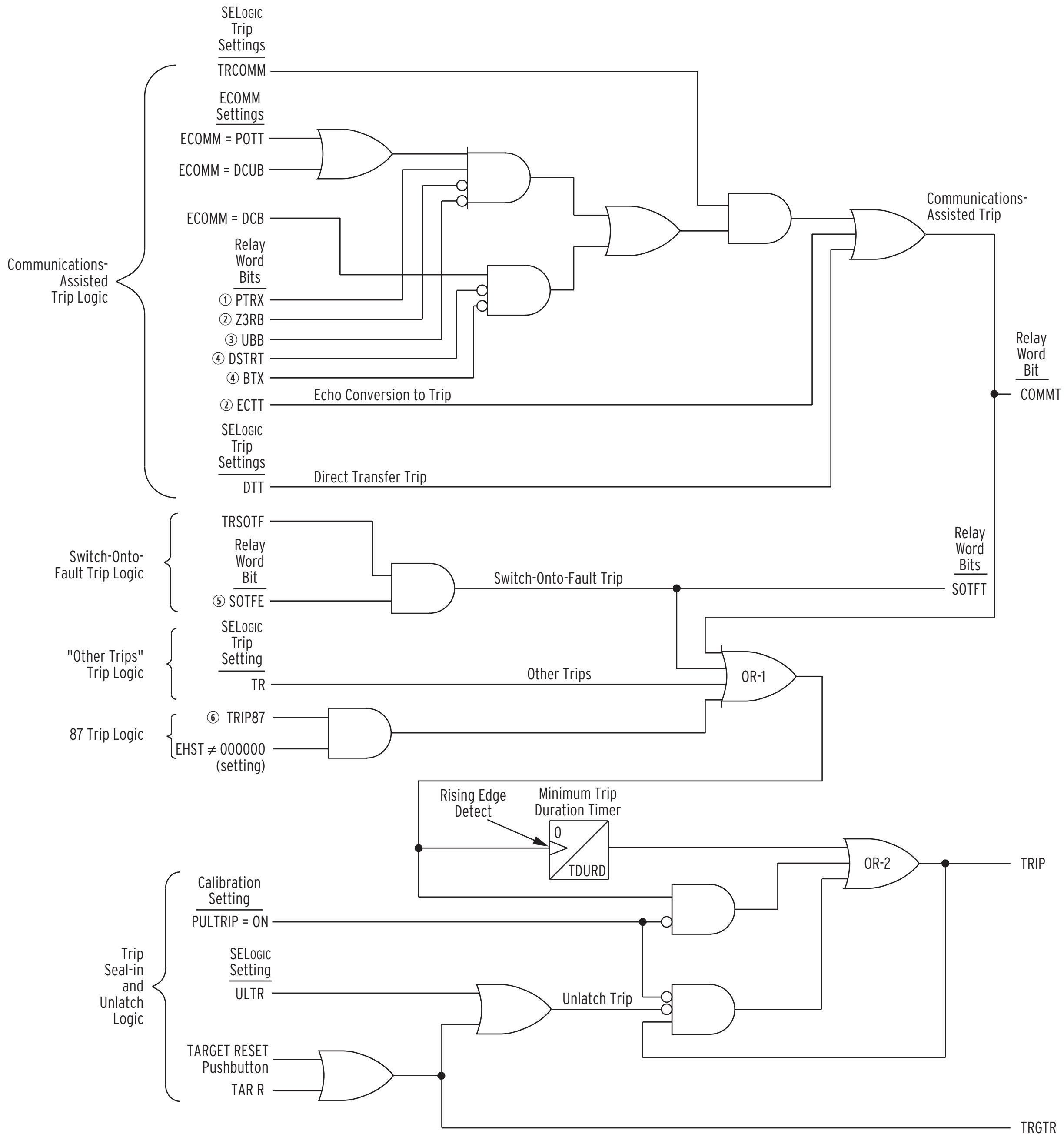


Figure 4.3 Trip Logic

① From Figure 4.8; ② from Figure 4.7; ③ from Figure 4.10; ④ from Figure 4.12; ⑤ from Figure 4.4; ⑥ from Figure 4.1

In addition, when setting EHST ≠ 000000, Relay Word bit TRIP asserts when any 87L element detects an internal fault.

Set Trip

Refer to *Figure 4.3*. All trip conditions:

- Communications-Assisted Trip, including Direct Transfer Trip
- Switch-Onto-Fault Trip

- "Other Trips" Trip Logic
- Other High-Speed 87L Trips

are combined into OR-1 gate. The output of OR-1 gate is routed into the Minimum Trip Duration Timer (setting TDURD).

The Minimum Trip Duration Timer (with setting TDURD) outputs a logical 1 for a time duration of "TDURD" cycles any time it sees a **rising edge** on its input (logical 0 to logical 1 transition), if it is not already timing (timer is reset). The TDURD timer ensures that the TRIP Relay Word bit remains asserted at logical 1 for a **minimum** of "TDURD" cycles. If the PULTRIP setting is set to ON (factory default), then the trip signal will return to a logical 0 after TDURD cycles even if the output of OR-1 gate remains at logical 1 beyond the TDURD time. If PULTRIP is set to OFF, and if the output of OR-1 gate is logical 1 beyond the TDURD time, Relay Word bit TRIP remains asserted at logical 1 for as long as the output of OR-1 gate remains at logical 1, regardless of other trip logic conditions. For most applications, you should leave PULTRIP set to ON. If you wish to change this setting to OFF, contact your customer service representative or the factory for assistance.

The Minimum Trip Duration Timer can be set no less than four cycles.

The **OPEN** command is included in the trip logic in the factory settings:

TR = **TRIP + OC**

Relay Word bit OC asserts for execution of the **OPEN** Command. See *OPE Command (Open Breaker) on page 8.44* for more information on the **OPEN** Command.

If a user wants to supervise the **OPEN** command with optoisolated input IN105, the following setting is made:

TR = **... + OC * IN105**

With this setting, the **OPEN** command can provide a trip only if optoisolated input IN105 is asserted. This is just one **OPEN** command supervision example—many variations are possible.

A COMM target LED option for the **OPEN** command is discussed in the *Front-Panel Target LEDs on page 4.28*.

Unlatch Trip

Once Relay Word bit TRIP is asserted to logical 1, it remains asserted at logical 1 until all the following conditions come true:

- Minimum Trip Duration Timer stops timing (logic output of the TDURD timer goes to logical 0)
- Output of OR-1 gate in *Figure 4.3* deasserts to logical 0
- One of the following occurs:
  - SELOGIC control equation setting ULTR asserts to logical 1,
  - The front-panel {TARGET RESET} pushbutton is pressed,
  - Or the **TAR R** (Target Reset) command is executed via the serial port.

The front-panel {TARGET RESET} pushbutton and the **TAR R** (Target Reset) serial port command are primarily used during testing. Use these to force the TRIP Relay Word bit to logical 0 if test conditions are such that setting ULTR does not assert to logical 1 to automatically deassert the TRIP Relay Word bit.

Other Applications for the Target Reset Function

Note that the combination of the **{TARGET RESET}** pushbutton and the **TAR R** (Target Reset) serial port command is also available as Relay Word bit TRGTR. See *Figure 4.15* and accompanying text for applications for Relay Word bit TRGTR.

Settings Example (Using Setting TR)

In this example the "communications-assisted," "87 Trip Logic," and "switch-onto-fault" trip logic at the top of *Figure 4.3* are not used. The SELOGIC control equation trip setting TR is now the only input into OR-1 gate and flows into the "seal-in and unlatch" logic for Relay Word bit TRIP.

The settings for the trip logic SELOGIC control equation settings are:

TR = **51NGT + 51QT + OC** (trip conditions)

ULTR = **!(50L + 51NG)** (unlatch trip conditions)

The factory setting for the Minimum Trip Duration Timer setting is:

TDURD = **9.000 cycles**

See the settings sheets in *Section 7: Settings* for setting ranges.

Set Trip

In SELOGIC control equation setting TR = 51NGT + 51QT + OC:

- Time-overcurrent elements 51NGT and 51QT trip directly. Time-overcurrent and definite-time overcurrent elements can be torque controlled (e.g., elements 51NGT and 51QT are torque controlled by SELOGIC control equation settings 51NGTC and 51QTC, respectively). Check torque control settings to see if any control is applied to time-overcurrent and definite-time overcurrent elements. Such control is not apparent by mere inspection of trip setting TR or any other SELOGIC control equation trip setting.
- Relay Word bit OC asserts for execution of the **OPEN** Command. See *OPE Command (Open Breaker) on page 8.44* for more information on the **OPEN** Command.

With setting TDURD = 9.000 cycles, once the TRIP Relay Word bit asserts via SELOGIC control equation setting TR, it remains asserted at logical 1 for a minimum of 9 cycles.

Unlatch Trip

In SELOGIC control equation setting ULTR =!(50L + 51NG):

- Both elements must be deasserted before the trip logic unlatches and the TRIP Relay Word bit deasserts to logical 0.

Additional Settings Examples

The setting for SELOGIC control equation setting ULTR is a trip element unlatch condition. A circuit breaker status unlatch trip condition can be programmed as shown in the following examples.

Unlatch Trip With 52a Circuit Breaker Auxiliary Contact

A 52a circuit breaker auxiliary contact is wired to optoisolated input **IN101**.

52A = **IN101** (SELOGIC control equation circuit breaker status setting—see *Optoisolated Inputs on page 5.12*)

ULTR = **!52A**

Input **IN101** has to be de-energized (52a circuit breaker auxiliary contact has to be open) before the trip logic unlatches and the TRIP Relay Word bit deasserts to logical 0.

ULTR = **!52A = NOT(52A)**

Unlatch Trip With 52b Circuit Breaker Auxiliary Contact

A 52b circuit breaker auxiliary contact is wired to optoisolated input **IN101**.

52A = **!IN101**

(SELOGIC control equation circuit breaker status setting—see *Optoisolated Inputs on page 5.12*)

ULTR = **!52A**

Input **IN101** must be energized (52b circuit breaker auxiliary contact has to be closed) before the trip logic unlatches and the TRIP Relay Word bit deasserts to logical 0.

Program an Output Contact for Tripping

In the factory settings, the resultant of the trip logic in *Figure 4.3* is routed to output contact **OUT102** with the following SELOGIC control equation setting:

OUT102 = **TRIP**

The user can also route the trip logic to the high-current interrupting contacts **OUT201–OUT206**.

If more TRIP output contacts are needed, program other output contacts with the TRIP Relay Word bit. Examples of uses for additional TRIP output contacts:

- Keying an external breaker failure relay
- Keying communication equipment in a Direct Transfer Trip scheme

See *Output Contacts on page 5.21* for more information on programming output contacts.

Switch-Onto-Fault Trip Logic

Switch-Onto-Fault (SOTF) trip logic provides a programmable time window for selected elements to trip right after the circuit breaker closes. "Switch-onto-fault" implies that a circuit breaker is closed into an existing fault condition, such as when safety grounds are accidentally left attached to a line. If the circuit breaker is closed into such a condition, the resulting fault needs to be cleared right away. An instantaneous element is usually set to trip in the three-pole open (3PO) logic and the SOTF trip logic.

Refer to the switch-onto-fault trip logic in *Figure 4.3* (middle of figure). The SOTF trip logic permits tripping if both the following occur:

- ➤ An element asserts in SELOGIC control equation trip setting TRSOTF
- ➤ Relay Word bit SOTFE is asserted to logical 1

Relay Word bit SOTFE (the output of the SOTF logic) provides the effective time window for an element in trip setting TRSOTF (e.g., TRSOTF = 50P2) to trip after the circuit breaker closes. *Figure 4.4* and the following discussion describe the three-pole open (3PO) logic and the SOTF logic.

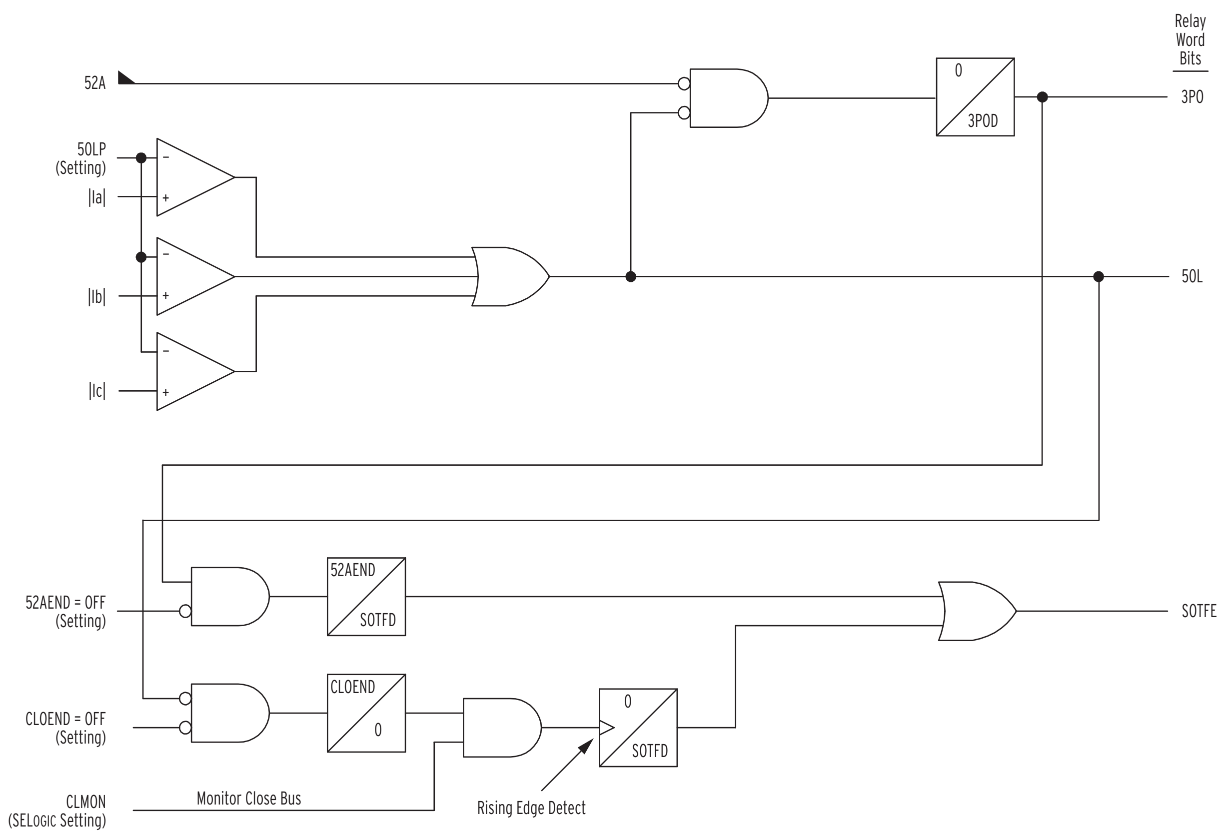


Figure 4.4 Three-Pole Open Logic (Top) and Switch-Onto-Fault Logic (Bottom)

Three-Pole Open Logic

Three-pole open (3PO) logic is the top half of *Figure 4.4*. It is not affected by enable setting ESOTF (see *SEL-311M Settings Sheets* following *Section 7: Settings*).

The open circuit breaker condition is determined by load current (50L) and circuit breaker status (52A = logical 0).

The 3POD dropout time qualifies circuit breaker closure, whether detected by circuit breaker status (52A) or load current level (50L). When the circuit breaker is closed:

3PO = **logical 0** (circuit breaker closed)

Determining Three-Pole Open Condition Without Circuit Breaker Auxiliary Contact

If a circuit breaker auxiliary contact is not connected to the SEL-311M, SELOGIC control equation setting 52A may be set:

52A = **0** (numeral 0)

With SELOGIC control equation setting 52A continually at logical 0, 3PO logic is controlled solely by load detection element 50L. Phase pickup 50LP is set below load current levels.

When the circuit breaker is open, Relay Word bit 50L drops out (= logical 0) and the 3PO condition asserts:

3PO = **logical 1** (circuit breaker open)

When the circuit breaker is closed, Relay Word bit 50L picks up (= logical 1; current above phase pickup 50LP) and the 3PO condition deasserts after the 3POD dropout time:

3PO = **logical 0** (circuit breaker closed)

Note that the 3PO condition is also routed to the permissive overreaching transfer trip (POTT) logic (see *Figure 4.7*), loss-of-potential (LOP) logic (see *Figure 3.32*), and line current differential protection logic (see *Figure 3.12* and *Figure 3.13*).

Circuit Breaker Operated Switch-Onto-Fault Logic

Circuit breaker operated switch-onto-fault logic is enabled by making time setting 52AEND (52AEND ≠ OFF) and enable setting ESOTF (ESOTF = Y). Time setting 52AEND qualifies the three-pole open (3PO) condition and then asserts Relay Word bit SOTFE:

SOTFE = **logical 1**

Note that SOTFE is asserted when the circuit breaker is open. This allows elements set in the SELOGIC control equation trip setting TRSOTF to operate if a fault occurs when the circuit breaker is open (see *Figure 4.3*). In such a scenario (e.g., flashover inside the circuit breaker tank), the tripping via setting TRSOTF cannot help in tripping the circuit breaker (the circuit breaker is already open), but can initiate breaker failure protection, if a breaker failure scheme is implemented in the SEL-311M or externally.

When the circuit breaker is closed, the 3PO condition deasserts (3PO = logical 0) after the 3POD dropout time (setting 3POD is usually set for no more than a cycle). The SOTF logic output, SOTFE, continues to remain asserted at logical 1 for dropout time SOTFD time.

Close Bus Operated Switch-Onto-Fault Logic

Close bus operated switch-onto-fault logic is enabled by making time setting CLOEND (CLOEND ≠ OFF). Time setting CLOEND qualifies the deassertion of the load detection element 50L (indicating that the circuit breaker is open).

Circuit breaker closure is detected by monitoring the dc close bus. This is accomplished by wiring an optoisolated input on the SEL-311M (e.g., **IN105**) to the dc close bus. When a manual close or automatic closure occurs, optoisolated input **IN105** is energized. SELOGIC control equation setting CLMON (close bus monitor) monitors the optoisolated input **IN105**:

CLMON = **IN105**

When optoisolated input **IN105** is energized, CLMON asserts to logical 1. At the instant that optoisolated input **IN105** is energized (close bus is energized), the circuit breaker is still open so the output of the CLOEND timer continues to be asserted to logical 1. Thus, the ANDed combination of these conditions latches in the SOTFD timer. The SOTFD timer outputs a logical 1 for a time duration of "SOTFD" cycles any time it sees a rising edge on its input (logical 0 to logical 1 transition), if it is not already timing. The SOTF logic output, SOTFE, asserts to logical 1 for SOTFD time.

Switch-Onto-Fault Logic Output (SOTFE)

Relay Word bit SOTFE is the output of the circuit breaker operated SOTF logic or the close bus operated SOTF logic described previously. Time setting SOTFD in each of these logic paths provides the effective time window for the instantaneous elements in SELOGIC control equation trip setting TRSOTF to trip after the circuit breaker closes (see *Figure 4.3*-middle of figure). Time setting SOTFD is usually set around 30 cycles.

Switch-Onto-Fault Trip Logic Trip Setting (TRSOTF)

An instantaneous element is usually set to trip in the SELOGIC control equation trip setting TRSOTF (e.g., TRSOTF = 50P1).

If the voltage potential for the relay is from the line-side of the circuit breaker, the instantaneous overcurrent element in the SELOGIC control equation trip setting TRSOTF should be nondirectional. When the circuit breaker is open and the line is de-energized, the relay sees zero voltage. If a close-in three-phase fault condition exists on the line (e.g., safety grounds accidentally left attached to the line after a clearance) and then the circuit breaker is closed, the relay continues to see zero voltage. The directional elements have no voltage for reference and cannot operate. In this case, the instantaneous overcurrent element in the SOTF trip logic should be nondirectional.

Communications-Assisted Trip Logic (General Overview)

The SEL-311M includes communications-assisted tripping schemes that provide unit-protection for transmission lines with the help of communications. No external coordination devices are required.

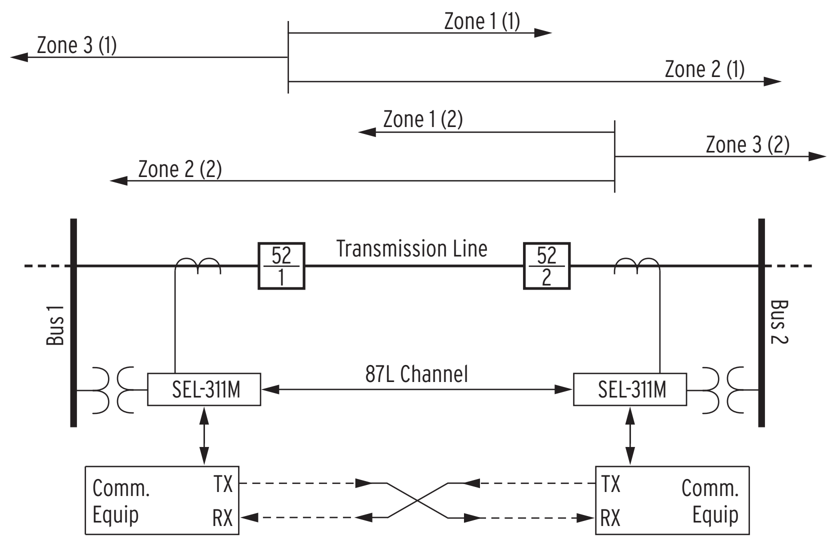


Figure 4.5 Communications-Assisted Tripping Scheme

Refer to *Figure 4.5* and the top half of *Figure 4.3*.

The six available tripping schemes are:

- Direct Transfer Trip (DTT)
- Direct Underreaching Transfer Trip (DUTT)
- Permissive Overreaching Transfer Trip (POTT)
- Permissive Underreaching Transfer Trip (PUTT)
- Directional Comparison Unblocking (DCUB)
- Directional Comparison Blocking (DCB)

Enable Setting ECOMM

The POTT, PUTT, DCUB, and DCB tripping schemes are enabled with enable setting ECOMM. Setting choices are:

ECOMM = **N** (no communications-assisted trip scheme enabled)

ECOMM = **POTT** (POTT or PUTT scheme)

ECOMM = **DCUB** (DCUB scheme for two-terminal line [communications from one remote terminal])

ECOMM = **DCB** (DCB scheme)

These tripping schemes can all work in two-terminal line applications.

In most cases, these tripping schemes require Zone/Level 3 elements set direction reverse (setting DIR3 = R); see *Figure 4.5*. Note that Zone 1 and Zone 2 are fixed in the forward direction.

See *Directional Control Settings on page 3.72* for more information on Zone/Level direction settings DIR3 and DIR4.

POTT, PUTT, DCUB, and DCB communications-assisted tripping schemes are explained in subsections that follow.

Use MIRRORED BITS® communications to implement any of these tripping schemes efficiently and economically. MIRRORED BITS technology is generally used with either POTT or DCUB tripping schemes. If the communications channel is reliable and noise-free, e.g. dark fiber, then POTT gives unsurpassed security and very good dependability. If the communications channel is less than perfect, but communications channel failures are not likely to be coincident with external faults, then DCUB gives a very good combination of security and dependability.

Trip Setting TRCOMM

The POTT, PUTT, DCUB, and DCB tripping schemes use SELOGIC control equation trip setting TRCOMM for those tripping elements that are supervised by the communications-assisted trip logic (see top half of *Figure 4.3*).

Trip Settings TRSOTF and TR

In a communications-assisted trip scheme, the SELOGIC control equation trip settings TRSOTF and TR can also be used, in addition to setting TRCOMM.

Setting TRSOTF can be set as described in *Switch-Onto-Fault Trip Logic on page 4.8*.

Setting TR is typically set with unsupervised Level 1 underreaching elements (fixed direction forward):

67NG1 Level 1 directional ground instantaneous overcurrent element

67Q1 Level 1 directional negative-sequence instantaneous overcurrent element

and other time-delayed elements (e.g., Level 2 definite-time overcurrent elements).

Trip Setting DTT

The DTT and DUTT tripping schemes are realized with SELOGIC control equation trip setting DTT, discussed at the beginning of this section.

Use Existing SEL-321 Relay Application Guides for the SEL-311M Relay

The communications-assisted tripping schemes settings in the SEL-311M are very similar to those in the SEL-321 Relay. Existing SEL-321 application guides can also be used in setting up these schemes in the SEL-311M. The following application guides are available from SEL:

AG93-06 Applying the SEL-321 Relay to Directional Comparison Blocking (DCB) Schemes

AG95-29 Applying the SEL-321 Relay to Permissive Overreaching Transfer Trip (POTT) Schemes

AG96-19 Applying the SEL-321 Relay to Directional Comparison Unblocking (DCUB) Schemes

The major differences are how the optoisolated input settings and the trip settings are made. The following explanations describe these differences.

Permissive Overreaching Transfer Trip Logic

Enable the Permissive Overreaching Transfer Trip (POTT) logic by setting ECOMM = POTT. The POTT logic in *Figure 4.7* is also enabled for directional comparison unblocking schemes (ECOMM = DCUB). The POTT logic performs the following tasks:

- Keys communication equipment to send permissive trip when any element included in the SELOGIC control equation communications-assisted trip equation TRCOMM asserts and the current reversal logic is not asserted.
- Prevents keying and tripping by the POTT logic following a current reversal.
- Echoes the received permissive signal to the remote terminal.
- Prevents channel lockup during echo and test.
- Provides a secure means of tripping for weak- and/or zero-infeed line terminals.

Use Existing SEL-321 Relay POTT Application Guide for the SEL-311M

Use the existing SEL-321 POTT application guide (AG95-29) to help set up the SEL-311M in a POTT scheme (see *Communications-Assisted Trip Logic (General Overview) on page 4.11* for more setting comparison information on the SEL-321/SEL-311M Relays).

External Inputs

See *Optoisolated Inputs on page 5.12* for more information on optoisolated inputs.

PT—Received Permissive Trip Signal(s)

In two-terminal line POTT applications, a permissive trip signal is received from one remote terminal. One optoisolated input on the SEL-311M (e.g., input **IN104**) is driven by a communications equipment receiver output (see *Figure 4.9*). Make SELOGIC control equation setting PT:

PT = **IN104** (two-terminal line application)

SELOGIC control equation setting PT in *Figure 4.6* is routed to control Relay Word bit PT if enable setting ECOMM = POTT. Relay Word bit PT is then an input into the POTT logic in *Figure 4.7* (for echo keying).

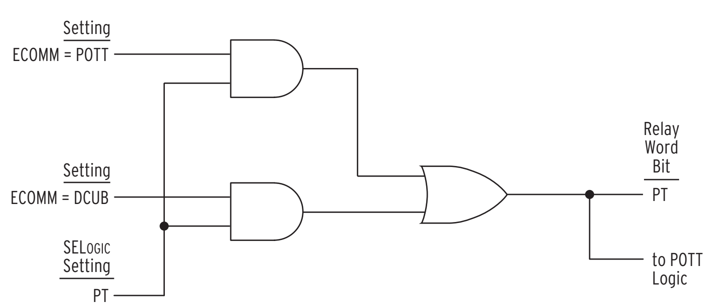


Figure 4.6 Permissive Input Logic Routing to POTT Logic

Also note that SELOGIC control equation setting PT is routed to control Relay Word bit PTRX in *Figure 4.8* if enable setting ECOMM = POTT. Relay Word bit PTRX is the permissive trip receive input into the trip logic in *Figure 4.3*.

Timer Settings

See *Section 7: Settings* for setting ranges.

Z3RBD—Zone (Level) 3 Reverse Block Delay

Current-reversal guard timer-typically set at 5 cycles.

EBLKD—Echo Block Delay

Prevents echoing of received PT for settable delay after dropout of local permissive elements in trip setting TRCOMM-typically set at 10 cycles. Set to OFF to defeat EBLKD.

ETDPU—Echo Time Delay Pickup

Sets minimum time requirement for received PT, before echo begins—typically set at 2 cycles. Set to OFF for no echo.

EDURD—Echo Duration

Limits echo duration, to prevent channel lockup—typically set at 4.0 cycles.

Logic Outputs

The following logic outputs can be tested by assigning them to output contacts. See *Output Contacts on page 5.21* for more information on output contacts.

Z3RB—Zone (Level) 3 Reverse Block

Current-reversal guard asserted (operates as an input into the trip logic in *Figure 4.3* and the DCUB logic in *Figure 4.10*).

ECTT—Echo Conversion to Trip

PT received, converted to a trip condition for a Weak-Infeed Condition (operates as an input into the trip logic in *Figure 4.3*).

Weak-Infeed Logic and Settings

In some applications, with all sources in service, one terminal may not contribute enough fault current to operate the protective elements. If the fault lies within the Zone 1 reach of the strong terminal, the fault currents may redistribute after the strong terminal line breaker opens to permit sequential tripping of the weak-infeed terminal line breaker. If currents do not redistribute sufficiently to operate the protective elements at the weak-infeed terminal, it is still desirable to open the local breaker. This prevents the low-level currents from maintaining the fault arc. When the fault location is near the weak terminal, the Zone 1 elements of the strong terminal do not pick up, and the fault is not cleared rapidly. This is because the weak terminal protective elements do not operate. Note that while the weak-infeed terminal contributes little fault current, the phase voltage(s) are depressed.

SEL-311M Weak-Infeed Logic

Enable the weak-infeed logic by setting EWFC = Y.

The SEL-311M provides additional logic (see *Figure 4.7*) for weak-infeed terminals to permit rapid tripping of both line terminals for internal faults near the weak terminal. The strong terminal is permitted to trip via the permissive signal echoed back from the weak terminal. The weak-infeed logic generates a trip at the weak terminal if all of the following are true:

- A permissive trip (PT) signal is received for ETDPU time.
- A phase undervoltage or ground overvoltage element is picked up.
- No reverse-looking elements are picked up.
- The circuit breaker is closed.

After these four conditions are met, the weak-infeed logic sets the Echo-Conversion-To-Trip (ECTT) bit in the Relay Word. The ECTT bit is included in the trip logic (see *Figure 4.3*) and a trip signal is issued to the local breaker when the conditions described above are true.

Typical phase undervoltage setting (27PP1P) is 70–80 percent of the lowest expected system operating voltage. The ground overvoltage setting should be set to approximately twice the expected standing $3V_0$ voltage. With the 59N1 element set at twice the nominal standing $3V_0$ voltage, the instrument measures only fault-induced zero-sequence voltage.

KEY—Key Permissive Trip

Signals communications equipment to transmit permissive trip. For example, SELOGIC control equation setting OUT105 is set:

OUT105 = **KEY**

Output contact **OUT105** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 4.9*).

EKEY—Echo Key Permissive Trip

Permissive trip signal keyed by Echo logic (used in testing).

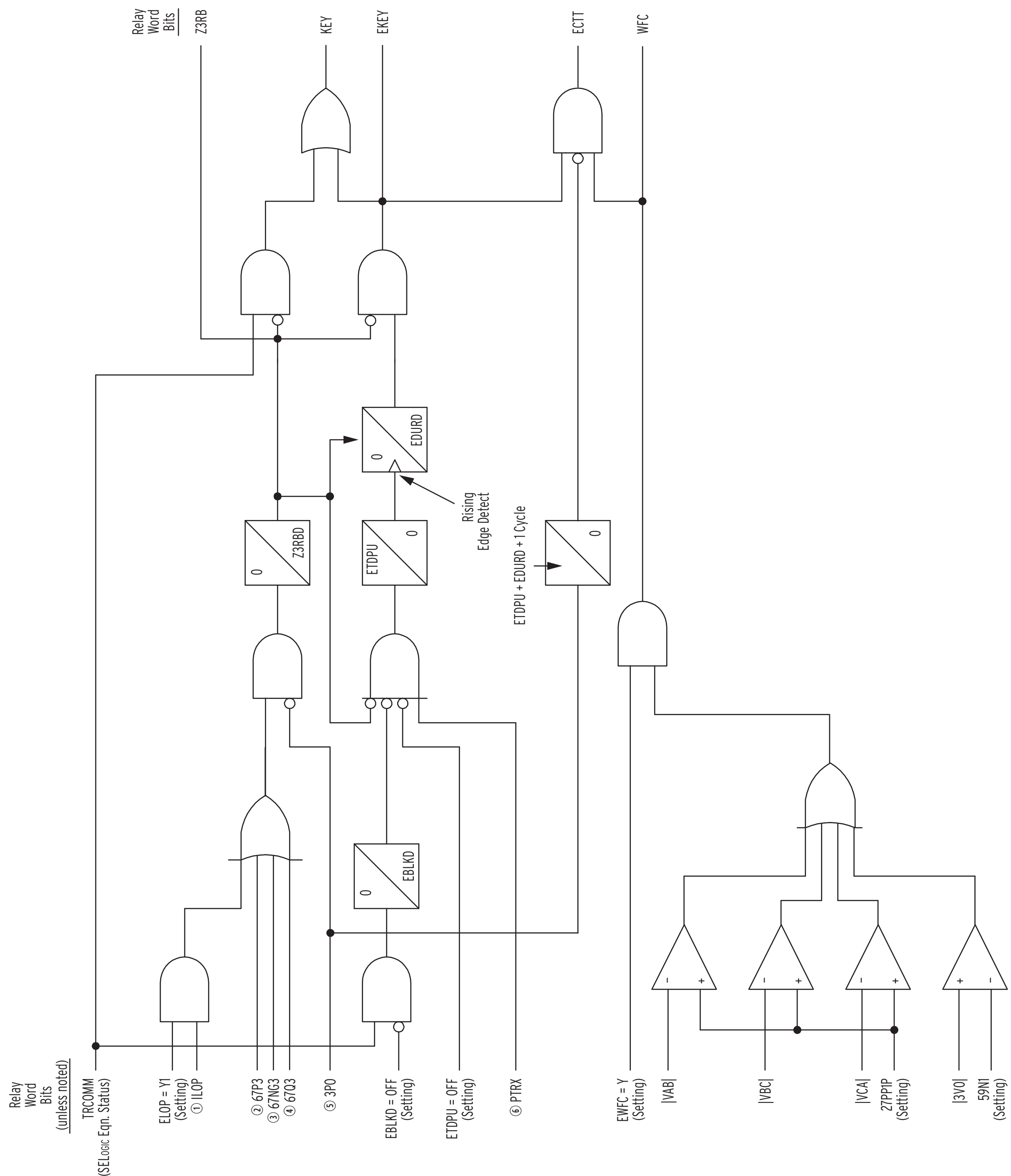


Figure 4.7 POTT Logic

① From Figure 3.32 ② from Figure 3.14; ③ from Figure 3.17; ④ from Figure 3.18; ⑤ from Figure 4.4; ⑥ from Figure 4.8

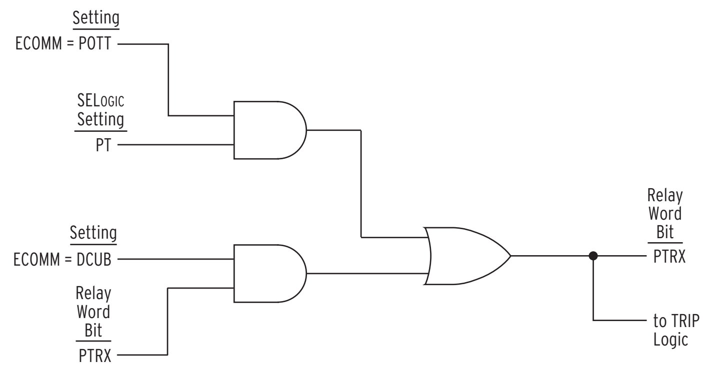


Figure 4.8 Permissive Input Logic Routing to Trip Logic

Variations for Permissive Underreaching Transfer Trip (PUTT) Scheme

Refer to *Figure 4.5* and *Figure 4.7*. In a PUTT scheme, keying is provided by Level 1 underreaching elements (fixed direction forward), instead of with Relay Word bit KEY. This is accomplished by setting the output contact used to key permissive trip, **OUT105** for example, with these elements:

67NG1 Zone 1 directional ground instantaneous overcurrent element

67Q1 Zone 1 directional negative-sequence instantaneous overcurrent element

instead of with element KEY (see *Figure 4.9*):

OUT105 = **67NG1 + 67Q1** (Note: only use enabled elements)

If echo keying is desired, add the echo key permissive trip logic output, as follows:

OUT105 = **67NG1 + 67Q1 + EKEY**

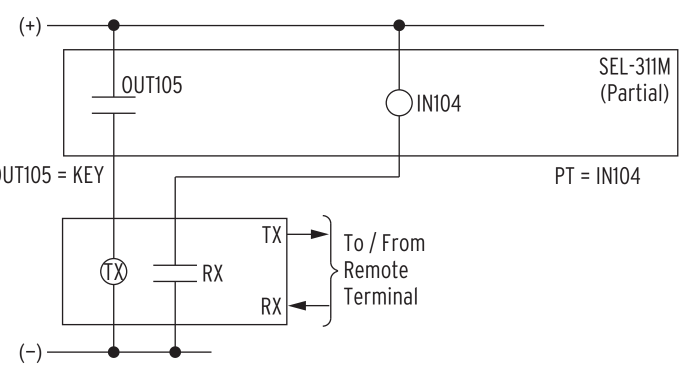


Figure 4.9 SEL-311M Connections to Communications Equipment for a Two-Terminal Line POTT Scheme

Directional Comparison Unblocking Logic

Enable the Directional Comparison Unblocking (DCUB) logic by setting ECOMM = DCUB (directional comparison unblocking scheme for two-terminal line—communications from **one** remote terminal). The DCUB logic in *Figure 4.10* is an extension of the POTT logic in *Figure 4.7*. Thus, the relay requires all the POTT settings and logic, plus settings and logic exclusive to DCUB.

The DCUB logic in *Figure 4.10* takes in the loss-of-guard and permissive trip outputs from the communications receivers (see *Figure 4.11*) and makes permissive (PTRX) and unblocking block (UBB) logic output decisions.

Use Existing SEL-321 DCUB Application Guide for the SEL-311M

Use the existing SEL-321 DCUB application guide (AG96-19) to help set up the SEL-311M in a DCUB scheme (see *Communications-Assisted Trip Logic (General Overview) on page 4.11* for more setting comparison information on the SEL-321/SEL-311ML Relays).

External Inputs

See *Optoisolated Inputs on page 5.12* for more information on optoisolated inputs.

PT—Received Permissive Trip Signal

In two-terminal line DCUB applications (setting ECOMM = DCUB), a permissive trip signal is received from **one** remote terminal. One optoisolated input on the SEL-311M (e.g., input **IN104**) is driven by a communications equipment receiver output (see *Figure 4.11*). Make SELOGIC control equation setting PT:

PT = **IN104** (two-terminal line application)

SELOGIC control equation setting PT is routed into the DCUB logic in *Figure 4.10* for “unblocking block” and “permissive trip receive” logic decisions.

As explained in *Permissive Overreaching Transfer Trip Logic on page 4.13*, the SELOGIC control equation setting PT in *Figure 4.6* is routed in various combinations to control Relay Word bit PT, depending on enable setting ECOMM = DCUB. Relay Word bit PT is then an input into the POTT logic in *Figure 4.7* (for echo keying).

LOG—Loss-of-Guard Signal(s)

In two-terminal line DCUB applications (setting ECOMM = DCUB), a loss-of-guard signal is received from one remote terminal. One optoisolated input on the SEL-311M (e.g., input **IN105**) is driven by a communications equipment receiver output (see *Figure 4.11*). Make SELOGIC control equation setting LOG:

LOG = **IN105** (two-terminal line application)

SELOGIC control equation setting LOG is routed into the DCUB logic in *Figure 4.10* for “unblocking block” and “permissive trip receive” logic decisions.

Timer Settings

See *Section 7: Settings* for setting ranges.

GARD1D—Guard-Present Delay

Sets minimum time requirement for reinstating permissive tripping following a loss-of-channel condition-typically set at 10 cycles.

UBDURD—DCUB Disable Delay

Prevents tripping by POTT logic after a settable time following a loss-of-channel condition—typically set at 9 cycles (150 ms).

UBEND—DCUB Duration Delay

Sets minimum time required to declare a loss-of-channel condition—typically set at 0.5 cycles.

Logic Outputs

The following logic outputs can be tested by assigning them to output contacts. See *Output Contacts on page 5.21* for more information on output contacts.

UBB—Unblocking Block Output(s)

In two-terminal line DCUB applications (setting ECOMM = DCUB), UBB disables tripping if the loss-of-channel condition continues for longer than time UBDURD.

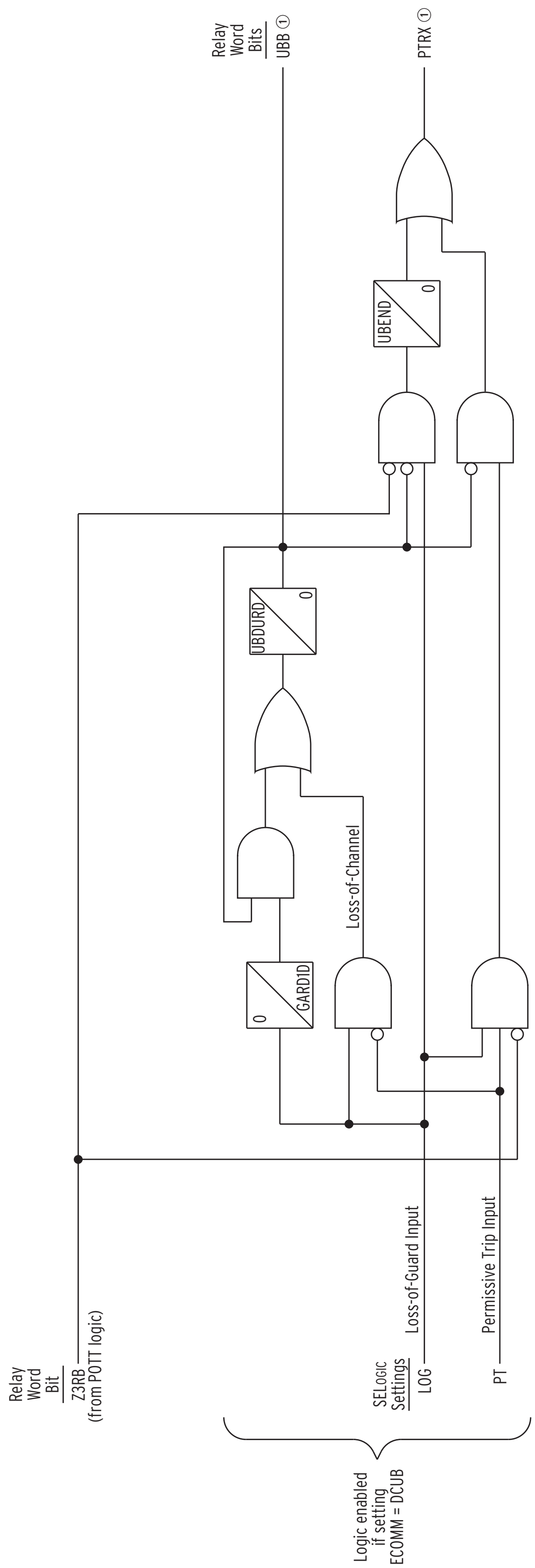


Figure 4.10 DCUB Logic
① To Figure 4.3

PTRX—Permissive Trip Receive Output

In two-terminal line DCUB applications (setting ECOMM = DCUB), PTRX asserts for loss-of-channel or an actual received permissive trip.

The PTRX Relay Word bit is then routed in various combinations in *Figure 4.8* to control Relay Word bit PTRX, depending on enable setting ECOMM. Relay Word bit PTRX is the permissive trip receive input into the trip logic in *Figure 4.3*.

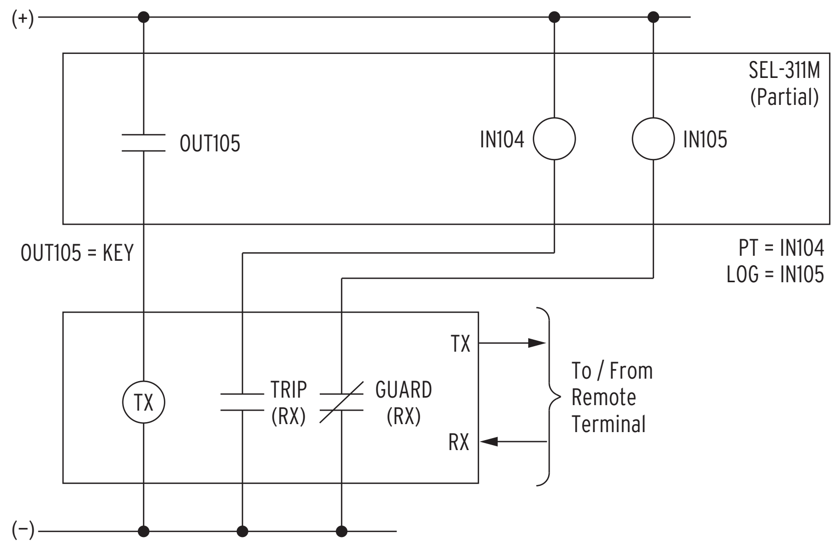


Figure 4.11 SEL-311M Connections to Communications Equipment for a Two-Terminal Line DCUB Scheme (Setting ECOMM = DCUB)

Directional Comparison Blocking Logic

Enable the Directional Comparison Blocking (DCB) logic by setting ECOMM = DCB. The DCB logic in *Figure 4.12* performs the following tasks:

➤ Provides the individual carrier coordination timers for the Level 2 directional elements 67NG2 and 67Q2 Relay Word bits. These delays allow time for the block trip signal to arrive from the remote terminal. For example:

TRCOMM = **672S**

➤ Instantaneously keys the communications equipment to transmit block trip for reverse faults and extends this signal for a settable time following the dropout of all Level 3 directional elements (67NG3 and 67Q3).

➤ Latches the block trip send condition by the directional overcurrent following a close-in zero-voltage three-phase fault where the polarizing memory expires. Latch is removed when the polarizing memory voltage returns or current is removed.

➤ Extends the received block signal by a settable time.

Use Existing SEL-321 DCB Application Guide for the SEL-311M

Use the existing SEL-321 DCB application guide (AG93-06) to help set up the SEL-311M in a DCB scheme (see *Communications-Assisted Trip Logic (General Overview) on page 4.11* for more setting comparison information on the SEL-321/SEL-311M Relays).

External Inputs

See *Optoisolated Inputs on page 5.12* for more information on optoisolated inputs.

BT–Received Block Trip Signal(s)

In two-terminal line DCB applications, a block trip signal is received from one remote terminal. One optoisolated input on the SEL-311M (e.g., input **IN104**) is driven by a communications equipment receiver output (see *Figure 4.13*). Make SELOGIC control equation setting BT:

BT = **IN104** (two-terminal line application)

SELOGIC control equation setting BT is routed through a dropout timer (BTXD) in the DCB logic in *Figure 4.12*. The timer output, Relay Word bit BTX, is routed to the trip logic in *Figure 4.3*.

Timer Settings

See *Section 7: Settings* for setting ranges.

Z3XPU–Zone (Level) 3 Reverse Pickup Time Delay

Current-reversal guard pickup timer—typically set at 2 cycles.

Z3XD–Zone (Level) 3 Reverse Dropout Extension

Current-reversal guard dropout timer—typically set at 5 cycles.

BTXD–Block Trip Receive Extension

Sets reset time of block trip received condition (BTX) after the reset of block trip input BT.

21SD and 67SD–Zone 2 Short Delay

Carrier coordination delays for the output of Zone 2 overreaching element 67SD are typically set at 1 to 2 cycles.

Logic Outputs

The following logic outputs can be tested by assigning them to output contacts. See *Output Contacts on page 5.21* for more information on output contacts.

DSTRT–Directional Carrier Start

Program an output contact for directional carrier start. For example, SELOGIC control equation setting OUT105 is set:

OUT105 = **DSTRT**

Output contact **OUT105** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 4.13*).

DSTART includes current reversal guard logic.

NSTRT—Nondirectional Carrier Start

Program an output contact to include nondirectional carrier start, in addition to directional start. For example, SELOGIC control equation setting OUT105 is set:

OUT105 = **DSTRT + NSTRT**

Output contact **OUT105** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 4.13*).

STOP—Stop Carrier

Program to an output contact to stop carrier. For example, SELOGIC control equation setting OUT106 is set:

OUT106 = **STOP**

Output contact **OUT106** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 4.13*).

BTX—Block Trip Extension

The received block trip input (e.g., BT = IN104) is routed through a dropout timer (BTXD) in the DCB logic in *Figure 4.12*. The timer output (BTX) is routed to the trip logic in *Figure 4.3*.

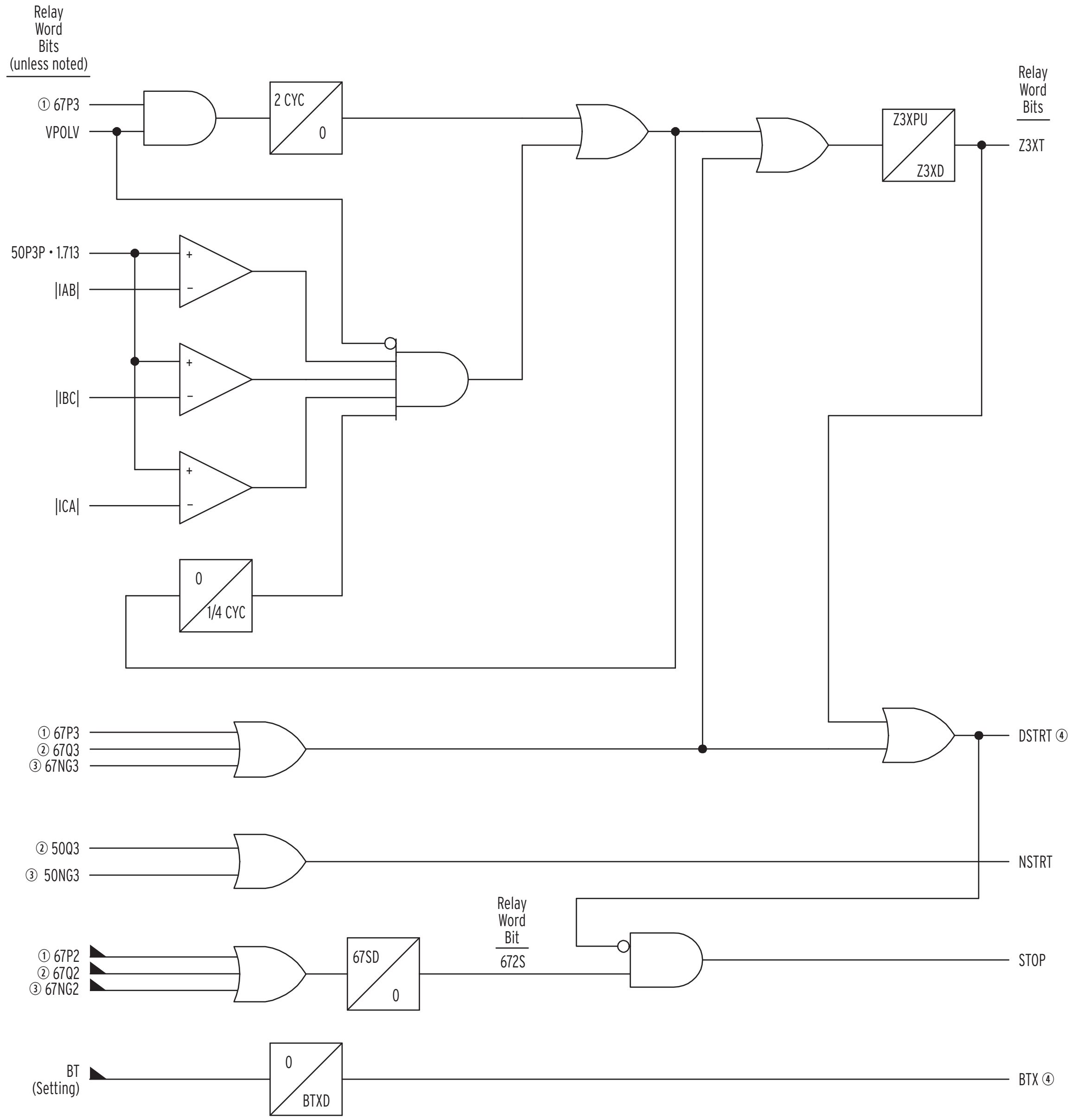


Figure 4.12 DCB Logic

① FromFigure 3.14; ② from Figure 3.25; ③ from Figure 3.21; ④ to Figure 4.3

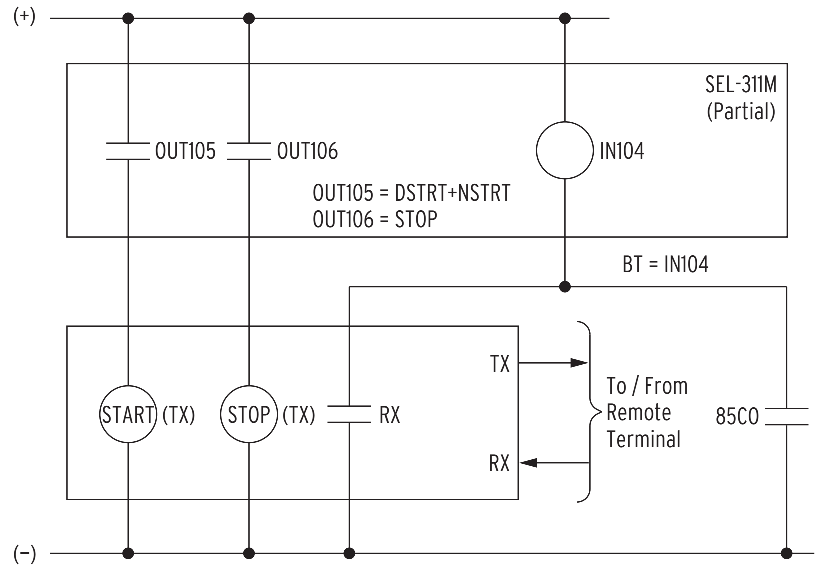


Figure 4.13 SEL-311M Connections to Communications Equipment for a Two-Terminal Line DCB Scheme

Close Logic

The close logic in *Figure 4.14* provides flexible circuit breaker closing with SELOGIC control equation settings:

52A (breaker status)

CL (close conditions)

ULCL (unlatch close conditions, other than circuit breaker status, or close failure)

and setting:

CFD (Close Failure Time)

See the settings sheet in *Section 7: Settings* for setting ranges.

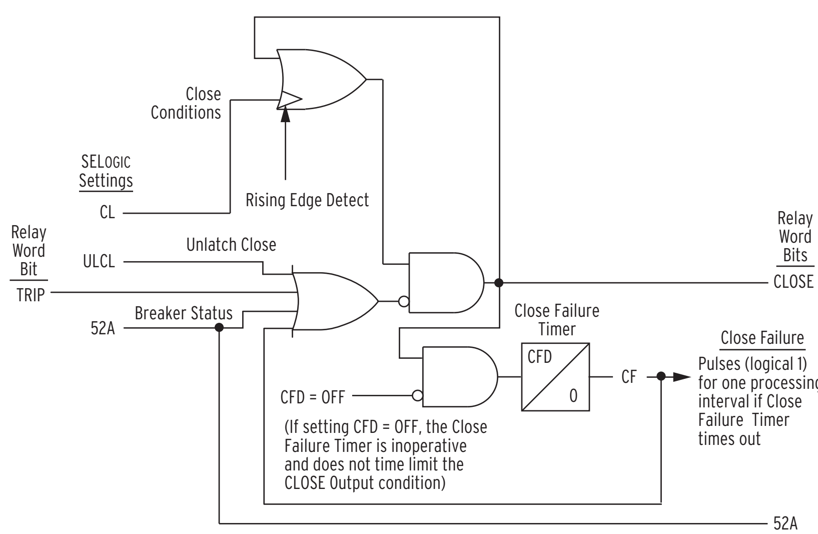


Figure 4.14 Close Logic

Set Close

If all the following are true:

- ➤ The unlatch close condition is not asserted (ULCL = logical 0).
- ➤ The circuit breaker is open (52A = logical 0).
- ➤ Relay Word bit TRIP is not asserted (TRIP = logical 0).

Then the CLOSE Relay Word bit can be asserted to logical 1 if SELOGIC control equation setting CL goes from logical 0 to logical 1 (rising edge transition).

The **CLOSE** command is the only value in the close logic in the factory default settings:

CL = **CC**

Relay Word bit CC asserts for execution of the **CLOSE** Command. See *CLO Command (Close Breaker) on page 8.43* for more information on the **CLOSE** Command. More discussion follows later on the factory settings for setting CL.

If you want to supervise the **CLOSE** command with optoisolated input **IN106**, the following addition is made:

CL = **CC * IN106**

With this setting, the **CLOSE** command can provide a close only if optoisolated input **IN106** is asserted. This is just one **CLOSE** command supervision example-many variations and additional conditions may be incorporated.

Unlatch Close

If the CLOSE Relay Word bit is asserted, it stays asserted until one of the following occurs:

- ➤ The unlatch close condition asserts (ULCL = logical 1).
- ➤ The circuit breaker closes (52A = logical 1).
- ➤ Relay Word bit TRIP asserts (TRIP = logical 1).

The Close Failure Timer is inoperative if setting CFD = OFF.

Factory Settings Example

The factory settings for the close logic SELOGIC control equation settings are:

52A = **IN101**

CL = **CC**

ULCL = **TRIP + TRIP87**

The factory setting for the Close Failure Timer setting is:

CFD = **60.00 cycles**

See the settings sheets at the end of *Section 7: Settings* for setting ranges.

Set Close

The SELOGIC control equation setting CL is the only logic input that can set the CLOSE Relay Word bit.

In SELOGIC control equation setting CL = CC, Relay Word bit CC asserts for execution of the **CLOSE** Command. See *CLO Command (Close Breaker) on page 8.43* for more information on the **CLOSE** Command.

Unlatch Close

SELOGIC control equation setting ULCL has a default of TRIP + TRIP87. This prevents the CLOSE Relay Word bit from being asserted any time the TRIP or TRIP87 Relay Word bits are asserted. See *Figure 4.3*.

SELOGIC control equation setting 52A is set with optoisolated input **IN101**. Input **IN101** is connected to a 52a circuit breaker auxiliary contact. When a closed circuit breaker condition is detected, the CLOSE Relay Word bit is deasserted to logical 0. Setting 52A can handle a 52a or 52b circuit breaker auxiliary contact connected to an optoisolated input (see *Optoisolated Inputs on page 5.12* for more 52A setting examples).

With setting CFD = 60.00 cycles, once the CLOSE Relay Word bit asserts, it remains asserted at logical 1 no longer than a maximum of 60 cycles. If the Close Failure Timer times out, Relay Word bit CF asserts to logical 1, forcing the CLOSE Relay Word bit to logical 0 (opening output 103 with the default setting OUT103 = CLOSE).

Defeat the Close Logic

If SELOGIC control equation circuit breaker auxiliary setting 52A is set with numeral 0 (52A = 0), then the close logic is inoperable.

Circuit Breaker Status

Refer to the bottom of *Figure 4.14*. Note that SELOGIC control equation setting 52A (circuit breaker status) is available as Relay Word bit 52A. This makes it convenient to set other SELOGIC control equations. For example, if the following setting is made:

52A = **IN101** (52a auxiliary contact wired to input **IN101**)

or

52A = **!IN101** (52b auxiliary contact wired to input **IN101**)

then if breaker status is used in other SELOGIC control equations, it can be entered as 52A—you do not have to enter IN101 (for a 52a) or !IN101 (for a 52b). For example, refer to *Rotating Default Display on page 5.25*. If circuit breaker status indication is controlled by display point setting DP2:

DP2 = **IN101**

This can be entered instead as:

DP2 = **52A**

(presuming SELOGIC control equation setting 52A = IN101 is made).

Program an Output Contact for Closing

In the factory settings, the resultant of the close logic in *Figure 4.14* is routed to output contact **OUT103** with the following SELOGIC control equation:

OUT103 = **CLOSE**

See *Output Contacts on page 5.21* for more information on programming output contacts.

Front-Panel Target LEDs

The SEL-311M front-panel target LEDs are divided into three categories as shown in *Table 4.1*:

- Status target LEDs
- SELOGIC control equation target LEDs
- Fault type target LEDs

Table 4.1 SEL-311M Front-Panel Target LED Definitions

LED Number	LED Label	Definition	Category
1	EN	Relay Enabled—see *Relay Self-Tests on page 11.15*	Status
2	TRIP	Indication that a trip occurred, by any of the protection or control elements	SELOGIC Control Equation
3	TIME	Time-delayed trip	
4	COMM	Communications-assisted trip (not 87L or 87W)	
5	87	Trip caused by line current differential element or 87L DTT bit or 87WF	
6	50/51	Instantaneous/time-overcurrent trip	
7	27	Undervoltage trip	
8	59	Overvoltage trip	
9	A	Phase A involved in the fault	Fault Type
10	B	Phase B involved in the fault	
11	C	Phase C involved in the fault	
12	G	Ground involved in the fault	
13	32	Directional power trip	SELOGIC Control Equation
14	81	Frequency trip	
15	25	Synchronism	
16	87CH FAIL	Line current differential channel failure	

Refer also to *Figure 2.2* for the placement of the target LEDs on the front panel.

SELOGIC Control Equation Target LED Information

SELOGIC control equations control LEDs 2–8 and 13–16 (see Settings Sheet 18 of 28 in *Section 7: Settings*). Use the **SHO L** command to view the default settings associated with LEDs 2–8 and 13–16. The following descriptions of the SELOGIC control equation target LEDs are for the factory default settings. An example of changing the factory default settings is provided later in this section.

TRIP Target LED

The **TRIP** target LED illuminates at the rising edge of the TRIP Relay Word bit and latches with factory default settings.

TIME Target LED

The **TIME** target LED illuminates at the rising edge of trip if SELOGIC control equation setting FAULT has been asserted for more than 3 cycles as indicated by the assertion of TFLT Relay Word bit. FAULT is usually set with time-overcurrent element pickups (e.g., FAULT = 51NG + 51Q) to detect fault inception. If tripping occurs more than 3 cycles after fault inception, the **TIME** target illuminates and latches.

SELOGIC control equation setting FAULT also controls maximum/minimum metering. If FAULT is asserted, maximum/minimum metering is blocked (see *Local Maximum/Minimum Metering on page 6.9*). Fault current values are not accrued as maximum current values in maximum/minimum metering.

COMM Target LED

The **COMM** target LED illuminates and latches at the rising edge of trip if the trip is the result of communications-assisted trip logic as indicated by Relay Word bit COMMT (see *Figure 4.3*, top half of figure).

Another Application for the COMM Target LED

If none of the traditional communications-assisted trip logic is used (i.e., SELOGIC control equation setting TRCOMM is not used), consideration can be given to using the **COMM** target LED to indicate tripping via remote communications channels (e.g., via serial port commands or SCADA asserting optoisolated inputs). Use SELOGIC control equation setting DTT (Direct Transfer Trip) to accomplish this (see *Figure 4.3*).

For example, if either the **OPEN** command or remote bit RB1 (see *CON Command (Control Remote Bit) on page 8.45*) is used to trip via the serial port and they should illuminate the **COMM** target LED, set them in SELOGIC control equation setting DTT:

DTT = **... + OC + RB1**

Additionally, if SCADA asserts optoisolated input **IN104** to trip and it should illuminate the **COMM** target LED, set it in SELOGIC control equation setting DTT also:

DTT = **... + IN104 + ...**

Relay Word bits set in SELOGIC control equation setting DTT do not have to be set in SELOGIC control equation setting TR—both settings directly assert the TRIP Relay Word bit. The only difference between settings DTT and TR is that setting DTT causes the **COMM** target LED to illuminate.

Many other variations of the above DTT settings examples are possible.

50/51 Target LED

The **50/51** target LED illuminates and latches at the rising edge of trip when any overcurrent element in the SELOGIC control equation LED_50_51 is asserted.

27 Target LED

The **27** target LED illuminates and latches at the assertion of Relay Word bit 3P27 if the breaker is not open as indicated by Relay Word bit 3PO.

59 Target LED

The **59** target LED illuminates and latches at the assertion of Relay Word bit 3P59.

32 Target LED

The **32** target LED illuminates and latches at the rising edge of trip when any three-phase directional power element (see *Power Elements on page 3.53*) is asserted.

81 Target LED

The **81** target LED illuminates and latches at the rising edge of trip when any frequency element (see *Frequency Elements on page 3.49*) is asserted.

25 Target LED

The **25** target LED illuminates if either or both synchronism check element 25A1 and synchronism check element 25A2 assert and the local 3PO is asserted.

87CH FAIL LED

The **87CH FAIL** LED illuminates when the relay detects a problem with any active 87L Communications Channel. See *Section 8: Communications* for more information about the **87CH FAIL** LED.

FAULT TYPE Target LEDs

A, B, and C Target LEDs

The **A** (Phase A) target LED illuminates solid at the rising edge of trip if a protection element causes the trip and Phase A is involved in the fault (likewise for the **B** [Phase B] and **C** [Phase C] target LEDs). The **A**, **B**, or **C** target LEDs blink in one-half second intervals if PNSA, PNSB, or PNSC (respectively) assert and a rising edge of trip does not occur.

G Target LED

The **G** target LED illuminates solid at the rising edge of trip if ground is involved in the fault. The **G** target LED blinks in one-half second intervals if PNSA, PNSB, or PNSC assert and a rising edge of trip does not occur.

A solid illumination of the **A**, **B**, **C**, or **G** target LEDs has priority over blinking. For example, the relay trips the breaker for a fault condition and the **TRIP**, **A**, and **B** LEDs solidly illuminate indicating a phase-phase fault. The fault condition is cleared and the breaker closed without resetting the front-panel LEDs via the **{TARGET RESET/LAMP TEST}** front-panel pushbutton or the **TAR R** command via the serial port. After the breaker is closed, C-phase becomes grounded causing Relay Word bit PNSC to assert. The relay front-panel **C** and **G** LEDs will begin to blink in one-half second intervals with **A**, **B**, and **TRIP** LEDs solidly asserted (from the previous fault).

Target Reset/Lamp Test Front-Panel Pushbutton

When the **{TARGET RESET/LAMP TEST}** front-panel pushbutton is pressed:

➤ All front-panel LEDs illuminate for one (1) second.

➤ All latched target LEDs (target LEDs numbered 2–6 and 13–14 in *Table 4.1*) are extinguished (unlatched).

Other Applications for the Target Reset Function

Refer to the bottom of *Figure 4.3*. The combination of the **{TARGET RESET}** pushbutton and the **TAR R** (Target Reset) serial port command is available as Relay Word bit TRGTR. Relay Word bit TRGTR pulses to logical 1 for one processing interval when either the **{TARGET RESET}** pushbutton is pushed or the **TAR R** (Target Reset) serial port command is executed.

Relay Word bit TRGTR can be used to unlatch logic. If a breaker failure trip occurs (SV7T asserts), the occurrence can be displayed on the front panel with seal-in logic and a rotating default display (see *Rotating Default Display on page 5.25* and *Rotating Default Display on page 9.8*):

SV8 = **(SV8 + SV7T) * !TRGTR**

DP3 = **SV8**

DP3_1 = **BREAKER FAILURE**

DP3_0 = **(blank)**

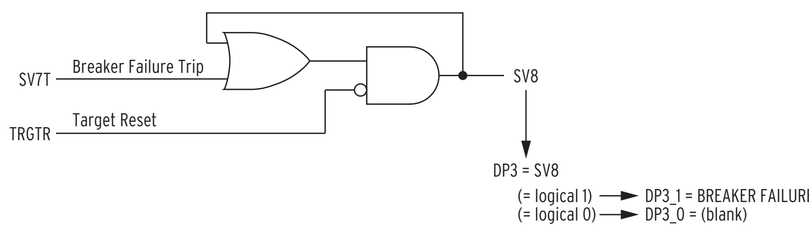
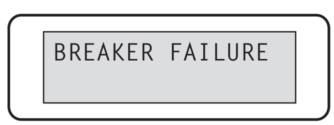


Figure 4.15 Seal-in of Breaker Failure Occurrence for Message Display

If a breaker failure trip has occurred, the momentary assertion of SV7T (breaker failure trip) will cause SV8 in *Figure 4.15* to seal in. Asserted SV8 in turn asserts DP3, causing the message:



to display in the rotating default display.

This message can be removed from the display rotation by pushing the **{TARGET RESET}** pushbutton (Relay Word bit TRGTR pulses to logical 1, unlatching SV8 and in turn deasserting DP3). Thus, front-panel rotating default displays can be easily reset along with the front-panel targets by pushing the **{TARGET RESET}** pushbutton.

Changing Factory Settings Example

The factory setting for the 59 SELOGIC control equation target LED is:

LED_59 = **(3P59 + 59) * !TRGTR**

Relay Word bit TRGTR is used to unlatch the logic. Relay Word bit 59 is used to latch the logic.

If you wanted to change the target **59** LED to indicate if any phase-voltage experienced an overvoltage condition. For this example we will assume that PT nominal voltage setting (VNOM) is 120 and we are using the Level 2 phase overvoltage elements and want the **59** LED to illuminate if any phase voltage exceeds 125% of nominal voltage.

59P2P = **125% • 120** (nominal voltage)

59P2P = **150**

if A-, B-, or C-phase voltage exceeds 150 V then 59A2, 59B2, or 59C2 assert, respectively.

LED_59 = **(59A2 + 59B2 +59C2 + 59) * !TRGTR**

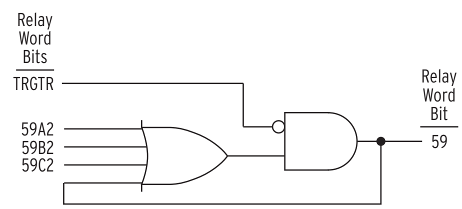


Figure 4.16 Seal-in of Overvoltage Occurrence

If an overvoltage condition occurs on any phase that exceeds 150 V, the **59** SELOGIC control equation target LED asserts and latches.

Section 5

SELOGIC Control Equation Programming

Overview

Functions use operands (inputs) and operators to generate outputs. Complex functions are created by using the outputs of several functions as operands in the new function.

Embedded relay functions such as protection elements, tripping and closing logic, and event report triggering use logic built into the SEL-311M. In some cases, these embedded functions can be customized because they include SELOGIC® control equations as inputs. The outputs of these functions and equations are generally made available as Relay Word bits. Each function and equation is discussed in the appropriate protection, control, and monitoring section.

Custom functions may be constructed with SELOGIC control equations using operands such as SELOGIC variables and embedded relay functions.

NOTE: All SELOGIC control equations must be set to NA, 0, 1, a single Relay Word bit, or a combination of Relay Word bits.

This section describes use of SELOGIC control equation programming to customize relay operation and automate substations. This section covers the following topics:

- ➤ SELOGIC control equation operands
- ➤ SELOGIC control equation operators
- ➤ SELOGIC control equation functions

SELOGIC Control Equation Capacity

SELOGIC control equation available capacity is a measure of remaining execution capacity and settings storage capacity. For maximum efficiency, use parentheses only when necessary and set unused equations to NA rather then 0 or 1.

Each SELOGIC control equation has a 15-operand maximum. Use a SELOGIC control equation variable (SV1–SV16) as an intermediate setting step if more operands are required.

Because the relay executes the logic at a deterministic interval, there is a limit to the amount of SELOGIC control equation programming that the relay can execute. Rather than limit parameters to guarantee that an application does not exceed the maximum processing requirements, the relay measures and calculates the available capacity when SELOGIC control equations are entered. The relay will not allow entry of programming that will cause the relay to be unable to complete all SELOGIC control equations each processing interval.

The relay calculates capacities based on the total amount of SELOGIC control equation programming executed in Global, Group, Logic, and several other settings areas.

SELOGIC Control Equation Operands

Outputs from embedded relay functions are generally available for use as operands in SELOGIC control equations. Use these operands to customize the operation of your SEL-311M and use the SEL-311M to automate substation operation. The operands available for use in SELOGIC control equations are summarized in *Table 5.1*.

Table 5.1 Summary of SELOGIC Control Equation Operands

Operand Type	Relay Word Bit Operands
Constants	0, 1
Inputs	Status Inputs, Optoisolated Inputs Local Bits (see *Section 9: Front-Panel Operations*) Remote Bits (see *Remote Bits on page 5.13*) Receive MIRRORED BITS™ (see *Appendix D: MIRRORED BITS Communications*)
Elements	Protection and Control Elements (see *Section 3: Protection Functions*)
Functions	Variables/Timers, Latch Bits
Outputs	Trip and Close Outputs, Contact Outputs Transmit MIRRORED BITS (See *Appendix D: MIRRORED BITS Communications*)

Relay Word Bits

Data within the relay are available for use in SELOGIC control equations. Relay Word bits include received digital values including optoisolated inputs, control bits, and remote bits. They also include calculated digital values such as SELOGIC control equation variables, SELOGIC control equation functions, and protection and control elements. *Section 7: Settings* contains a list of Relay Word bits available within the SEL-311M.

SELOGIC Control Equation Operators

Use Boolean operators to combine values with a resulting Boolean value. Edge-trigger operators provide a pulse output. Combine the operators and operands to form statements that evaluate complex logic. *Table 5.2* contains a summary of operators available in the SEL-311M.

Operator Precedence

When you combine several operators and operands within a single expression, the SEL-311M evaluates the operators from left to right starting with the highest precedence operators working down to the lowest precedence. This means that if you write an equation with three AND (*) operators, for example SV1*SV2*SV3, each AND will be evaluated from the left to the right. If you substitute !SV4 for SV3 to make SV1*SV2*!SV4, the relay evaluates the NOT (!) operation of SV4 first and uses the result in subsequent evaluation of the expression. Operator precedence is shown in *Table 5.2*.

Table 5.2 Operator Precedence

Operator	Description
/	Rising Edge Trigger
\	Falling Edge Trigger
( )	Parenthesis
!	Boolean Complement (NOT)
*	Boolean AND
+	Boolean OR

Parentheses Operators

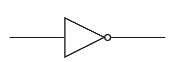
Use parentheses to control the execution order of operations in a SELOGIC control equation. More than one set of parentheses () can be used in a SELOGIC control equation setting. For example, the following SELOGIC control equation setting has two sets of parentheses:

SV7 = **(SV7 + IN101) * (50P1 + 50NG1)**

In the above example, the logic within the parentheses is processed first and then the two parentheses results are ANDed together. Parentheses cannot be "nested" (parentheses within parentheses) in a SELOGIC control equation setting.

Boolean NOT Operator (!)

Use the NOT (!) operator to invert a Boolean value. Create a NOT function using the NOT operator. This function would be described mathematically by the equation f(A) = NOT A and graphically by the following IEEE symbol:



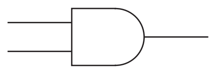
Boolean AND Operator (*)

Use AND (*) to combine two Boolean values according to the truth table shown in *Table 5.3*.

Table 5.3 AND Operator Truth Table

Value A	Value B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

Create an AND function using the AND operator. This function would be described mathematically by the equation f(A,B) = A AND B and graphically by the following IEEE symbol:



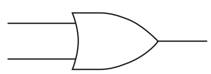
Boolean OR Operator (+)

Use OR (+) to combine two Boolean values according to the truth table shown in *Table 5.4*.

Table 5.4 OR Operator Truth Table

Value A	Value B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

Create an OR function using the OR operator. This function would be described mathematically by the equation f(A,B) = A OR B and graphically by the following IEEE symbol:



Rising Edge Trigger Operator (/)

The rising edge trigger operator (/) is a time-based function that creates a pulse when a rising edge is detected, as shown in *Figure 5.1*. Use the rising edge trigger operator to sense when a value changes from logical 0 to logical 1 and take action only after the value changes state.

The rising edge trigger operator applies to individual Relay Word bits only, not to groups of elements within parentheses. For example, the SELogic control equation event report generation setting uses several rising-edge operators:

ER = **/51P1 + /51NG1 + /OUT103**

When a logical 0 to logical 1 transition of ER is detected, the SEL-311M generates an event report (if the relay is not already generating a report that encompasses the new transition). The rising-edge operators in the ER equation enable detection of each individual transition.

Suppose a ground fault occurs and a breaker failure condition finally results. *Figure 5.1* demonstrates the action of the rising-edge operator (/) on the individual elements in setting ER.

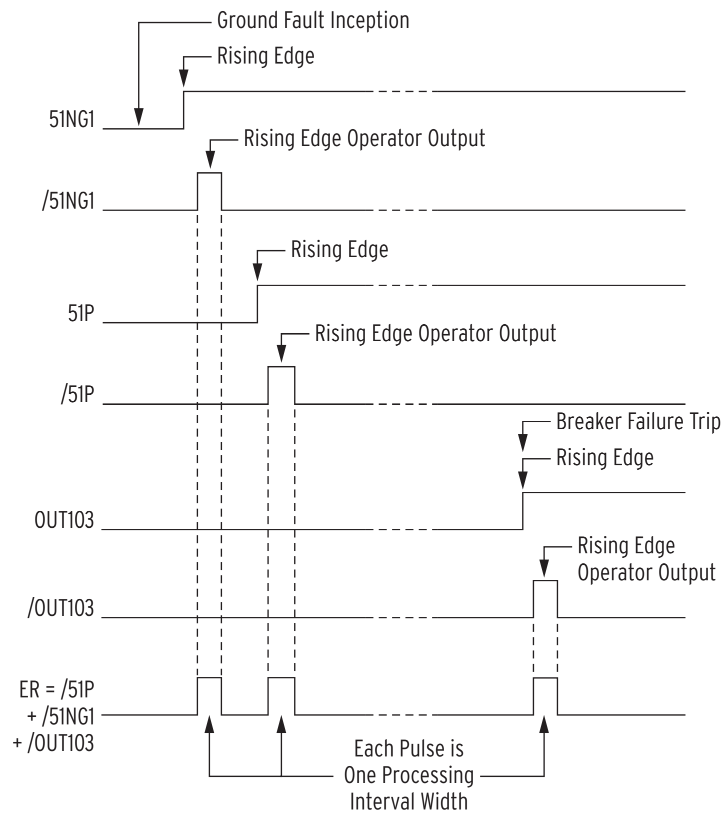


Figure 5.1 Rising Edge Operator Example

Note in *Figure 5.1* that setting ER detects three separate rising edges, because of the application of rising-edge operators. The rising edge operator (/) in front of a Relay Word bit detects this logical 0 to logical 1 transition as a rising edge and as a result asserts to logical 1 for one processing interval. The assertions of 51NG1 and 51P are close enough that they will be on the same event report (generated by 51NG1 asserting first). The assertion of OUT103 for a breaker failure condition is some appreciable time later and will generate another event report, if the first event report capture has ended when OUT103 asserts.

If the rising-edge operators were not applied and setting ER was:

ER = **51P + 51N1 + OUT103**

the ER setting would not detect the assertion of OUT103, because 51NG1 and 51P would continue to be asserted at logical 1.

Falling Edge Trigger Operator (\)

The falling edge operator (\) is a time-based function that creates a pulse when a falling edge is detected, as shown in *Figure 5.2*. Use the falling edge operator (\) to sense when a value changes from logical 1 to logical 0 and take action only after the value changes state.

The argument of a falling edge operator (\) statement must be a single Relay Word bit within the SEL-311M. An example of the relay detecting a falling edge of a calculated quantity is shown in *Figure 5.2*.

For example, suppose the SELogic control equation event report generation setting is set with the detection of the falling edge of an underfrequency element:

ER = **... + \81D1T**

When frequency goes above the corresponding pickup level 81D1P, Relay Word bit 81D1T deasserts and an event report is generated (if the relay is not already generating a report that encompasses the new transition). This allows a recovery from an underfrequency condition to be observed. *Figure 5.2* demonstrates the action of the falling edge operator (\) on the underfrequency element in setting ER.

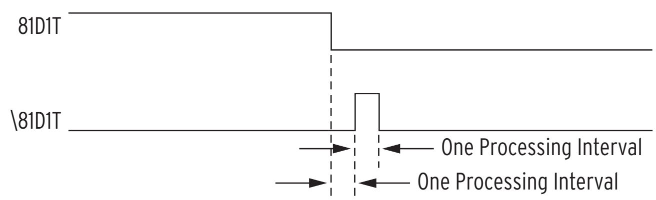


Figure 5.2 Falling Edge Operator Example

SELOGIC Control Equation Limitations

Any single SELOGIC control equation setting is limited to 15 Relay Word bits that can be combined together with the SELOGIC control equation operators listed in *Table 5.2*. If this limit must be exceeded, use a SELOGIC control equation variable (SELOGIC control equation settings SV1–SV16) as an intermediate setting step.

For example, assume that the trip equation (SELOGIC control equation trip setting TR) needs more than 15 Relay Word bits in its equation setting. Instead of placing all Relay Word bits into TR, program some of them into the SELOGIC control equation setting SV1. Next use the resultant SELOGIC control equation variable output (Relay Word bit SV1) in the SELOGIC control equation trip setting TR.

Note that the SELOGIC control equation variables (SELOGIC control equation settings SV1 through SV16) are processed after the trip equation (SELOGIC control equation trip setting TR). Thus, any tripping via Relay Word bits SV1–SV16 can be delayed as much as 1/4 cycle. For most applications, this is probably of no consequence.

The SELOGIC control equation settings as a whole are limited to no more than 447 elements and 49 rising edge or falling edge operators.

SELOGIC control equation settings that are set directly to 1 (logical 1) or 0 (logical 0) also have to be included in these limitations—each such setting counted as one element.

After SELOGIC control equation settings changes have been made and the settings are saved, the SEL-311M responds with the following message:

```
xxx Elements and yy Edges remain available
```

indicating that “xxx” Relay Word bits can still be used and “yy” rising or falling edge operators can still be applied in the SELOGIC control equations for the particular settings group.

Processing Order and Processing Interval

The relay processes the Relay Words, SELOGIC, and backup protection algorithms every 1/4 cycle and performs associated updates at the end of the 1/4-cycle interval. However, the differential protection algorithms are processed every 1/16 cycle. The Relay Word bits remain in their current state, asserted or deasserted, until the next processing interval. Setting EHST appropriately allows the high-speed differential processing to directly trip the high-speed output contacts (OUT201–OUT206) without delays from the 1/4-cycle processing interval.

SELOGIC Control Equation Functions

Variables/Timers

The SEL-311M has sixteen (16) SELOGIC control equation variables/timers. Each SELOGIC control equation variable/timer has a SELOGIC control equation setting input and variable/timer outputs as shown in *Figure 5.3*.

These timers have pickup and dropout time settings (SV*n*PU and SV*n*DO, *n* = 1 through 16).

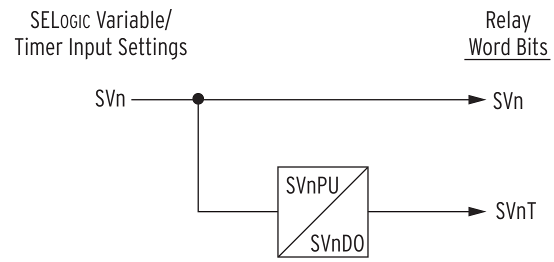


Figure 5.3 SELOGIC Control Equation Variables/Timers

Example

In the SELOGIC control equation settings, a SELOGIC control equation timer can be used for a simple undervoltage scheme:

SV6 = **27AB * 27BC * 27CA * !3PO**

Relay Word bits are run through a timer for undervoltage timing. Timer pickup setting SV6PU is set to the breaker failure time (SV6PU = 9.00 cycles). Timer dropout setting SV6DO is set for a 0-cycle dropout (SV6DO = 0.00 cycles). The output of the timer (Relay Word bit SV6T) operates output contact OUT105.

OUT105 = **SV6T**

Timer Reset Conditions

If power to the relay is lost, settings are changed for the active setting group, or the active setting group is changed, the SELOGIC control equation variables/timers are reset. Relay Word bits SV*n* and SV*n*T (*n* = 1 through 16) are reset to logical 0 and corresponding timer settings SV*n*PU and SV*n*DO are reloaded after power restoration, settings change, or active setting group.

SELOGIC Control Equations: Examples

Example: Tripping

If tripping does not involve switch-onto-fault trip logic, "communications-assisted," or "87 logic," the SELOGIC control equation trip setting TR is the only trip setting needed (see *Figure 4.3*).

Note that *Figure 4.3* appears quite complex. But since tripping does not involve switch-onto-fault trip, "communications-assisted," or "87 logic," logic in this example, the only effective inputs in *Figure 4.3* are SELOGIC control equation trip settings TR and TR.

TRSOTF = **0** not used-set directly to logical 0

TR = **51PT OR 51NGT OR 50P1** fuse saving example

ULTR = **NOT (51P OR 51NG)**

TR3X = **0**

TRA = **0**

TRB = **0**

TRC = **0**

Analysis of Trip Setting TR

Again, the example trip equation is as follows:

TR = **51PT OR 51NGT OR 50P1**

The Relay Word bit definitions are as follows:

51PT	phase time-overcurrent element timed out
51NGT	ground time-overcurrent element timed out
50P1	phase instantaneous overcurrent element asserted

A trip will eventually result if time-overcurrent element 51PT or 51NGT times out. If ground time-overcurrent element 51NGT times out, Relay Word bit 51NGT is in the following state:

51NGT = 1

Trip Output Contact

To assert output contact **OUT101** to trip a circuit breaker, make the following SELOGIC control equation output contact setting:

OUT101 = **TRIP**

Note that this simple output contact setting example is different from the standard relay trip/close output settings discussed in *Output Contacts on page 5.21*.

Example: Phase Time-Overcurrent Element 51PT

Examine a phase time-overcurrent element as an example of protection element operation via the logic output of Relay Word bits. The following Relay Word bits are the logic outputs of the phase time-overcurrent element:

51P	indication that the maximum phase-current magnitude is above the level of the phase time-overcurrent pickup setting 51PP
51PT	indication that the phase time-overcurrent element has timed out on its curve
51PR	indication that the phase time-overcurrent element is fully reset

Pickup Indication

If the maximum phase current is at or below the level of the phase time-overcurrent pickup setting 51PP, Relay Word bit 51P is in state 0.

If the maximum phase current is above the level of the phase time-overcurrent pickup setting 51PP, Relay Word bit 51P is in state 1.

The 51PT element is either timing on its curve or is already timed out.

Time–Out Indication

If phase time-overcurrent element 51PT is not timed out on its curve, Relay Word bit 51PT is in state 0.

If phase time-overcurrent element 51PT is timed out on its curve, Relay Word bit 51PT is in state 1.

Reset Indication

If phase time-overcurrent element 51PT is not fully reset, Relay Word bit 51PR is in state 0. The 51PT element is either:

- Timing on its curve
- Already timed out
- Timing to reset (one-cycle reset or electromechanical emulation—see *Figure 3.19*)

If phase time-overcurrent element is fully reset, Relay Word bit 51PR is in state 1.

Relay Word Bit Applications

Common uses for Relay Word bits 51P, 51PT, and 51PR:

51P	Testing, such as assigning to an output contact for pickup testing, trip unlatch logic.
51PT	Trip logic.
51PR	Testing, such as assigning to an output contact for reset indication.

Latch Bits

Latch control switches (Latch Bits are the outputs of these switches) replace traditional latching relays. Traditional latching relays maintain their output contact state. The SEL-311M latch control switches retain their state even when power to the relay is lost. If the latch control switch is set to a programmable output contact and power to the relay is lost, the state of the latch control switch is stored in nonvolatile memory, but the output contact will go to its de-energized state. When power to the relay is restored, the programmable output contact will go back to the state of the latch control switch after relay initialization.

Traditional latching relay output contact states are changed by pulsing the latching relay inputs (see *Figure 5.4*). Pulse the set input to close (set) the latching relay output contact. Pulse the reset input to open (reset) the latching relay output contact. Often the external contacts wired to the latching relay inputs are from remote control equipment (e.g., SCADA, RTU).

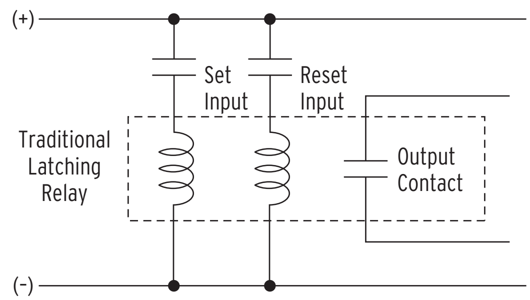


Figure 5.4 Traditional Latching Relay

Sixteen latch control switches in the SEL-311M provide latching relay functionality. See *Figure 5.5* and *Latch Bits Set/Reset Equations* ***(See*** *Figure 5.5) on page SETSET.19*.

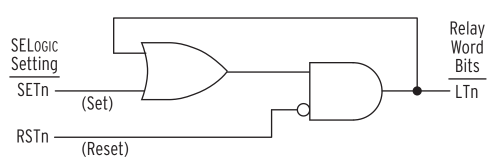


Figure 5.5 Latch Control Switches Drive Latch Bits LT1 Through LT16

The output of the latch control switch in *Figure 5.5* is a Relay Word bit LT*n* (*n* = 1 through 16), called a latch bit. The latch control switch logic in *Figure 5.5* repeats for each latch bit LT1 through LT16. Use these latch bits in SELOGIC control equations.

These latch control switches each have the following SELOGIC control equation settings:

SET*n* (set latch bit LT*n* to logical 1)

RST*n* (reset latch bit LT*n* to logical 0)

If setting SET*n* asserts to logical 1, latch bit LT*n* asserts to logical 1. If setting RST*n* asserts to logical 1, latch bit LT*n* deasserts to logical 0. If both settings SET*n* and RST*n* assert to logical 1, setting RST*n* has priority and latch bit LT*n* deasserts to logical 0.

Latch Bits: Application Ideas

Latch control switches can be used for such applications as:

- Ground relay enable/disable
- Sequence coordination enable/disable

Latch control switches can be applied to almost any control scheme. The following is an example of using a latch control switch to enable/disable the relay in the SEL-311M.

Latch Bits: Nonvolatile State

Power Loss

The states of the latch bits (LT1–LT16) are retained if power to the relay is lost and then restored. If a latch bit is asserted (e.g., LT2 = logical 1) when power is lost, it is asserted (LT2 = logical 1) when power is restored. If a latch bit is deasserted (e.g., LT3 = logical 0) when power is lost, it is deasserted (LT3 = logical 0) when power is restored. This feature makes the latch bit feature behave the same as traditional latching relays. In a traditional installation, if power is lost to the panel, the latching relay output contact position remains unchanged.

Note: If a latch bit is set to a programmable output contact, such as OUT103 = LT2, and power to the relay is lost, the state of the latch bit is stored in nonvolatile memory but the output contact will go to its de-energized state. When power to the relay is restored, the programmable output contact will go back to the state of the latch bit after relay initialization.

Settings Change or Active Setting Group Change

If individual settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed, the states of the latch bits (Relay Word bits LT1 through LT16) are retained, much like in the preceding *Power Loss* explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the latch bits (the relay is not momentarily disabled).

If the individual settings change or active setting group change causes a change in SELOGIC control equation settings SET*n* or RST*n* (*n* = 1 through 16), the retained states of the latch bits can be changed, subject to the newly enabled settings SET*n* or RST*n*.

Make Latch Control Switch Settings With Care

The latch bit states are stored in nonvolatile memory so they can be retained during power loss, settings change, or active setting group change. The nonvolatile memory is rated for a finite number of writes for all cumulative latch bit state changes. Exceeding the limit can result in a FLASH self-test failure. **An average of 70 cumulative latch bit state changes per day can be made for a 25-year relay service life**.

This requires that SELOGIC control equation settings SET*n* and RST*n* for any given latch bit LT*n* (*n* = 1 through 16) be set with care. Settings SET*n* and RST*n* must not result in continuous cyclical operation of latch bit LT*n*. Use timers to qualify conditions set in settings SET*n* and RST*n*. If any optoisolated inputs IN101 through IN106 are used in settings SET*n* and RST*n*, the inputs have their own debounce timer that can help in providing the necessary time qualification.

Optoisolated Inputs

Optoisolated inputs **IN101–IN106** are located on the main board of the SEL-311M (see *Figure 2.5*). These inputs have debounce timers; the default time is 0.5 cycles.

Figure 5.6 shows the resultant Relay Word bits (Relay Word bits IN101–IN106) that follow corresponding timers.

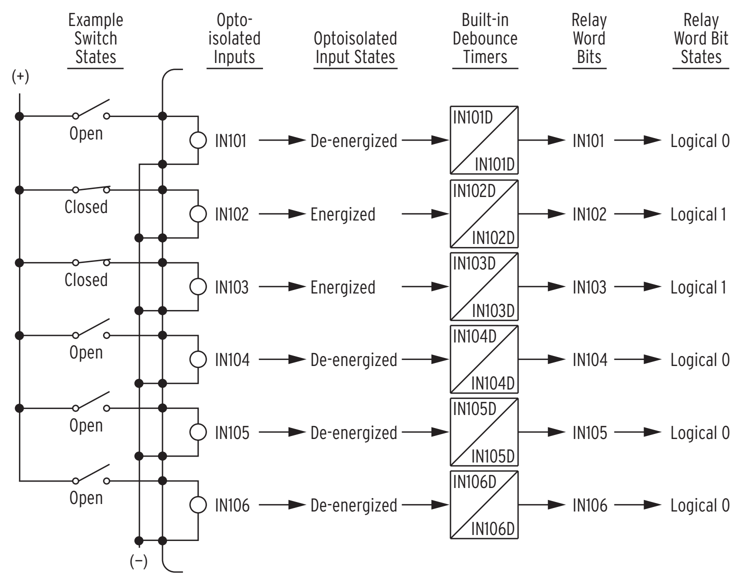


Figure 5.6 Example Operation of Optoisolated Inputs

Screw and torque information for optoisolated inputs IN101–IN106 is found in *Section 2: Installation*.

Input Debounce Timers

See *Figure 5.6*.

Each input has settable pickup/dropout timers (IN101D–IN106D) for input energization/de-energization debounce. Note that a given time setting (e.g., IN101D = 0.50) is applied to both the pickup and dropout time for the corresponding input.

Time settings IN101D–IN106D are settable from 0.00 to 1.00 cycles. The relay takes the entered time setting and internally runs the timer at the nearest 1/16-cycle. For example, if setting IN105D = 0.80, internally the timer runs at the nearest 1/16-cycle: 3/4-cycles (6/8 = 0.75).

For most applications, the input pickup/dropout debounce timers should be set in 1/4-cycle increments.

The relay updates Relay Word bits IN101–IN106 every 1/16-cycle.

If more than a cycle of debounce is needed, use a SELOGIC control equation variable timer (see *Figure 5.3*).

Remote Bits

Up to 16 remote control switches are operated via the serial communications port only. They may be operated using any of the following:

- SEL ASCII command CONTROL as described in *Section 8: Communications*.
- Fast Operate commands as described in *Appendix C: SEL Communications Processors*.

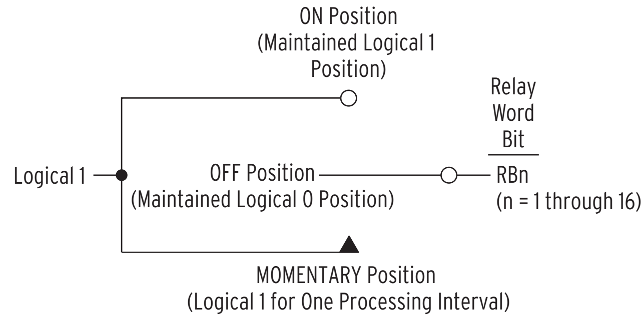


Figure 5.7 ON/OFF/MOMENTARY Remote Control Switch

The output of the switch in *Figure 5.7* is a Relay Word bit (RB1–RB16) called a Remote Bit and repeats for each Remote Bit. Use these Remote Bits in SELOGIC control equations.

Remote Bit RB*n* may be in the ON (RB*n* = logical 1) position, in the OFF (RB*n* = logical 0) position, or maintained in the OFF (RB*n* = logical 0) position and pulsed to the MOMENTARY (RB*n* = logical 1) position for one processing interval (1/4 cycle).

The state of each remote bit (Relay Word bits RB1 through RB16) is retained if relay settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed.

Remote Bits: Application Ideas

With SELOGIC control equations, the remote bits can be used in applications similar to those that use local bits.

Also, remote bits can be used much as optoisolated inputs are used in operating latch control switches. Pulse (momentarily operate) the remote bits for this application.

Remote Bits: Momentary Position

This subsection describes how the momentary position of the remote control switch operates using the SEL ASCII command CONTROL. It operates in the same manner when used with a Fast Operate.

Use the **CON *n*** command and **PRB *n*** subcommand to put the remote control switch in the momentary ON position for one processing interval, regardless of its initial state. The remote control switch is then placed in the OFF position.

If RB*n* is initially at logical 0, pulsing it with the **CON *n*** command and **PRB *n*** subcommand will change RB*n* to a logical 1 for one processing interval, and then return it to a logical 0. If RB*n* is initially at logical 1 instead, pulsing it with the **CON *x*** command and **PRB *x*** subcommand will change RB*n* to a logical 0.

Remote Bit: Volatile State

The states of the remote bits (Relay Word bits RB1 through RB16) are not retained if power to the relay is lost and then restored. The remote control switches always come back in the OFF position (corresponding remote bit is deasserted to logical 0) when power is restored to the relay.

Multiple Setting Groups

The SEL-311M has six (6) independent setting groups. Each setting group has complete relay (overcurrent, frequency, etc.) and SELOGIC control equation settings. The active setting group can be:

- Shown or selected with the SEL ASCII serial port GROUP command as described in *Section 8: Communications*.
- Shown or selected with the **MAIN** menu **Set/Show** menu item and the **Active Group** submenu item as described in *Section 9: Front-Panel Operations*.
- Selected with SELOGIC control equation settings SS1 through SS6. Settings SS1 through SS6 have priority over all other selection methods. Use remote bits in these equations to select setting groups with Fast Operate commands as described in *Appendix C: SEL Communications Processors*.

Setting Groups: Application Ideas

Setting groups can be used for such applications as:

- Environmental conditions such as winter storms, periods of high summer heat, etc.
- Hot-line tag that disables closing and sensitizes protection
- Commissioning and operation

Active Setting Group Indication

Only one setting group can be active at a time. Relay Word bits SG1 through SG6 indicate the active setting group.

For example, if setting Group 4 is the active setting group, Relay Word bit SG4 asserts to logical 1, and the other Relay Word bits SG1, SG2, SG3, SG5, and SG6 are all deasserted to logical 0.

Active Setting Group Selection

Each setting group has its own set of SELOGIC control equation settings SS1 through SS6.

The operation of these settings is explained with the following example:

Assume the active setting group starts out as setting Group 3. Corresponding Relay Word bit SG3 is asserted to logical 1 as an indication that setting Group 3 is the active setting group.

With setting Group 3 as the active setting group, setting SS3 has priority. If setting SS3 is asserted to logical 1, setting Group 3 remains the active setting group, regardless of the activity of settings SS1, SS2, SS4, SS5, and SS6. With settings SS1 through SS6 all deasserted to logical 0, setting Group 3 still remains the active setting group.

With setting Group 3 as the active setting group, if setting SS3 is deasserted to logical 0 and one of the other settings (e.g., setting SS5) asserts to logical 1, the relay switches from setting Group 3 as the active setting group to another setting group (e.g., setting Group 5) as the active setting group, after qualifying time setting TGR:

TGR	Group Change Delay Setting	(settable from 0.00 to 16000.00 cycles)

In this example, TGR qualifies the assertion of setting SS5 before it can change the active setting group.

Active Setting Group Changes

The relay is disabled for less than 1 second while in the process of changing active setting groups. Relay elements, timers, and logic are reset, unless indicated otherwise in the specific logic description. For example, local bit (LB1 through LB16), remote bit (RB1 through RB16), and latch bit (LT1 through LT16) states are retained during an active setting group change. The output contacts do not change state until the relay enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group. For instance, if setting OUT105 = 1 (logical 1) in Group 2, and setting OUT105 = 1 (logical 1) in Group 3, and the relay is switched from Group 2 to Group 3, OUT105 stays energized before, during, and after the group change. However, if the Group 3 setting was OUT105 = 0 (logical 0) instead, then OUT105 remains energized until the relay enables in Group 3, solves the SELOGIC equations, and causes OUT105 to de-energize. See *Figure 5.14* for examples of output contacts in the de-energized state (i.e., corresponding output contact coils de-energized).

Example 1: Active Setting Group Switching

Use a single optoisolated input to switch between two setting groups in the SEL-311M. In this example, optoisolated input IN105 on the relay is connected to a SCADA contact in *Figure 5.8*. Each pulse of the SCADA contact changes the active setting group from one setting group, such as setting Group 1, to another, such as setting Group 4. The SCADA contact is not maintained, just pulsed to switch from one active setting group to another.

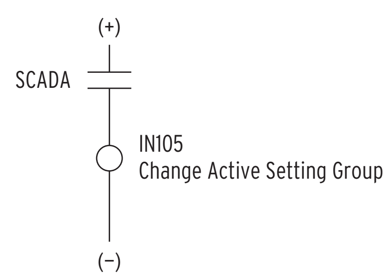


Figure 5.8 SCADA Contact Pulses Input IN105 to Switch Active Setting Group Between Setting Groups 1 and 4

If setting Group 1 is the active setting group and the SCADA contact is pulsed, setting Group 4 becomes the active setting group. If the SCADA contact is pulsed again, setting Group 1 becomes the active setting group again. The setting group control operates in a cyclical manner.

This logic is implemented in the SELOGIC control equation settings in *Table 5.5*.

Table 5.5 SELogic Control Equation Settings for Switching Active Setting Group Between Setting Groups 1 and 4

Setting Group 1	Setting Group 4
SV8PU = 60.00	SV8PU = 60.00
SV8DO = 0.00	SV8DO = 0.00
SV8 = SG1	SV8 = SG4
Global Settings	
SS1 = IN105*SV8T*! SG1	
SS2 = 0	
SS3 = 0	
SS4 = IN105*SV8T*! SG4	
SS5 = 0	
SS6 = 0	

SELogic control equation timer input setting SV8 in *Table 5.5* has logic output SV8T, shown in operation in *Figure 5.9* for both setting Groups 1 and 4. The settings for SS1 and SS4 induced expressions that steer the IN105 assertion to the appropriate setting. SS1 is only allowed to operate when the relay is not in group 1, and SS4 is only allowed to operate when the relay is not in group 4. These details are explained below.

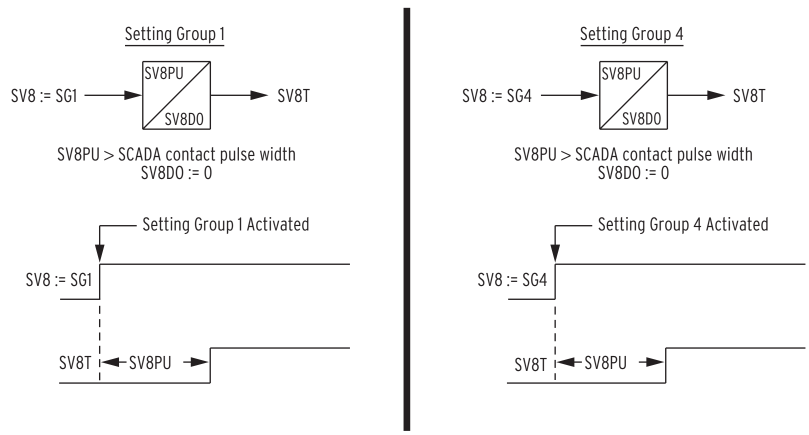


Figure 5.9 SELogic Control Equation Variable Timer SV8T Used in Setting Group Switching

In this example, timer SV8T is used in both setting groups: different timers could have been used with the same operational result. The timers reset during the setting group change, allowing the same timer to be used in both setting groups.

Timer pickup setting SV8PU is set greater than the pulse width of the SCADA contact (*Figure 5.8*). This allows only one active setting group change, such as from setting Group 1 to 4, for each pulse of the SCADA contact, and subsequent assertion of input IN105. The function of the SELogic control equations in *Table 5.5* becomes more apparent in the following example scenario.

Start Out in Setting Group 1

The relay has been in setting Group 1 for some time, with timer logic output SV8T asserted to logical 1, thus enabling SELOGIC control equation setting SS4 for the assertion of input IN105. The inclusion of AND NOT SG1 (. . .*!SG1) in the setting for SS1 prevents SS1 from detecting the next IN105 assertion. See *Figure 5.10*.

Switch to Setting Group 4

The SCADA contact pulses input IN105, and the active setting group changes to setting Group 4 after qualifying time setting TGR (perhaps set at a cycle or so to qualify the assertion of setting SS4). Optoisolated input IN105 also has its own built-in debounce timer (IN105D) available.

Note that *Figure 5.10* shows both setting Group 1 and setting Group 4 settings. The setting Group 1 settings (near the top of *Figure 5.10*) are enabled only when setting Group 1 is the active setting group and likewise for the setting Group 4 settings near the bottom of the figure. The group selection settings, SS1 and SS4, are global settings, and are enabled in every setting group.

Setting Group 4 is now the active setting group, and Relay Word bit SG4 asserts to logical 1. After the relay has been in setting Group 4 for a time period equal to SV8PU, the timer logic output SV8T asserts to logical 1, thus enabling SELOGIC control equation setting SS1 for a new assertion of input IN105. The inclusion of AND NOT SG4 (. . .*!SG4) in the setting for SS4 prevents SS4 from detecting the next IN105 assertion.

Note that input IN105 is still asserted because setting Group 4 is activated. Pickup time SV8PU keeps the continued assertion of input IN105 from causing the active setting group to revert back again to setting Group 1 for a single assertion of input IN105. This keeps the active setting group from being changed at a time interval less than time SV8PU.

Switch Back to Setting Group 1

The SCADA contact pulses input IN105 a second time, and the active setting group changes back to setting Group 1 after qualifying time setting TGR. The timing is shown in *Figure 5.10*.

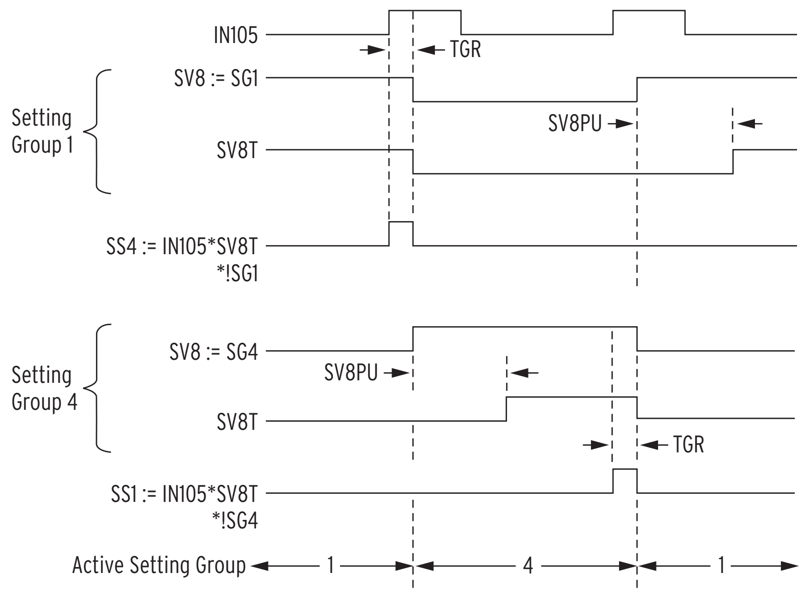


Figure 5.10 Active Setting Group Switching (With Single Input) Timing

Example 2: Active Setting Group Switching

Use three optoisolated inputs to switch between the six setting groups in the SEL-311M. In this example, optoisolated inputs IN101, IN102, and IN103 on the relay are connected to a rotating selector switch as shown in *Figure 5.11*.

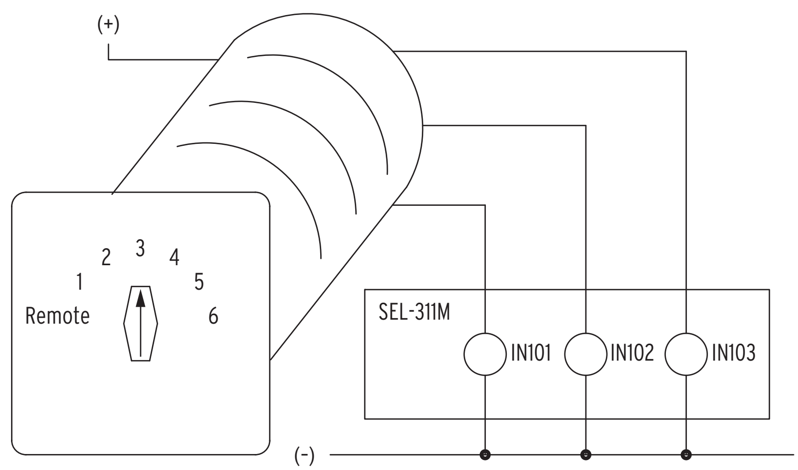


Figure 5.11 Rotating Selector Switch Connected to Inputs IN101, IN102, and IN103 for Active Setting Group Switching

The selector switch has multiple internal contacts arranged to assert inputs IN101, IN102, and IN103, dependent on the switch position. As shown in *Table 5.6*, when the selector switch is moved from one position to another, a different setting group is activated. The logic is implemented in the SELogic control equation settings in *Table 5.6*.

Table 5.6 Active Setting Group Switching Input Logic (Sheet 1 of 2)

Input States			Active Setting Group	SELogic Settings
IN103	IN102	IN101		
0	0	0	Remote	
0	0	1	Group 1	SS1 = ! IN103*!IN102*IN101
0	1	0	Group 2	SS2 = !IN103*IN102*!IN101

Table 5.6 Active Setting Group Switching Input Logic (Sheet 2 of 2)

Input States			Active Setting Group	SELogic Settings
IN103	IN102	IN101		
0	1	1	Group 3	SS3 = !IN103* IN102*IN101
1	0	0	Group 4	SS4 = IN103*!IN102*!IN101
1	0	1	Group 5	SS5 = IN103*!IN102*IN101
1	1	0	Group 6	SS6 = IN103*IN102*!IN101

The settings in *Table 5.6* are made in group settings.

Selector Switch Starts Out in Position 3

If the selector switch is in position 3 in *Figure 5.11*, setting Group 3 is the active setting group (Relay Word bit SG3 = logical 1). Inputs IN101 and IN102 are energized and IN103 is de-energized:

SS3 = **!IN103*IN102*IN101**
= **!(logical 0)*!(logical 1)*(logical 1) = logical 1**

To get from the position 3 to position 5 on the selector switch, the switch passes through the position 4. The switch is only briefly in position 4:

SS4 = **IN103*!IN102*!IN101**
= **(logical 1)*!(logical 0)*!(logical 0) = logical 1**

but not long enough to be qualified by time setting TGR to change the active setting group to setting Group 4, see *Figure 5.12*. For such a rotating selector switch application, qualifying time setting TGR is typically set at 180 to 300 cycles. Set TGR long enough to allow the selector switch to pass through intermediate positions, without changing the active setting group, until the switch rests on the desired setting group position.

Selector Switch Switched to Position 5

If the selector switch rests on position 5 in *Figure 5.11*, setting Group 5 becomes the active setting group (after qualifying time setting TGR; Relay Word bit SG5 = logical 1). Inputs IN101 and IN103 are energized and IN102 is de-energized:

SS5 = **IN103*!IN102*IN101**
= **!(logical 1)*!(logical 0)*(logical 1) = logical 1**

To get from position 5 to position REMOTE on the selector switch, the switch passes through the positions 4, 3, 2, and 1. The switch is only briefly in these positions, but not long enough to be qualified by time setting TGR to change the active setting group to any one of these setting groups, see *Figure 5.12*.

Selector Switch Now Rests on Position REMOTE

If the selector switch rests on position REMOTE in *Figure 5.11*, all inputs IN101, IN102, and IN103 are de-energized and all settings SS1 through SS6 in *Table 5.6* are at logical 0. The last active setting group (Group 5 in this example) remains the active setting group (Relay Word bit SG5 = logical 1).

With settings SS1 through SS6 all at logical 0, use the serial port **GROUP** command or the front-panel **{GROUP}** pushbutton to switch the active setting group from Group 5, in this example, to another desired setting group. The timing is shown in *Figure 5.12*.

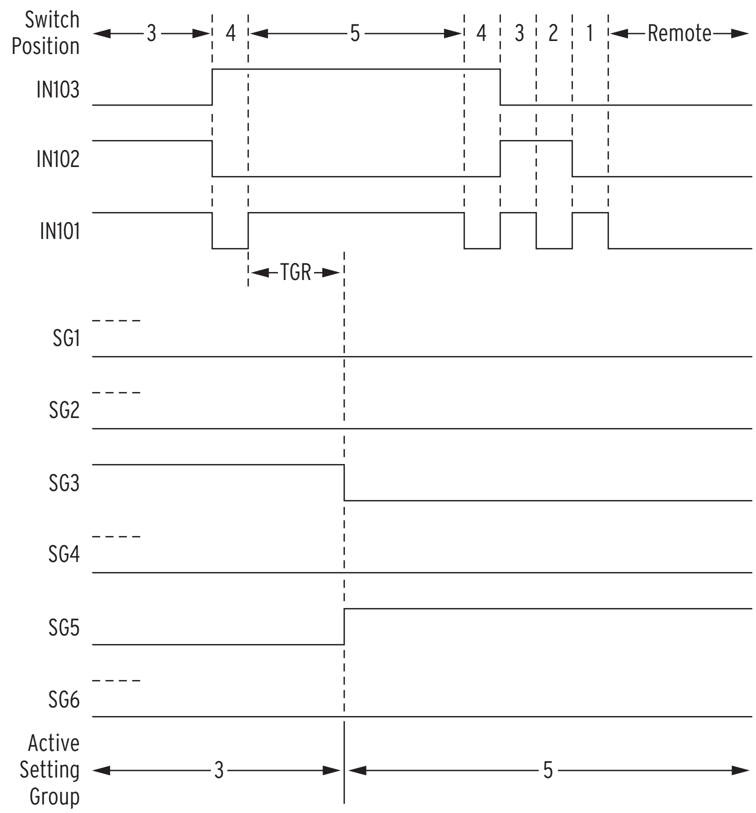


Figure 5.12 Active Setting Group Switching (With Rotating Selector Switch) Time Line

Active Setting: Nonvolatile State

Power Loss

The active setting group is retained if power to the relay is lost and then restored. If a particular setting group is active (e.g., setting Group 5) when power is lost, the same setting group is active when power is restored.

Settings Change

If individual settings are changed for the active setting group or one of the other setting groups, the active setting group is retained, much like in the preceding explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the active setting group, so the relay is not momentarily disabled.

If the individual settings change causes a change in one or more SELOGIC control equation settings SS1 through SS6, the active setting group can be changed, subject to the newly enabled SS1 through SS6 settings.

Make Active Setting Group Switching Settings with Care

The active setting group is stored in nonvolatile memory so it can be retained during power loss or settings change. The nonvolatile memory is rated for a finite number of writes for all setting group changes. Exceeding the limit can result in a FLASH self-test failure. **An average of four (4) setting group changes per day can be made for a 25-year relay service life**.

This requires that SELOGIC control equation settings SS1 through SS6 be set with care. Settings SS1 through SS6 must not result in continuous cyclical changing of the active setting group. Time setting TGR qualifies settings SS1 through SS6 before changing the active setting group. If optoisolated inputs IN101 through IN106 are used in settings SS1 through SS6, the inputs have their own built-in debounce timer that can help in providing the necessary time qualification.

Output Contacts

The SEL-311M comes standard with six Form A (OUT101–OUT106), two Form C (OUT107 and ALARM), and six high-speed (OUT201–OUT206) output contacts. See *Figure 5.13* for a definition of the output contact Forms.

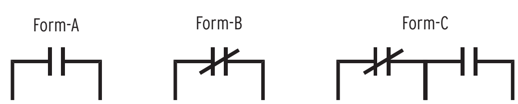


Figure 5.13 Output Contact Forms

Figure 2.6 shows the output contact terminal locations on the SEL-311M Relay module rear panel. Refer to *Section 2: Installation* for connector and tightening torque information.

SEL-311M output contacts are normally operated using SELOGIC control equation OUTn (n = 101–107) or one of several other methods.

These two methods are ordinarily only used in testing:

- SEL ASCII command PULSE as described in *Section 8: Communications*.
- Front-panel HMI Control menu and Output Contacts submenu as described in *Section 9: Front-Panel Operations*.

Figure 5.14 shows the example operation of Relay Word bits that in turn control corresponding output contacts.

SELOGIC control equation settings OUT*n* and serial port ASCII commands **PULSE OUT*n*** are shown as inputs into the logic in *Figure 5.14*. Front-Panel HMI, not shown in *Figure 5.14*, has the same logical effect as the serial port ASCII commands **PULSE OUT*n*** in *Figure 5.14*—it is just a different means to the same result (assertion of Relay Word bit OUT*n*).

SCADA Operation

To operate output contacts via SCADA, use the following method of operation.

> Fast Operate commands as described in *Appendix C: SEL Communications Processors*.

The method must first be programmed using SELOGIC control equation OUT*n* (*n* = 101–106, 201–206). For example, remote bit RB1 may be used to control output OUT202 with the setting OUT202 = RB1. See *Remote Bits on page 5.13*.

Output Contact Operation

The assertion of a Relay Word bit causes the energization of the corresponding output contact coil. Depending on the contact type (Form A or Form B), the output contact closes or opens. A Form A output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. A Form B output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized.

Notice that *Figure 5.14* shows all four possible combinations of output contact coil states (energized or de-energized) and output contact types (Form A or Form B).

The output SELOGIC equations are located in the logic settings class, see *Figure 5.14* and *Output Contact Equations (See Figure 5.14) on page SETSET.23*.

In most applications, monitor the normally closed side of the Form C contact (**ALARM**) for fail-safe alarm operation. When the SEL-311M is not enabled (for example, if ac power and the battery are not connected), the normally closed contact would be in the closed position, indicating the alarm condition. When the SEL-311M is powered-up and operational, the normally closed contact would be open, indicating a non-alarm condition.

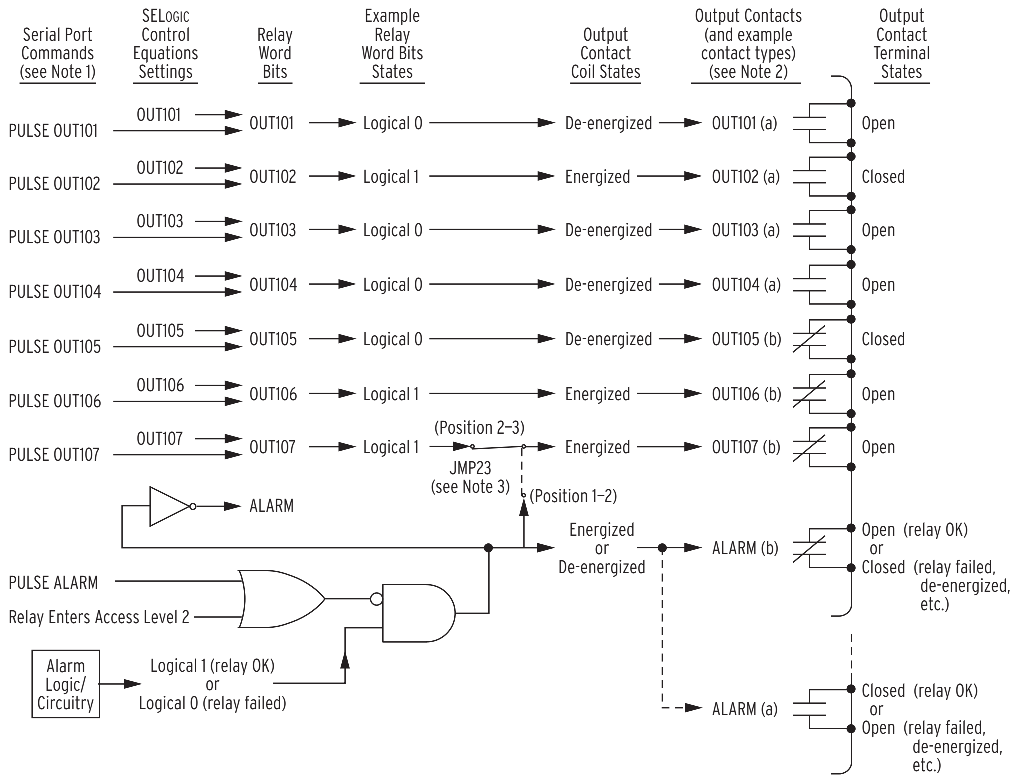


Figure 5.14 Logic Flow for Example Output Contact Operation

Note 1: **PULSE** command is also available via the front panel (**{CNTRL}** pushbutton, "output contact testing" option). Execution of the **PULSE** command results in a logical 1 input into the above logic (one-second default pulse width).

Note 2: Output contacts **OUT101** through **ALARM** are configurable as a or b type output contacts. See Table 2.2 and accompanying text in Section 2: Installation for more information on selecting output contact type.

Note 3: Main board jumper JMP23 allows output contact **OUT107** to operate as: regular output contact **OUT107** (JMP23 in position 2–3; an extra Alarm output contact (JMP23 in position 1–2). See Table 2.3 for more information on jumper JMP23.

Use of High-Speed Contacts OUT201-OUT206 With Fast, Sensitive Loads

High-speed contacts **OUT201–OUT206** are intended for use as high-speed trip contacts. **OUT201–OUT206** can also be used with sensitive, fast contact inputs, such as might be found on some communications gear.

Load sensitivity is described by minimum assertion voltage (per unit of nominal dc control voltage), minimum pickup time (milliseconds to energize the load at nominal control voltage), and load resistance. Use **OUT201–OUT206** with any load that satisfies *Equation 5.1* and does not assert below 20 percent of nominal dc control voltage.

The high-speed contacts **OUT201–OUT206** are designed to operate with trip and close coils.

$$R_L \le 500 \bullet T_{pu} \qquad \textbf{Equation 5.1}$$

where:

R_L = load resistance in kΩ

T_{pu} = minimum load response time, in milliseconds

For example, a 125 V contact input on an SEL-311M does not assert below half the nominal dc control voltage. The input draws 4 mA at nominal voltage, so R_L = 125 V / 4 mA = 31 kΩ. With the debounce timer set to 2 ms, this input easily satisfies *Equation 5.1*, with a safety factor of over 30.

$$31 \le 500 \bullet 2$$

$$31 \le 1000 \qquad \textbf{Equation 5.2}$$

ALARM Output Contact and 87HWAL

Refer to *Figure 5.14* and *Relay Self-Tests on page 11.15*.

When the relay is operational, the alarm logic/circuitry keeps the **ALARM** output contact coil energized. Depending on the **ALARM** output contact type (a or b), the **ALARM** output contact closes or opens as demonstrated in *Figure 5.14*. An "a" type output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. A "b" type output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized.

The Relay Word bit ALARM is deasserted to logical 0 when the relay is operational. When the relay enters Access Level 2, the ALARM Relay Word bit momentarily asserts to logical 1 (and the **ALARM** output contact coil is de-energized momentarily).

To verify **ALARM** output contact mechanical integrity, execute the serial port command **PULSE ALARM**. Execution of this command momentarily de-energizes the ALARM output contact coil.

Notice in *Figure 5.14* that all possible combinations of **ALARM** output contact coil states (energized or de-energized) and output contact types (a or b) are demonstrated. See *Output Contact Jumpers on page 2.10* for output contact type options.

Contact output **OUT107** can be configured in one of the following ways:

- Use it as a regular contact similar to **OUT101–OUT106** by placing jumper JMP23 in position 2-3.
- Use it as an extra relay alarm by placing jumper JMP23 in position 1-2.
- Use it as an alarm contact for the 87L hardware by placing jumper JMP23 in position 2-3 and setting OUT107 = 87HWAL.

  This is how **OUT107** is configured in a standard relay shipment. Configured this way, Relay Word bit 87HWAL asserts and contact **OUT107** closes when an internal problem occurs in the 87L hardware that prevents the relay from performing line current differential protection. (Other Relay Word bits assert for communications channel failures.) It is also possible to configure contact **OUT107** as a normally closed alarm contact and set OUT107 = !87HWAL so that loss of control power also closes contact **OUT107**.

Rotating Default Display

The rotating default display on the relay front panel replaces indicating panel lights. Traditional indicating panel lights are turned on and off by circuit breaker auxiliary contacts, front-panel switches, SCADA contacts, etc. They indicate such conditions as circuit breaker open/closed.

Traditional Indicating Panel Lights Replaced With Rotating Default Display

The indicating panel lights are not needed if the rotating default display feature in the SEL-311M is used. *Figure 5.15* shows the elimination of the indicating panel lights through use of the rotating default display.

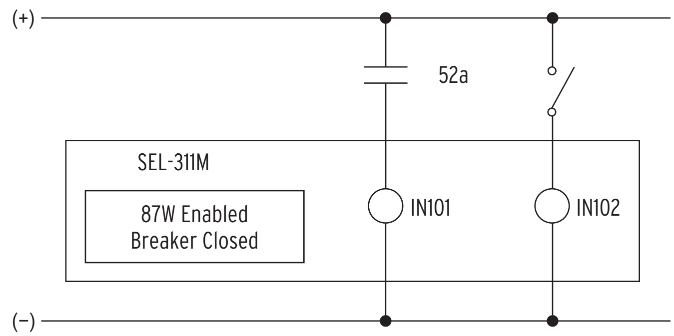


Figure 5.15 Rotating Default Display Replaces Traditional Panel Light Installations

There are sixteen (16) of these default displays available in the SEL-311M. Each default display has two complementary screens (e.g., `BREAKER CLOSED` and `BREAKER OPEN`) available.

General Operation of Rotating Default Display Settings

SELOGIC control equation display point setting DP*n* (*n* = 1–16) controls the display of corresponding, complementary text settings:

DP*n*_1 (displayed when DP*n* = logical 1)

DP*n*_0 (displayed when DP*n* = logical 0)

Make each text setting through the serial port, using the command **SET T**. View these text settings by using the serial port command **SHO T** (see *Section 7: Settings* and *Section 8: Communications*). These text settings are displayed on the SEL-311M front-panel display on a time-variable rotation through use of Global setting SCROLD (see *Rotating Default Display on page 9.8* for more specific operation information).

The following settings examples use optoisolated inputs IN101 and IN102 in the display points settings. Local bits (LB1–LB16), latch bits (LT1–LT16), remote bits (RB1–RB16), setting group indicators (SG1–SG6), and any other combination of Relay Word bits in a SELOGIC control equation setting can also be used in display point setting DP*n*.

Settings Examples

The settings examples provide the replacement solution shown in *Figure 5.15* for traditional indicating panel lights.

Status Indication

Make SELOGIC control equation display point setting DP1:

DP1 = **IN102**

and make

87WB = **!IN102**

Make corresponding, complementary text settings:

DP1_1 = **87W ENABLED**

DP1_0 = **87W DISABLED**

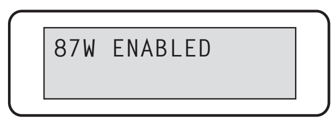
Display point setting DP1 controls the display of the text settings.

In *Figure 5.15*, optoisolated input IN102 is energized to enable the zero-sequence current differential element, resulting in:

DP1 = **IN102 = logical 1**

87WB = **!IN102 = logical 0**

This results in the display of corresponding text setting DP1_1 on the front-panel display:

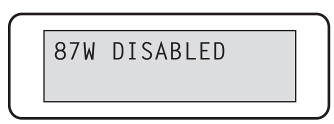


In *Figure 5.15*, optoisolated input IN102 is de-energized to disable the zero-sequence current differential element, resulting in:

DP1 = **IN102 = logical 0**

87WB = **!IN102 = logical 1**

This results in the display of corresponding text setting DP1_0 on the front-panel display:



Circuit Breaker Status Indication

Make SELOGIC control equation display point setting DP2:

DP2 = **IN101**

Make corresponding, complementary text settings:

DP2_1 = **BREAKER CLOSED**

DP2_0 = **BREAKER OPEN**

Display point setting DP2 controls the display of the text settings.

Circuit Breaker Closed

In *Figure 5.15*, optoisolated input **IN101** is energized when the 52a circuit breaker auxiliary contact is closed, resulting in:

DP2 = **IN101 = logical 1**

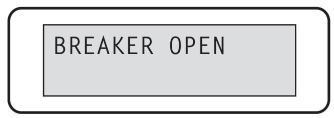
This results in the display of corresponding text setting DP2_1 on the front-panel display:

Circuit Breaker Open

In *Figure 5.15*, optoisolated input **IN101** is de-energized when the 52a circuit breaker auxiliary contact is open, resulting in:

DP2 = **IN101 = logical 0**

This results in the display of corresponding text setting DP2_0 on the front-panel display:



Additional Settings Examples

Display Only One Message

To display just one screen, but not its complement, set only one of the text settings. For example, to display just the BREAKER CLOSED condition, but not the BREAKER OPEN condition, make the following settings:

DP2 = **IN101** (52a circuit breaker auxiliary contact connected to input **IN101**–see *Figure 5.15*)

DP2_1 = **BREAKER CLOSED** (displays when DP2 = logical 1)

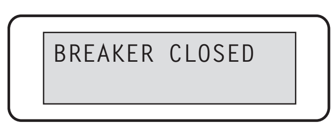
DP2_0 = (blank)

Circuit Breaker Closed

In *Figure 5.15*, optoisolated input **IN101** is energized when the 52a circuit breaker auxiliary contact is closed, resulting in:

DP2 = **IN101 = logical 1**

This results in the display of corresponding text setting DP2_1 on the front-panel display:



Circuit Breaker Open

In *Figure 5.15*, optoisolated input **IN101** is de-energized when the 52a circuit breaker auxiliary contact is open, resulting in:

DP2 = **IN101 = logical 0**

Corresponding text setting DP2_0 is not set (it is "blank"), so no message is displayed on the front-panel display.

Continually Display a Message

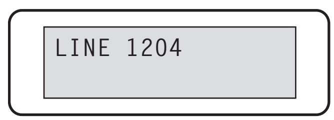
To continually display a message in the rotation, set the SELOGIC control equation display point setting directly to 0 (logical 0) or 1 (logical 1) and the corresponding text setting. For example, if an SEL-311M is protecting a 230 kV transmission line, labeled "Line 1204," the line name can be continually displayed with the following settings

DP5 = **1** (set directly to logical 1)

DP5_1 = **LINE 1204** (displays when DP5 = logical 1)

DP5_0 = ("blank")

This results in the continual display of text setting DP5_1 on the front-panel display:



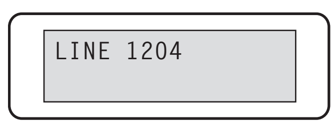
This can also be realized with the following settings:

DP5 = **0** (set directly to logical 0)

DP5_1 = ("blank")

DP5_0 = **LINE 1204** (displays when DP5 = logical 0)

This results in the continual display of text setting DP5_0 on the front-panel display:



Active Setting Group Switching Considerations

The SELOGIC control equation display point settings DP*n* (*n* = 1–16) are available separately in each setting group. The corresponding text settings DP*n*_1 and DP*n*_0 are made only once and used in all setting groups.

Refer to *Figure 5.15* and the following discussion of an example setting group switching discussion.

Setting Group 1 Is the Active Setting Group

When setting Group 1 is the active setting group, optoisolated input **IN102** operates as an enable/disable switch with the following settings:

SELOGIC control equation settings:

DP1 = **IN102** and

87WB = **!IN102**

Text settings:

DP1_1 = 87W ENABLED (displayed when DP1 = logical 1)

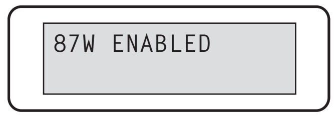
DP1_0 = 87W DISABLED (displayed when DP1 = logical 0)

Relay Enabled

In *Figure 5.15*, optoisolated input IN102 is energized to enable the zero-sequence current differential element, resulting in:

DP1 = **IN102 = logical 1**

This results in the display of corresponding text setting DP1_1 on the front-panel display:



Relay Disabled

In *Figure 5.15*, optoisolated input IN102 is de-energized to disable the zero-sequence current differential element, resulting in:

DP1 = **IN102 = logical 0**

This results in the display of corresponding text setting DP1_0 on the front-panel display:

Now the active setting group is switched from setting Group 1 to 4.

Switch to Setting Group 4 as the Active Setting Group

When setting Group 4 is the active setting group, the zero-sequence current differential element is always enabled and optoisolated input IN102 has no control over the relay. The text settings cannot be changed (they are used in all setting groups), but the SELOGIC control equation settings can be changed:

SELOGIC control equation settings:

87WB = **0** (set directly to logical 0—relay permanently enables the zero-sequence current differential element)

DP1 = **1** (set directly to logical 1)

Text settings (remain the same for all setting groups):

DP1_1 = 87W ENABLED (displayed when DP1 = logical 1)

DP1_0 = 87W DISABLED (displayed when DP1 = logical 0)

Because SELOGIC control equation display point setting DP1 is always at logical 1, the corresponding text setting DP1_1 continually displays in the rotating default displays:

```
87W ENABLED
```

Additional Rotating Default Display Example

See *Figure 4.15* and accompanying text in *Section 4: Trip, Close, and Target Logic* for an example of resetting a rotating default display with the {TARGET RESET} pushbutton.

Displaying Time-Overcurrent Elements on the Rotating Default Display

The LCD can display the pickup settings for the time-overcurrent elements in primary units via a special character sequence in the display points equations. As with the previously described display points, the operator does not need to press any buttons to see this information.

To program a display point to show the pickup setting of a time-overcurrent element, first enter the two-character sequence :: (double colon) followed by the name of the desired time-overcurrent element pickup settings for 51PP, 51NGP, or 51QP.

For example, with the factory default settings for CTR, setting DP4_0 = ::51PP and E51P = Y; and 51PP = 0.10 will display 100.00 A pri.

The relay calculates the value to display by multiplying the 51PP setting (0.1 A secondary) by the CTR setting (1000), arriving at 100.00 A primary. The relay displays the display point DP4_0 because the factory default SELOGIC control equation DP4 = 0 (logical 0).

The calculations for the remaining time-overcurrent elements are similar, except for 51NGP, which is multiplied by the CTRN setting.

If the display point setting does not match the format correctly, the relay will display the setting text string as it was actually entered, without substituting the time-overcurrent element setting value.

EXAMPLE 5.1 Displaying Time-Overcurrent Elements Example

This example demonstrates use of the rotating display to show time-overcurrent elements in primary units. This example will set the 51PP and 51NGP to display in the rotating default display.

Set the following:

Table 5.7 Settings for Displaying Time-Overcurrent Elements

SET	SET T	SET L
CTR = 200	DP4_0 = PHASE TRIPS AT	DP4 = 0
CTRN = 200	DP5_0 = ::51PP	DP5 = 0
E51P = Y	DP6_0 = GROUND TRIPS AT	DP6 = 0
E51NG = Y	DP7_0 = ::51NGP	DP7 = 0
51PP = 0.1		
51NGP = 0.75		

Setting DPn = 0 and using the DPn_0 in the text settings allows the setting to permanently rotate in the display. The DPn logic equation can be set to control the text display-turning it on and off under certain conditions. With the relay set as shown above, the LCD will show the following:

```
PHASE TRIPS AT
  100.00 A pri
```

then,

```
GROUND TRIPS AT
   250.00 A pri
```

With the description string set on the even display points "DP4, DP6, ..." and the control set on the odd display points "DP5, DP7, ..." each screen the relay scrolls through will have a description with the value below it.

For additional format control for the setting elements only, use the following **SET T** control string:

Dpi_j = **XXX;;[;]ABCDE;YYY**

where:

- i is a number between 1 and 16, representing the 16 display points, and j is either 1 or 0 representing logic high or low, respectively.
- XXX is an optional pre-label. YYY is an optional post label that is preceded by a single semicolon (;) character. The label character count is the sum of the characters used in the pre and post labels.
- ABCDE is a relay setting variable from the table below.

Table 5.8 Relay Setting Variables

SET T Setting Variable	Displays Relay Setting Value	Display Format/Resolution	Maximum Label Character Count
;;51PP	51PP	xxxxxxx.xx	6
;;51NGP	51GP	xxxxxxx.xx	6
;;51QP	51QP	xxxxxxx.xx	6
;;;000	51PP	xxxxxxx	9
;;;001	51GP	xxxxxxx	9
;;;002	51QP	xxxxxxx	9

For example, setting DP1_0 = OC PU;;51PP;A will display:

```
OC PU  100.00A
```

Or setting DP1_0 = OC PU;;;000;A will display:

```
OC PU  100A
```

Displaying Metering Quantities on the Rotating Default Display

Display points can be programmed to display metering quantities automatically, making this information available without the use of pushbuttons. The values shown in *Table 5.9* can be set to automatically display on the rotating LCD screen.

Table 5.9 Mnemonic Settings for Metering on the Rotating Default Display (Sheet 1 of 4)

Mnemonic	Display	Description
IA	I A = x . x x x A y y y °	IA input current
IB	I B = x . x x x A y y y °	IB input current
IC	I C = x . x x x A y y y °	IC input current
VA	V A = x . x x x K V y y y °	VA input voltage
VB	V B = x . x x x K V y y y °	VB input voltage
VC	V C = x . x x x K V y y y °	VC input voltage
VS	V S = x . x x x K V y y y °	VS input voltage
IG	I G = x . x x x A y y y °	IG = IA + IB +IC (residual)
3IO	3 I O = x . x x x A y y y °	3IO = IG (zero-sequence)
I1	I 1 = x . x x x A y y y °	positive-sequence current
3I2	3 I 2 = x . x x x A y y y °	negative-sequence current
3V0	3 V 0= x . x x x K V y y y °	zero-sequence current
V1	V 1 = x . x x x K V y y y °	positive-sequence voltage
V2	V 2 = x . x x x K V y y y °	negative-sequence voltage
MWA	M W A = x x . x x x	A megawatts
MWB	M W B = x x . x x x	B megawatts
MWC	M W C = x x . x x x	C megawatts
MW3	M W 3 P = x x . x x x	three-phase megawatts
MVARA	M V A R A = x x . x x x	A megavars
MVARB	M V A R B = x x . x x x	B megavars
MVARC	M V A R C = x x . x x x	C megavars
MVAR3	M V A R 3 P = x x . x x x	three-phase megavars
PFA	P F A = x . x x L E A D	A power factor
PFB	P F B = x . x x L A G	B power factor
PFC	P F C = x . x x L A G	C power factor
PF3	P F 3 P = x . x x L E A D	three-phase power factor
FREQ	F R Q = x x . x	system frequency from VA
VDC	V D C = x x x . x v	DC voltage
IADEM	I A D E M = x . x x x	IA demand current
IAPK	I A P E A K = x . x x x	IA peak current
IBDEM	I B D E M = x . x x x	IB demand current
IBPK	I B P E A K = x . x x x	IB peak current
ICDEM	I C D E M = x . x x x	IC demand current
ICPK	I C P E A K = x . x x x	IC peak current
INDEM	I N D E M = x . x x x	IN demand current
INPK	I N P E A K = x . x x x	IN peak current

Table 5.9 Mnemonic Settings for Metering on the Rotating Default Display (Sheet 2 of 4)

Mnemonic	Display	Description
3I2DEM	3 I 2 D E M = x . x x x	3I2 demand current
3I2PK	3 I 2 P E A K = x . x x x	3I2 peak current
IAL	I A L = x x x x A y y y	IA Local Current
IBL	I B L = x x x x A y y y	IB Local Current
ICL	I C L = x x x x A y y y	IC Local Current
INL	I N L = x x x x A y y y	IN Local Current
3I0L	3 I 0 L = x x x x A y y y	Local Zero-Sequence Current
3I2L	3 I 2 L = x x x x A y y y	Local Negative-Sequence Current
I1L	I 1 L = x x x x A y y y	Local Positive-Sequence Current
3V0L	3V 0 L = x x x x V y y y	Local Zero-Sequence Voltage
IAX	I A X = x x x x A y y y	IA Channel X Current
IBX	I B X = x x x x A y y y	IB Channel X Current
ICX	I C X = x x x x A y y y	IC Channel X Current
INX	I N X = x x x x A y y y	IN Channel X Current
3I0X	3 I 0 X = x x x x A y y y	Channel X Zero-Sequence Current
3I2X	3 I 2 X = x x x x A y y y	Channel X Negative-Sequence Current
I1X	I 1 X = x x x x A y y y	Channel X Positive-Sequence Current
3V0X	3V 0 X = x x x x V y y y	Channel X Zero-Sequence Voltage
IAY	I A Y = x x x x A y y y	IA Channel Y Current
IBY	I B Y = x x x x A y y y	IB Channel Y Current
ICY	I C Y = x x x x A y y y	IC Channel Y Current
INY	I N Y = x x x x A y y y	IN Channel Y Current
3I0Y	3 I 0 Y = x x x x A y y y	Channel Y Zero-Sequence Current
3I2Y	3 I 2 Y = x x x x A y y y	Channel Y Negative-Sequence Current
I1Y	I 1 Y = x x x x A y y y	Channel Y Positive-Sequence Current
3V0Y	3V 0 Y - x x x x V y y y	Channel Y Zero-Sequence Voltage
IAD	Σ I A = x x x x A y y y	IA Vector Sum Current
IBD	Σ I B = x x x x A y y y	IB Vector Sum Current
ICD	Σ I C = x x x x A y y y	IC Vector Sum Current
3I0D	Σ 3 I 0 = x x x x A y y y	Vector Sum Zero-Sequence Current
3I2D	Σ 3 I 2 = x x x x A y y y	Vector Sum Negative-Sequence Current
I1D	Σ I 1 = x x x x A y y y	Vector Sum Positive-Sequence Current
IAA	α I A = x x x . y y y	IA Alpha Plane
IBA	α I B = x x x . y y y	IB Alpha Plane
ICA	α I C = x x x . y y y	IC Alpha Plane
MWADI	M W A I N D E M = x . x x x	A demand megawatts in
MWAPI	M W A I N P K = x . x x x	A peak megawatts in
MWBDI	M W B I N D E M = x . x x x	B demand megawatts in
MWBPI	M W B I N P K = x . x x x	B peak megawatts in
MWCDI	M W C I N D E M = x . x x x	C demand megawatts in
MWCPI	M W C I N P K = x . x x x	C peak megawatts in

Table 5.9 Mnemonic Settings for Metering on the Rotating Default Display (Sheet 3 of 4)

Mnemonic	Display	Description
MW3DI	M W 3 I N D E M = x . x x x	Three-phase demand megawatts in
MW3PI	M W 3 I N P K = x . x x x	Three-phase peak megawatts in
MVRADI	M V R A I D E M = x . x x x	A demand megavars in
MVRAPI	M V R A I P K = x . x x x	A peak megavars in
MVRBDI	M V R B I D E M = x . x x x	B demand megavars in
MVRBPI	M V R B I P K = x . x x x	B peak megavars in
MVRCDI	M V R C I D E M = x . x x x	C demand megavars in
MVRCPI	M V R C I P K = x . x x x	C peak megavars in
MVR3DI	M V R 3 I D E M = x . x x x	Three-phase demand megavars in
MVR3PI	M V R 3 I P K = x . x x x	Three-phase peak megavars in
MWADO	M W A O D E M = x . x x x	A demand megawatts out
MWAPO	M W A O P K = x . x x x	A peak megawatts out
MWBDO	M W B O D E M = x . x x x	B demand megawatts out
MWBPO	M W B O P K = x . x x x	B peak megawatts out
MWCDO	M W C O D E M = x . x x x	C demand megawatts out
MWCPO	M W C O P K = x . x x x	C peak megawatts out
MW3DO	M W 3 O D E M = x . x x x	Three-phase demand megawatts out
MW3PO	M W 3 O P K = x . x x x	Three-phase peak megawatts out
MVRADO	M V R A O D E M = x . x x x	A demand megavars out
MVRAPO	M V R A O P K = x . x x x	A peak megavars out
MVRBDO	M V R B O D E M = x . x x x	B demand megavars out
MVRBPO	M V R B O P K = x . x x x	B peak megavars out
MVRCDO	M V R C O D E M = x . x x x	C demand megavars out
MVRCPO	M V R C O P K = x . x x x	C peak megavars out
MVR3DO	M V R 3 O D E M = x . x x x	Three-phase demand megavars out
MVR3PO	M V R 3 O P K = x . x x x	Three-phase peak megavars out
MWHAI	M W h A I N = x x . x x x	A megawatt-hours in
MWHAO	M W h A O U T = x x . x x x	A megawatt-hours out
MWHBI	M W h B I N = x x . x x x	B megawatt-hours in
MWHBO	M W h B O U T = x x . x x x	B megawatt-hours out
MWHCI	M W h C I N = x x . x x x	C megawatt-hours in
MWHCO	M W h C O U T = x x . x x x	C megawatt-hours out
MWH3I	M W h 3 I N = x x . x x x	Three-phase megawatt-hours in
MWH3O	M W h 3 O U T = x x . x x x	Three-phase megawatt-hours out
MVRHAI	M V A R h A I = x x . x x x	A megavar-hours in
MVRHAO	M V A R h A O = x x . x x x	A megavar-hours out
MVRHBI	M V A R h B I = x x . x x x	B megavar-hours in
MVRHBO	M V A R h B O = x x . x x x	B megavar-hours out
MVRHCI	M V A R h C I = x x . x x x	C megavar-hours in
MVRHCO	M V A R h C O = x x . x x x	C megavar-hours out

Table 5.9 Mnemonic Settings for Metering on the Rotating Default Display (Sheet 4 of 4)

Mnemonic	Display	Description
MVRH3I	M V A R h 3 I = x x . x x x	Three-phase megavar-hours in
MVRH3O	M V A R h 3 O = x x . x x x	Three-phase megavar-hours out

To program a display point to display one of the metering quantities from *Table 5.11*, first enter the two-character sequence :: (double colon) followed by the name of the desired metering quantity (e.g., IA, VA, MW3, etc.).

If the display point setting does not match the format correctly, the relay will display the setting text string as it was actually entered, without substituting the metering value.

EXAMPLE 5.2 Displaying Metering Values Example

This example demonstrates use of the rotating display to show metering quantities automatically on the rotating default display. This example will set the MW3, MVAR3, PF3, and FREQ to display in the rotating default display.

Set the following:

Table 5.10 Settings for Displaying Metering Values Example

SET T	SET L
DP1_0 = ::MW3	DP1 = 0
DP2_0 = ::MVAR3	DP2 = 0
DP3_0 = ::PF3	DP3 = 0
DP4_0 = ::FREQ	DP4 = 0

Setting DPn = 0 and using the DPn_0 in the text settings allows the setting to permanently rotate in the display. The DPn logic equation can be set to control the text display-turning it on and off under certain conditions. With the relay set as shown above, the LCD will show the following:

```
  MW 3P= XXXX.X
MVAR 3P= XXXX.X
```

then,

```
PF 3P=XX.XX XXXX
FRQ=XX.X
```

Displaying Breaker Monitor Output Information on the Rotating Default Display

Display points can be programmed to display breaker monitor output information automatically, making this information available without using pushbuttons. The values shown *Table 5.11* in can be set to automatically display on the rotating LCD screen.

Table 5.11 Mnemonic Settings for Self-Check Status on the Rotating Default Display

Mnemonic	Display														Description
BRKDATE	R S T		D	A	T	:	m	m	/	d	d	/	y	y	last reset date
BRKTIME	R S T		T	I	M	:	h	h	:	m	m	:	s	s	last reset time
CTRLTR	C T R L			T	R	I	P	S	=	x	x	x	x	x	internal trip count
OPSCNTR	O P S		C	N	T	R	+	A		x	x	x	x	x	internal trip count
CTRLIA	C T R L			I	A	=	x	x	x	x	x		k	A	internal trip Σ IA
CTRLIB	C T R L			I	B	=	x	x	x	x	x		k	A	internal trip Σ IB
CTRLIC	C T R L			I	C	=	x	x	x	x	x		k	A	internal trip Σ IC
EXTTR	E X T	x	T	R	I	P	S	=		x	x	x	x	x	external trip count
EXTIA	E X T		I	A	=		x	x	x	x	x		k	A	external trip Σ IA
EXTIB	E X T		I	B	=		x	x	x	x	x		k	A	external trip Σ IB
EXTIC	E X T		I	C	=		x	x	x	x	x		k	A	external trip Σ IC
WEARA	W E A R			A	=						y	y	y	%	A phase wear monitor
WEARB	W E A R			B	=						y	y	y	%	B phase wear monitor
WEARC	W E A R			C	=						y	y	y	%	C phase wear monitor

To program a display point to display one of the Breaker Monitor outputs above, first enter the two-character sequence :: (double colon) followed by the name of the desired breaker monitor output (e.g., EXTTR, CTRLTR, CTRLIA, etc.).

If the display point setting does not match the format correctly, the relay will display the setting text string as it was actually entered, without substituting the breaker monitor output value.

EXAMPLE 5.3 Displaying Breaker Monitor Outputs Example

This example demonstrates use of the rotating display to show metering quantities automatically on the rotating default display. This example will set the EXTTR CTRLTR, CTRLIA, EXTIA, and WEARA to display in the rotating default display.

Set the following:

Table 5.12 Settings for Displaying Breaker Monitor Outputs Example

SET T	SET L
DP1_0 = ::EXTTR	DP1 = 0
DP2_0 = ::CTRLTR	DP2 = 0
DP3_0 = ::CTRLIA	DP3 = 0
DP4_0 = ::EXTIA	DP4 = 0
DP5_0 = ::WEARA	DP5 = 0

Setting DPn = 0 and using the DPn_0 in the text settings allows the setting to permanently rotate in the display. The DPn logic equation can be set to control the text display-turning it on and off under certain conditions. With the relay set as shown above, the LCD will show the following:

```
EXT TRIPS=XXXXX
CTRL TRIPS=XXXXX
```

then,

```
CTRL IA=XXXXXX kA
EXT IA=XXXXXX kA
```

and then,

```
WEAR A=   XXX %
```

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Section 6
Metering and Monitoring

Overview

The SEL-311M Relay metering functions include:

- ➤ Instantaneous Metering
- ➤ Demand Metering
- ➤ Energy Metering
- ➤ Maximum/Minimum Metering

The SEL-311M monitoring functions include:

- ➤ Breaker Monitor
- ➤ Station DC Battery Monitor

This section explains these functions in detail.

Metering

The SEL-311M provides the following metering functions:

- ➤ Instantaneous Metering
- ➤ Local Demand Metering
- ➤ Local Maximum/Minimum Metering
- ➤ Local Energy Metering

All the metering functions listed above, except instantaneous metering, are based on local current and local voltage. The instantaneous metering displays both local and remote quantities.

Instantaneous Metering

The magnitudes displayed are in primary values, and the angles are referenced to the local I1 phase differential current.

The instantaneous metering in the SEL-311M provides the quantities shown below:

```
=>>MET <Enter>

[RID setting]                     Date: mm/dd/yy    Time: hh:mm:ss.sss
[TID setting]

Local              A         B         C        3I0       3I2        I1
I MAG (A Pri) ****.***  ****.***  ****.***  ****.***  ****.***  ****.***
I ANG (DEG)    ***.**    ***.**    ***.**    ***.**    ***.**    ***.**

Channel X          A         B         C        3I0       3I2        I1
I MAG (A Pri) ****.***  ****.***  ****.***  ****.***  ****.***  ****.***
I ANG (DEG)    ***.**    ***.**    ***.**    ***.**    ***.**    ***.**

Channel Y          A         B         C        3I0       3I2        I1
I MAG (A Pri) ****.***  ****.***  ****.***  ****.***  ****.***  ****.***
I ANG (DEG)    ***.**    ***.**    ***.**    ***.**    ***.**    ***.**

Vector Sum         A         B         C        3I0       3I2        I1
I MAG (A Pri) ****.***  ****.***  ****.***  ****.***  ****.***  ****.***
I ANG (DEG)    ***.**    ***.**    ***.**    ***.**    ***.**    ***.**

Alpha Plane        A         B         C
RADIUS        ****.***  ****.***  ****.***
ANG (DEG)      ***.**    ***.**    ***.**

=>>
```

Figure 6.1 Instantaneous Metering (Local and Remote)

The quantities reported depend on the number of terminals that comprise the line current differential scheme, number of channels connected to the relay, and the terminal configuration (2 or N) of the SEL-311M.

The current magnitude and angles listed under “Local” in *Figure 6.1* are always reported because they pertain to the local relay.

The current magnitudes and angles listed under Channel X, Channel Y, and Vector Sum, as well as the alpha plane values, are reported based on the number of terminals, number of channels, and the terminal configuration.

The Vector Sum of currents always represents the total current entering the protected line.

Channel X and Channel Y quantities always represent the currents received from the remote relays connected to those respective channels.

Figure 6.2 shows the instantaneous meter display for other local quantities.

The magnitudes displayed are in primary values, and the angles are referenced to the A-phase voltage if this voltage is greater than 13 V secondary. If the A-phase voltage is 13 V or less, the angles are referenced to the local A-phase current.

```
=>>MET B <Enter>

[RID setting]                      Date: mm/dd/yy    Time: hh:mm:ss.sss
[TID setting]
               A         B         C         N         G
I MAG (A)   ****.***  ****.***  ****.***  ****.***  ****.***
I ANG (DEG)  ***.**    ***.**    ***.**    ***.**    ***.**

               A         B         C         S
V MAG (kV)  ****.***  ****.***  ****.***  ****.***
V ANG (DEG)  ***.**    ***.**    ***.**    ***.**

               A         B         C         3P
MW          ****.**   ****.**   ****.**   ****.**
MVAR        ****.**   ****.**   ****.**   ****.**
PF             *.**      *.**      *.**      *.**
                LEAD      LAG       LEAD      LAG

               I1        3I2       3I0       V1        V2        3V0
MAG         ****.***  ****.***  ****.***  ****.***  ****.***  ****.***
ANG   (DEG)  ***.**    ***.**    ***.**    ***.**    ***.**    ***.**

FREQ (Hz)   **.**           VDC (V)    ***.*

=>>
```

Figure 6.2 Instantaneous Meter Display for Local Quantities

Figure 6.3 shows the instantaneous meter display for zero-sequence metering. The magnitudes displayed are in primary values, and the angles are referenced to the local I1 phase differential current.

```
=>>MET N <Enter>

SEL-311M                           Date: 11/19/03    Time: 17:06:56.479
EXAMPLE: BUS B, BREAKER 3

Local              IG        IN         3V0
MAG             ****.***  ****.***  ****.***
ANG (DEG)         ***.**    ***.**    ***.**

Channel X          IG        IN         3V0
MAG             ****.***  ****.***  ****.***
ANG (DEG)         ***.**    ***.**    ***.**

Vector Sum         IG        IN
MAG             ****.***  ****.***
ANG (DEG)         ***.**    ***.**

=>>
```

Figure 6.3 Instantaneous Meter Display for Zero-Sequence Metering.

Local Demand Metering

The SEL-311M offers the choice between two types of demand metering, settable with the enable setting:

EDEM = **THM** (Thermal Demand Meter)

or

EDEM = **ROL** (Rolling Demand Meter)

The demand metering settings (in *Table 6.1*) are available via the **SET** command (see *SEL-311M Settings Sheets* at the end of *Section 7: Settings*. Also refer to *MET Command (Metering Data) on page 8.29* and *MET D—Local Demand Metering on page 8.31*).

Depending on enable setting EDEM, these demand and peak demand values are thermal demand or rolling demand values. The differences between thermal and rolling demand metering are explained in the following discussion.

Comparison of Thermal and Rolling Demand Meters

The example in *Figure 6.4* shows the response of thermal and rolling demand meters to a step current input. The current input is at a magnitude of zero and then suddenly goes to an instantaneous level of 1.0 per unit (a “step”).

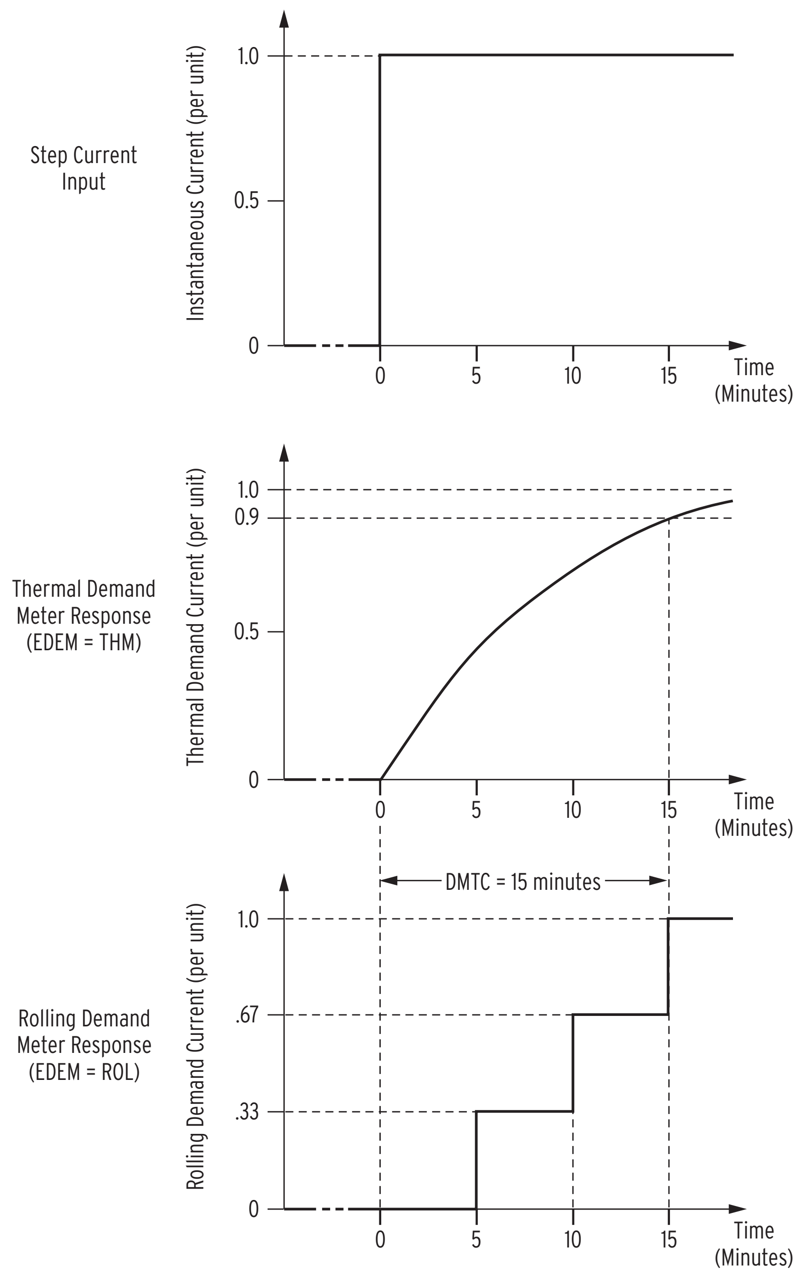

Figure 6.4 Response of Thermal and Rolling Demand Meters to a Step Input (Setting DMTC = 15 Minutes)

Thermal Demand Meter Response (EDEM = THM)

The response of the thermal demand meter in *Figure 6.4* (middle) to the step current input (top) is analogous to the parallel RC circuit in *Figure 6.5*.

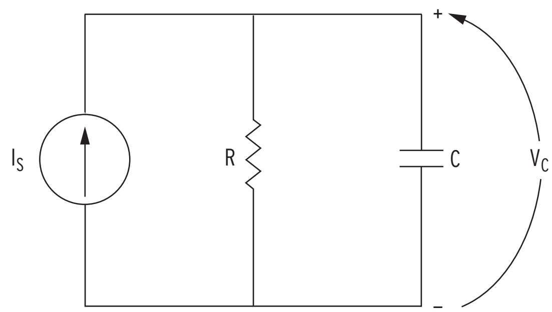

Figure 6.5 Current I_S Applied to Parallel RC Circuit

In the analogy:

- ➤ Current I_S in *Figure 6.5* corresponds to the step current input in *Figure 6.4* (top).
- ➤ Voltage V_C across the capacitor in *Figure 6.5* corresponds to the response of the thermal demand meter in *Figure 6.4* (middle).

If current I_S in *Figure 6.5* has been at zero (I_S = 0.0 per unit) for some time, voltage V_C across the capacitor in *Figure 6.5* is also at zero (V_C = 0.0 per unit). If current I_S is suddenly stepped up to some constant value (I_S = 1.0 per unit), voltage V_C across the capacitor starts to rise toward the 1.0 per unit value. This voltage rise across the capacitor is analogous to the response of the thermal demand meter in *Figure 6.4* (middle) to the step current input (top).

In general, just as voltage V_C across the capacitor in *Figure 6.5* cannot change instantaneously, the thermal demand meter response cannot change instantaneously for increasing or decreasing current. The thermal demand meter response time is based on the demand meter time constant setting DMTC (see *Table 6.1*). Note in *Figure 6.4* that the thermal demand meter response (middle) is at 90 percent (0.9 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC = 15 minutes, referenced to when the step current input is first applied.

The SEL-311M updates thermal demand values approximately every two seconds.

Rolling Demand Meter Response (EDEM = ROL)

The response of the rolling demand meter in *Figure 6.4* (bottom) to the step current input (top) is calculated with a sliding time-window arithmetic average calculation. The width of the sliding time-window is equal to the demand meter time constant setting DMTC (see *Table 6.1*). Note in *Figure 6.4* that the rolling demand meter response (bottom) is at 100 percent (1.0 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC = 15 minutes, referenced to when the step current input is first applied.

The rolling demand meter integrates the applied signal (e.g., step current) input in five-minute intervals. The integration is performed approximately every two seconds. The average value for an integrated five-minute interval is derived and stored as a five-minute total. The rolling demand meter then averages a number of the five-minute totals to produce the rolling demand meter response. In the *Figure 6.4* example, the rolling demand meter averages the three latest five-minute totals because setting DMTC = 15 (15/5 = 3). The rolling demand meter response is updated every five minutes, after calculation of a new five-minute total.

The following is a step-by-step calculation of the rolling demand response example in *Figure 6.4* (bottom).

Time = 0 Minutes. Presume that the instantaneous current has been at zero for quite some time before “Time = 0 minutes” (or the demand meters were reset). The 3 five-minute intervals in the sliding time-window at “Time = 0 minutes” each integrate into the following five-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
0.0 per unit	–15 to –10 minutes
0.0 per unit	–10 to –5 minutes
0.0 per unit	–5 to 0 minutes
0.0 per unit	

Rolling demand meter response at “Time = 0 minutes” = 0.0/3 = 0.0 per unit

Time = 5 Minutes. The 3 five-minute intervals in the sliding time-window at “Time = 5 minutes” each integrate into the following five-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
0.0 per unit	–10 to –5 minutes
0.0 per unit	–5 to –0 minutes
1.0 per unit	0 to 5 minutes
1.0 per unit	

Rolling demand meter response at “Time = 5 minutes” = 1.0/3 = 0.33 per unit

Time = 10 Minutes. The 3 five-minute intervals in the sliding time-window at “Time = 10 minutes” each integrate into the following five-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
0.0 per unit	–5 to 0 minutes
1.0 per unit	0 to 5 minutes
1.0 per unit	5 to 10 minutes
2.0 per unit	

Rolling demand meter response at “Time = 10 minutes” = 2.0/3 = 0.67 per unit

Time = 15 Minutes. The 3 five-minute intervals in the sliding time-window at “Time = 15 minutes” each integrate into the following five-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
1.0 per unit	0 to 5 minutes
1.0 per unit	5 to 10 minutes
1.0 per unit	10 to 15 minutes
3.0 per unit	

Rolling demand meter response at “Time = 15 minutes” = 3.0/3 = 1.0 per unit

Demand Meter Settings

NOTE: Changing setting EDEM or DMTC resets the demand meter values to zero. This also applies to changing the active setting group, and setting EDEM or DMTC is different in the new active setting group. Demand current pickup settings PDEMP, NDEMP, and QDEMP can be changed without affecting the demand meters.

The examples in this section discuss demand current, but MW and MVAR demand values are also available, as stated at the beginning of this subsection.

The demand current pickup settings in *Table 6.1* are applied to demand current meter outputs as shown in *Figure 6.6*. For example, when ground demand current $I_{N(DEM)}$ goes above corresponding demand pickup NDEMP, Relay Word bit NDEM asserts to logical 1. Use these demand current logic outputs (PDEM, NDEM, and QDEM) to alarm for high loading or unbalance conditions.

Table 6.1 Demand Meter Settings and Settings Range

Setting	Definition	Range
EDEM	Demand meter type	THM = thermal ROL = rolling
DMTC	Demand meter time constant	5, 10, 15, 30, or 60 minutes
PDEMP QDEMP	Phase demand current pickup Negative-sequence demand current pickup	OFF 0.10–3.20 A (1 A nominal) 0.5–16 A (5 A nominal) in 0.01 A steps
NDEMP	Ground demand current pickup	OFF 0.005–0.640 A (0.2 A nominal) in 0.001 A steps

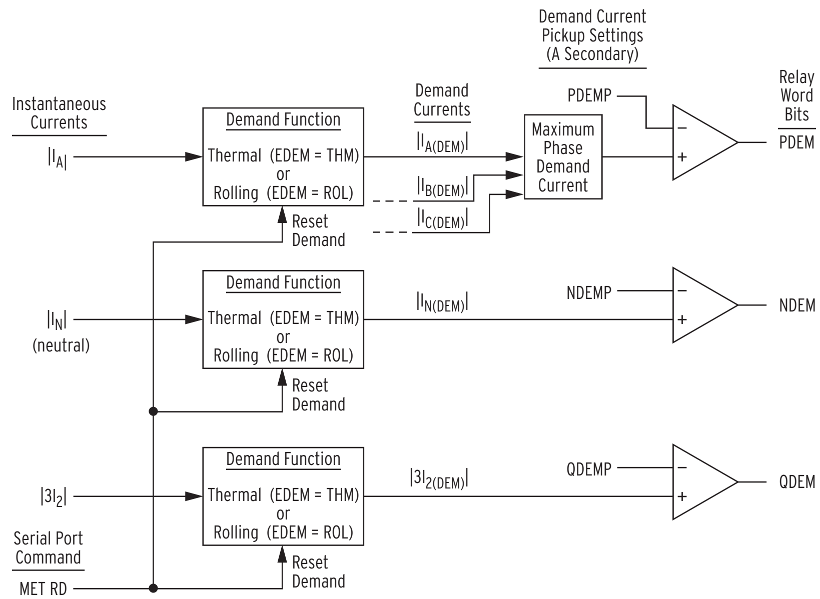

Figure 6.6 Demand Current Logic Outputs

View or Reset Demand Metering Information

Via Serial Port

See *MET Command (Metering Data) on page 8.29* and *MET D—Local Demand Metering on page 8.31*. The **MET D** command displays local demand and local peak demand metering for the following values:

Currents

$I_{A,B,C}$ Input currents (A primary)

I_N Neutral ground current (A primary)

$3I_2$	Negative-sequence current (A primary)
Power	
$MW_{A,B,C}$	Single-phase megawatts
$MVAR_{A,B,C}$	Single-phase megavars
MW_{3P}	Three-phase megawatts
$MVAR_{3P}$	Three-phase megavars

The **MET RD** command resets the demand metering values. The **MET RP** command resets the peak demand metering values.

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **MET D**, **MET RD**, and **MET RP** are also available via the front-panel **{METER}** pushbutton. See *Figure 9.2*.

Demand Metering Updating and Storage

The SEL-311M updates demand values approximately every two seconds.

The relay stores peak demand values to nonvolatile storage once per day (it overwrites the previous stored value if it is exceeded). Should the relay lose control power, it will restore the peak demand values saved by the relay at 23:50 hours on the previous day.

Peak recording is momentarily suspended when SELOGIC control equation setting FAULT is asserted (= logical 1). See the explanation for the FAULT setting in *Maximum/Minimum Metering Updating and Storage on page 6.9*. It is not necessary to suspend demand metering during a fault since fault quantities will not significantly change demand quantities that are calculated using a minimum time constant of five minutes.

Local Energy Metering

View or Reset Energy Metering Information

Via Serial Port

See *MET E—Local Energy Metering on page 8.32*. The **MET E** command displays accumulated single- and three-phase megawatt and megavar hours. The **MET RE** command resets the accumulated single- and three-phase megawatt and megavar hours.

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **MET E** and **MET RE** are also available via the front-panel **{METER}** pushbutton. See *Figure 9.2*.

Energy Metering Updating and Storage

The SEL-311M updates energy values approximately every two seconds.

The relay stores energy values to nonvolatile storage once per day (it overwrites the previous stored value). Should the relay lose control power, it will restore the energy values saved by the relay at 23:50 hours on the previous day.

Local Maximum/ Minimum Metering

View or Reset Maximum/Minimum Metering Information

Via Serial Port

See *MET M—Local Maximum/Minimum Metering on page 8.32*. The **MET M** command displays maximum/minimum metering for the following values:

Currents	
$I_{A,B,C,N}$	Input currents (A primary)
I_G	Residual ground current (A primary; $I_G = 3_{I0} = I_A + I_B + I_C$)
Voltages	
$V_{A,B,C}$	Input voltages (kV primary)
V_S	Input voltage (kV primary)
Power	
MW_{3P}	Three-phase megawatts
$MVAR_{3P}$	Three-phase megavars

The **MET RM** command resets the maximum/minimum metering values.

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **MET M** and **MET RM** are also available via the front-panel **{METER}** pushbutton. See *Figure 9.2*.

Maximum/Minimum Metering Updating and Storage

The SEL-311M updates maximum/minimum values, if the following conditions are met:

- SELOGIC control equation setting FAULT is deasserted (= logical 0, default).
- Maximum/minimum recording resumes one minute after FAULT deasserts.
- The metering value is above the previous maximum or below the previous minimum for two cycles.
- For voltage values, the voltage is above 13 V secondary.
- For current values, the currents are above 0.05 A secondary {1 A nominal}
- Megawatt and megavar values are subject to the above voltage and current thresholds.

The SEL-311M stores maximum/minimum values to nonvolatile storage once per day (it overwrites the previous stored value if it is exceeded). Should the relay lose control power, it will restore the maximum/minimum values saved by the relay at 23:50 hours on the previous day.

Breaker Monitor

The breaker monitor in the SEL-311M helps in scheduling circuit breaker maintenance. The breaker monitor is enabled with the enable setting:

EBMON = **Y**

The breaker monitor settings in *Table 6.3* are available via the **SET G** and **SET L** commands (see *Table 7.1* and also *SEL-311M Settings Sheets* at the end of *Section 7: Settings*). Also refer to *BRE Command (Breaker Monitor Data) on page 8.22* and *BRE n Command (Preload/Reset Breaker Wear) on page 8.42*.

The breaker monitor is set with breaker maintenance information provided by circuit breaker manufacturers. This breaker maintenance information lists the number of close/open operations that are permitted for a given current interruption level. The following is an example of breaker maintenance information for an example circuit breaker.

Table 6.2 Breaker Maintenance Information for an Example Circuit Breaker

Current Interruption Level (kA)	Permissible Number of Close/Open Operations[a]
0.00–1.20	10,000
2.00	3,700
3.00	1,500
5.00	400
8.00	150
10.00	85
20.00	12

[a] The action of a circuit breaker closing and then later opening is counted as one close/open operation.

The breaker maintenance information in *Table 6.2* is plotted in *Figure 6.7*.

Connect the plotted points in *Figure 6.7* for a breaker maintenance curve. To estimate this breaker maintenance curve in the SEL-311M breaker monitor, three set points are entered:

- Set Point 1

  maximum number of close/open operations with corresponding current interruption level

- Set Point 2

  number of close/open operations that correspond to some midpoint current interruption level

- Set Point 3

  number of close/open operations that correspond to the maximum current interruption level

These three points are entered with the settings in *Table 6.3*.

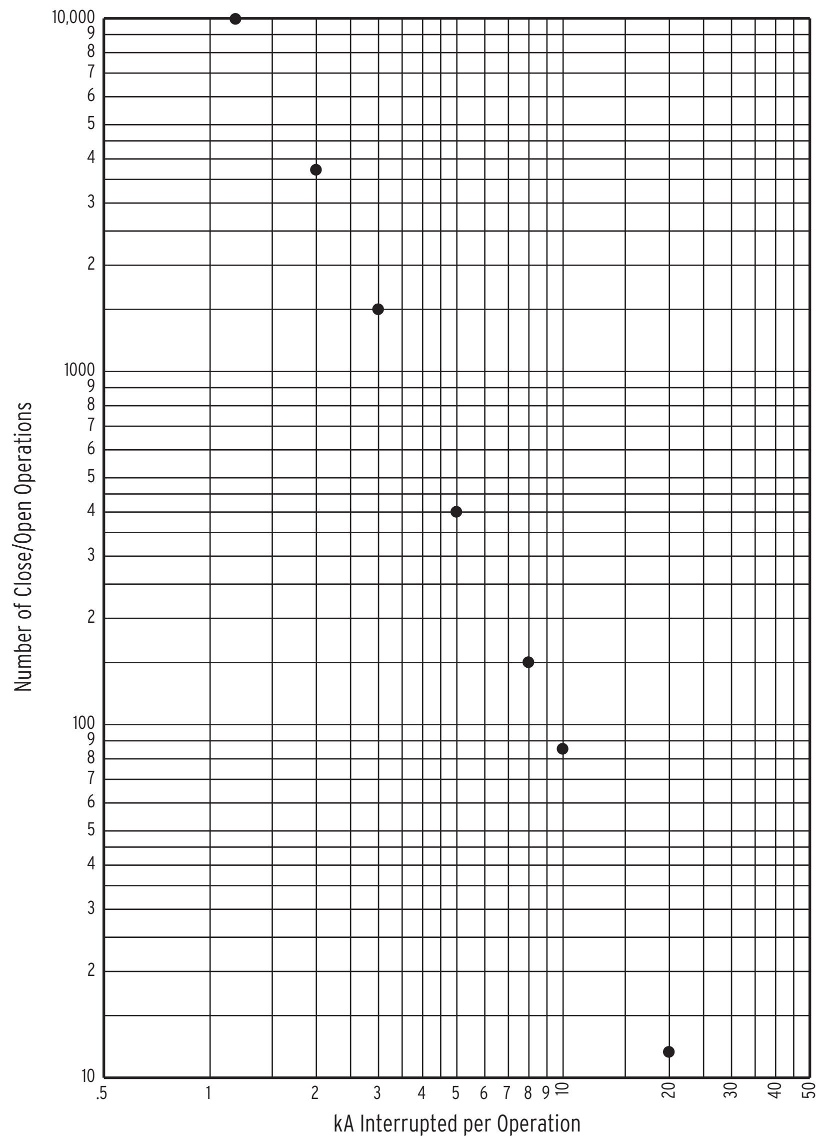

Figure 6.7 Plotted Breaker Maintenance Points for an Example Circuit Breaker

Breaker Monitor Setting Example

Table 6.3 Breaker Monitor Settings and Settings Ranges

Setting	Definition	Range
COSP1	Close/Open set point 1-maximum	0–65000 close/open operations
COSP2	Close/Open set point 2-middle	0–65000 close/open operations
COSP3	Close/Open set point 3-middle	0–65000 close/open operations
KASP1[a]	kA Interrupted set point 1-minimum	0.00–999.00 kA in 0.01 kA steps
KASP2	kA Interrupted set point 1-middle	0.00–999.00 kA in 0.01 kA steps
KASP3[a]	kA Interrupted set point 1-maximum	0.00–999.00 kA in 0.01 kA steps
BKMON	SELOGIC control equation breaker monitor initiation setting	Relay Word bits referenced in *Table 7.5* and *Table 7.6*

[a] The ratio of settings KASP3/KASP1 must be: 5 ≤ KASP3/KASP1 ≤ 100.

The following settings are made from the breaker maintenance information in *Table 6.2* and *Figure 6.7*:

COSP1 = **10000**

COSP2 = **150**

COSP3 = **12**

KASP1 = **1.20**

KASP2 = **8.00**

KASP3 = **20.00**

Figure 6.8 shows the resultant breaker maintenance curve.

Breaker Maintenance Curve Details

In *Figure 6.8*, note that set points KASP1, COSP1 and KASP3, COSP3 are set with breaker maintenance information from the two extremes in *Table 6.2* and *Figure 6.7*.

In this example, set point KASP2, COSP2 happens to be from an in-between breaker maintenance point in the breaker maintenance information in *Table 6.2* and *Figure 6.7*, but it does not have to be. Set point KASP2, COSP2 should be set to provide the best "curve-fit" with the plotted breaker maintenance points in *Figure 6.7*.

Each phase (A, B, and C) has its own breaker maintenance curve (like that in *Figure 6.8*), because the separate circuit breaker interrupting contacts for phases A, B, and C do not necessarily interrupt the same magnitude current (depending on fault type and loading).

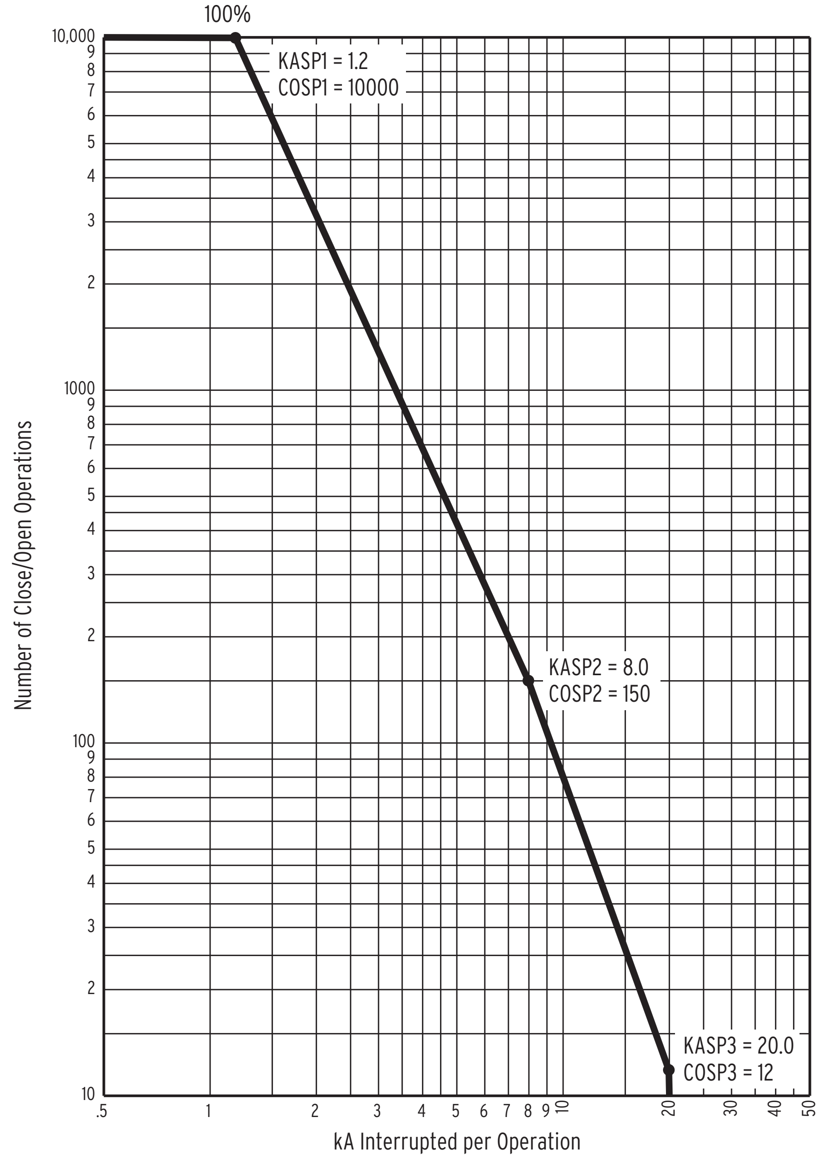

Figure 6.8 SEL-311M Breaker Maintenance Curve for an Example Circuit Breaker

In *Figure 6.8*, note that the breaker maintenance curve levels off horizontally to the left of set point KASP1, COSP1. This is the close/open operation limit of the circuit breaker (COSP1 = 10000), regardless of interrupted current value.

Also, note that the breaker maintenance curve falls vertically below set point KASP3, COSP3. This is the maximum interrupted current limit of the circuit breaker (KASP3 = 20.0 kA). If the interrupted current is greater than setting KASP3, the interrupted current is accumulated as a current value equal to setting KASP3.

Operation of SELOGIC Control Equation Breaker Monitor Initiation Setting BKMON

The SELOGIC control equation breaker monitor initiation setting BKMON in *Table 6.3* determines when the breaker monitor reads in current values (Phases A, B, and C) for the breaker maintenance curve and the breaker monitor accumulated currents/trips (see *BRE Command (Breaker Monitor Data) on page 8.22*).

The BKMON setting looks for a rising edge (logical 0 to logical 1 transition) as the indication to read in current values. The acquired current values are then applied to the breaker maintenance curve and the breaker monitor accumulated currents/trips.

For example, the SELOGIC control equation breaker monitor initiation setting may be set:

BKMON = **TRIP** (TRIP is the logic output of *Figure 4.3*)

Refer to *Figure 6.9*. When BKMON asserts (Relay Word bit TRIP goes from logical 0 to logical 1), the breaker monitor reads in the current values and applies them to the breaker monitor maintenance curve and the breaker monitor accumulated currents/trips.

As detailed in *Figure 6.9*, the breaker monitor actually reads in the current values 1.5 cycles after the assertion of BKMON. This helps especially if an instantaneous trip occurs. The instantaneous element trips when the fault current reaches its pickup setting level. The fault current may still be “climbing” to its full value, after which it levels off. The 1.5-cycle delay reading the current values allows time for the fault current to level off.

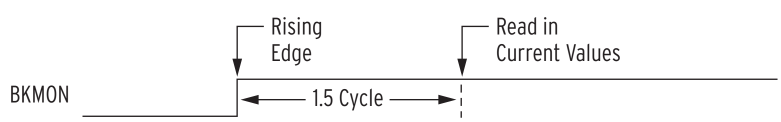

Figure 6.9 Operation of SELOGIC Control Equation Breaker Monitor Initiation Setting

The operation of the breaker monitor maintenance curve, when new current values are read in, is explained in the following example.

Breaker Monitor Operation Example

As stated earlier, each phase (A, B, and C) has its own breaker maintenance curve. For this example, presume that the interrupted current values occur on a single phase in *Figure 6.10*–*Figure 6.13*. Also, presume that the circuit breaker interrupting contacts have no wear initially (brand new or recent maintenance performed).

Note in the following four figures (*Figure 6.10*–*Figure 6.13*) that the interrupted current in a given figure is the same magnitude for all the interruptions (e.g., in *Figure 6.11*, 2.5 kA is interrupted 290 times). This is not realistic, but helps in demonstrating the operation of the breaker maintenance curve and how it integrates for varying current levels.

0 Percent to 10 Percent Breaker Wear

Refer to *Figure 6.10*, in which 7.0 kA is interrupted 20 times, pushing the breaker maintenance curve from the 0 percent wear level to the 10 percent wear level.

Compare the 100 percent and 10 percent curves and note that for a given current value, the 10 percent curve has only 1/10 of the close/open operations of the 100 percent curve.

10 Percent to 25 Percent Breaker Wear

Refer to *Figure 6.11*. The current value changes from 7.0 kA to 2.5 kA. The 2.5 kA current is interrupted 290 times (290 close/open operations = 480 – 190), pushing the breaker maintenance curve from the 10 percent wear level to the 25 percent wear level.

Compare the 100 percent and 25 percent curves and note that for a given current value, the 25 percent curve has only 1/4 of the close/open operations of the 100 percent curve.

25 Percent to 50 Percent Breaker Wear

Refer to *Figure 6.12*. The current value changes from 2.5 kA to 12.0 kA. The 12.0 kA current is interrupted 11 times (11 close/open operations = 24 – 13), pushing the breaker maintenance curve from the 25 percent wear level to the 50 percent wear level.

Compare the 100 percent and 50 percent curves and note that for a given current value, the 50 percent curve has only 1/2 of the close/open operations of the 100 percent curve.

50 Percent to 100 Percent Breaker Wear

Refer to *Figure 6.13*. The current value changes from 12.0 kA to 1.5 kA. The 1.5 kA current is interrupted 3000 times (3000 close/open operations = 6000 – 3000), pushing the breaker maintenance curve from the 50 percent wear level to the 100 percent wear level.

When the breaker maintenance curve reaches 100 percent for a particular phase, the percentage wear remains at 100 percent (even if additional current is interrupted), until reset by the **BRE R** command (see *View or Reset Breaker Monitor Information on page 6.20*. Current and trip counts continue to be accumulated, until reset by the **BRE R** command.

Additionally, logic outputs assert for alarm or other control applications—see the following discussion.

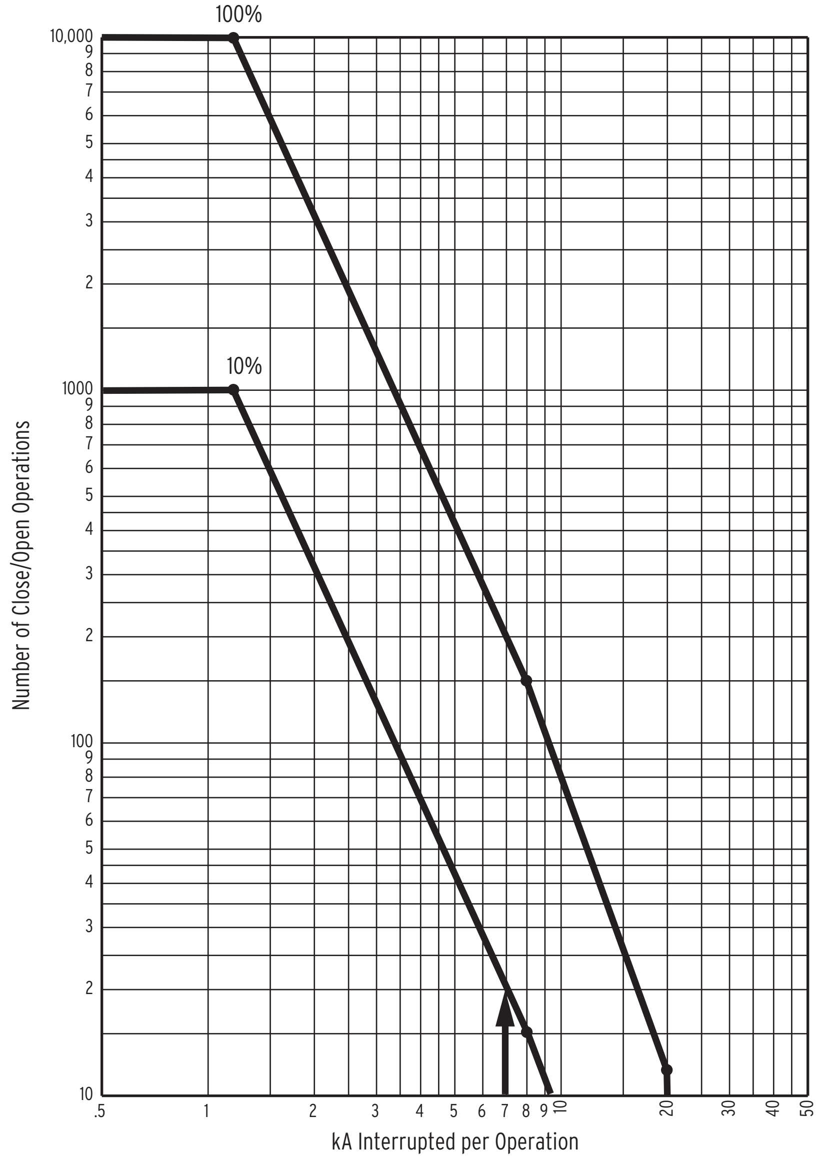

Figure 6.10 Breaker Monitor Accumulates 10 Percent Wear

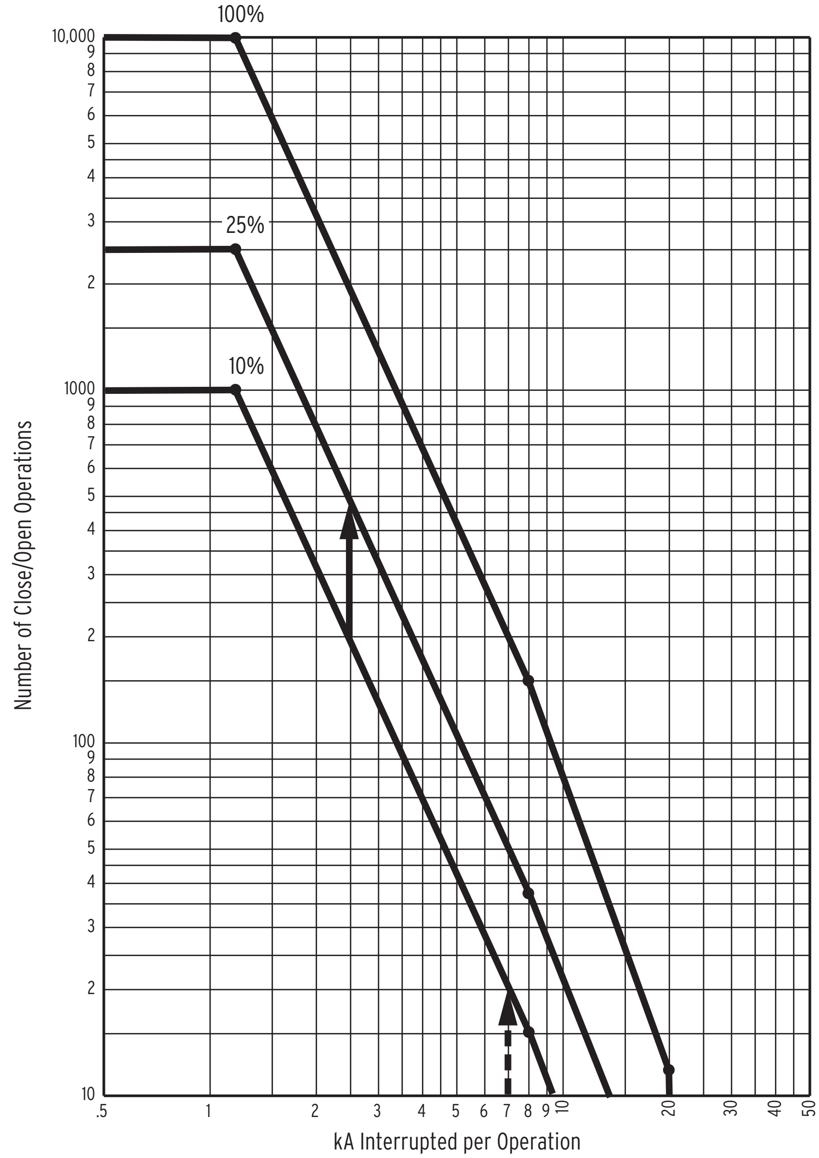

Figure 6.11 Breaker Monitor Accumulates 25 Percent Wear

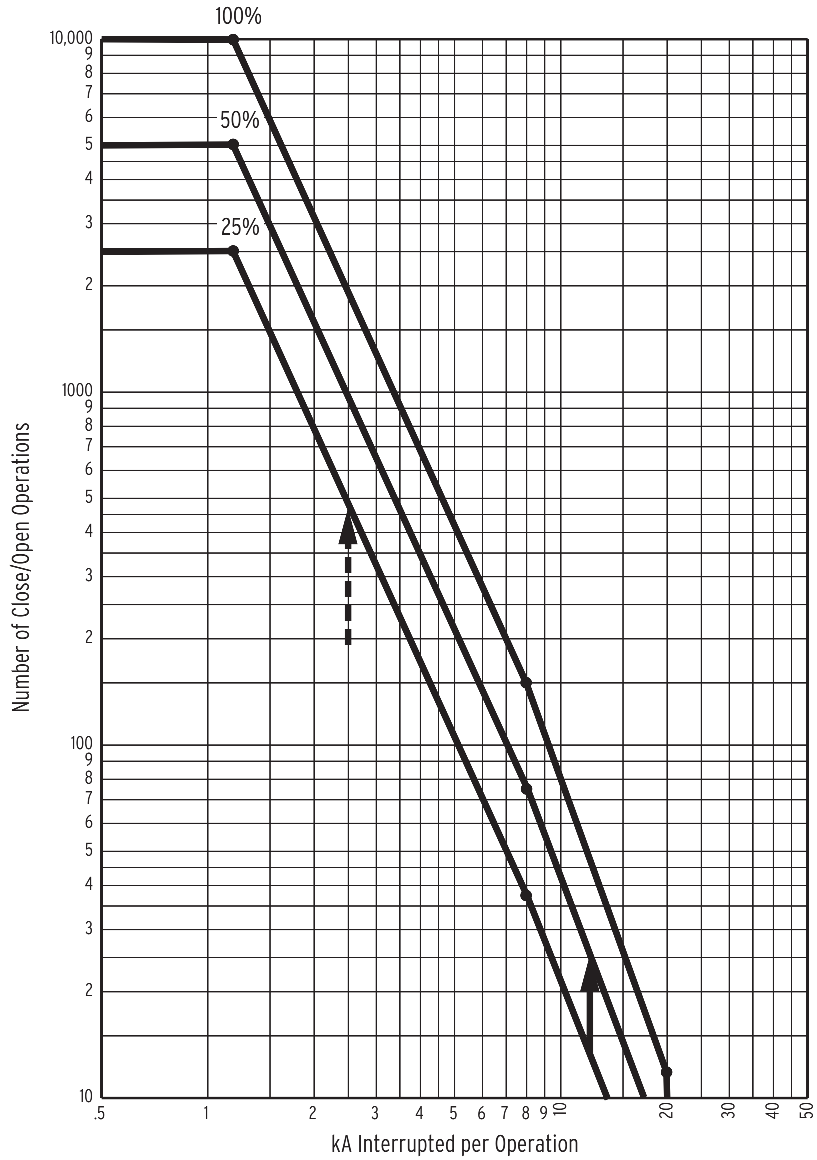

Figure 6.12 Breaker Monitor Accumulates 50 Percent Wear

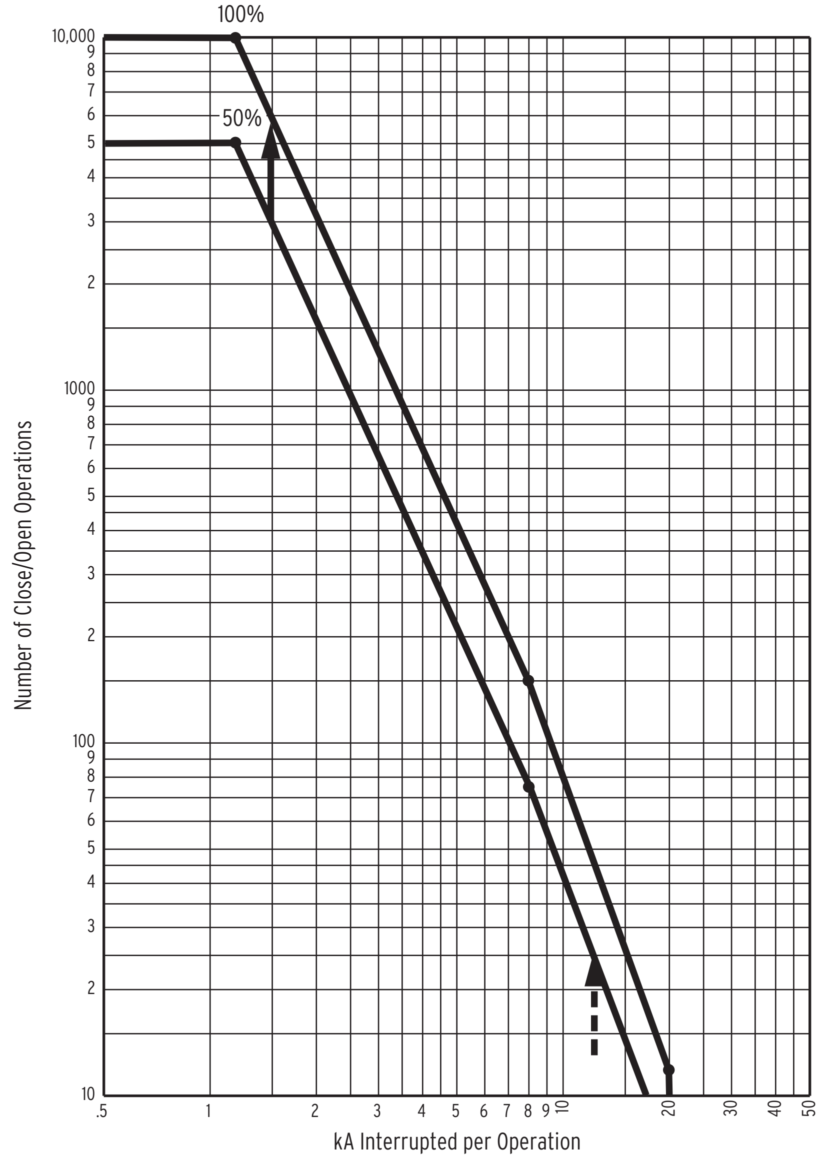

Figure 6.13 Breaker Monitor Accumulates 100 Percent Wear

Breaker Monitor Output

When the breaker maintenance curve for a particular phase (A, B, or C) reaches the 100 percent wear level (see *Figure 6.13*), a corresponding Relay Word bit (BCWA, BCWB, or BCWC) asserts.

Table 6.4 Breaker Monitor Output Relay Word Bits

Relay Word Bits	Definition
BCWA	Phase A breaker contact wear has reached the 100% wear level
BCWB	Phase B breaker contact wear has reached the 100% wear level
BCWC	Phase C breaker contact wear has reached the 100% wear level
BCW	BCWA + BCWB + BCWC

Example Applications

These logic outputs can be used to alarm:

OUT105 = **BCW**

View or Reset Breaker Monitor Information

Accumulated breaker wear/operations data is retained if the relay loses power or the breaker monitor is disabled (setting EBMON = N). The accumulated data can only be reset if the **BRE R** command is executed (see the following discussion on the **BRE R** command).

Via Serial Port

See *BRE Command (Breaker Monitor Data) on page 8.22*. The **BRE** command displays the following information:

- Accumulated number of relay-initiated trips
- Accumulated interrupted current from relay-initiated trips
- Accumulated number of externally initiated trips
- Accumulated interrupted current from externally initiated trips
- Percent circuit breaker contact wear for each phase
- Date when the preceding items were last reset (via the **BRE R** command)

See *BRE n Command (Preload/Reset Breaker Wear) on page 8.42*. The **BRE W** command allows the internal trips and currents, the external trips and currents, and the percent breaker wear to be preloaded for each individual phase.

The **BRE R** command resets the accumulated values and the percent wear for all three phases. For example, if breaker contact wear has reached the 100 percent wear level for A-phase, the corresponding Relay Word bit BCWA asserts (BCWA = logical 1). Execution of the **BRE R** command resets the wear levels for all three phases back to 0 percent and consequently causes Relay Word bit BCWA to deassert (BCWA = logical 0).

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **BRE** and **BRE R** are also available via the front-panel **{OTHER}** pushbutton. See *Figure 9.3*.

Determination of Relay-Initiated Trips and Externally Initiated Trips

See *BRE Command (Breaker Monitor Data) on page 8.22*. Note in the **BRE** command response that the accumulated number of trips and accumulated interrupted current are separated into two groups of data: that generated by relay-initiated trips (Rly Trips) and that generated by externally initiated trips (Ext Trips). The categorization of this data is determined by the status of the TRIP Relay Word bit when the SELOGIC control equation breaker monitor initiation setting BKMON operates.

Refer to *Figure 6.9* and the accompanying explanation. If BKMON newly asserts (logical 0 to logical 1 transition), the relay reads in the current values (Phases A, B, and C). Now the decision has to be made: where is this current and trip count information accumulated? Under relay-initiated trips or externally initiated trips?

To make this determination, the status of the TRIP Relay Word bit is checked at the instant BKMON newly asserts (TRIP is the logic output of *Figure 4.3*). If TRIP is asserted (TRIP = logical 1), the current and trip count information is accumulated under relay-initiated trips (Rly Trips). If TRIP is deasserted (TRIP = logical 0), the current and trip count information is accumulated under externally initiated trips (Ext Trips).

Regardless of whether the current and trip count information is accumulated under relay-initiated trips or externally initiated trips, this same information is routed to the breaker maintenance curve for continued breaker wear integration (see *Figure 6.10*–*Figure 6.13*).

Setting Example

As discussed previously, the SELOGIC control equation breaker monitor initiation may be set:

BKMON = **TRIP + TRIP87**

Thus, any new assertion of BKMON will be deemed a relay trip, and the current and trip count information is accumulated under relay-initiated trips (Rly Trips).

Additional Example

Refer to *Figure 6.14*. Output contact **OUT201** is set to provide tripping:

OUT201 = **TRIP + TRIP87**

Note that optoisolated input **IN106** monitors the trip bus. If the trip bus is energized by output contact **OUT201**, an external control switch, or some other external trip, then **IN106** is asserted.

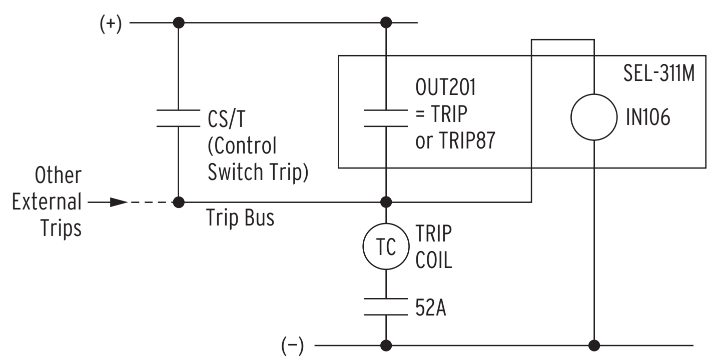

Figure 6.14 Input IN106 Connected to Trip Bus for Breaker Monitor Initiation

If the SELOGIC control equation breaker monitor initiation setting is set:

BKMON = **IN106**

then the SEL-311M breaker monitor sees all trips.

If output contact **OUT201** asserts, energizing the trip bus, the breaker monitor will deem it a relay-initiated trip. This is because when BKMON is newly asserted (input **IN106** energized), the TRIP Relay Word bit is asserted. Thus, the current and trip count information is accumulated under relay-initiated trips (Rly Trips). If EHST = 000000, placing TRIP87 in the TR equation assures a differential trip is counted as a relay-initiated trip.

If the control switch trip (or some other external trip) asserts, energizing the trip bus, the breaker monitor will deem it an externally initiated trip. This is because when BKMON is newly asserted (input IN106 energized), the TRIP Relay Word bit is deasserted. Thus, the current and trip count information is accumulated under externally initiated trips (Ext Trips).

Station DC Battery Monitor

The station dc battery monitor in the SEL-311M can alarm for under- or overvoltage dc battery conditions and give a view of how much the station dc battery voltage dips when tripping, closing, and other dc control functions take place. The monitor measures the station dc battery voltage applied to the rear-panel terminals labeled Z25 and Z26 (see *Figure 1.3* and *Figure 2.2*). The station dc battery monitor settings (DCLOP and DCHIP) are available via the **SET G** command (see *Table 7.1* and also *Global Settings* ***(Serial Port Command SET G and Front Panel)*** in the *SEL-311M Settings Sheets* at the back of *Section 7: Settings*).

DC Under- and Overvoltage Elements

Refer to *Figure 6.15*. The station dc battery monitor compares the measured station battery voltage (Vdc) to the undervoltage (low) and overvoltage (high) pickups DCLOP and DCHIP. The setting range for pickup settings DCLOP and DCHIP is:

OFF, 20 to 300 Vdc, .01 Vdc increments

This range allows the SEL-311M to monitor nominal battery voltages of 24, 48, 110, 125, and 250 V. When testing the pickup settings DCLOP and DCHIP, do not operate the SEL-311M outside of the power supply limits listed in *Section 1: Introduction and Specifications*.

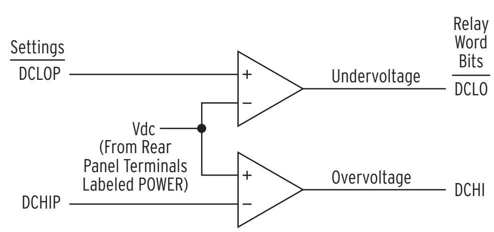

Figure 6.15 DC Under- and Overvoltage Elements

Logic outputs DCLO and DCHI in *Figure 6.15* operate as follows:

DCLO = 1 (logical 1), if $V_{dc} \leq$ pickup setting DCLOP
= 0 (logical 0), if $V_{dc} >$ pickup setting DCLOP
DCHI = 1 (logical 1), if $V_{dc} \geq$ pickup setting DCHIP
= 0 (logical 0), if $V_{dc} <$ pickup setting DCHIP

Create Desired Logic for DC Under- and Overvoltage Alarming

Pickup settings DCLOP and DCHIP are set independently. Thus, they can be set:

DCLOP < DCHIP or DCLOP > DCHIP

Figure 6.16 shows the resultant dc voltage elements that can be created with SELOGIC control equations for these two setting cases. In these two examples, the resultant dc voltage elements are time-qualified by timer SV4T and then routed to output contact OUT106 for alarm purposes.

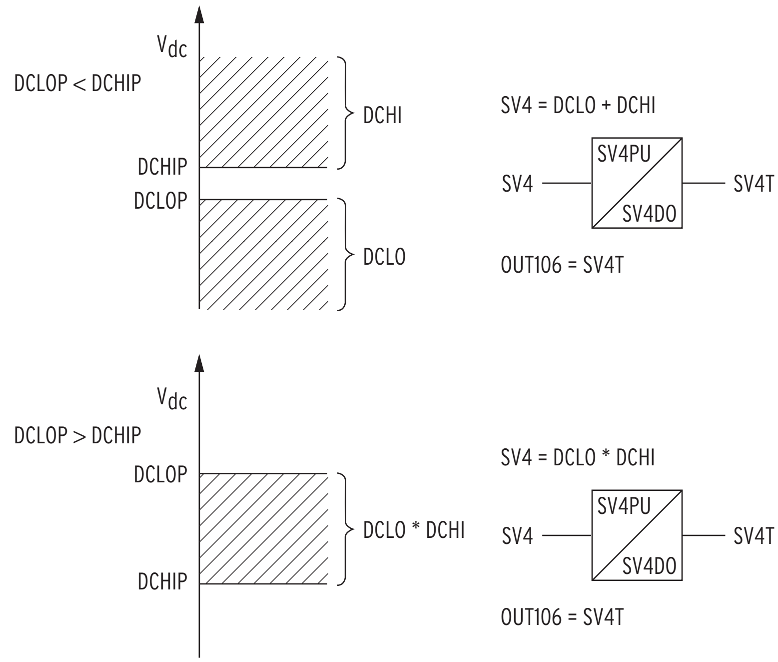

Figure 6.16 Create DC Voltage Elements With SELOGIC Control Equations

DCLO < DCHI (Top of Figure 6.16)

Output contact **OUT106** asserts when:

$V_{dc} \leq$ DCLOP or $V_{dc} \geq$ DCHIP

Pickup settings DCLOP and DCHIP are set such that output contact **OUT106** asserts when dc battery voltage goes below or above allowable limits.

If the relay loses power entirely (Vdc = 0 Vdc)

$V_{dc} = <$ DCLOP

then output contact **OUT106** should logically assert (according to top of *Figure 6.16*), but cannot because of the total loss of power (all output contacts deassert on total loss of power). Thus, the resultant dc voltage element at the bottom of *Figure 6.16* would probably be a better choice—see following discussion.

DCLO > DCHI (Bottom of Figure 6.16)

Output contact **OUT106** asserts when:

DCHIP $\leq V_{dc} \leq$ DCLOP

Pickup settings DCLOP and DCHIP are set such that output contact **OUT106** asserts when dc battery voltage stays between allowable limits.

If the relay loses power entirely (V_{dc} = 0 Vdc)

$V_{dc} = <$ DCHIP

then output contact **OUT106** should logically deassert (according to bottom of *Figure 6.16*), and this is surely what happens for a total loss of power (all output contacts deassert on total loss of power).

Output Contact Type Considerations (a or b)

Refer to *Output Contacts on page 5.21* (especially *Figure 5.13*). Consider the output contact type (a or b) needed for output contact **OUT106** in the bottom of *Figure 6.16* (dc voltage alarm example).

If SELOGIC control equation setting OUT106 is asserted (OUT106 = SV4T = logical 1; dc voltage OK), the state of output contact **OUT106** (according to contact type) is:

- closed (a type output contact)
- open (b type output contact)

If SELOGIC control equation setting OUT106 is deasserted (OUT106= SV4T = logical 0; dc voltage not OK), the state of output contact **OUT106** (according to contact type) is:

- open (a type output contact)
- closed (b type output contact)

If the relay loses power entirely, all output contacts deassert, and the state of output contact **OUT106** (according to contact type) is:

- open (a type output contact)
- closed (b type output contact)

Additional Application

Other than alarming, the dc voltage elements can be used to disable the zero-sequence differential current element.

For example, if the station dc batteries have a problem and the station dc battery voltage is declining, disable the element:

87WB = **!SV4T + ...** [= NOT(SV4T) + ...]

Timer output SV4T is from the bottom of *Figure 6.16*. When dc voltage falls below pickup DCHIP, timer output SV4T drops out (= logical 0), disabling the element:

87WB = **!SV4T + ...** = NOT(SV4T) + ... = NOT(logical 0) + ... = logical 1

View Station DC Battery Voltage

Via Serial Port

See *MET B k—Instantaneous Local Metering on page 8.30*. The **MET B** command displays the station dc battery voltage (labeled VDC).

Via Front Panel

The information available via the previously discussed **MET** serial port command is also available via the front-panel **{METER}** pushbutton. See *Figure 9.2*.

Analyze Station DC Battery Voltage

See *Section 10: Analyzing Events*. The station dc battery voltage is displayed in column Vdc in the example event report in *Figure 10.4*. Changes in station dc battery voltage for an event (e.g., circuit breaker tripping) can be observed. Use the **EVE** command to retrieve event reports as discussed in *Section 10: Analyzing Events*.

Station DC Battery Voltage Dips During Circuit Breaker Tripping

Event reports are automatically generated when the TRIP Relay Word bit asserts (TRIP is the logic output of *Figure 4.3*). For example, output contact **OUT101** is set to trip:

OUT101 = **TRIP**

When output contact **OUT101** closes and energizes the circuit breaker trip coil, any change in station dc battery voltage can be observed in column Vdc in the event report.

To generate an event report for external trips, make connections similar to *Figure 6.14* and program optoisolated input **IN106** (monitoring the trip bus) in the SELOGIC control equation event report generation setting, e.g.:

ER = **/IN106 + ...**

When the trip bus is energized, any change in station dc battery voltage can be observed in column Vdc in the event report.

Station DC Battery Voltage Dips During Circuit Breaker Closing

To generate an event report when the SEL-311M closes the circuit breaker, make the SELOGIC control equation event report generation setting:

ER = **/OUT102 + ...**

In this example, output contact **OUT102** is set to close:

OUT102 = **CLOSE** (CLOSE is the logic output of *Figure 4.14*)

When output contact **OUT102** closes and energizes the circuit breaker close coil, any change in station dc battery voltage can be observed in column Vdc in the event report.

This event report generation setting (ER = /OUT102 + ...) might be made just as a test setting. Generate several event reports when doing circuit breaker close testing and observe the “signature” of the station dc battery voltage in column Vdc in the event reports.

Station DC Battery Voltage Dips Anytime

To generate an event report whenever there is a change in station dc battery voltage dip, set the dc voltage element directly in the SELOGIC control equation event report generation setting:

ER = **\SV4T + ...**

Timer output SV4T is an example dc voltage element from the bottom of *Figure 6.16*. Any time dc voltage falls below pickup DCHIP, timer output SV4T drops out (logical 1 to logical 0 transition), creating a falling-edge condition that generates an event report.

Also, the Sequential Event Recorder (SER) report can be used to time-tag station dc battery voltage dips (see *Sequential Events Recorder Report on page 10.37*).

Operation of Station DC Battery Monitor When AC Voltage Is Powering the Relay

If the SEL-311M has a 125/250 Vac/Vdc supply, it can be powered by ac voltage (85 to 264 Vac) connected to the rear-panel terminals labeled POWER. When powering the relay with ac voltage, the dc voltage elements in *Figure 6.15* see the average of the sampled ac voltage powering the relay-which is very near zero volts (as displayed in column Vdc in event reports). Pickup settings DCLOP and DCHIP should be set off (DCLOP = OFF, DCHIP = OFF) since they are of no real use.

If a "raw" event report is displayed (with the **EVE R** command), column Vdc will display the sampled ac voltage waveform, rather than the average.

Section 7
Settings

Overview

Change or view settings with the **SET** and **SHOWSET** serial port commands and the front-panel {SET} pushbutton. *Table 7.1* lists the serial port **SET** commands.

Table 7.1 Serial Port SET Commands

Command	Settings Type	Description	Settings Sheets[a]
SET *m*	Relay	Line current differential, overcurrent and voltage elements, timers, etc., for settings group *m* (*m* = 1, 2, 3, 4, 5, 6).	*SET.1–SET.18*
SET L *m*	Logic	SELOGIC® control equations for settings group *m* (*m* = 1, 2, 3, 4, 5, 6).	*SET.19–SET.26*
SET G	Global	Battery and breaker monitors, optoisolated input debounce timers, etc.	*SET.27–SET.28*
SET R	SER	Sequential Events Recorder trigger conditions.	*SET.30*
SET T	Text	Front-panel default display and local control text.	*SET.31–SET.35*
SET P *m*	Port	Serial port settings for Serial Port *m* (*m* = 1, 2, 3, or F).	*SET.36*
SET X	Channel	Differential communications Channel X settings.	*SET.38*
SET Y	Channel	Differential communications Channel Y settings.	*SET.38*

[a] Located at the end of this section.

View settings with the respective serial port **SHOWSET** commands (**SHO**, **SHO L**, **SHO G**, **SHO R**, **SHO T**, **SHO P**, **SHO X**, and **SHO Y**). See *SHO Command (Show/View Settings) on page 8.33*.

Settings Changes Via the Front Panel

The relay front-panel {SET} pushbutton provides access to the Relay, Global, Port, and Channel settings only. Thus, the corresponding Relay, Global, Port, and Channel settings sheets that follow in this section can also be used when making these settings via the front panel. Refer to *Figure 9.3* for information on settings changes via the front panel.

Settings Changes Via the Serial Port

NOTE: In this manual, commands you type appear in bold/uppercase: **METER**. Computer keys you press appear in bold/brackets: **<Enter>**.

See *Section 8: Communications* for information on serial port communications and relay access levels. The **SET** commands in *Table 7.1* operate at Access Level 2 (screen prompt: =>>). To change a specific setting, enter the command:

SET *n m s* TERSE

where:

- *n* = L, G, R, T, P, X, or Y (parameter *n* is not entered for the Relay settings. See *Table 7.1*).
- *m* = group (1…6) or port (1…3, F). The relay selects the active group or port if *m* is not specified.
- *s* = the name of the specific setting you wish to jump to and begin setting. If *s* is not entered, the relay starts at the first setting.
- TERSE = instructs the relay to skip the SHOWSET display after the last setting. Use this parameter to speed up the **SET** command. If you wish to review the settings before saving, do not use the TERSE option.

When you issue the **SET** command, the relay presents a list of settings, one at a time. Enter a new setting, or press **<Enter>** to accept the existing setting. Editing keystrokes are shown in *Table 7.2*.

Table 7.2 SET Command Editing Keystrokes

Press Key(s)	Results
<Enter>	Retains setting and moves to the next setting.
^ <Enter>	Returns to previous setting.
< <Enter>	Returns to previous section.
> <Enter>	Moves to next section.
END <Enter>	Exits editing session, then prompts you to save the settings.
<Ctrl+X>	Aborts editing session without saving changes.

The relay checks each entry to ensure that it is within the setting range. If it is not, an `Out of Range` message is generated, and the relay prompts for the setting again.

When all the settings are entered, the relay displays the new settings and prompts for approval to enable them. Answer **Y <Enter>** to enable the new settings. If changes are made to Global, SER, Text, or Channel settings (see *Table 7.1*), the relay is disabled while it saves the new settings. If changes are made to a Port setting, the relay is not disabled while it saves the new settings. If changes are made to the Relay or Logic settings for the active setting group (see *Table 7.1*), the relay is disabled while it saves the new settings. The **ALARM** contact closes momentarily (for b contact, opens for an a contact; see *Figure 5.14*) and the **EN** LED extinguishes (see *Table 4.1*) while the relay is disabled. The relay is disabled for about one second. If Logic settings are changed for the active group, the relay can be disabled for up to 15 seconds.

If changes are made to the Relay or Logic settings for a setting group other than the active setting group (see *Table 7.1*), the relay is not disabled while it saves the new settings. The **ALARM** contact closes momentarily (for b contact, opens for an a contact; see *Figure 5.14*), but the **EN** LED remains on (see *Table 4.1*) while the new settings are saved.

Time-Overcurrent Curves

The following information describes the curve timing for the curve and time dial settings made for the time-overcurrent elements (see *Figure 3.19*, *Figure 3.20*, and *Figure 3.21*; and *Figure 7.1*–*Figure 7.10*). The time-overcurrent relay curves in *Figure 7.1*–*Figure 7.5* conform to IEEE C37.112-1996 IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays. *Figure 7.6*–*Figure 7.10* represent IEC defined relay curves.

T_p = operating time in seconds
T_r = electromechanical induction-disk emulation reset time in seconds (if electromechanical reset setting is made)
TD = time dial setting
M = applied multiples of pickup current [for operating time (T_p), M>1; for reset time (T_r), M≤1].

Table 7.3 Equations Associated With U.S. Curves

Curve Type	Operating Time	Reset Time	Figure
U1 (Moderately Inverse)	$T_p = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$	*Figure 7.1*
U2 (Inverse)	$T_p = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$	*Figure 7.2*
U3 (Very Inverse)	$T_p = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$	*Figure 7.3*
U4 (Extremely Inverse)	$T_p = TD \bullet \left(0.02434 + \frac{5.64}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.64}{1 - M^2}\right)$	*Figure 7.4*
U5 (Short-Time Inverse)	$T_p = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$	*Figure 7.5*

Table 7.4 Equations Associated With IEC Curves

Curve Type	Operating Time	Reset Time	Figure
C1 (Standard Inverse)	$T_p = TD \bullet \frac{0.14}{M^{0.02} - 1}$	$T_R = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$	*Figure 7.6*
C2 (Very Inverse)	$T_p = TD \bullet \frac{13.5}{M - 1}$	$T_R = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$	*Figure 7.7*
C3 (Extremely Inverse)	$T_p = TD \bullet \frac{80}{M^2 - 1}$	$T_R = TD \bullet \left(\frac{80}{1 - M^2}\right)$	*Figure 7.8*
C4 (Long-Time Inverse)	$T_p = TD \bullet \frac{120}{M - 1}$	$T_R = TD \bullet \left(\frac{120}{1 - M}\right)$	*Figure 7.9*
C5 (Short-Time Inverse)	$T_p = TD \bullet \frac{0.05}{M^{0.04} - 1}$	$T_R = TD \bullet \left(\frac{4.85}{1 - M^2}\right)$	*Figure 7.10*

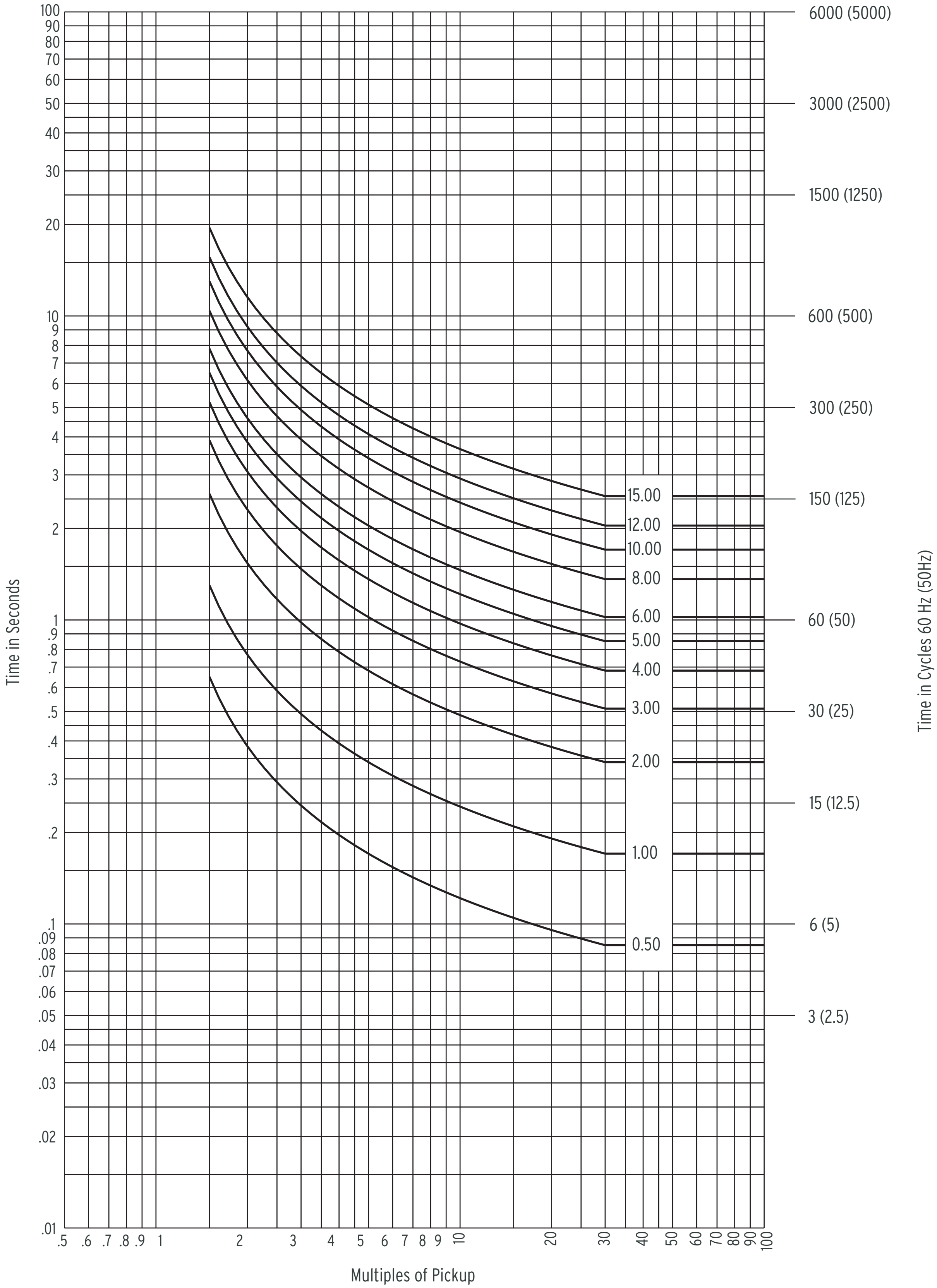

Figure 7.1 U. S. Moderately Inverse Curve: U1

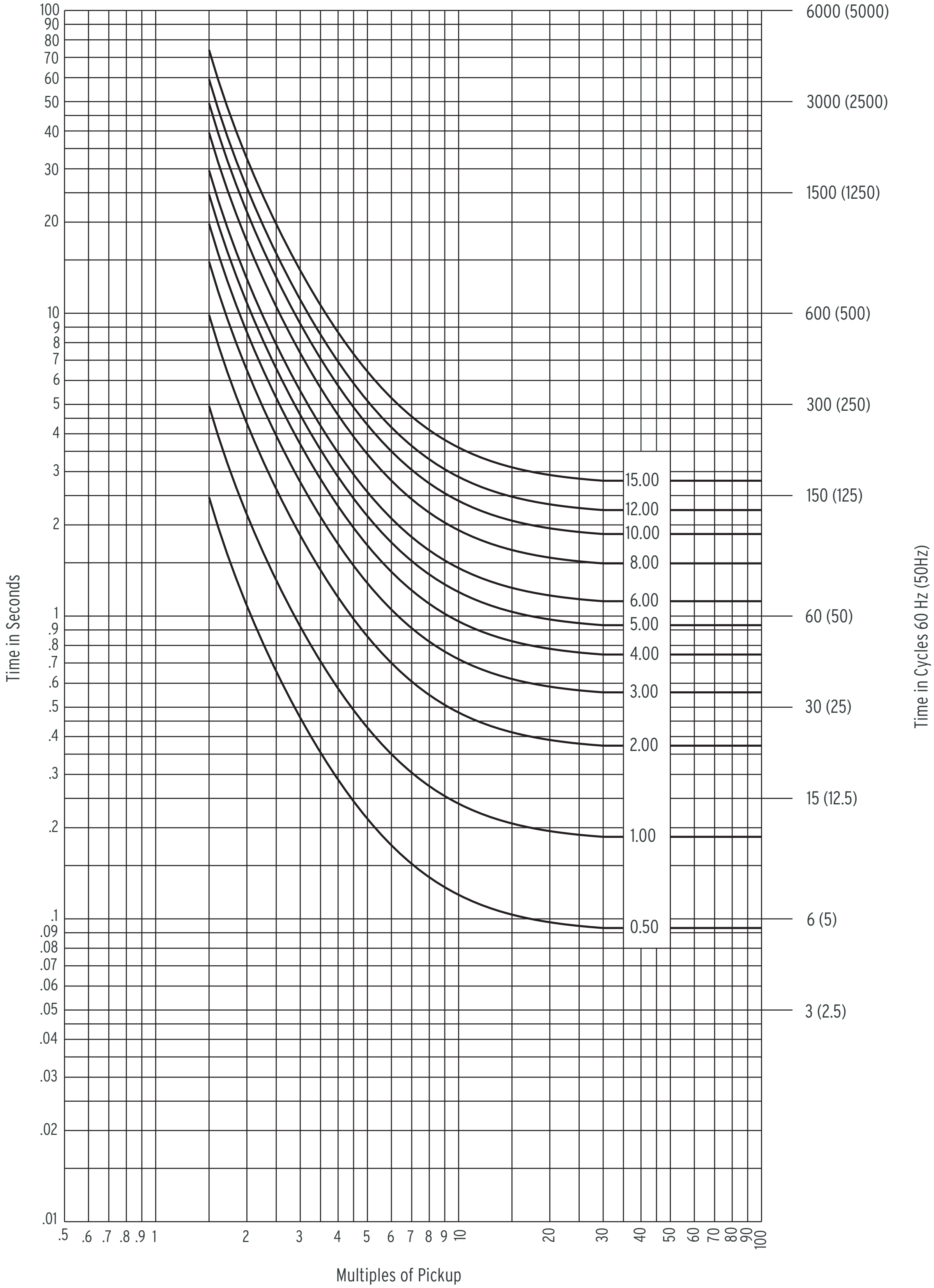

Figure 7.2 U. S. Inverse Curve: U2

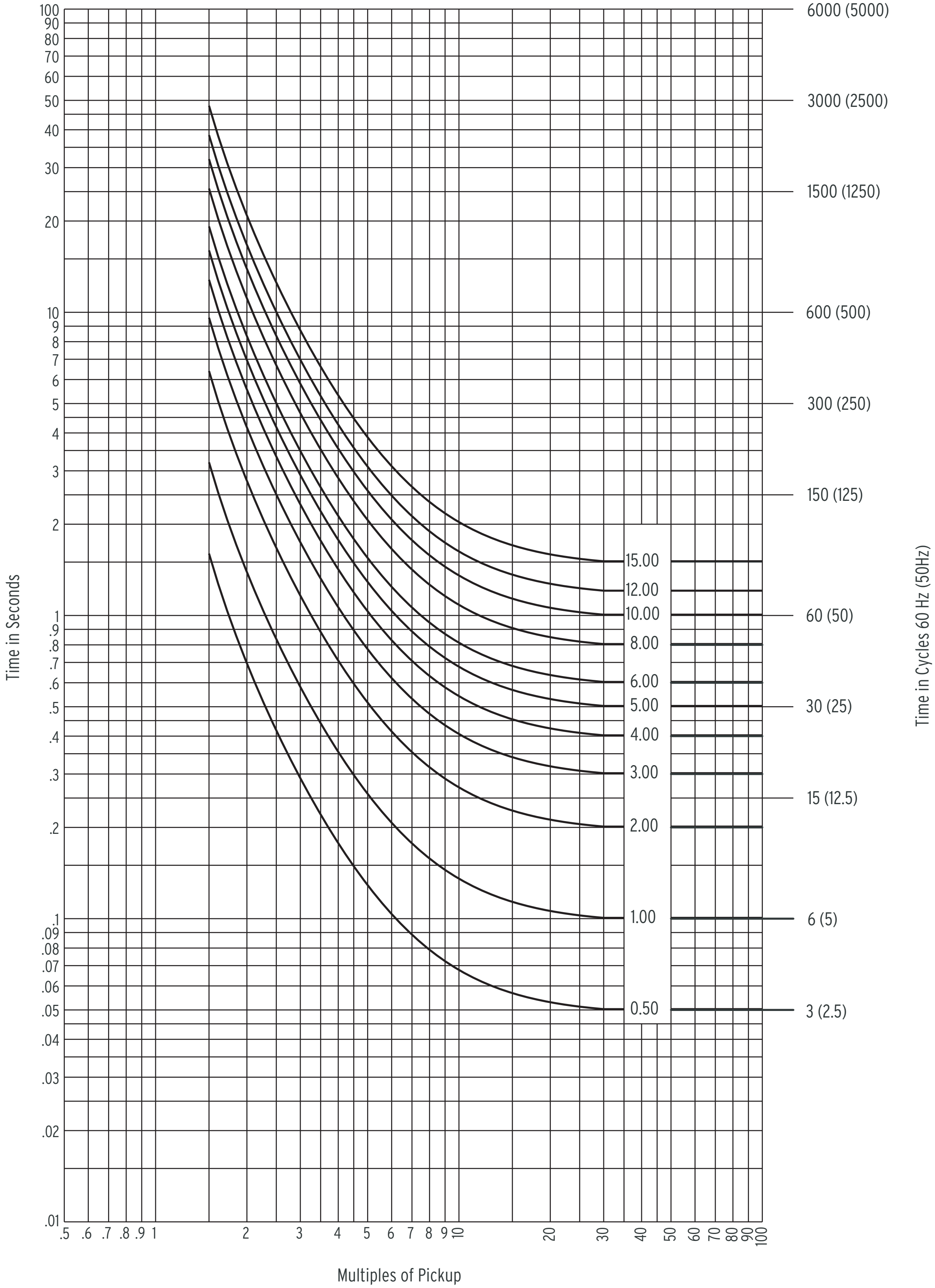

Figure 7.3 U. S. Very Inverse Curve: U3

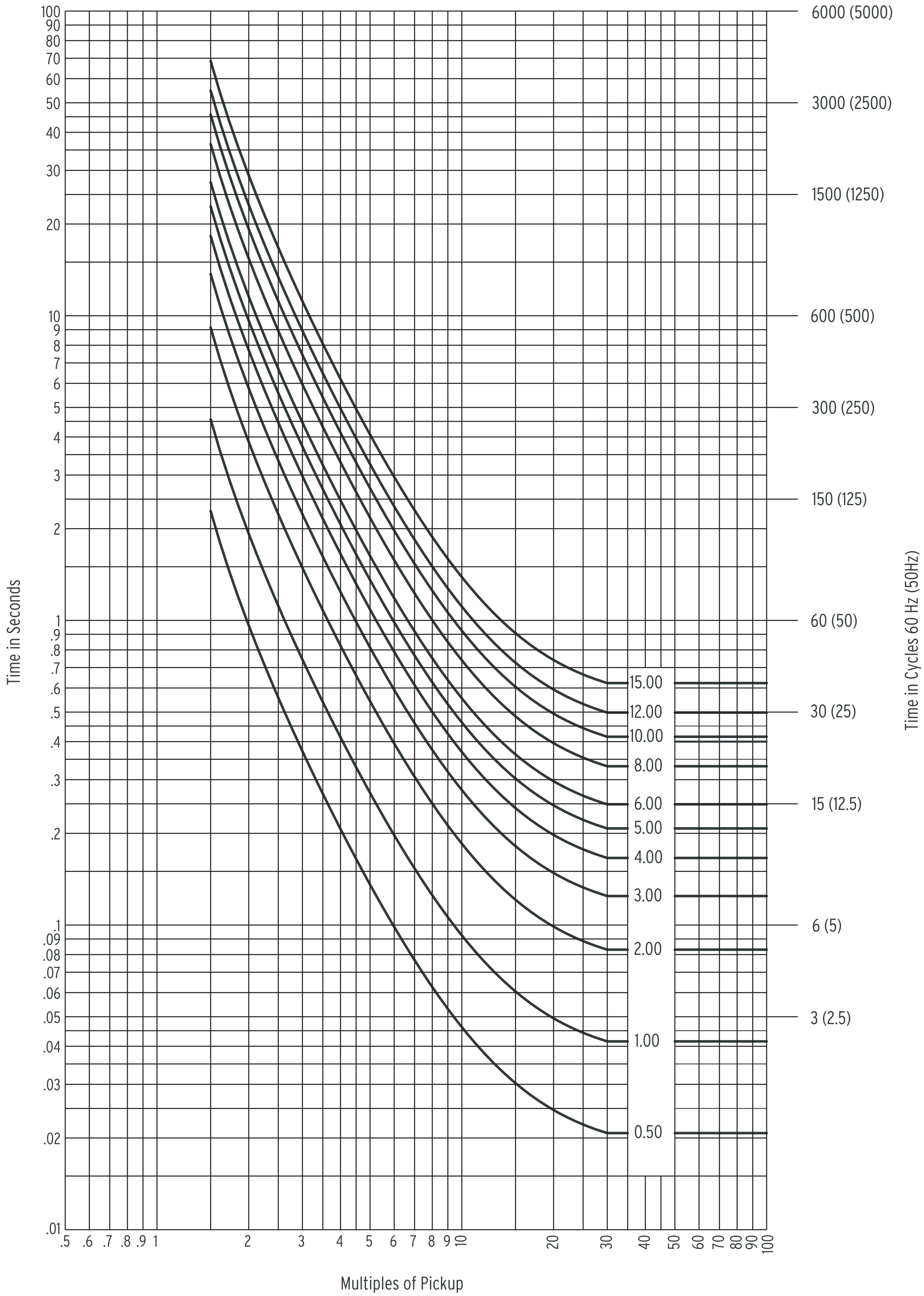

Figure 7.4 U. S. Extremely Inverse Curve: U4

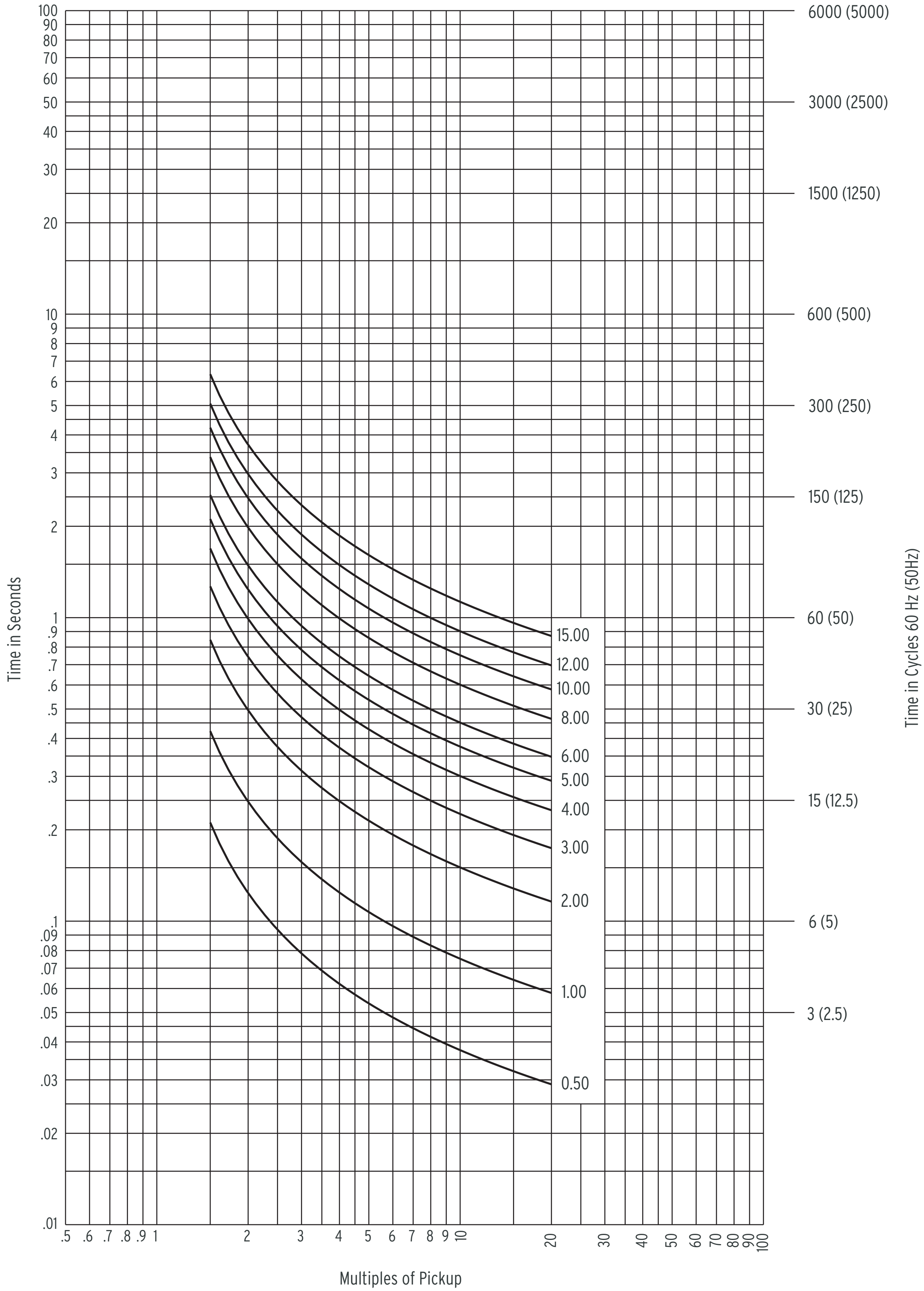

Figure 7.5 U. S. Short-Time Inverse Curve: U5

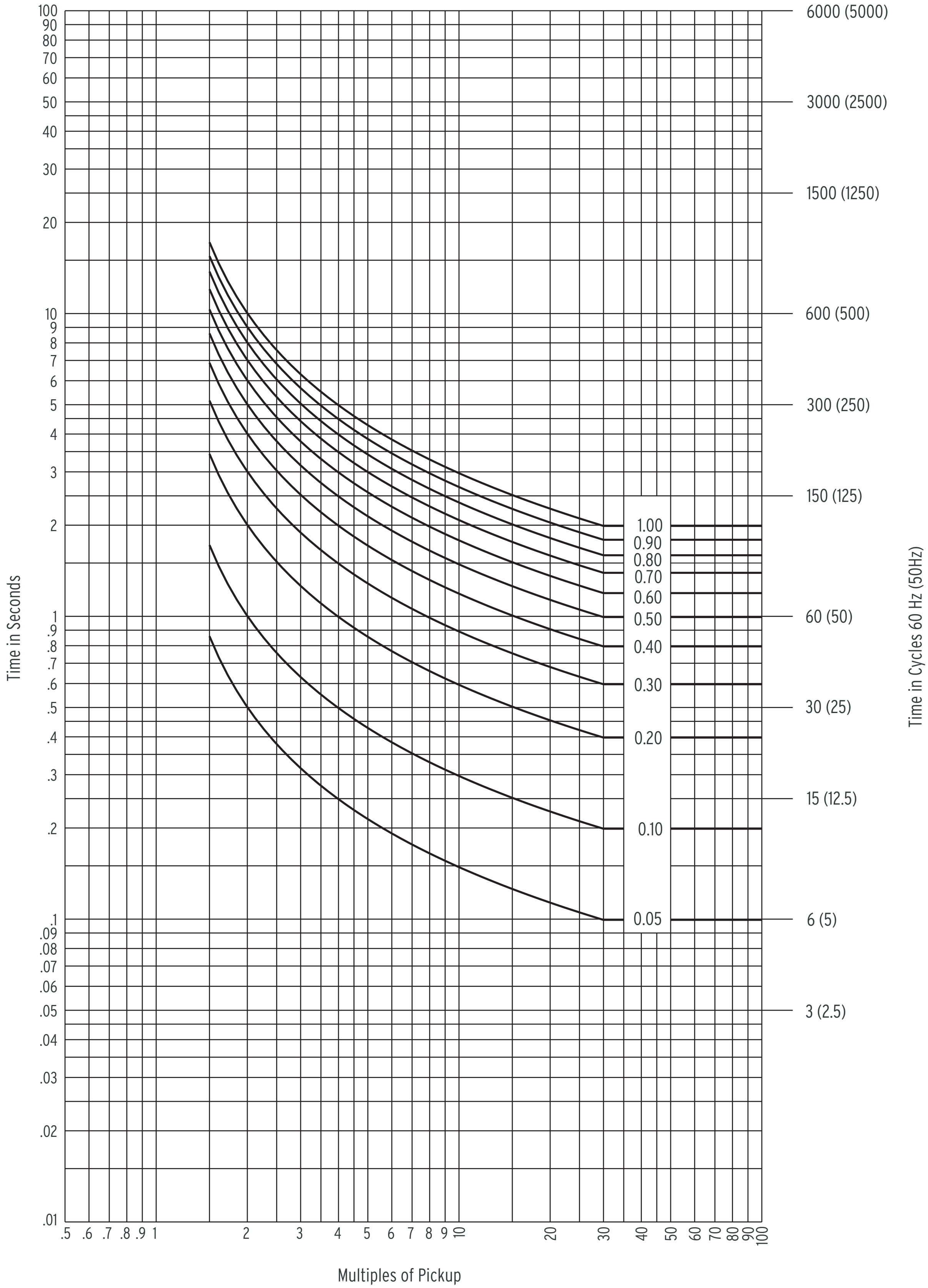

Figure 7.6 IEC Class A Curve (Standard Inverse): C1

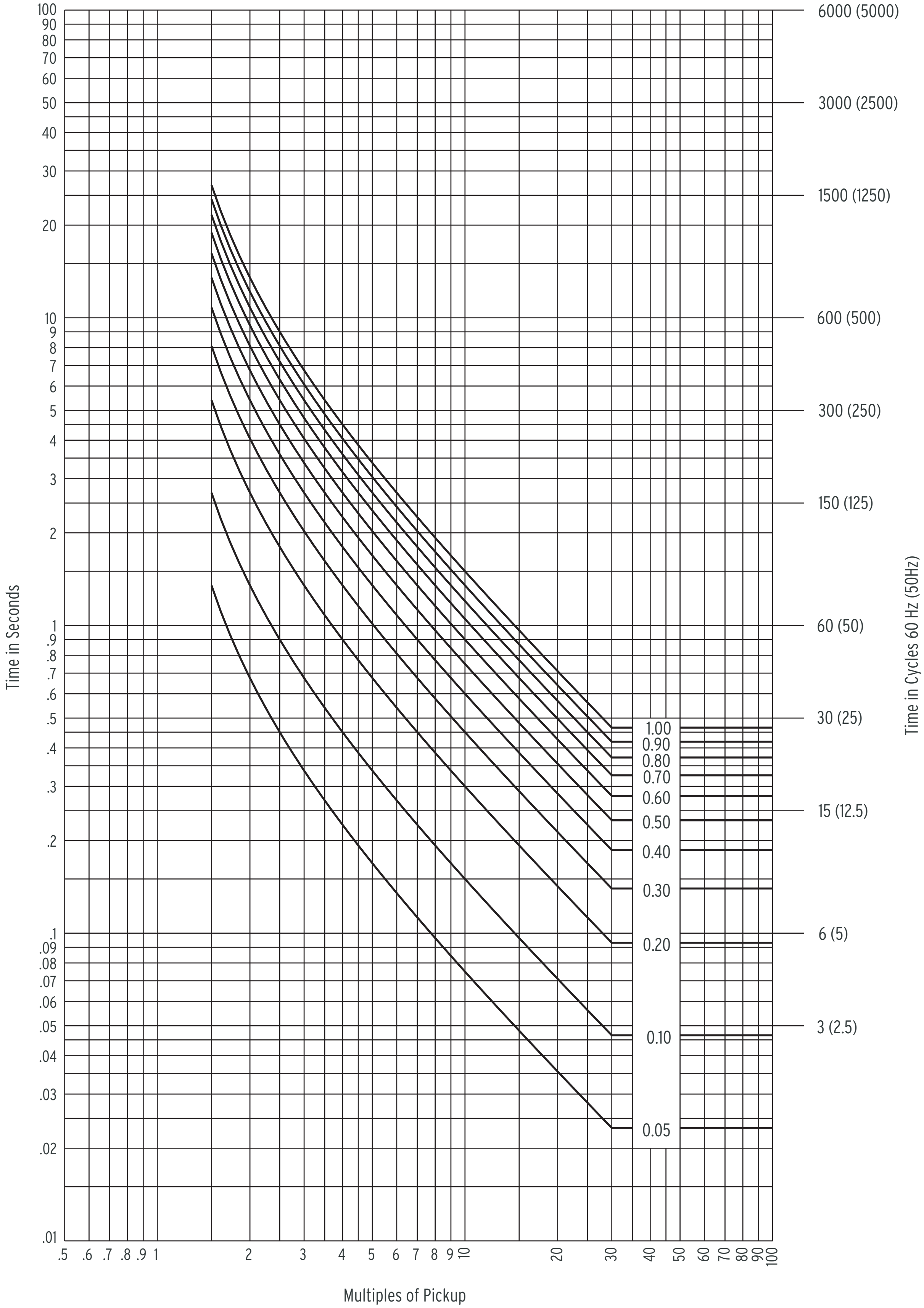

Figure 7.7 IEC Class B Curve (Very Inverse): C2

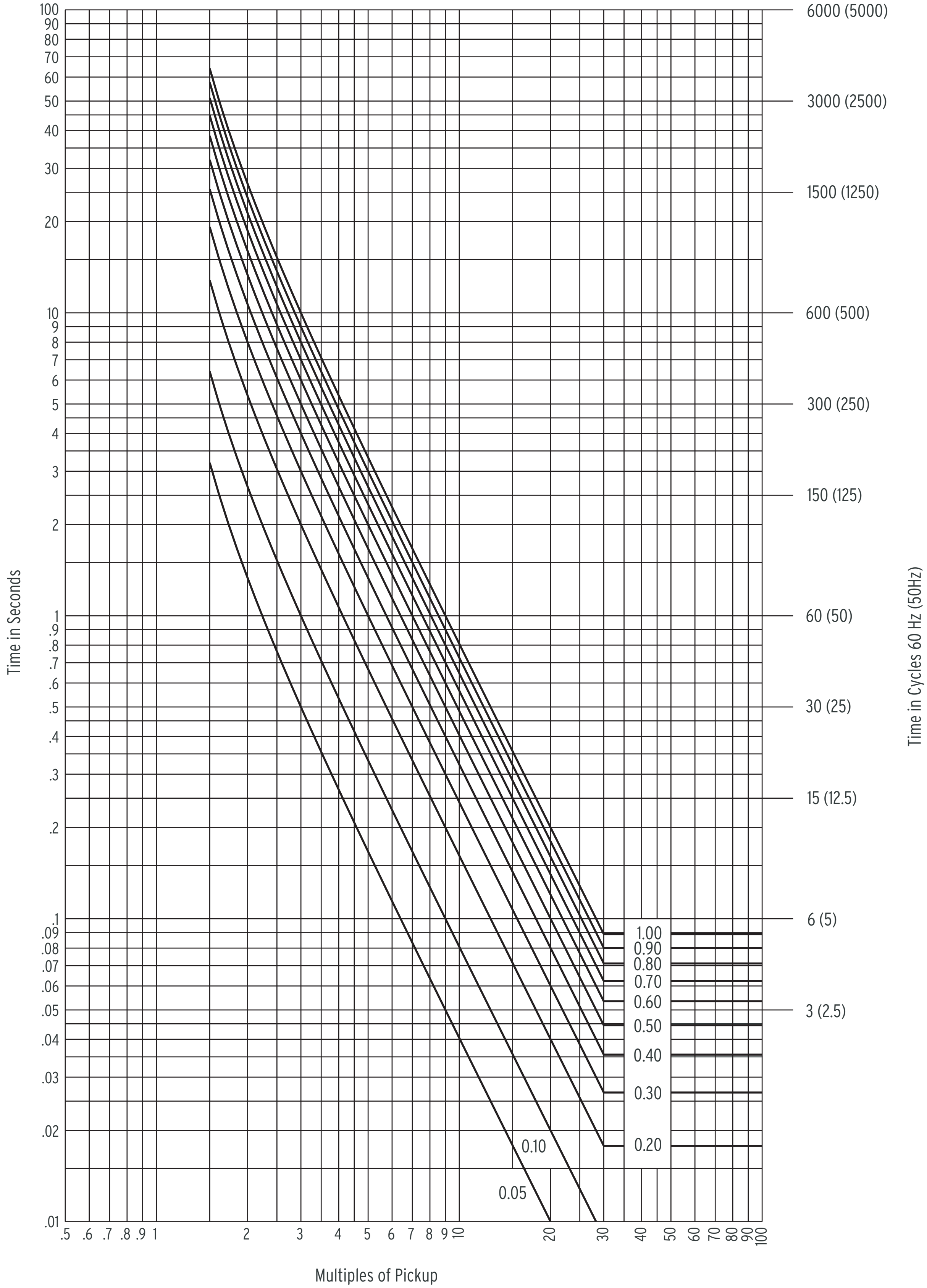

Figure 7.8 IEC Class C Curve (Extremely Inverse): C3

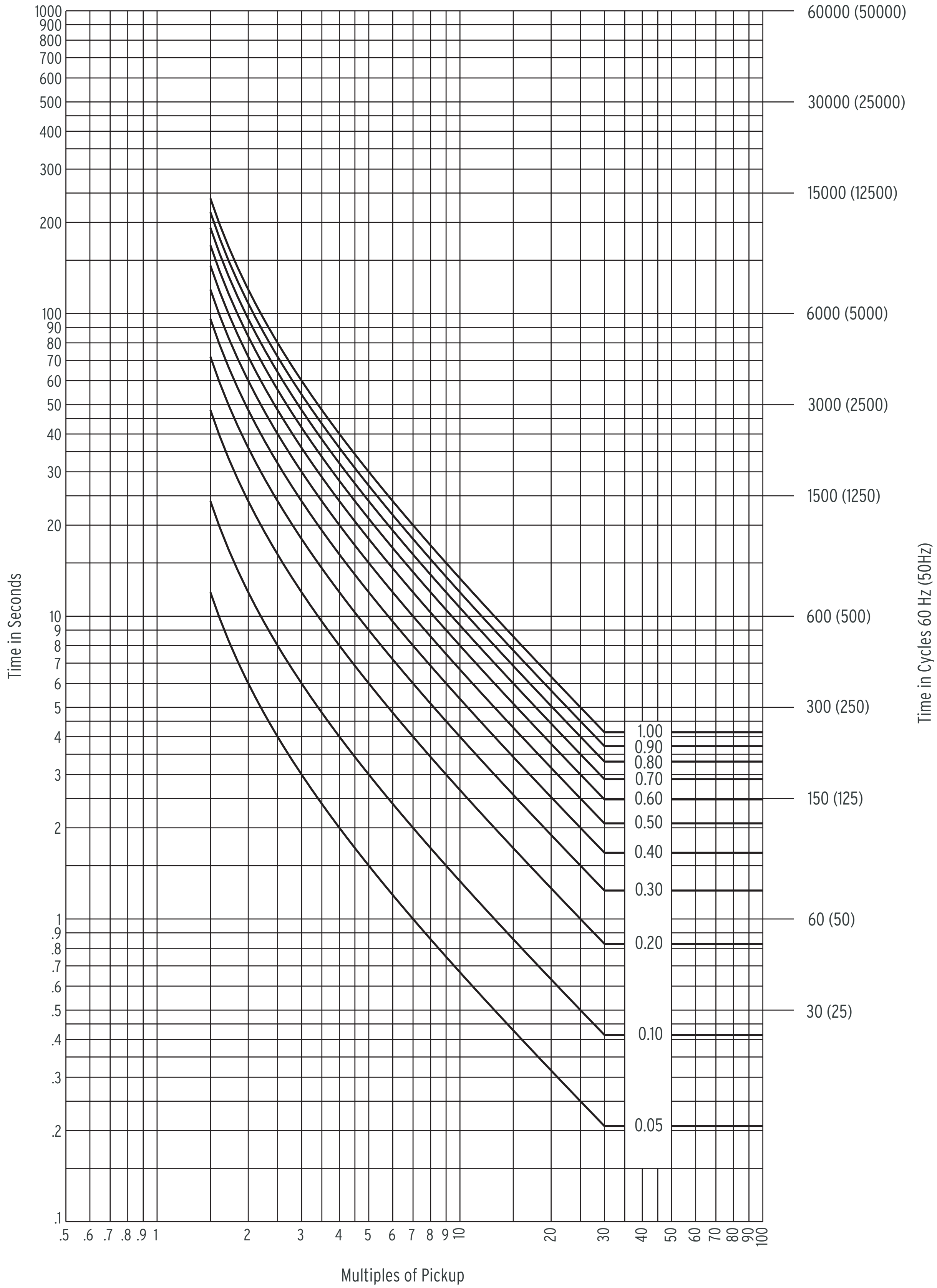

Figure 7.9 IEC Long-Time Inverse Curve: C4

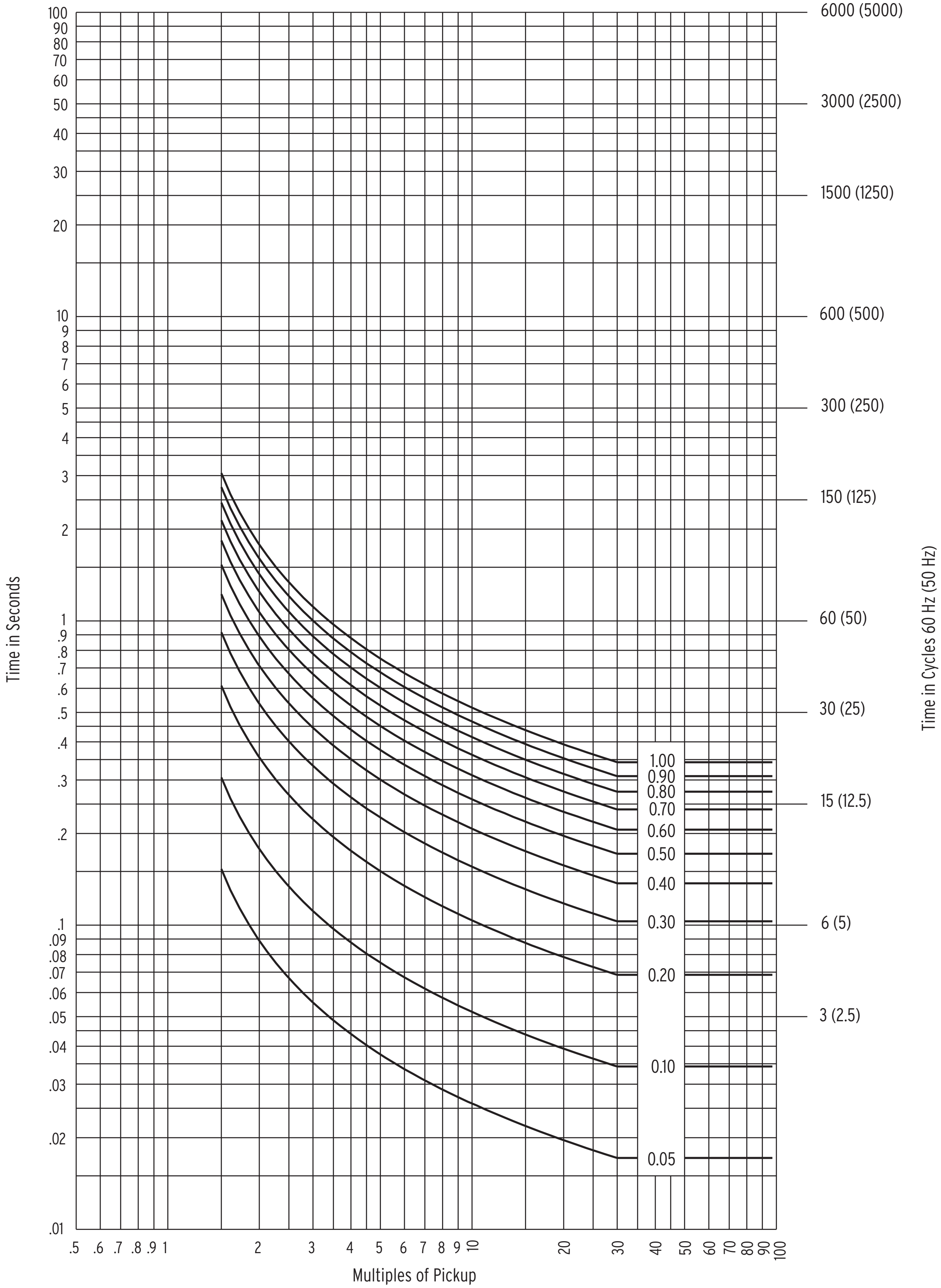

Figure 7.10 IEC Short-Time Inverse Curve: C5

Relay Word Bits (Used in SELOGIC Control Equations)

Relay Word bits are used in SELOGIC control equation settings. Numerous SELOGIC control equation settings examples are given in *Section 3–Section 8: Communications*. SELOGIC control equation settings can also be set directly to 1 (logical 1) or 0 (logical 0). *Section 5: SELOGIC Control Equation Programming* gives SELOGIC control equation details, examples, and limitations.

The Relay Word bit row numbers correspond to the row numbers used in the **TAR** command (see *TAR Command (Display Relay Element Status) on page 8.40*). Rows 0 and 1 are reserved for the display of the two front-panel target LED rows.

Table 7.5 Relay Word Bits (Sheet 1 of 2)

Row	Relay Word Bits							
0	EN	TRP	TIME	COMM	87	50_51	27	59
1	A	B	C	G	32	81	25	87CH FAIL
2	51P	51PT	51PR	51PTC	*	*	*	51NGTC
3	51Q	51QT	51QR	51QTC	*	*	*	*
4	50P1	50P2	50P3	50P4	50NG1	50NG2	50NG3	50NG4
5	67P1	67P2	67P3	67P4	67NG1	67NG2	67NG3	67NG4
6	67P1T	67P2T	67P3T	67P4T	67NG1T	67NG2T	67NG3T	67NG4T
7	50Q1	50Q2	50Q3	50Q4	*	*	*	672S
8	67Q1	67Q2	67Q3	67Q4	*	*	*	*
9	67Q1T	67Q2T	67Q3T	67Q4T	*	*	*	*
10	50QF	50QR	50P32	32PE	*	*	*	*
11	F32P	R32P	F32Q	R32Q	F32PQ	R32PQ	*	*
12	3V0	E32IV	VPOLV	LOP	ILOP	V1VAL	32QE	87WB
13	27A1	27B1	27C1	27A2	27B2	27C2	27S1	27S2
14	27A3	27B3	27C3	27A4	27B4	27C4	27S3	27S4
15	27AB1	27BC1	27CA1	27AB2	27BC2	27CA2	*	3P27
16	27AB3	27BC3	27CA3	27AB4	27BC4	27CA4	*	*
17	59A1	59B1	59C1	59A2	59B2	59C2	59S1	59S2
18	59A3	59B3	59C3	59A4	59B4	59C4	59S3	59S4
19	59AB1	59BC1	59CA1	59AB2	59BC2	59CA2	3P59	59V1
20	59AB3	59BC3	59CA3	59AB4	59BC4	59CA4	*	*
21	59N1	59N2	59N3	59N4	59Q1	59Q2	59Q3	59Q4
22	59VA	59VP	59VS	SF	ALTSF	25A1	25A2	*
23	52A	BSYNCH	CLOSE	COMMT	BCWA	BCWB	BCWC	BCW
24	81D1	81D2	81D3	81D4	81D5	81D6	*	27B81
25	81D1T	81D2T	81D3T	81D4T	81D5T	81D6T	CF	TFLT
26	*	*	IN106	IN105	IN104	IN103	IN102	IN101
27	LB8	LB7	LB6	LB5	LB4	LB3	LB2	LB1
28	LB16	LB15	LB14	LB13	LB12	LB11	LB10	LB9

Table 7.5 Relay Word Bits (Sheet 2 of 2)

Row	Relay Word Bits							
29	RB8	RB7	RB6	RB5	RB4	RB3	RB2	RB1
30	RB16	RB15	RB14	RB13	RB12	RB11	RB10	RB9
31	LT8	LT7	LT6	LT5	LT4	LT3	LT2	LT1
32	LT16	LT15	LT14	LT13	LT12	LT11	LT10	LT9
33	SV4T	SV3T	SV2T	SV1T	SV4	SV3	SV2	SV1
34	SV8T	SV7T	SV6T	SV5T	SV8	SV7	SV6	SV5
35	SV12T	SV11T	SV10T	SV9T	SV12	SV11	SV10	SV9
36	SV16T	SV15T	SV14T	SV13T	SV16	SV15	SV14	SV13
37	ALARM	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
38	SOTFE	50L	CLMON	3PO	3POD	TRIP	OC	CC
39	PT	Z3RB	KEY	EKEY	ECTT	WFC	LOG	*
40	PTRX	UBB	BT	BTX	Z3XT	DSTRT	NSTRT	STOP
41	ZLOAD	ZLOUT	ZLIN	DCHI	DCLO	PDEM	NDEM	QDEM
42	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
43	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
44	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
45	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
46	LBOKB	CBADB	RBADB	ROKB	LBOKA	CBADA	RBADA	ROKA
47	PWRA1	PWRB1	PWRC1	PWRA2	PWRB2	PWRC2	3PWR1	3PWR2
48	PWRA3	PWRB3	PWRC3	PWRA4	PWRB4	PWRC4	3PWR3	3PWR4
49	TRGTR	87HWAL	87BSY	IAMET	IBMET	ICMET	INMET	V0GAIN
50	SG6	SG5	SG4	SG3	SG2	SG1	*	PLAY
51	201LOG	202LOG	203LOG	204LOG	205LOG	206LOG	*	*
52	OUT201	OUT202	OUT203	OUT204	OUT205	OUT206	87LPE	*
53	FTABC	FTAG	FTBG	FTCG	FTAB	FTBC	FTCA	*
54	87L	87LA	87LB	87LC	TRIP87	*	CHYAL	CHXAL
55	87LOPA	87LAE	R87LA	CTAA	*	*	*	*
56	87LOPB	87LBE	R87LB	CTBA	*	*	*	*
57	87LOPC	87LCE	R87LC	CTCA	*	*	*	*
58	*	*	TESTY	3POY	*	*	TESTX	3POX
59	R8X	R7X	R6X	R5X	R4X	R3X	R2X	R1X
60	T8X	T7X	T6X	T5X	T4X	T3X	T2X	T1X
61	R8Y	R7Y	R6Y	R5Y	R4Y	R3Y	R2Y	R1Y
62	T8Y	T7Y	T6Y	T5Y	T4Y	T3Y	T2Y	T1Y
63	DBADY	AVAY	RBADY	ROKY	DBADX	AVAX	RBADX	ROKX
64	50LA	50RA	50LB	50RB	50LC	50RC	*	*
65	V0VALL	GNDSWL	V0VALR	GNDSWR	B87W	50FW	87WE	87WF
66	F32N	R32N	PNSA	PNSB	PNSC	32NE	50NF	50NR
67	51NG	51NGT	51NGR	*	*	*	*	*

Table 7.6 Relay Word Bit Definitions (Sheet 1 of 19)

Row	Bit	Definition	Primary Application
0	EN	Relay Enabled (see *Table 4.1*)	Target
	TRP	Relay Trip	
	TIME	Time Trip	
	COMM	Communications-Assisted Trip	
	87	Line Current Differential Trip	
	50_51	Instantaneous and Time-Overcurrent Trip	
	27	Undervoltage Trip	
	59	Overvoltage Trip	
1	A	Phase A is involved in the fault (see *Table 4.1*)	
	B	Phase B is involved in the fault	
	C	Phase C is involved in the fault	
	G	Ground is involved in the fault	
	32	Directional Element Trip	
	81	Frequency Element Trip	
	25	Synchronism Check	
	87CH FAIL	Differential Channel Failure	
2	51P	Maximum phase current above pickup setting 51PP for phase time-overcurrent element 51PT (see *Figure 3.19*)	Testing, Control
	51PT	Phase time-overcurrent element 51PT timed out (see *Figure 3.19*)	Tripping
	51PR	Phase time-overcurrent element 51PT reset (see *Figure 3.19*)	Testing
	51PTC	Phase time-overcurrent element torque control switch asserted (see *Figure 3.19*)	Tripping
	*		
	*		
	*		
	51NGTC	Ground time-overcurrent element torque control switch asserted (see *Figure 3.20*)	
3	51Q[a]	Negative-sequence current above pickup setting 51QP for negative-sequence time-overcurrent element 51QT (see *Figure 3.21*)	Testing, Control
	51QT	Negative-sequence time-overcurrent element 51QT timed out (see *Figure 3.21*)	Tripping
	51QR	Negative-sequence time-overcurrent element 51QT reset (see *Figure 3.21*)	Testing
	51QTC	Negative-sequence time-overcurrent element torque control switch asserted (see *Figure 3.21*)	Tripping
	*		
	*		
	*		
	*		

Table 7.6 Relay Word Bit Definitions (Sheet 2 of 19)

Row	Bit	Definition	Primary Application
4	50P1	Level 1 phase instantaneous overcurrent element (A, B, or C) above pickup setting 50P1P; see *Figure 3.14*)	
	50P2	Level 2 phase instantaneous overcurrent element (A, B, or C) above pickup setting 50P2P; see *Figure 3.14*)	
	50P3	Level 3 phase instantaneous overcurrent element (A, B, or C) above pickup setting 50P3P; see *Figure 3.14*)	
	50P4	Level 4 phase instantaneous overcurrent element (A, B, or C) above pickup setting 50P4P; see *Figure 3.14*)	
	50NG1	Level 1 neutral/ground instantaneous overcurrent element (A, B, or C) above pickup setting 50NG1P; see *Figure 3.17*)	
	50NG2	Level 2 neutral/ground instantaneous overcurrent element (A, B, or C) above pickup setting 50NG2P; see *Figure 3.17*)	
	50NG3	Level 3 neutral/ground instantaneous overcurrent element (A, B, or C) above pickup setting 50NG3P; see *Figure 3.17*)	
	50NG4	Level 4 neutral/ground instantaneous overcurrent element (A, B, or C) above pickup setting 50NG4P; see *Figure 3.17*)	
5	67P1	Level 1 torque controlled phase instantaneous overcurrent element (derived from 50P1; see *Figure 3.14*)	
	67P2	Level 2 torque controlled phase instantaneous overcurrent element (derived from 50P2; see *Figure 3.14*)	
	67P3	Level 3 torque controlled phase instantaneous overcurrent element (derived from 50P3; see *Figure 3.14*)	
	67P4	Level 4 torque controlled phase instantaneous overcurrent element (derived from 50P4; see *Figure 3.14*)	
	67NG1	Level 1 torque controlled neutral/ground instantaneous overcurrent element (derived from 50NG1; see *Figure 3.17*)	
	67NG2	Level 2 torque controlled neutral/ground instantaneous overcurrent element (derived from 50NG2; see *Figure 3.17*)	
	67NG3	Level 3 torque controlled neutral/ground instantaneous overcurrent element (derived from 50NG3; see *Figure 3.17*)	
	67NG4	Level 4 torque controlled neutral/ground instantaneous overcurrent element (derived from 50NG4; see *Figure 3.17*)	
6	67P1T	Level 1 phase definite-time overcurrent element 67P1T timed out (derived from 67P1; see *Figure 3.14*)	
	67P2T	Level 2 phase definite-time overcurrent element 67P2T timed out (derived from 67P2; see *Figure 3.14*)	
	67P3T	Level 3 phase definite-time overcurrent element 67P3T timed out (derived from 67P3; see *Figure 3.14*)	
	67P4T	Level 4 phase definite-time overcurrent element 67P4T timed out (derived from 67P4; see *Figure 3.14*)	
	67NG1T	Level 1 neutral/ground definite-time overcurrent element 67NG1T timed out (derived from 67NG1; see *Figure 3.17*)	
	67NG2T	Level 2 neutral/ground definite-time overcurrent element 67NG2T timed out (derived from 67NG2; see *Figure 3.17*)	
	67NG3T	Level 3 neutral/ground definite-time overcurrent element 67NG3T timed out (derived from 67NG3; see *Figure 3.17*)	
	67NG4T	Level 4 neutral/ground definite-time overcurrent element 67NG4T timed out (derived from 67NG4; see *Figure 3.17*)	

Table 7.6 **Relay Word Bit Definitions** (Sheet 3 of 19)

Row	Bit	Definition	Primary Application
7	50Q1 1	Level 1 negative-sequence instantaneous overcurrent element (negative-sequence current above pickup setting 50Q1P; see *Figure 3.18*)	
	50Q2 1	Level 2 negative-sequence instantaneous overcurrent element (negative-sequence current above pickup setting 50Q2P; see *Figure 3.18*)	
	50Q3 1	Level 3 negative-sequence instantaneous overcurrent element (negative-sequence current above pickup setting 50Q3P; see *Figure 3.18*)	
	50Q4 1	Level 4 negative-sequence instantaneous overcurrent element (negative-sequence current above pickup setting 50Q4P; see *Figure 3.18*)	
	*		
	*		
	*		
	672S	67P2 + 67NG2 + 67Q2 (and 67SD timer expired) (see *Figure 4.12*)	
8	67Q1	Level 1 torque controlled negative-sequence instantaneous overcurrent element (derived from 50Q1; see *Figure 3.18*)	
	67Q2	Level 2 torque controlled negative-sequence instantaneous overcurrent element (derived from 50Q2; see *Figure 3.18*)	
	67Q3	Level 3 torque controlled negative-sequence instantaneous overcurrent element (derived from 50Q3; see *Figure 3.18*)	
	67Q4	Level 4 torque controlled negative-sequence instantaneous overcurrent element (derived from 50Q4; see *Figure 3.18*)	
	*		
	*		
	*		
	*		
9	67Q1T	Level 1 torque controlled negative-sequence definite-time overcurrent element 67Q1T timed out (derived from 67Q1; see *Figure 3.18*)	
	67Q2T	Level 2 torque controlled negative-sequence definite-time overcurrent element 67Q2T timed out (derived from 67Q2; see *Figure 3.18*)	
	67Q3T	Level 3 torque controlled negative-sequence definite-time overcurrent element 67Q3T timed out (derived from 67Q3; see *Figure 3.18*)	
	67Q4T	Level 4 torque controlled negative-sequence definite-time overcurrent element 67Q4T timed out (derived from 67Q4; see *Figure 3.18*)	
	*		
	*		
	*		
	*		

Table 7.6 Relay Word Bit Definitions (Sheet 4 of 19)

Row	Bit	Definition	Primary Application
10	50QF	Forward direction negative-sequence overcurrent threshold exceeded (see *Figure 3.37*)	Directional threshold
	50QR	Reverse direction negative-sequence overcurrent threshold exceeded (see *Figure 3.37*)	
	50P32	Phase directional element 3-phase pickup element (see *Figure 3.38*)	
	32PE	Enable for positive-sequence voltage-polarized directional element (see *Figure 3.38*)	
	*		
	*		
	*		
	*		
11	F32P	Forward positive-sequence voltage-polarized directional element (see *Figure 3.38*)	
	R32P	Reverse positive-sequence voltage-polarized directional element (see *Figure 3.38*)	
	F32Q	Forward negative-sequence voltage-polarized directional element (see *Figure 3.37*)	
	R32Q	Reverse negative-sequence voltage-polarized directional element (see *Figure 3.37*)	
	F32PQ	Forward voltage-polarized directional element (see *Figure 3.38*)	
	R32PQ	Reverse voltage-polarized directional element (see *Figure 3.38*)	
	*		
	*		
12	3V0	Local zero-sequence voltage element (see *Figure 3.35*)	
	E32IV	Voltage-polarized directional element enable (see *Figure 3.35*)	
	VPOLV	Positive-sequence polarization voltage valid (see *Figure 3.38*)	Indication
	LOP	Loss-of-potential (see *Figure 3.32*)	Testing, Special directional control schemes
	ILOP	Internal loss-of-potential (see *Figure 3.32*)	Directional control enable
	V1VAL	Positive-sequence voltage valid in synchronism check element (see *Figure 3.32*)	
	32QE	Enable for negative-sequence voltage-polarized directional element (see *Figure 3.37*)	
	87WB	Ground directional element enable blocking *Figure 3.13*	

Table 7.6 Relay Word Bit Definitions (Sheet 5 of 19)

Row	Bit	Definition	Primary Application
13	27A1	A-phase instantaneous undervoltage element (A-phase voltage below pickup setting 27P1P; see *Figure 3.22*)	Control
	27B1	B-phase instantaneous undervoltage element (B-phase voltage below pickup setting 27P1P; see *Figure 3.22*)	
	27C1	C-phase instantaneous undervoltage element (C-phase voltage below pickup setting 27P1P; see *Figure 3.22*)	
	27A2	A-phase instantaneous undervoltage element (A-phase voltage below pickup setting 27P2P; see *Figure 3.22*)	
	27B2	B-phase instantaneous undervoltage element (B-phase voltage below pickup setting 27P2P; see *Figure 3.22*)	
	27C2	C-phase instantaneous undervoltage element (C-phase voltage below pickup setting 27P2P; see *Figure 3.22*)	
	27S1	Voltage input VS instantaneous undervoltage element (Channel VS voltage below pickup setting 27S1P; see *Figure 3.22*)	
	27S2	Voltage input VS instantaneous undervoltage element (Channel VS voltage below pickup setting 27S2P; see *Figure 3.22*)	
14	27A3	A-phase instantaneous undervoltage element (A-phase voltage below pickup setting 27P3P; see *Figure 3.22*)	
	27B3	B-phase instantaneous undervoltage element (B-phase voltage below pickup setting 27P3P; see *Figure 3.22*)	
	27C3	C-phase instantaneous undervoltage element (C-phase voltage below pickup setting 27P3P; see *Figure 3.22*)	
	27A4	A-phase instantaneous undervoltage element (A-phase voltage below pickup setting 27P4P; see *Figure 3.22*)	
	27B4	B-phase instantaneous undervoltage element (B-phase voltage below pickup setting 27P4P; see *Figure 3.22*)	
	27C4	C-phase instantaneous undervoltage element (C-phase voltage below pickup setting 27P4P; see *Figure 3.22*)	
	27S3	Voltage input VS instantaneous undervoltage element (Channel VS voltage below pickup setting 27S3P; see *Figure 3.22*)	
	27S4	Voltage input VS instantaneous undervoltage element (Channel VS voltage below pickup setting 27S4P; see *Figure 3.22*)	
15	27AB1	AB phase-to-phase instantaneous undervoltage element (AB phase-to-phase voltage below pickup setting 27PP1P; see *Figure 3.23*)	
	27BC1	BC phase-to-phase instantaneous undervoltage element (BC phase-to-phase voltage below pickup setting 27PP1P; see *Figure 3.23*)	
	27CA1	CA phase-to-phase instantaneous undervoltage element (CA phase-to-phase voltage below pickup setting 27PP1P; see *Figure 3.23*)	
	27AB2	AB phase-to-phase instantaneous undervoltage element (AB phase-to-phase voltage below pickup setting 27PP2P; see *Figure 3.23*)	
	27BC2	BC phase-to-phase instantaneous undervoltage element (BC phase-to-phase voltage below pickup setting 27PP2P; see *Figure 3.23*)	
	27CA2	CA phase-to-phase instantaneous undervoltage element (CA phase-to-phase voltage below pickup setting 27PP2P; see *Figure 3.23*)	
	*		
	3P27	27A * 27B * 27C (see *Figure 3.22*)	

Table 7.6 Relay Word Bit Definitions (Sheet 6 of 19)

Row	Bit	Definition	Primary Application
16	27AB3	AB phase-to-phase instantaneous undervoltage element (AB phase-to-phase voltage below pickup setting 27PP3P; see *Figure 3.23*)	
	27BC3	BC phase-to-phase instantaneous undervoltage element (BC phase-to-phase voltage below pickup setting 27PP3P; see *Figure 3.23*)	
	27CA3	CA phase-to-phase instantaneous undervoltage element (CA phase-to-phase voltage below pickup setting 27PP3P; see *Figure 3.23*)	
	27AB4	AB phase-to-phase instantaneous undervoltage element (AB phase-to-phase voltage below pickup setting 27PP4P; see *Figure 3.23*)	
	27BC4	BC phase-to-phase instantaneous undervoltage element (BC phase-to-phase voltage below pickup setting 27PP4P; see *Figure 3.23*)	
	27CA4	CA phase-to-phase instantaneous undervoltage element (CA phase-to-phase voltage below pickup setting 27PP4P; see *Figure 3.23*)	
	*		
	*		
17	59A1	A-phase instantaneous overvoltage element (A-phase voltage above pickup setting 59P1P; see *Figure 3.22*)	
	59B1	B-phase instantaneous overvoltage element (B-phase voltage above pickup setting 59P1P; see *Figure 3.22*)	
	59C1	C-phase instantaneous overvoltage element (C-phase voltage above pickup setting 59P1P; see *Figure 3.22*)	
	59A2	A-phase instantaneous overvoltage element (A-phase voltage above pickup setting 59P2P; see *Figure 3.22*)	
	59B2	B-phase instantaneous overvoltage element (B-phase voltage above pickup setting 59P2P; see *Figure 3.22*)	
	59C2	C-phase instantaneous overvoltage element (C-phase voltage above pickup setting 59P2P; see *Figure 3.22*)	
	59S1	Voltage input VS instantaneous undervoltage element (Channel VS voltage below pickup setting 59S1P)	
	59S2	Voltage input VS instantaneous undervoltage element (Channel VS voltage below pickup setting 59S2P)	
18	59A3	A-phase instantaneous overvoltage element (A-phase voltage above pickup setting 59P3P)	
	59B3	B-phase instantaneous overvoltage element (B-phase voltage above pickup setting 59P3P)	
	59C3	C-phase instantaneous overvoltage element (C-phase voltage above pickup setting 59P3P)	
	59A4	A-phase instantaneous overvoltage element (A-phase voltage above pickup setting 59P4P)	
	59B4	B-phase instantaneous overvoltage element (B-phase voltage above pickup setting 59P4P)	
	59C4	C-phase instantaneous overvoltage element (C-phase voltage above pickup setting 59P4P)	
	59S3	Voltage input VS instantaneous undervoltage element (Channel VS voltage below pickup setting 59S3P)	
	59S4	Voltage input VS instantaneous undervoltage element (Channel VS voltage below pickup setting 59S4P)	

Table 7.6 Relay Word Bit Definitions (Sheet 7 of 19)

Row	Bit	Definition	Primary Application
19	59AB1	AB phase-to-phase instantaneous overvoltage element (AB phase-to-phase voltage above pickup setting 59PP1P; see *Figure 3.23*)	
	59BC1	BC phase-to-phase instantaneous overvoltage element (BC phase-to-phase voltage above pickup setting 59PP1P; see *Figure 3.23*)	
	59CA1	CA phase-to-phase instantaneous overvoltage element (CA phase-to-phase voltage above pickup setting 59PP1P; see *Figure 3.23*)	
	59AB2	AB phase-to-phase instantaneous overvoltage element (AB phase-to-phase voltage above pickup setting 59PP2P; see *Figure 3.23*)	
	59BC2	BC phase-to-phase instantaneous overvoltage element (BC phase-to-phase voltage above pickup setting 59PP2P; see *Figure 3.23*)	
	59CA2	CA phase-to-phase instantaneous overvoltage element (CA phase-to-phase voltage above pickup setting 59PP2P; see *Figure 3.23*)	
	3P59	59A * 59B * 59C (see *Figure 3.22*)	
	59V1	Positive-sequence instantaneous overvoltage element (positive-sequence voltage above pickup setting 59V1P; see *Figure 3.23*)	
20	59AB3	AB phase-to-phase instantaneous overvoltage element (AB phase-to-phase voltage above pickup setting 59PP3P; see *Figure 3.23*)	
	59BC3	BC phase-to-phase instantaneous overvoltage element (BC phase-to-phase voltage above pickup setting 59PP3P; see *Figure 3.23*)	
	59CA3	CA phase-to-phase instantaneous overvoltage element (CA phase-to-phase voltage above pickup setting 59PP3P; see *Figure 3.23*)	
	59AB4	AB phase-to-phase instantaneous overvoltage element (AB phase-to-phase voltage above pickup setting 59PP4P; see *Figure 3.23*)	
	59BC4	BC phase-to-phase instantaneous overvoltage element (BC phase-to-phase voltage above pickup setting 59PP4P; see *Figure 3.23*)	
	59CA4	CA phase-to-phase instantaneous overvoltage element (CA phase-to-phase voltage above pickup setting 59PP4P; see *Figure 3.23*)	
	*		
	*		
21	59N1	Zero-sequence instantaneous overvoltage element (zero-sequence voltage above pickup setting 59N1P; see *Figure 3.23*)	
	59N2	Zero-sequence instantaneous overvoltage element (zero-sequence voltage above pickup setting 59N2P; see *Figure 3.23*)	
	59N3	Zero-sequence instantaneous overvoltage element (zero-sequence voltage above pickup setting 59N3P; see *Figure 3.23*)	
	59N4	Zero-sequence instantaneous overvoltage element (zero-sequence voltage above pickup setting 59N4P; see *Figure 3.23*)	
	59Q1	Negative-sequence instantaneous overvoltage element (negative-sequence voltage above pickup setting 59Q1P; see *Figure 3.23*)	
	59Q2	Negative-sequence instantaneous overvoltage element (negative-sequence voltage above pickup setting 59Q2P; see *Figure 3.23*)	
	59Q3	Negative-sequence instantaneous overvoltage element (negative-sequence voltage above pickup setting 59Q3P; see *Figure 3.23*)	
	59Q4	Negative-sequence instantaneous overvoltage element (negative-sequence voltage above pickup setting 59Q4P; see *Figure 3.23*)	

Table 7.6 Relay Word Bit Definitions (Sheet 8 of 19)

Row	Bit	Definition	Primary Application
22	59VA	Channel VA voltage window element (channel VA voltage between threshold settings 25VLO and 25VHI; see *Figure 3.24*)	
	59VP	Phase voltage window element (selected phase voltage [VP] between threshold settings 25VLO and 25VHI; see *Figure 3.24*)	
	59VS	Channel VS voltage window element (channel VS voltage between threshold settings 25VLO and 25VHI; see *Figure 3.24*)	
	SF	Slip frequency between voltages VP and VS less than setting 25SF (see *Figure 3.24*)	
	ALTSF	Slip frequency calculation bypass (see *Figure 3.24*)	
	25A1	Synchronism check element (see *Figure 3.25*)	
	25A2	Synchronism check element (see *Figure 3.25*)	
	*		
23	52A	Circuit breaker status (asserts to logical 1 when circuit breaker is closed; see *Figure 4.14*)	
	BSYNCH	Block synchronism check element (see *Figure 3.24*)	
	CLOSE	Close logic output asserted (see *Figure 4.14*)	Output contact assignment
	COMMT	Communication-assisted trip element (see *Figure 4.3*)	
	BCWA	A-phase breaker contact wear has reached 100% wear level (see *Breaker Monitor Output on page 6.19*)	Monitoring
	BCWB	B-phase breaker contact wear has reached 100% wear level (see *Breaker Monitor Output on page 6.19*)	
	BCWC	C-phase breaker contact wear has reached 100% wear level (see *Breaker Monitor Output on page 6.19*)	
	BCW	BCWA + BCWB + BCWC	
24	81D1	Level 1 instantaneous frequency element (with corresponding pickup setting 81D1P; see *Figure 3.29*)	Testing
	81D2	Level 2 instantaneous frequency element (with corresponding pickup setting 81D2P; see *Figure 3.29*)	
	81D3	Level 3 instantaneous frequency element (with corresponding pickup setting 81D3P; see *Figure 3.29*)	
	81D4	Level 4 instantaneous frequency element (with corresponding pickup setting 81D4P; see *Figure 3.29*)	
	81D5	Level 5 instantaneous frequency element (with corresponding pickup setting 81D5P; see *Figure 3.29*)	
	81D6	Level 6 instantaneous frequency element (with corresponding pickup setting 81D6P; see *Figure 3.29*)	
	*		
	27B81	Undervoltage element for frequency element blocking (any phase voltage below pickup setting 27B81P; see *Figure 3.27*, *Figure 3.28*, and *Figure 3.29*)	

Table 7.6 Relay Word Bit Definitions (Sheet 9 of 19)

Row	Bit	Definition	Primary Application
25	81D1T	Level 1 definite-time frequency element 81D1T timed out (derived from 81D1; see *Figure 3.29*)	Tripping, Control
	81D2T	Level 2 definite-time frequency element 81D2T timed out (derived from 81D2; see *Figure 3.29*)	
	81D3T	Level 3 definite-time frequency element 81D3T timed out (derived from 81D3; see *Figure 3.29*)	
	81D4T	Level 4 definite-time frequency element 81D4T timed out (derived from 81D4; see *Figure 3.29*)	
	81D5T	Level 5 definite-time frequency element 81D5T timed out (derived from 81D5; see *Figure 3.29*)	
	81D6T	Level 6 definite-time frequency element 81D6T timed out (derived from 81D6; see *Figure 3.29*)	
	CF	Close failure (see *Figure 4.14*)	
	TFLT	Three-cycle delayed pickup of SELOGIC control equation FAULT (see *Maximum/Minimum Metering Updating and Storage on page 6.9*)	
26	*		
	*		
	IN106	Optoisolated input IN106 asserted (see *Figure 5.6*)	Relay input status, control via optoisolated inputs
	IN105	Optoisolated input IN105 asserted (see *Figure 5.6*)	
	IN104	Optoisolated input IN104 asserted (see *Figure 5.6*)	
	IN103	Optoisolated input IN103 asserted (see *Figure 5.6*)	
	IN102	Optoisolated input IN102 asserted (see *Figure 5.6*)	
	IN101	Optoisolated input IN101 asserted (see *Figure 5.6*)	
27	LB8	Local Bit 8 asserted (see *Local Control on page 9.5*)	Local control via front panel-replacing traditional panel-mounted control switches
	LB7	Local Bit 7 asserted (see *Local Control on page 9.5*)	
	LB6	Local Bit 6 asserted (see *Local Control on page 9.5*)	
	LB5	Local Bit 5 asserted (see *Local Control on page 9.5*)	
	LB4	Local Bit 4 asserted (see *Local Control on page 9.5*)	
	LB3	Local Bit 3 asserted (see *Local Control on page 9.5*)	
	LB2	Local Bit 2 asserted (see *Local Control on page 9.5*)	
	LB1	Local Bit 1 asserted (see *Local Control on page 9.5*)	
28	LB16	Local Bit 16 asserted (see *Local Control on page 9.5*)	
	LB15	Local Bit 15 asserted (see *Local Control on page 9.5*)	
	LB14	Local Bit 14 asserted (see *Local Control on page 9.5*)	
	LB13	Local Bit 13 asserted (see *Local Control on page 9.5*)	
	LB12	Local Bit 12 asserted (see *Local Control on page 9.5*)	
	LB11	Local Bit 11 asserted (see *Local Control on page 9.5*)	
	LB10	Local Bit 10 asserted (see *Local Control on page 9.5*)	
	LB9	Local Bit 9 asserted (see *Local Control on page 9.5*)	

Table 7.6 Relay Word Bit Definitions (Sheet 10 of 19)

Row	Bit	Definition	Primary Application
29	RB8	Remote Bit 8 asserted (see *Figure 5.7*)	Remote control via serial port
	RB7	Remote Bit 7 asserted (see *Figure 5.7*)	
	RB6	Remote Bit 6 asserted (see *Figure 5.7*)	
	RB5	Remote Bit 5 asserted (see *Figure 5.7*)	
	RB4	Remote Bit 4 asserted (see *Figure 5.7*)	
	RB3	Remote Bit 3 asserted (see *Figure 5.7*)	
	RB2	Remote Bit 2 asserted (see *Figure 5.7*)	
	RB1	Remote Bit 1 asserted (see *Figure 5.7*)	
30	RB16	Remote Bit 16 asserted (see *Figure 5.7*)	
	RB15	Remote Bit 15 asserted (see *Figure 5.7*)	
	RB14	Remote Bit 14 asserted (see *Figure 5.7*)	
	RB13	Remote Bit 13 asserted (see *Figure 5.7*)	
	RB12	Remote Bit 12 asserted (see *Figure 5.7*)	
	RB11	Remote Bit 11 asserted (see *Figure 5.7*)	
	RB10	Remote Bit 10 asserted (see *Figure 5.7*)	
	RB9	Remote Bit 9 asserted (see *Figure 5.7*)	
31	LT8	Latch Bit 8 asserted (see *Figure 5.5*)	Latched control -replacing traditional latching relays
	LT7	Latch Bit 7 asserted (see *Figure 5.5*)	
	LT6	Latch Bit 6 asserted (see *Figure 5.5*)	
	LT5	Latch Bit 5 asserted (see *Figure 5.5*)	
	LT4	Latch Bit 4 asserted (see *Figure 5.5*)	
	LT3	Latch Bit 3 asserted (see *Figure 5.5*)	
	LT2	Latch Bit 2 asserted (see *Figure 5.5*)	
	LT1	Latch Bit 1 asserted (see *Figure 5.5*)	
32	LT16	Latch Bit 16 asserted (see *Figure 5.5*)	
	LT15	Latch Bit 15 asserted (see *Figure 5.5*)	
	LT14	Latch Bit 14 asserted (see *Figure 5.5*)	
	LT13	Latch Bit 13 asserted (see *Figure 5.5*)	
	LT12	Latch Bit 12 asserted (see *Figure 5.5*)	
	LT11	Latch Bit 11 asserted (see *Figure 5.5*)	
	LT10	Latch Bit 10 asserted (see *Figure 5.5*)	
	LT9	Latch Bit 9 asserted (see *Figure 5.5*)	

Table 7.6 Relay Word Bit Definitions (Sheet 11 of 19)

Row	Bit	Definition	Primary Application
33	SV4T	SELogic control equation variable timer output SV4T asserted (see *Figure 5.3*)	Control
	SV3T	SELogic control equation variable timer output SV3T asserted (see *Figure 5.3*)	
	SV2T	SELogic control equation variable timer output SV2T asserted (see *Figure 5.3*)	
	SV1T	SELogic control equation variable timer output SV1T asserted (see *Figure 5.3*)	
	SV4	SELogic control equation variable timer input SV4 asserted (see *Figure 5.3*)	Testing, Seal-in functions, etc.
	SV3	SELogic control equation variable timer input SV3 asserted (see *Figure 5.3*)	
	SV2	SELogic control equation variable timer input SV2 asserted (see *Figure 5.3*)	
	SV1	SELogic control equation variable timer input SV1 asserted (see *Figure 5.3*)	
34	SV8T	SELogic control equation variable timer output SV8T asserted (see *Figure 5.3*)	Control
	SV7T	SELogic control equation variable timer output SV7T asserted (see *Figure 5.3*)	
	SV6T	SELogic control equation variable timer output SV6T asserted (see *Figure 5.3*)	
	SV5T	SELogic control equation variable timer output SV5T asserted (see *Figure 5.3*)	
	SV8	SELogic control equation variable timer input SV8 asserted (see *Figure 5.3*)	Testing, Seal-in functions, etc.
	SV7	SELogic control equation variable timer input SV7 asserted (see *Figure 5.3*)	
	SV6	SELogic control equation variable timer input SV6 asserted (see *Figure 5.3*)	
	SV5	SELogic control equation variable timer input SV5 asserted (see *Figure 5.3*)	
35	SV12T	SELogic control equation variable timer output SV12T asserted (see *Figure 5.3*)	Control
	SV11T	SELogic control equation variable timer output SV11T asserted (see *Figure 5.3*)	
	SV10T	SELogic control equation variable timer output SV10T asserted (see *Figure 5.3*)	
	SV9T	SELogic control equation variable timer output SV9T asserted (see *Figure 5.3*)	
	SV12	SELogic control equation variable timer input SV12 asserted (see *Figure 5.3*)	Testing, Seal-in functions, etc.
	SV11	SELogic control equation variable timer input SV11 asserted (see *Figure 5.3*)	
	SV10	SELogic control equation variable timer input SV10 asserted (see *Figure 5.3*)	
	SV9	SELogic control equation variable timer input SV9 asserted (see *Figure 5.3*)	

Table 7.6 Relay Word Bit Definitions (Sheet 12 of 19)

Row	Bit	Definition	Primary Application
36	SV16T	SELogic control equation variable timer output SV16T asserted (see *Figure 5.3*)	Control
	SV15T	SELogic control equation variable timer output SV15T asserted (see *Figure 5.3*)	
	SV14T	SELogic control equation variable timer output SV14T asserted (see *Figure 5.3*)	
	SV13T	SELogic control equation variable timer output SV13T asserted (see *Figure 5.3*)	
	SV16	SELogic control equation variable timer input SV16 asserted (see *Figure 5.3*)	Testing, Seal-in functions, etc.
	SV15	SELogic control equation variable timer input SV15 asserted (see *Figure 5.3*)	
	SV14	SELogic control equation variable timer input SV14 asserted (see *Figure 5.3*)	
	SV13	SELogic control equation variable timer input SV13 asserted (see *Figure 5.3*)	
37	ALARM	ALARM output contact indicating that relay failed or **PULSE ALARM** command executed (see *Figure 5.14*)	Relay output status, Control
	OUT107	Output contact **OUT107** asserted (see *Figure 5.14*)	
	OUT106	Output contact **OUT106** asserted (see *Figure 5.14*)	
	OUT105	Output contact **OUT105** asserted (see *Figure 5.14*)	
	OUT104	Output contact **OUT104** asserted (see *Figure 5.14*	
	OUT103	Output contact **OUT103** asserted (see *Figure 5.14*)	
	OUT102	Output contact **OUT102** asserted (see *Figure 5.14*)	
	OUT101	Output contact **OUT101** asserted (see *Figure 5.14*)	
38	SOTFE	Switch-onto-fault condition (see *Figure 4.4*)	
	50L	Phase instantaneous overcurrent element for closed circuit breaker detection (any phase current above pickup setting 50LP; see *Figure 4.4*)	
	CLMON	Close bus monitor (see *Figure 4.4*)	
	3PO	Three-pole open condition (see *Figure 4.4*)	
	3POD	Three-pole open time delay (see *Figure 4.4*)	
	TRIP	Trip logic output asserted (see *Figure 4.3*)	Output contact assignment
	OC	Asserts 1/4 cycle for Open Command execution (see *OPE Command (Open Breaker) on page 8.44*)	Control
	CC	Asserts 1/4 cycle for Close Command execution (see *CLO Command (Close Breaker) on page 8.43*)	
39	PT	Permissive trip signal to POTT logic (see *Figure 4.6*)	
	Z3RB	Current reversal guard asserted (see *Figure 4.7*)	POTT Logic
	KEY	Transmit permissive trip signal (see *Figure 4.7*)	
	EKEY	Echo received permissive trip signal (see *Figure 4.7*)	
	ECTT	Echo conversion to trip signal (see *Figure 4.7*)	
	WFC	Weak-infeed condition detected (see *Figure 4.7*)	
	LOG	Loss of Guard signal (see *Figure 4.10*)	
	SOTFT	Switch-onto-fault trip signal	

Table 7.6 Relay Word Bit Definitions (Sheet 13 of 19)

Row	Bit	Definition	Primary Application
40	PTRX	Permissive trip signal to trip logic (see *Figure 4.10*)	
	UBB	Unblocking block to trip logic (see *Figure 4.10*)	
	BT	Block trip picked up (see *Figure 4.12*)	
	BTX	Block extension picked up (see *Figure 4.12*)	
	Z3XT	Current reversal guard timer picked up (see *Figure 4.12*)	
	DSTRT	Directional start element picked up (see *Figure 4.12*)	
	NSTRT	Nondirectional start element picked up (see *Figure 4.12*)	
	STOP	Stop element picked up (see *Figure 4.12*)	
41	ZLOAD	ZLOUT + ZLIN (see *Figure 3.33*)	Special phase overcurrent element control
	ZLOUT	Load encroachment "load out" element (see *Figure 3.33*)	
	ZLIN	Load encroachment "load in" element (see *Figure 3.33*)	
	DCHI	Station dc battery instantaneous overvoltage element (see *Figure 6.15*)	Indication
	DCLO	Station dc battery instantaneous undervoltage element (see *Figure 6.15*)	
	PDEM	Phase demand current above pickup setting PDEMP (see *Figure 6.6*)	
	NDEM	Neutral demand current above pickup setting NDEMP (see *Figure 6.6*)	
	QDEM	Negative-sequence demand current above pickup setting QDEMP (see *Figure 6.6*)	
42	RMB8A	Channel A, received bit 8 (see *Figure D.2*)	Relay-to-relay communication (see *Appendix D*)
	RMB7A	Channel A, received bit 7 (see *Figure D.2*)	
	RMB6A	Channel A, received bit 6 (see *Figure D.2*)	
	RMB5A	Channel A, received bit 5 (see *Figure D.2*)	
	RMB4A	Channel A, received bit 4 (see *Figure D.2*)	
	RMB3A	Channel A, received bit 3 (see *Figure D.2*)	
	RMB2A	Channel A, received bit 2 (see *Figure D.2*)	
	RMB1A	Channel A, received bit 1 (see *Figure D.2*)	
43	TMB8A	Channel A, transmit bit 8 (see *Figure D.2*)	
	TMB7A	Channel A, transmit bit 7 (see *Figure D.2*)	
	TMB6A	Channel A, transmit bit 6 (see *Figure D.2*)	
	TMB5A	Channel A, transmit bit 5 (see *Figure D.2*)	
	TMB4A	Channel A, transmit bit 4 (see *Figure D.2*)	
	TMB3A	Channel A, transmit bit 3 (see *Figure D.2*)	
	TMB2A	Channel A, transmit bit 2 (see *Figure D.2*)	
	TMB1A	Channel A, transmit bit 1 (see *Figure D.2*)	
44	RMB8B	Channel B, received bit 8 (see *Figure D.2*)	
	RMB7B	Channel B, received bit 7 (see *Figure D.2*)	
	RMB6B	Channel B, received bit 6 (see *Figure D.2*)	
	RMB5B	Channel B, received bit 5 (see *Figure D.2*)	
	RMB4B	Channel B, received bit 4 (see *Figure D.2*)	
	RMB3B	Channel B, received bit 3 (see *Figure D.2*)	
	RMB2B	Channel B, received bit 2 (see *Figure D.2*)	
	RMB1B	Channel B, received bit 1 (see *Figure D.2*)	

Table 7.6 Relay Word Bit Definitions (Sheet 14 of 19)

Row	Bit	Definition	Primary Application
45	TMB8B	Channel B, transmit bit 8 (see *Figure D.2*)	
	TMB7B	Channel B, transmit bit 7 (see *Figure D.2*)	
	TMB6B	Channel B, transmit bit 6 (see *Figure D.2*)	
	TMB5B	Channel B, transmit bit 5 (see *Figure D.2*)	
	TMB4B	Channel B, transmit bit 4 (see *Figure D.2*)	
	TMB3B	Channel B, transmit bit 3 (see *Figure D.2*)	
	TMB2B	Channel B, transmit bit 2 (see *Figure D.2*)	
	TMB1B	Channel B, transmit bit 1 (see *Figure D.2*)	
46	LBOKB	Channel B, received MIRRORED BIT data OK in loopback mode	Testing, Indication (see *Appendix D*)
	CBADB	Channel B, channel unavailability over threshold	
	RBADB	Channel B, outage duration over threshold	
	ROKB	Channel B, received MIRRORED BIT data OK	
	LBOKA	Channel A, received MIRRORED BIT data OK in loopback mode	
	CBADA	Channel A, channel unavailability over threshold	
	RBADA	Channel A, outage duration over threshold	
	ROKA	Channel A, received MIRRORED BIT data OK	
47	PWRA1	Level 1 A-phase power element (see *Figure 3.30*)	Tripping Control
	PWRB1	Level 1 B-phase power element	
	PWRC1	Level 1 C-phase power element	
	PWRA2	Level 2 A-phase power element	
	PWRB2	Level 2 B-phase power element	
	PWRC2	Level 2 C-phase power element	
	3PWR1	PWRA1*PWRB1*PWRC1	
	3PWR2	PWRA2*PWRB2*PWRC2	
48	PWRA3	Level 3 A-phase power element (see *Figure 3.30*)	
	PWRB3	Level 3 B-phase power element	
	PWRC3	Level 3 C-phase power element	
	PWRA4	Level 4 A-phase power element	
	PWRB4	Level 4 B-phase power element	
	PWRC4	Level 4 C-phase power element	
	3PWR3	PWRA3*PWRB3*PWRC3	
	3PWR4	PWRA4*PWRB4*PWRC4	

Table 7.6 Relay Word Bit Definitions (Sheet 15 of 19)

Row	Bit	Definition	Primary Application
49	TRGTR	Target Reset. TRGTR pulses to logical 1 for one processing interval when either the {TARGET RESET} pushbutton is pushed or the **TAR R** serial port command is executed (see *Figure 4.3*)	Tripping
	87HWAL	Differential board self-test alarm	
	87BSY	Differential board self-test alarm	
	*		
	*		
	*		
	*		
	V0GAIN		
50	SG6	Setting group 6 active (see *Multiple Setting Groups on page 5.14*)	Control
	SG5	Setting group 5 active (see *Multiple Setting Groups on page 5.14*)	
	SG4	Setting group 4 active (see *Multiple Setting Groups on page 5.14*)	
	SG3	Setting group 3 active (see *Multiple Setting Groups on page 5.14*)	
	SG2	Setting group 2 active (see *Multiple Setting Groups on page 5.14*)	
	SG1	Setting group 1 active (see *Multiple Setting Groups on page 5.14*)	
	*		
	PLAY	Event playback	
51	201LOG	SELogic control equation OUT201 evaluates to Logical 1 (see *Figure 4.2*)	Testing
	202LOG	SELogic control equation OUT202 evaluates to Logical 1 (see *Figure 4.2*)	
	203LOG	SELogic control equation OUT203 evaluates to Logical 1 (see *Figure 4.2*)	
	204LOG	SELogic control equation OUT204 evaluates to Logical 1 (see *Figure 4.2*)	
	205LOG	SELogic control equation OUT205 evaluates to Logical 1 (see *Figure 4.2*)	
	206LOG	SELogic control equation OUT206 evaluates to Logical 1 (see *Figure 4.2*)	
	*		
	*		
52	OUT201	State of output contact OUT201 (see *Figure 4.2*)	Control, Indication
	OUT202	State of output contact OUT202 (see *Figure 4.2*)	
	OUT203	State of output contact OUT203 (see *Figure 4.2*)	
	OUT204	State of output contact OUT204 (see *Figure 4.2*)	
	OUT205	State of output contact OUT205 (see *Figure 4.2*)	
	OUT206	State of output contact OUT206 (see *Figure 4.2*)	
	87LPE	Enable phase differential calculation (see *Relay Word Bit 87LPE on page 8.5*)	
	*		

Table 7.6 Relay Word Bit Definitions (Sheet 16 of 19)

Row	Bit	Definition	Primary Application
53	FTABC	ABC fault type declaration	Indication
	FTAG	AG fault type declaration	
	FTBG	BG fault type declaration	
	FTCG	CG fault type declaration	
	FTAB	AB fault type declaration	
	FTBC	BC fault type declaration	
	FTCA	CA fault type declaration	
	*		
54	87L	ORed combination of 87LA, 87LB, 87LC, (see *Figure 3.12*)	Testing, Control
	87LA	A-Phase differential trip output (see *Figure 3.12*)	
	87LB	B-Phase differential trip output (see *Figure 3.12*)	
	87LC	C-Phase differential trip output (see *Figure 3.12*)	
	TRIP87	Line current differential trip logic output asserted (see *Figure 4.1* and *Figure 4.3*)	
	*		
	CHYAL	Status of Channel Y (see *Section 8*)	Alarming
	CHXAL	Status of Channel X (see *Section 8*)	
55	87LOPA	A-phase differential current enable level detector (see *Figure 3.12*)	Testing, Control
	87LAE	A-phase differential calculation enable (see *Figure 3.12*)	
	R87LA	A-phase restraint region detection output (see *Figure 3.12*)	
	CTAA	A-phase CT alarm level detector (see *Figure 3.12*)	Alarming
	*		
	*		
	*		
	*		
56	87LOPB	B-phase differential current enable level detector	Testing, Control
	87LBE	B-phase differential calculation enable	
	R87LB	B-phase restraint region detection output	
	CTBA	B-phase CT alarm level detector	Alarming
	*		
	*		
	*		
	*		
57	87LOPC	C-phase differential current enable level detector	Testing, Control
	87LCE	C-phase differential calculation enable	
	R87LC	C-phase restraint region detection output	
	CTCA	C-phase CT alarm level detector	Alarming
	*		
	*		
	*		
	*		

Table 7.6 Relay Word Bit Definitions (Sheet 17 of 19)

Row	Bit	Definition	Primary Application
58	*		
	*		
	TESTY	Differential Channel Y in test mode (see *Section 8*)	Testing
	3POY	Differential Channel Y receive three pole open	
	*		
	*		
	TESTX	Differential Channel X in test mode (see *Section 8*)	
	3POX	Differential Channel X receive three pole open	
59	R8X	Received Channel X bit 8 (see *Section 8*)	
	R7X	Received Channel X bit 7 (see *Section 8*)	
	R6X	Received Channel X bit 6 (see *Section 8*)	
	R5X	Received Channel X bit 5 (see *Section 8*)	
	R4X	Received Channel X bit 4 (see *Section 8*)	
	R3X	Received Channel X bit 3 (see *Section 8*)	
	R2X	Received Channel X bit 2 (see *Section 8*)	
	R1X	Received Channel X bit 1 (see *Section 8*)	
60	T8X	Transmitted Channel X bit 8 (see *Section 8*)	
	T7X	Transmitted Channel X bit 7 (see *Section 8*)	
	T6X	Transmitted Channel X bit 6 (see *Section 8*)	
	T5X	Transmitted Channel X bit 5 (see *Section 8*)	
	T4X	Transmitted Channel X bit 4 (see *Section 8*)	
	T3X	Transmitted Channel X bit 3 (see *Section 8*)	
	T2X	Transmitted Channel X bit 2 (see *Section 8*)	
	T1X	Transmitted Channel X bit 1 (see *Section 8*)	
61	R8Y	Received Channel Y bit 8 (see *Section 8*)	
	R7Y	Received Channel Y bit 7 (see *Section 8*)	
	R6Y	Received Channel Y bit 6 (see *Section 8*)	
	R5Y	Received Channel Y bit 5 (see *Section 8*)	
	R4Y	Received Channel Y bit 4 (see *Section 8*)	
	R3Y	Received Channel Y bit 3 (see *Section 8*)	
	R2Y	Received Channel Y bit 2 (see *Section 8*)	
	R1Y	Received Channel Y bit 1 (see *Section 8*)	
62	T8Y	Transmitted Channel Y bit 8 (see *Section 8*)	
	T7Y	Transmitted Channel Y bit 7 (see *Section 8*)	
	T6Y	Transmitted Channel Y bit 6 (see *Section 8*)	
	T5Y	Transmitted Channel Y bit 5 (see *Section 8*)	
	T4Y	Transmitted Channel Y bit 4 (see *Section 8*)	
	T3Y	Transmitted Channel Y bit 3 (see *Section 8*)	
	T2Y	Transmitted Channel Y bit 2 (see *Section 8*)	
	T1Y	Transmitted Channel Y bit 1 (see *Section 8*)	

Table 7.6 Relay Word Bit Definitions (Sheet 18 of 19)

Row	Bit	Definition	Primary Application
63	DBADY	One-way delay on Channel Y exceeds setting DBADYP (see *Section 8*)	Alarming, Testing
	AVAY	Channel Y unavailability exceeds setting AVAYP (see *Section 8*)	
	RBADY	Channel Y dropout exceeds setting RBADYP (see *Section 8*)	
	ROKY	Channel Y instantaneous receive status (see *Section 8*)	
	DBADX	One-way delay on Channel X exceeds setting DBADXP (see *Section 8*)	
	AVAX	Channel X unavailability exceeds setting AVAXP (see *Section 8*)	
	RBADX	Channel X dropout exceeds setting RBADXP (see *Section 8*)	
	ROKX	Channel X instantaneous receive status (see *Section 8*)	
64	50LA	Local A-phase overcurrent element output (see *Figure 3.12*)	Testing
	50RA	Remote A-phase overcurrent element output (see *Figure 3.12*)	
	50LB	Local B-phase overcurrent element output	
	50RB	Remote B-phase overcurrent element output	
	50LC	Local C-phase overcurrent element output	
	50RC	Remote C-phase overcurrent element output	
	*		
	*		
65	V0VALL	Local zero-sequence voltage valid (see *Figure 3.13*)	
	GNDSWL	Local ground switch asserted	
	V0VALR	Remote zero-sequence voltage valid	
	GNDSWR	Remote ground switch asserted	
	B87W	Block of ground differential element (87W) (see *Figure 3.13*)	
	50FW	Ground differential element minimum sensitivity threshold met (see *Figure 3.13*)	
	87WE	Ground differential element enable logic satisfied (see *Figure 3.13*)	
	87WF	Ground differential element forward declaration (see *Figure 3.13*)	
66	F32N	Zero-Seq. Ground Directional Element Forward Declaration (see *Figure 3.36*)	Tripping
	R32N	Zero-Seq. Ground Directional Element Reverse Declaration (see *Figure 3.36*)	
	PNSA	Primary Neutral Shift A	
	PNSB	Primary Neutral Shift B	
	PNSC	Primary Neutral Shift C	
	32NE	Ground directional element enable (see *Figure 3.35*)	
	50NF	Forward direction neutral overcurrent threshold exceeded (see *Figure 3.35*)	
	50NR	Reverse direction neutral overcurrent threshold exceeded (see *Figure 3.35*)	

Table 7.6 Relay Word Bit Definitions (Sheet 19 of 19)

Row	Bit	Definition	Primary Application
67	51NG	Ground current above pickup setting 51GP for residual ground time-overcurrent element 51GT (see *Figure 3.20*)	Testing, Control
	51NGT	Ground time-overcurrent element 51GT timed out (see *Figure 3.20*)	Tripping
	51NGR	Ground time-overcurrent element 51GT reset (see *Figure 3.20*)	Testing
	*		
	*		
	*		
	*		
	*		

[a] IMPORTANT: See Setting Setting Negative-Sequence Overcurrent Elements on page 3.80 for special instructions on setting negative-sequence overcurrent elements.

Settings Explanations

Note that most of the settings in the settings sheets that follow include references for additional information. The following explanations are for settings that do not have reference information anywhere else in the instruction manual. The *SEL-311M Settings Sheets* that follow this section include the definition and input range for each setting in the relay.

Identifier Labels

The SEL-311M has two identifier labels:

➤ the Relay Identifier (RID)

The Relay Identifier is typically used to identify the relay or the type of protection scheme.

➤ the Terminal Identifier (TID)

Typical terminal identifiers include an abbreviation of the substation name and line terminal.

The relay tags each report (event report, meter report, etc.) with the Relay Identifier and Terminal Identifier. This allows you to distinguish the report as one generated for a specific breaker and substation.

RID and TID settings may include the following characters:

➤ 0–9

➤ A–Z

➤ #

➤ &

➤ @

➤ -

➤ /

➤ .

➤ space

These two settings cannot be made via the front-panel interface.

Current Transformer Ratios

Phase and neutral ground current transformer ratios are set independently.

Potential Transformer Ratios and PT Nominal Secondary Voltage Settings

Relay setting PTR is the overall potential ratio from the primary system to the relay phase voltage inputs VA-VB-VC-N. For example, on a 12.5 kV phase-to-phase primary system with wye-connected 7200:120 V PTs, the correct PTR setting is 60.

Relay setting PTRS is the overall potential ratio from the synchronizing source to the relay VS-NS voltage inputs. For example, in a synchronism check application, with phase-to-ground voltage connected from a 12.5 kV phase-to-phase primary system through a 7200:120 V PT, the correct PTRS setting is 60.

Settings PTR and PTRS are used in event report and **METER** commands so that power system values can be reported in primary units.

Relay setting VNOM is the nominal secondary voltage connected to voltage inputs VA-VB-VCN. For wye-connected PTs, VNOM is a phase-to-neutral secondary voltage value. For example, for a 10 kV (phase-to-phase) system with wye-connected PTs rated 7200:120 V (PTR = 60), the setting for VNOM would be:

$$\frac{10000\text{ V}}{\sqrt{3} \bullet 60} = 96.22\text{ V}$$

Equation 7.1

In the loss-of-potential logic (see *Figure 3.32* and accompanying text), setting VNOM scales certain voltage thresholds for voltage measurement comparisons. In *Table 7.7*, a setting of VNOM = OFF is shown to disable/turn-off a number of features. Effectively, setting VNOM = OFF signifies that a full three-phase voltage source is not connected to voltage inputs VA-VBVC-N. Even with VNOM = OFF, voltage can still be connected to voltage inputs VA-VB-VC-N (e.g., single-phase voltage connected to voltage input VA-N) for the undervoltage block for frequency elements.

Table 7.7 Main Relay Functions That Change With VNOM = OFF

Relay Function	When VNOM = Numeric Value	When VNOM = OFF
Undervoltage block for frequency elements: 27B81	Requires all three voltages V_A, V_B, V_C to be greater than setting 27B81P in order to deassert	Requires one voltage VA to be greater than setting 27B81P in order to deassert
Load encroachment logic (enable setting ELOAD)	Available	Not available (can only set ELOAD = N)
Negative-sequence and positive-sequence voltage polarized directional elements	Available	32QE and 32PE are disabled, F32P/R32P disabled
Phase and negative-sequence element directional control	Available	Not available (defaults to “non-directional” in levels DIR3–DIR4)
Loss-of-Potential Logic (enable setting ELOP)	Available	Not available (can only set ELOP = N); Output Relay Word bits disabled (LOP = logical 0, V1VAL = logical 0)

Line Settings

Line impedance settings Z1MAG, Z1ANG, Z0MAG, and Z0ANG are used in automatically making directional element settings Z2F, Z2R, Z0F, and Z0R (see *Settings Made Automatically on page 3.72*).

The line impedance settings Z1MAG, Z1ANG, Z0MAG, and Z0ANG are set in Ω secondary. To convert line impedance (Ω primary) to Ω secondary:

Ω primary • (CTR/PTR) = Ω secondary

where:

CTR = phase (IA, IB, IC) current transformer ratio

PTR = phase (VA, VB, VC) potential transformer ratio

Enable Settings

The enable settings (E87L to EDP) control the setting subgroups that follow. For example, setting ELOAD = Y will enable the load encroachment settings that follow it. Hence, the enable settings are used to limit the number of settings that need to be made.

Other System Parameters

The global settings NFREQ and PHROT allow you to configure the SEL-311M to your specific system.

Set NFREQ equal to your nominal power system frequency, either 50 Hz or 60 Hz.

Set PHROT equal to your power system phase rotation, either ABC or ACB.

Set DATE_F to format the date displayed in relay reports and the front-panel display.

Set DATE_F to MDY to display dates in Month/Day/Year format.

Set DATE_F to YMD to display dates in Year/Month/Day format.

Set FMETER to SIMPLE if extremely low latency (˜50 ms) response times are needed for Fast Meter messages and you do not need to read the channel X remote analogs. (See *SEL Fast Meter, Fast Operate, and Fast SER on page C.2*.)

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SEL-311M Settings Sheets

Relay Settings (Serial Port Command SET and Front Panel)

Identifier Labels and Configuration Settings (See Settings Explanations on page 7.35)

Relay identifier (30 characters)

RID = ______________________________

Terminal identifier (30 characters)

TID = ______________________________

Local phase (IA, IB, IC) current transformer ratio (1–6000)

CTR = ______________________________

Neutral (IN) CT ratio (1–6000)

CTRN = ______________________________

Phase (VA, VB, VC) PT ratio (1.00–10000.00)

PTR = ______________________________

Synchronism voltage (VS) PT ratio (1.00–10000.00)

PTRS = ______________________________

PT nominal voltage (OFF, 25.00–300.00 V secondary)

VNOM = ______________________________

Line Parameter Settings (See Settings Explanations on page 7.35)

Positive-sequence line impedance magnitude
(0.25–1275.00 Ω secondary {1 A nom.})
(0.05–255.00 Ω secondary {5 A nom.}) Z1MAG = ________

Positive-sequence line impedance angle
(5.00–90.00 degrees) Z1ANG = ________

Zero-sequence line impedance magnitude
(0.25–1275.00 Ω secondary 0.2 A nom. IN) Z0MAG = ________

Zero-sequence line impedance angle (-90.00 to -5.00 degrees) Z0ANG = ________

Line Current Differential Configuration Settings

Number of 87L terminals (N, 2) E87L = ________

If E87L ≠ N, the following choices are available:

High-speed tripping output select – enter six 1s or 0s to enable or disable high-speed tripping on OUT206–OUT201 EHST = ________

Hot-standby channel feature (Y, N) EHSC = ________

Minimum Difference Current Enable Level Settings (E87L = 2)

Phase 87L (OFF, 0.20–2.00 A secondary {1 A nom.}) (OFF, 1.00–10.00 A secondary {5 A nom.})	87LPP =	________
Phase difference current alarm pickup (0.10–2.00 A secondary {1 A nom.}) (0.50–10.00 A secondary {5 A nom.})	CTALRM =	________

Restraint Region Characteristic Settings (E87L = 2)

Outer radius (2.00–8.00)	87LR =	________
Angle (90°–270°)	87LANG =	________

Ground Directional Element Settings (E87L = 2)

Minimum sensitivity threshold (0.005–5.000 A)	50FWP =	________
Forward ground directional threshold (-900000 to 0 W)	87WP =	________
Source adjustment angle (–90° to +90°)	W_ANG =	________

Instantaneous/Definite-Time Overcurrent Enable Settings

If ECOMM ≠ N, then E50P, E50NG, and E50Q must be set ≥ 3.

Phase element levels (N, 1–4) (see *Figure 3.14*)	E50P =	________
Neutral ground element levels (N, 1–4) (see *Figure 3.17*)	E50NG =	________
Negative-sequence element levels (N, 1–4) (see *Figure 3.18*)	E50Q =	________

Time-Overcurrent Enable Settings

Phase element (Y, N) (see *Figure 3.19*)	E51P =	________
Neutral ground element (Y, N) (see *Figure 3.20*)	E51NG=	________
Negative-sequence element (Y, N) (see *Figure 3.21*)	E51Q=	________

Other Enable Settings

If VNOM = OFF: ELOAD can only be set to N; ELOP can only be set to N.

Directional control (Y, AUTO, N) (see *Directional Control Settings on page 3.72*)	E32 =	________
Load encroachment (Y, N) (see *Figure 3.33*)	ELOAD =	________
Switch-onto-fault (Y, N) (see *Figure 4.4*)	ESOTF =	________
Voltage elements (N, 1–4) (see *Figure 3.22*, *Figure 3.23*)	EVOLT =	________
Synchronism check (Y, N) (see *Figure 3.24* and *Figure 3.25*)	E25 =	________
Frequency elements (N, 1–6) (see *Figure 3.29*)	E81 =	________
Loss-of-potential (Y, Y1, N) (see *Figure 3.32*)	ELOP =	________
Communications-assisted trip scheme (N, DCB, POTT, DCUB) (see *Communications-Assisted Trip Logic (General Overview) on page 4.11*)	ECOMM =	________
Power elements (N, 1–4) (see *Figure 3.30* and *Figure 3.31*)	EPWR =	________
SELOGIC® control equation variable timers (N, 1–16) (see *Figure 5.3*)	ESV =	________
SELOGIC latch bits (N, 1–16) (See *Figure 5.5*)	ELAT =	________
SELOGIC display points (N, 1–16) (See *Rotating Default Display on page 5.25*)	EDP =	________
Demand metering (THM = Thermal; ROL = Rolling) (see *Figure 6.4*)	EDEM =	________

Phase Inst./Def.-Time Overcurrent Elements (See Figure 3.14)

Number of phase element pickup settings dependent on preceding enable setting E50P = 1–4.

Level 1 (OFF, 0.05–20.00 A secondary {1 A nom.}) (OFF, 0.25–100.00 A secondary {5 A nom.})	50P1P =	________
Level 2 (OFF, 0.05–20.00 A secondary {1 A nom.}) (OFF, 0.25–100.00 A secondary {5 A nom.})	50P2P =	________
Level 3 (OFF, 0.05–20.00 A secondary {1 A nom.}) (OFF, 0.25–100.00 A secondary {5 A nom.})	50P3P =	________
Level 4 (OFF, 0.05–20.00 A secondary {1 A nom.}) (OFF, 0.25–100.00 A secondary {5 A nom.})	50P4P =	________

Phase Definite-Time Overcurrent Element Time Delays (See Figure 3.14)

Number of phase element time delay settings dependent on preceding enable setting E50P = 1–4.

Level 1 (0.00–16000.00 cycles in 0.25-cycle steps)	67P1D =	________
Level 2 (0.00–16000.00 cycles in 0.25-cycle steps)	67P2D =	________
Level 3 (0.00–16000.00 cycles in 0.25-cycle steps)	67P3D =	________
Level 4 (0.00–16000.00 cycles in 0.25-cycle steps)	67P4D =	________

Neutral Ground Inst./Def.-Time Overcurrent Elements (See Figure 3.17)

Number of neutral ground element pickup settings dependent on preceding enable setting E50NG = 1–4.

Level 1 (OFF, 0.005–5.00 A secondary {0.2 A nom.})	50NG1P =	________
Level 2 (OFF, 0.005–5.00 A secondary {0.2 A nom.})	50NG2P =	________

Level 3 (OFF, 0.005–5.00 A secondary {0.2 A nom.})	50NG3P =	____________
Level 4 (OFF, 0.005–5.00 A secondary {0.2 A nom.})	50NG4P =	____________

Neutral Ground Definite-Time Overcurrent Element Time Delay (See Figure 3.17)

Number of neutral ground element time delay settings dependent on preceding enable setting E50NG = 1–4.

Level 1 (0.00–16000.00 cycles in 0.25-cycle steps)	67NG1D =	____________
Level 2 (0.00–16000.00 cycles in 0.25-cycle steps)	67NG2D =	____________
Level 3 (0.00–16000.00 cycles in 0.25-cycle steps)	67NG3D =	____________
Level 4 (0.00–16000.00 cycles in 0.25-cycle steps)	67NG4D =	____________

Negative-Sequence Inst./Def.-Time Overcurrent Elements (See Figure 3.18)

Number of negative-sequence element time delay settings dependent on preceding enable setting E50Q = 1–4; see Section 3: Protection Functions for information on setting negative-sequence overcurrent elements.

Level 1 (OFF, 0.05–20.00 A secondary {1 A nom.}) (OFF, 0.25–100.00 A secondary {5 A nom.})	50Q1P =	____________
Level 2 (OFF, 0.05–20.00 A secondary {1 A nom.}) (OFF, 0.25–100.00 A secondary {5 A nom.})	50Q2P =	____________
Level 3 (OFF, 0.05–20.00 A secondary {1 A nom.}) (OFF, 0.25–100.00 A secondary {5 A nom.})	50Q3P =	____________
Level 4 (OFF, 0.05–20.00 A secondary {1 A nom.}) (OFF, 0.25–100.00 A secondary {5 A nom.})	50Q4P =	____________

Negative-Sequence Definite-Time Overcurrent Element Time Delay (See Figure 3.18)

Number of negative-sequence element time delay settings dependent on preceding enable setting E50Q = 1–4; see Section 3: Protection Functions for information on setting negative-sequence overcurrent elements.

Level 1 (0.00–16000.00 cycles in 0.25-cycle steps)	67Q1D =	______
Level 2 (0.00–16000.00 cycles in 0.25-cycle steps)	67Q2D =	______
Level 3 (0.00–16000.00 cycles in 0.25-cycle steps)	67Q3D =	______
Level 4 (0.00–16000.00 cycles in 0.25-cycle steps)	67Q4D =	______

Phase Time-Overcurrent Element (See Figure 3.19)

Make the following settings if preceding enable setting E51P = Y.

Pickup (OFF, 0.10–3.20 A secondary {1 A nom.}) (OFF, 0.50–16.00 A secondary {5 A nom.})	51PP =	______
Curve (U1–U5, C1–C5) (see *Figure 7.1*–*Figure 7.10*)	51PC =	______
Time dial (0.50–15.00 for curves U1–U5; 0.05–1.00 for curves C1–C5)	51PTD =	______
Electromechanical reset (Y, N)	51PRS =	______

Ground Time-Overcurrent Element (See Figure 3.20)

Make the following settings if preceding enable setting E51NG = Y.

Pickup (OFF, 0.001–3.20 A secondary {1 A nom.})	51NGP =	______
Curve (U1–U5, C1–C5) (see *Figure 7.1*–*Figure 7.10*)	51NGC =	______
Time dial (0.50–15.00 for curves U1–U5; 0.005–1.00 for curves C1–C5)	51NGTD =	______
Electromechanical reset (Y, N)	51NGRS =	______

Negative-Sequence Time-Overcurrent Element (See Figure 3.21)

Make the following settings if preceding enable setting E51Q = Y; see Section 3: Protection Functions for information on setting negative-sequence overcurrent elements.

Pickup (OFF, 0.10–3.20 A secondary {1 A nom.}) (OFF, 0.50–16.00 A secondary {5 A nom.})	51QP =	______________
Curve (U1–U5, C1–C5) (see *Figure 7.1*–*Figure 7.10*)	51QC =	______________
Time dial (0.50–15.00 for curves U1–U5; 0.05–1.00 for curves C1–C5)	51QTD =	______________
Electromechanical reset (Y, N)	51QRS =	______________

Load-Encroachment Elements (See Figure 3.33)

Make the following settings if preceding enable setting ELOAD = Y.

Forward load impedance (0.25–320.00 Ω secondary {1 A nom.}) (0.05–64.00 Ω secondary {5 A nom.})	ZLF =	______________
Reverse load impedance (0.25–320.00 Ω secondary {1 A nom.}) (0.05–64.00 Ω secondary {5 A nom.})	ZLR =	______________
Positive forward load angle (–90.00° to +90.00°)	PLAF =	______________
Negative forward load angle (–90.00° to +90.00°)	NLAF =	______________
Positive reverse load angle (+90.00° to +270.00°)	PLAR =	______________
Negative reverse load angle (+90.00° to +270.00°)	NLAR =	______________

PLAF must be set **greater** than or equal to NLAF, and PLAR must be **less** than or equal to NLAR.

Zone/Level 3 and 4 Directional Control

If ECOMM ≠ N, DIR3 can only be set to R (reverse).

Zone/Level 3 direction: Forward, Reverse (F, R)	DIR3 =	______________

Zone/Level 4 direction: Forward, Reverse (F, R)	DIR4 =	____________

Directional Elements (See Directional Control Settings on page 3.72)

If E32 = AUTO, these settings are made automatically. If E32 = OFF, these settings are hidden.

Forward directional Z2 threshold (–320.00–320.00 Ω secondary {1 A nom.}) (–64.00–64.00 Ω secondary {5 A nom.})	Z2F =	____________

Z2F must be less than Z2R by at least 0.1 Ω secondary (1 A nom.) or 0.02 Ω secondary (5 A nom.).

Reverse directional Z2 threshold (–320.00–320.00 Ω secondary {1 A nom.}) (–64.00–64.00 Ω secondary {5 A nom.})	Z2R =	____________
Forward directional 3I2 pickup (0.05–1.00 A secondary {1 A nom.}) (0.25–5.00 A secondary {5 A nom.})	50QFP =	____________
Reverse directional 3I2 pickup (0.05–1.00 A secondary {1 A nom.}) (0.25–5.00 A secondary {5 A nom.})	50QRP =	____________
Positive-sequence current restraint factor, I2/I1 (0.02–0.50, unitless)	a2 =	____________
Forward directional 3I0 pickup (0.005–1.00 A secondary {0.2 A nom.})	50NFP =	____________
Reverse directional 3I0 pickup (0.005–1.00 A secondary {0.2 A nom.})	50NRP =	____________
Positive-sequence restraint factor, IN/I1 (0.001–0.50, unitless {1 A nom}) (0.0002–0.10, unitless {5 A nom.})	a0N =	____________

Forward directional Z0 threshold (–320.00–320.00 Ω secondary {0.2 A nom.})	Z0F =	____________________

Z0F must be less than Z0R by at least 0.1 Ω secondary.

Reverse directional Z0 threshold (–320.00–320.00 Ω secondary {0.2 A nom.})	Z0R =	____________________

Voltage Elements (See Figure 3.22 and Figure 3.23)

Number of voltage elements settings dependent on preceding enable setting EVOLT = N, 1–4.

Phase Undervoltage Pickup (OFF, 2.0–300.0 V secondary)	27P1P	____________________
Phase Undervoltage Pickup (OFF, 2.0–300.0 V secondary)	27P2P	____________________
Phase Undervoltage Pickup (OFF, 2.0–300.0 V secondary)	27P3P	____________________
Phase Undervoltage Pickup (OFF, 2.0–300.0 V secondary)	27P4P	____________________
Phase Overvoltage Pickup (OFF, 2.0–300.0 V secondary)	59P1P	____________________
Phase Overvoltage Pickup (OFF, 2.0–300.0 V secondary)	59P2P	____________________
Phase Overvoltage Pickup (OFF, 2.0–300.0 V secondary)	59P3P	____________________
Phase Overvoltage Pickup (OFF, 2.0–300.0 V secondary)	59P4P	____________________
Zero-sequence (3V0) Overvoltage Pickup (OFF, 2.00–900.00 V secondary)	59N1P	____________________
Zero-sequence (3V0) Overvoltage Pickup (OFF, 2.00–900.00 V secondary)	59N2P	____________________

Zero-sequence (3V0) Overvoltage Pickup (OFF, 2.00–900.00 V secondary)	59N3P	______
Zero-sequence (3V0) Overvoltage Pickup (OFF, 2.00–900.00 V secondary)	59N4P	______
Negative-sequence (V2) Overvoltage Pickup (OFF, 2.0–300.0 V secondary)	59Q1P	______
Negative-sequence (V2) Overvoltage Pickup (OFF, 2.0–300.0 V secondary)	59Q2P	______
Negative-sequence (V2) Overvoltage Pickup (OFF, 2.0–300.0 V secondary)	59Q3P	______
Negative-sequence (V2) Overvoltage Pickup (OFF, 2.0–300.0 V secondary)	59Q4P	______
Positive-sequence (V1) Overvoltage Pickup (OFF, 2.00–300.00 V secondary)	59V1P	______
Channel VS Undervoltage Pickup (OFF, 2.00–300 V secondary)	27S1P	______
Channel VS Undervoltage Pickup (OFF, 2.00–300 V secondary)	27S2P	______
Channel VS Undervoltage Pickup (OFF, 2.00–300 V secondary)	27S3P	______
Channel VS Undervoltage Pickup (OFF, 2.00–300 V secondary)	27S4P	______
Channel VS Overvoltage Pickup (OFF, 2.00–300 V secondary)	59S1P	______

Channel VS Overvoltage Pickup (OFF, 2.00–300 V secondary)	59S2P	________
Channel VS Overvoltage Pickup (OFF, 2.00–300 V secondary)	59S3P	________
Channel VS Overvoltage Pickup (OFF, 2.00–300 V secondary)	59S4P	________
Phase-Phase Undervoltage Pickup (OFF, 2.00–520 V secondary)	27PP1P	________
Phase-Phase Undervoltage Pickup (OFF, 2.00–520 V secondary)	27PP2P	________
Phase-Phase Undervoltage Pickup (OFF, 2.00–520 V secondary)	27PP3P	________
Phase-Phase Undervoltage Pickup (OFF, 2.00–520 V secondary)	27PP4P	________
Phase-Phase Overvoltage Pickup (OFF, 2.00–520 V secondary)	59PP1P	________
Phase-Phase Overvoltage Pickup (OFF, 2.00–520 V secondary)	59PP2P	________
Phase-Phase Overvoltage Pickup (OFF, 2.00–520 V secondary)	59PP3P	________
Phase-Phase Overvoltage Pickup (OFF, 2.00–520 V secondary)	59PP4P	________

Synchronism Check Elements (See Figure 3.24 and Figure 3.25)

Make the following settings if preceding enable setting E25 = Y.

Voltage window—low threshold (2.00–300.00 V secondary)	25VLO =	________

Voltage window—high threshold (2.00–300.00 V secondary)	25VHI =	________
Maximum slip frequency (0.005–0.500 Hz)	25SF =	________
Maximum angle 1 (0.00°–80.00°)	25ANG1 =	________
Maximum angle 2 (0.00°–80.00°)	25ANG2 =	________
Synchronizing phase (VA, VB, VC, VAB, VBC, VCA)	SYNCP =	________
Breaker close time for angle compensation (OFF, 1.00–60.00 cycles in 0.25-cycle steps)	TCLOSD =	________

Frequency Elements (See Figure 3.29)

Make the following settings if preceding enable setting E81 = 1–6.

Phase undervoltage block (25.00–300.00 V secondary)	27B81P =	________
Level 1 pickup (OFF, 41.00–65.00 Hz)	81D1P =	________
Level 1 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	81D1D =	________
Level 2 pickup (OFF, 41.00–65.00 Hz)	81D2P =	________
Level 2 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	81D2D =	________
Level 3 pickup (OFF, 41.00–65.00 Hz)	81D3P =	________
Level 3 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	81D3D =	________
Level 4 pickup (OFF, 41.00–65.00 Hz)	81D4P =	________
Level 4 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	81D4D =	________
Level 5 pickup (OFF, 41.00–65.00 Hz)	81D5P =	________
Level 5 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	81D5D =	________

Level 6 pickup (OFF, 41.00–65.00 Hz)	81D6P =	______
Level 6 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	81D6D =	______

Switch-Onto-Fault (See Figure 4.4)

Make the following settings if preceding enable setting ESOTF = Y.

Close enable time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	CLOEND =	______
52A enable time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	52AEND =	______
SOTF duration (0.50–16000.00 cycles in 0.25-cycle steps)	SOTFD =	______

POTT Trip Scheme Settings (Also Used in DCUB Trip Schemes) (See Figure 4.7)

Make the following settings if preceding enable setting ECOMM = POTT or DCUB

Zone (level) 3 reverse block time delay (0.00–16000.00 cycles in 0.25-cycle steps)	Z3RBD =	______
Echo block time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	EBLKD =	______
Echo time delay pickup (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	ETDPU =	______
Echo duration time delay (0.00–16000.00 cycles in 0.25-cycle steps)	EDURD =	______
Weak-infeed enable (Y, N)	EWFC =	______

Additional DCUB Trip Scheme Settings (See Figure 4.10)

Make the following settings if preceding enable setting ECOMM = DCUB1 or DCUB2.

Guard present security time delay (0.00–16000.00 cycles in 0.25-cycle steps)	GARD1D =	______

DCUB disabling time delay (0.25–16000.00 cycles in 0.25-cycle steps)	UBDURD =	________
DCUB duration time delay (0.00–16000.00 cycles in 0.25-cycle steps)	UBEND =	________

DCB Trip Scheme Settings (See Figure 4.12)

Make the following settings if preceding enable setting ECOMM = DCB.

Zone (level) 3 reverse pickup time delay (0.00–60.00 cycles in 0.25-cycle steps)	Z3XPU =	________
Zone (level) 3 reverse dropout extension (0.00–60.00 cycles in 0.25-cycle steps)	Z3XD =	________
Block trip receive extension (0.00–16000.00 cycles in 0.25-cycle steps)	BTXD =	________
Level 2 overcurrent short delay (0.00–60.00 cycles in 0.25-cycle steps)	67SD =	________

Demand Metering Settings (See Figure 6.4 and Figure 6.6)

Make the following settings, whether preceding enable setting EDEM = THM or ROL.

Time constant (5, 10, 15, 30, 60 minutes)	DMTC =	________
Phase pickup (OFF, 0.10–3.20 A secondary {1 A nom.}) (OFF, 0.50–16.00 A secondary {5 A nom.})	PDEMP =	________
Neutral ground pickup (OFF, 0.10–3.20 A secondary {1 A nom.})	NDEMP =	________
Negative-sequence pickup (OFF, 0.10–3.20 A secondary {1 A nom.}) (OFF, 0.50–16.00 A secondary {5 A nom.})	QDEMP =	________

Other Settings

Minimum trip duration time (4.00–16000.00 cycles in 0.25-cycle steps) (see *Figure 4.3*)	TDURD =	________
Close failure time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps) (see *Figure 4.14*)	CFD =	________
Three-pole open time delay (0.00–60.00 cycles in 0.25-cycle steps) (usually set for no more than a cycle; see *Figure 4.4*)	3POD =	________
Load detection phase pickup (OFF, 0.05–20.00 A {1 A nom.}) (OFF, 0.25–100.00 A {5 A nom.}) (see *Figure 4.4*)	50LP =	________

Power Element Settings (See Figure 3.30 and Figure 3.31)

Number of power elements settings dependent on preceding enable setting EPWR = N, 1–4.

Phase power pickup (OFF, 0.40–2600.00 {1 A nom.}) (OFF, 2.00–13000.00 {5 A nom.})	PWR1P =	________
Power type (+WATTS, –WATTS, +VARS, –VARS)	PWR1T =	________
Power time delay (0.00–16000.00 cycles in 0.25-cycle steps)	PWR1D =	________
Phase power pickup (OFF, 0.40–2600.00 {1 A nom.}) (OFF, 2.00–13000.00 {5 A nom.})	PWR2P =	________
Power type (+WATTS, –WATTS, +VARS, –VARS)	PWR2T =	________
Power time delay (0.00–16000.00 cycles in 0.25-cycle steps)	PWR2D =	________

Phase power pickup (OFF, 0.40–2600.00 {1 A nom.}) (OFF, 2.00–13000.00 {5 A nom.})	PWR3P =	________
Power type (+WATTS, –WATTS, +VARS, –VARS)	PWR3T =	________
Power time delay (0.00–16000.00 cycles in 0.25-cycle steps)	PWR3D =	________
Phase power pickup (OFF, 0.40–2600.00 {1 A nom.}) (OFF, 2.00–13000.00 {5 A nom.})	PWR4P =	________
Power type (+WATTS, –WATTS, +VARS, –VARS)	PWR4T =	________
Power time delay (0.00–16000.00 cycles in 0.25-cycle steps)	PWR4D =	________

SELOGIC Control Equation Variable Timers (See Figure 5.3)

Number of timer pickup/dropout settings dependent on preceding enable setting ESV = 1–16.

SV1 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV1PU =	________
SV1 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV1DO =	________
SV2 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV2PU =	________
SV2 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV2DO =	________
SV3 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV3PU =	________
SV3 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV3DO =	________
SV4 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV4PU =	________
SV4 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV4DO =	________

SV5 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV5PU =	______________
SV5 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV5DO =	______________
SV6 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV6PU =	______________
SV6 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV6DO =	______________
SV7 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV7PU =	______________
SV7 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV7DO =	______________
SV8 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV8PU =	______________
SV8 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV8DO =	______________
SV9 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV9PU =	______________
SV9 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV9DO =	______________
SV10 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV10PU =	______________
SV10 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV10DO =	______________
SV11 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV11PU =	______________
SV11 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV11DO =	______________
SV12 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV12PU =	______________
SV12 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV12DO =	______________

SV13 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV13PU =	____________
SV13 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV13DO =	____________
SV14 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV14PU =	____________
SV14 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV14DO =	____________
SV15 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV15PU =	____________
SV15 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV15DO =	____________
SV16 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV16PU =	____________
SV16 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	SV16DO =	____________

SELOGIC Control Equation Settings (Serial Port Command SET L)

SELOGIC control equation settings consist of Relay Word bits (see Table 7.5) and SELOGIC control equation operators * (AND), + (OR), ! (NOT), / (rising edge), \ (falling edge), and ( ) (parentheses). Numerous SELOGIC control equation settings examples are given in Section 3–Section 6. SELOGIC control equation settings can also be set directly to 1 (logical 1) or 0 (logical 0). See Section 4: Trip, Close, and Target Logic.

Trip Logic Equations (See Figure 4.3)

Direct trip conditions	TR =	______________
Communications-assisted trip conditions	TRCOMM =	______________
Switch-onto-fault trip conditions	TRSOTF =	______________
Direct transfer trip conditions	DTT =	______________
Unlatch trip conditions	ULTR =	______________

Communications-Assisted Trip Scheme Input Equations

Permissive trip (used for ECOMM = POTT, DCUB; see *Figure 4.7*, *Figure 4.8*, and *Figure 4.10*)	PT =	______________
Loss-of-guard (used for ECOMM = DCUB; see *Figure 4.10*)	LOG =	______________
Block trip (used for ECOMM = DCB; see *Figure 4.12*)	BT =	______________

Close Logic Equations (See Figure 4.14)

Circuit breaker status	52A =	______________
Close conditions (other than **CLOSE** command)	CL =	______________
Unlatch close conditions	ULCL =	______________

Latch Bits Set/Reset Equations (See Figure 5.5)

Set Latch Bit LT1	SET1 =	______________
Reset Latch Bit LT1	RST1 =	______________
Set Latch Bit LT2	SET2 =	______________
Reset Latch Bit LT2	RST2 =	______________

Set Latch Bit LT3	SET3 =	
Reset Latch Bit LT3	RST3 =	
Set Latch Bit LT4	SET4 =	
Reset Latch Bit LT4	RST4 =	
Set Latch Bit LT5	SET5 =	
Reset Latch Bit LT5	RST5 =	
Set Latch Bit LT6	SET6 =	
Reset latch Bit LT6	RST6 =	
Set Latch Bit LT7	SET7 =	
Reset Latch Bit LT7	RST7 =	
Set Latch Bit LT8	SET8 =	
Reset Latch Bit LT8	RST8 =	
Set Latch Bit LT9	SET9 =	
Reset Latch Bit LT9	RST9 =	
Set Latch Bit LT10	SET10 =	
Reset Latch Bit LT10	RST10 =	
Set Latch Bit LT11	SET11 =	
Reset Latch Bit LT11	RST11 =	
Set Latch Bit LT12	SET12 =	
Reset Latch Bit LT12	RST12 =	
Set Latch Bit LT13	SET13 =	
Reset Latch Bit LT13	RST13 =	
Set Latch Bit LT14	SET14 =	
Reset latch Bit LT14	RST14 =	
Set Latch Bit LT15	SET15 =	
Reset Latch Bit LT15	RST15 =	
Set Latch Bit LT16	SET16 =	
Reset Latch Bit LT16	RST16 =	

Torque Control Equations for Inst./Def.-Time Overcurrent Elements

Note: torque control equation settings cannot be set directly to logical 0.

Level 1 phase (see *Figure 3.14*)	67P1TC =	

Level 2 phase (see *Figure 3.14*)	67P2TC =	____________
Level 3 phase (see *Figure 3.14*)	67P3TC =	____________
Level 4 phase (see *Figure 3.14*)	67P4TC =	____________
Level 1 neutral ground (see *Figure 3.17*)	67NG1TC =	____________
Level 2 neutral ground (see *Figure 3.17*)	67NG2TC =	____________
Level 3 neutral ground (see *Figure 3.17*)	67NG3TC =	____________
Level 4 neutral ground (see *Figure 3.17*)	67NG4TC =	____________
Level 1 negative-sequence (see *Figure 3.18*)	67Q1TC =	____________
Level 2 negative-sequence (see *Figure 3.18*)	67Q2TC =	____________
Level 3 negative-sequence (see *Figure 3.18*)	67Q3TC =	____________
Level 4 negative-sequence (see *Figure 3.18*)	67Q4TC =	____________

Torque Control Equations for Time-Overcurrent Elements

Note: torque control equation settings cannot be set directly to logical 0.

Phase element (see *Figure 3.19*)	51PTC =	____________
Ground element (see *Figure 3.20*)	51NGTC =	____________
Negative-sequence element (see *Figure 3.21*)	51QTC =	____________

SELOGIC Control Equation Variable Timer Input Equations (See Figure 5.3)

SELOGIC control equation Variable SV1	SV1 =	____________
SELOGIC control equation Variable SV2	SV2 =	____________
SELOGIC control equation Variable SV3	SV3 =	____________
SELOGIC control equation Variable SV4	SV4 =	____________

SELogic control equation Variable SV5	SV5 =	________
SELogic control equation Variable SV6	SV6 =	________
SELogic control equation Variable SV7	SV7 =	________
SELogic control equation Variable SV8	SV8 =	________
SELogic control equation Variable SV9	SV9 =	________
SELogic control equation Variable SV10	SV10 =	________
SELogic control equation Variable SV11	SV11 =	________
SELogic control equation Variable SV12	SV12 =	________
SELogic control equation Variable SV13	SV13 =	________
SELogic control equation Variable SV14	SV14 =	________
SELogic control equation Variable SV15	SV15 =	________
SELogic control equation Variable SV16	SV16 =	________

Output Contact Equations (See Figure 5.14)

Output Contact **OUT101**	OUT101 =	________________
Output Contact **OUT102**	OUT102 =	________________
Output Contact **OUT103**	OUT103 =	________________
Output Contact **OUT104**	OUT104 =	________________
Output Contact **OUT105**	OUT105 =	________________
Output Contact **OUT106**	OUT106 =	________________
Output Contact **OUT107**	OUT107 =	________________

Output Contact Equations—Differential Board (See Figure 5.14)

Output Contact **OUT201**	OUT201 =	________________
Output Contact **OUT202**	OUT202 =	________________
Output Contact **OUT203**	OUT203 =	________________
Output Contact **OUT204**	OUT204 =	________________
Output Contact **OUT205**	OUT205 =	________________
Output Contact **OUT206**	OUT206 =	________________

Display Point Equations (See Rotating Default Display on page 5.25 and Rotating Default Display on page 9.8)

Display Point DP1	DP1 =	________________
Display Point DP2	DP2 =	________________
Display Point DP3	DP3 =	________________
Display Point DP4	DP4 =	________________
Display Point DP5	DP5 =	________________
Display Point DP6	DP6 =	________________
Display Point DP7	DP7 =	________________
Display Point DP8	DP8 =	________________
Display Point DP9	DP9 =	________________
Display Point DP10	DP10 =	________________
Display Point DP11	DP11 =	________________
Display Point DP12	DP12 =	________________
Display Point DP13	DP13 =	________________
Display Point DP14	DP14 =	________________

Display Point DP15	DP15 =	________________
Display Point DP16	DP16 =	________________

Setting Group Selection Equations (See Multiple Setting Groups on page 5.14)

Select Setting Group 1	SS1 =	________________
Select Setting Group 2	SS2 =	________________
Select Setting Group 3	SS3 =	________________
Select Setting Group 4	SS4 =	________________
Select Setting Group 5	SS5 =	________________
Select Setting Group 6	SS6 =	________________

Other Equations

Event report trigger conditions (see *Section 10*)	ER =	________________
Fault indication (used in time target logic; used also to suspend demand metering updating and peak recording and block max./min. metering—see *Local Demand Metering on page 6.3* and *Local Maximum/Minimum Metering on page 6.9*)	FAULT =	________________
Block synchronism check elements (see *Figure 3.24*)	BSYNCH =	________________
Close bus monitor (see *Figure 4.4*)	CLMON =	________________
Breaker monitor initiation (see *Figure 6.9*)	BKMON =	________________
Block zero-sequence differential current element (see *Figure 3.13*)	87WB =	________________
Enable for zero-sequence voltage-polarized and channel IN current-polarized directional elements (see *Figure 3.35*)	E32IV =	________________

MIRRORED BITS® Transmit Equations (See Appendix D)

Channel A, transmit bit 1	TMB1A =	____________
Channel A, transmit bit 2	TMB2A =	____________
Channel A, transmit bit 3	TMB3A =	____________
Channel A, transmit bit 4	TMB4A =	____________
Channel A, transmit bit 5	TMB5A =	____________
Channel A, transmit bit 6	TMB6A =	____________
Channel A, transmit bit 7	TMB7A =	____________
Channel A, transmit bit 8	TMB8A =	____________
Channel B, transmit bit 1	TMB1B =	____________
Channel B, transmit bit 2	TMB2B =	____________
Channel B, transmit bit 3	TMB3B =	____________
Channel B, transmit bit 4	TMB4B =	____________
Channel B, transmit bit 5	TMB5B =	____________
Channel B, transmit bit 6	TMB6B =	____________
Channel B, transmit bit 7	TMB7B =	____________
Channel B, transmit bit 8	TMB8B =	____________

87L Transmit Bit Equations (See Appendix D)

Channel X, transmit bit 1	T1X =	____________
Channel X, transmit bit 2	T2X =	____________
Channel X, transmit bit 3	T3X =	____________
Channel X, transmit bit 4	T4X =	____________
Channel X, transmit bit 5	T5X =	____________
Channel X, transmit bit 6	T6X =	____________
Channel X, transmit bit 7	T7X =	____________
Channel X, transmit bit 8	T8X =	____________
Channel Y, transmit bit 1	T1Y =	____________
Channel Y, transmit bit 2	T2Y =	____________
Channel Y, transmit bit 3	T3Y =	____________
Channel Y, transmit bit 4	T4Y =	____________
Channel Y, transmit bit 5	T5Y =	____________
Channel Y, transmit bit 6	T6Y =	____________

Channel Y, transmit bit 7	T7Y =	____________
Channel Y, transmit bit 8	T8Y =	____________

Front-Panel LED SELOGIC Control Equations (See Front-Panel Target LEDs on page 4.28)

Front-Panel **TRIP** LED	LED_TRP =	____________
Front-Panel **TIME** LED	LED_TIME =	____________
Front-Panel **COMM** LED	LED_COMM =	____________
Front-Panel **87** LED	LED_87 =	____________
Front-Panel **50/51** LED	LED_50_51 =	____________
Front-Panel **27** LED	LED_27 =	____________
Front-Panel **59** LED	LED_59 =	____________
Front-Panel **32** LED	LED_32 =	____________
Front-Panel **81** LED	LED_81 =	____________
Front-Panel **25** LED	LED_25 =	____________
Front Panel **87CH FAIL** LED	LED_87CHFAIL =	____________

Global Settings (Serial Port Command SET G and Front Panel)

Settings Group Change Delay (See Multiple Setting Groups on page 5.14)

Group change delay (0.00–16000.00 cycles in 0.25-cycle steps)	TGR =	____________

Power System Configuration and Date Format (See Settings Explanations on page 7.35)

Nominal frequency (50 Hz, 60 Hz)	NFREQ =	____________
Phase rotation (ABC, ACB)	PHROT =	____________
Date format (MDY, YMD)	DATE_F =	____________

Front-Panel Display Operation (See Section 9: Front-Panel Operations)

Front-panel display time-out (0.00–30.00 minutes in 0.01-minute steps) (If FP_TO = 0, no time-out occurs and display remains on last display screen, e.g., continually display metering.)	FP_TO =	____________
Front-panel display update rate (1–60 seconds)	SCROLD =	____________

Event Report Parameters (See Section 10: Analyzing Events)

Length of event report (15, 30 cycles)	LER =	____________
Length of prefault in event report		
(1–14 cycles in 1-cycle steps for LER = 15)	PRE =	____________
(1–29 cycles in 1-cycle steps for LER = 30)		

Station DC Battery Monitor (See Figure 6.15 and Figure 6.16)

DC battery instantaneous undervoltage pickup (OFF, 20.00–300.00 Vdc)	DCLOP =	____________

DC battery instantaneous overvoltage pickup (OFF, 20.00–300.00 Vdc)	DCHIP =	________

Optoisolated Input Timers (See Figure 5.6)

Input **IN101** debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	IN101D =	________
Input **IN102** debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	IN102D =	________
Input **IN103** debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	IN103D =	________
Input **IN104** debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	IN104D =	________
Input **IN105** debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	IN105D =	________
Input **IN106** debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	IN106D =	________

Fast Meter Configuration

Fast Meter message type (STANDARD, SIMPLE)	FMETER=	________

Breaker Monitor Settings (See Breaker Monitor on page 6.10)

Breaker monitor enable (Y, N)	EBMON =	________

Make the following settings if preceding enable setting EBMON = Y.

Close/Open set point 1—max. (0–65000 operations)	COSP1 =	________
Close/Open set point 2—mid. (0–65000 operations)	COSP2 =	________
Close/Open set point 3—min. (0–65000 operations)	COSP3 =	________
kA Interrupted set point 1—min. (0.00–999.00 kA primary in 0.01 kA steps)	KASP1=	________

kA Interrupted set point 2—mid. (0.00–999.00 kA primary in 0.01 kA steps)	KASP2=	______________________
kA Interrupted set point 3—max. (0.00–999.00 kA primary in 0.01 kA steps)	KASP3=	______________________

Sequential Events Recorder Settings (Serial Port Command SET R)

Sequential Events Recorder settings are comprised of three trigger lists. Each trigger list can include up to 24 Relay Word bits delimited by commas. Enter NA to remove a list of these Relay Word bit settings. See Sequential Events Recorder Report on page 10.37.

SER Trigger List 1	SER1 =	______________________
SER Trigger List 2	SER2 =	______________________
SER Trigger List 3	SER3 =	______________________

Test Label Settings (Serial Port Command SET T)

Enter the following characters: 0–9, A–Z, #, &, @, -, /, ., space for each text label setting, subject to the specified character limit. Enter NA to null a label.

Local Bit Labels

Local Bit LB1 Name (14 characters)	NLB1 =	______________
Clear Local Bit LB1 Label (7 characters)	CLB1 =	______________
Set Local Bit LB1 Label (7 characters)	SLB1 =	______________
Pulse Local Bit LB1 Label (7 characters)	PLB1 =	______________
Local Bit LB2 Name (14 characters)	NLB2 =	______________
Clear Local Bit LB2 Label (7 characters)	CLB2 =	______________
Set Local Bit LB2 Label (7 characters)	SLB2 =	______________
Pulse Local Bit LB2 Label (7 characters)	PLB2 =	______________
Local Bit LB3 Name (14 characters)	NLB3 =	______________
Clear Local Bit LB3 Label (7 characters)	CLB3 =	______________
Set Local Bit LB3 Label (7 characters)	SLB3 =	______________
Pulse Local Bit LB3 Label (7 characters)	PLB3 =	______________
Local Bit LB4 Name (14 characters)	NLB4 =	______________
Clear Local Bit LB4 Label (7 characters)	CLB4 =	______________
Set Local Bit LB4 Label (7 characters)	SLB4 =	______________
Pulse Local Bit LB4 Label (7 characters)	PLB4 =	______________
Local Bit LB5 Name (14 characters)	NLB5 =	______________
Clear Local Bit LB5 Label (7 characters)	CLB5 =	______________
Set Local Bit LB5 Label (7 characters)	SLB5 =	______________

Pulse Local Bit LB5 Label (7 characters)	PLB5 =	____________
Local Bit LB6 Name (14 characters)	NLB6 =	____________
Clear Local Bit LB6 Label (7 characters)	CLB6 =	____________
Set Local Bit LB6 Label (7 characters)	SLB6 =	____________
Pulse Local Bit LB6 Label (7 characters)	PLB6 =	____________
Local Bit LB7 Name (14 characters)	NLB7 =	____________
Clear Local Bit LB7 Label (7 characters)	CLB7 =	____________
Set Local Bit LB7 Label (7 characters)	SLB7 =	____________
Pulse Local Bit LB7 Label (7 characters)	PLB7 =	____________
Local Bit LB8 Name (14 characters)	NLB8 =	____________
Clear Local Bit LB8 Label (7 characters)	CLB8 =	____________
Set Local Bit LB8 Label (7 characters)	SLB8 =	____________
Pulse Local Bit LB8 Label (7 characters)	PLB8 =	____________
Local Bit LB9 Name (14 characters)	NLB9 =	____________
Clear Local Bit LB9 Label (7 characters)	CLB9 =	____________
Set Local Bit LB9 Label (7 characters)	SLB9 =	____________
Pulse Local Bit LB9 Label (7 characters)	PLB9 =	____________
Local Bit LB10 Name (14 characters)	NLB10 =	____________
Clear Local Bit LB10 Label (7 characters)	CLB10 =	____________
Set Local Bit LB10 Label (7 characters)	SLB10 =	____________
Pulse Local Bit LB10 Label (7 characters)	PLB10 =	____________
Local Bit LB11 Name (14 characters)	NLB11 =	____________

Clear Local Bit LB11 Label (7 characters)	CLB11 =	
Set Local Bit LB11 Label (7 characters)	SLB11 =	
Pulse Local Bit LB11 Label (7 characters)	PLB11 =	
Local Bit LB12 Name (14 characters)	NLB12 =	
Clear Local Bit LB12 Label (7 characters)	CLB12 =	
Set Local Bit LB12 Label (7 characters)	SLB12 =	
Pulse Local Bit LB12 Label (7 characters)	PLB12 =	
Local Bit LB13 Name (14 characters)	NLB13 =	
Clear Local Bit LB13 Label (7 characters)	CLB13 =	
Set Local Bit LB13 Label (7 characters)	SLB13 =	
Pulse Local Bit LB13 Label (7 characters)	PLB13 =	
Local Bit LB14 Name (14 characters)	NLB14 =	
Clear Local Bit LB14 Label (7 characters)	CLB14 =	
Set Local Bit LB14 Label (7 characters)	SLB14 =	
Pulse Local Bit LB14 Label (7 characters)	PLB14 =	
Local Bit LB15 Name (14 characters)	NLB15 =	
Clear Local Bit LB15 Label (7 characters)	CLB15 =	
Set Local Bit LB15 Label (7 characters)	SLB15 =	
Pulse Local Bit LB15 Label (7 characters)	PLB15 =	
Local Bit LB16 Name (14 characters)	NLB16 =	
Clear Local Bit LB16 Label (7 characters)	CLB16 =	
Set Local Bit LB16 Label (7 characters)	SLB16 =	

Pulse Local Bit LB16 Label (7 characters)	PLB16 =	________________

Display Point Labels (See Rotating Default Display on page 5.25 and Rotating Default Display on page 9.8)

Display if DP1 = logical 1 (16 characters)	DP1_1 =	________________
Display if DP1 = logical 0 (16 characters)	DP1_0 =	________________
Display if DP2 = logical 1 (16 characters)	DP2_1 =	________________
Display if DP2 = logical 0 (16 characters)	DP2_0 =	________________
Display if DP3 = logical 1 (16 characters)	DP3_1 =	________________
Display if DP3 = logical 0 (16 characters)	DP3_0 =	________________
Display if DP4 = logical 1 (16 characters)	DP4_1 =	________________
Display if DP4 = logical 0 (16 characters)	DP4_0 =	________________
Display if DP5 = logical 1 (16 characters)	DP5_1 =	________________
Display if DP5 = logical 0 (16 characters)	DP5_0 =	________________
Display if DP6 = logical 1 (16 characters)	DP6_1 =	________________
Display if DP6 = logical 0 (16 characters)	DP6_0 =	________________
Display if DP7 = logical 1 (16 characters)	DP7_1 =	________________
Display if DP7 = logical 0 (16 characters)	DP7_0 =	________________
Display if DP8 = logical 1 (16 characters)	DP8_1 =	________________
Display if DP8 = logical 0 (16 characters)	DP8_0 =	________________
Display if DP9 = logical 1 (16 characters)	DP9_1 =	________________
Display if DP9 = logical 0 (16 characters)	DP9_0 =	________________
Display if DP10 = logical 1 (16 characters)	DP10_1 =	________________
Display if DP10 = logical 0 (16 characters)	DP10_0 =	________________

Display if DP11 = logical 1 (16 characters)	DP11_1 =	________________
Display if DP11 = logical 0 (16 characters)	DP11_0 =	________________
Display if DP12 = logical 1 (16 characters)	DP12_1 =	________________
Display if DP12 = logical 0 (16 characters)	DP12_0 =	________________
Display if DP13 = logical 1 (16 characters)	DP13_1 =	________________
Display if DP13 = logical 0 (16 characters)	DP13_0 =	________________
Display if DP14 = logical 1 (16 characters)	DP14_1 =	________________
Display if DP14 = logical 0 (16 characters)	DP14_0 =	________________
Display if DP15 = logical 1 (16 characters)	DP15_1 =	________________
Display if DP15 = logical 0 (16 characters)	DP15_0 =	________________
Display if DP16 = logical 1 (16 characters)	DP16_1 =	________________
Display if DP16 = logical 0 (16 characters)	DP16_0 =	________________

Port Settings (Serial Port Command SET P and Front Panel)

Protocol Settings (See Below)

Protocol (SEL, MBA, MBB, MB8A, MB8B)	PROTO =	__________

Protocol Settings Set PROTO = SEL for standard SEL ASCII protocol. For MIRRORED BITS, set PROTO = MBA, MBB, MB8A, or MB8B. Refer to Appendix D: MIRRORED BITS Communications.

Communications Settings

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400)	SPEED =	__________
Data Bits (6, 7, 8)	BITS =	__________
Parity (O, E, N) {Odd, Even, None}	PARITY =	__________
Stop Bits (1, 2)	STOP =	__________

Other Port Settings (See Below)

Time-out (0–30 minutes) *Set T_OUT to the number of minutes of serial port inactivity for an automatic log out. Set T_OUT = 0 for no port time-out.*	T_OUT =	__________
Send Auto Messages to Port (Y, N) *Set AUTO = Y to allow automatic messages at the serial port.*	AUTO =	__________
Enable Hardware Handshaking (Y, N, MBT) (Refer to Appendix D for details on setting MBT.) *Set RTSCTS = Y to enable hardware handshaking. With RTSCTS = Y, the relay will not send characters until the CTS input is asserted. Also, if the relay is unable to receive characters, it deasserts the RTS line. Setting RTSCTS is not applicable to serial Port 1 (EIA-485).*	RTSCTS =	__________

Fast Operate Enable (Y, N) *Set FASTOP = Y to enable binary Fast Operate messages at the serial port. Set FASTOP = N to block binary Fast Operate messages. Refer to Appendix C for the description of the SEL-311M Relay Fast Operate commands.*	FASTOP =	______________________

Channel Settings (Serial Port Command SET X and SET Y and Front Panel)

87L Channel X Configuration Settings

Channel X address check (Y, N)	EADDCX =	______
If EADDCX = Y		
Channel X transmit address (1–16)	TA_X =	______
Channel X receive address (1–16)	RA_X =	______
Continuous dropout alarm (1–1000 seconds)	RBADXP =	______
Packets lost in last 10,000 (1–5000)	AVAXP =	______
One-way channel delay alarm (1–24 ms)	DBADXP =	______
Timing source (I = Internal; E = External)	TIMRX =	______

87L Channel Y Configuration Settings

Channel Y address check (Y, N)	EADDCY =	______
If EADDCY = Y		
Channel Y transmit address (1–16)	TA_Y =	______
Channel Y receive address (1–16)	RA_Y =	______
Continuous dropout alarm (1–1000 seconds)	RBADYP =	______
Packets lost in last 10,000 (1–5000)	AVAYP =	______
One-way channel delay alarm (1–24 ms)	DBADYP =	______
Timing source (I = Internal; E = External)	TIMRY =	______

Section 8
Communications

Overview

The SEL-311M Relay provides:

- ➤ Line current differential communications
- ➤ Communications with EIA-232 and EIA-485 serial ports.

This first part of this section describes line current differential (87L) communications, the 87L channel monitors, and settings related to 87L communications. The rest of the section describes serial communications used to set, control, and interrogate the relay.

A communications interface and protocol are required for communicating with the relay. A communications interface is the physical connection on a device. Serial ports that conform to the EIA-232 standard (often called RS-232) use DB-9 or DB-25 connectors as the physical interface. The relay has two rear-panel serial ports and one front-panel serial port that use DB-9 connectors. It also has one rear-panel serial port that uses a screw-terminal connector. Once a physical connection has been established, use a communications protocol to interact with the relay. A communications protocol is a language used to perform relay operations and collect data.

87L Communications Interfaces

Order the relay with up to two line current differential interfaces. Each interface is factory configured as IEEE Standard C37.94 Multimode Fiber-Optic Interface.

Channel configuration settings support optimization of the interface for the channel in a particular application. The following subsections describe the interface.

Use the **SET X** command to access the channel configuration settings and channel monitor settings for line current differential channel interface X. Use the **SET Y** command for channel interface Y. Alternatively, use the front-panel **SET** command (see *Figure 9.3*).

Channel Configuration Settings

IEEE Standard C37.94 Multimode Fiber-Optic Interface

IEEE Standard C37.94 defines a direct relay-to-multiplexer interface over inexpensive multimode fiber-optic cable. This prevents problems associated with grounding electrical interfaces and also provides excellent noise immunity. The Standard defines the data structure and encoding, and also defines the physical interface (connectors, light wavelength, fiber type, etc.) ensuring that all C37.94 compliant relays interface with all C37.94 compliant multiplexers.

Connect the SEL-311M to a C37.94 compliant multiplexer as shown in *Figure 2.3*. Use the **SET X** or **SET Y** commands to make setting TIMRX = E (TIMRY = E for Channel Y) in both relays. This configures the SEL-311M to synchronize the transmit date rate to exactly match the receive data rate set by the multiplexer.

C37.94 defines several troubleshooting aids, including a Yellow Alarm bit. At present, the SEL-311M does not report the status of the receive Yellow Alarm bit, nor does it generate a Yellow Alarm bit. Consult the documentation provided with your multiplexer to determine when and if the multiplexer asserts the Yellow Alarm indicators.

Back-to-Back Connections

For back-to-back connections, use the **SET X** or **SET Y** commands to make setting TIMRX = E (TIMRY = E for Channel Y) in one relay, and TIMRX = I (TIMRY = I for Channel Y) in the other relay. The relay with TIMRY = E synchronizes to the relay with setting TIMRY = I, providing error free operation.

The IEEE C37.94 interface is suitable for distances up to 2 km, either between the relay and the multiplexer or directly between relays.

Dual Channel Applications

Each channel interface is totally independent. Configure each without regard to the configuration of the other. In addition, the channel configurations need not depend on the function of the channel. Configure each channel regardless of whether it is the primary or standby channel in a two-terminal configuration. (Use the **SET** command to choose how each channel is used with setting E87L.) In addition, the Channel Monitor settings described in *87L Communications Monitoring on page 8.3* are totally independent of channel assignment. Set each channel monitor as required by the particular channel application, and per expected channel performance.

87L Communications Monitoring

The SEL-311M provides the following to indicate problems with the 87L interface and/or channel and aid in troubleshooting:

- Front-panel **87CH FAIL** indicator (LED) that illuminates when the relay detects a problem on either Channel X or Channel Y.
- Rear-panel **TX** and **RX** indicators that illuminate when the relay transmits and receives valid 87L packets from another line current differential relay.
- Interface and channel testing with loopback, end-to-end, and back-to-back tests.
- Communications report

This subsection describes these features and settings, which are applicable to all interface types. See *Section 11: Testing and Troubleshooting* for a description on how to use these features to troubleshoot an interface and/or channel problem.

Front Panel 87CH FAIL LED

The availability monitor detects channel degradation or failure by counting lost packets. A packet is lost if it is not received, is received out of order, is corrupted, or contains an incorrect address. The delay monitor measures round trip channel delay, and alarms if the estimated one-way delay exceeds a threshold.

Together, the two monitors continuously check each channel for excessive delay, continuous dropout, and packets lost out of the previous 10,000. Relay Word bits CHXAL and CHYAL assert when any of those three parameters exceed a user-defined threshold. CHXAL and CHYAL do not affect protection, and are not an indication that 87L and 87W protection are not available. Relay Word bit 87LPE deasserts when 87L protection is not available due to a channel problem. When either CHXAL or CHYAL assert, or when 87LPE deasserts, front-panel LED **87CH FAIL** illuminates. Several settings control the alarm thresholds for the channel monitors, as described below. Access those settings described below with the **SET X** and **SET Y** commands. There are no settings associated with 87LPE.

Setting EADDCX and EADDCY (Address Checking)

Set EADDCX = Y (EADDCY = Y for Channel Y) to enable receive message address checking. Transmitted messages contain an address field. When EADDCX = Y, the transmitting relay places the address defined by setting TA_X (or setting TA_Y for Channel Y) in the transmitted message. The receiving relay checks to ensure that the address contained in the message matches the local RA_X setting (or RA_Y setting for Channel Y). If the received address does not match the receive address setting, the relay discards the message as if it were corrupted.

Address checking serves two purposes.

- The first purpose is to avoid misoperations due to inadvertent loopbacks in the network or multiplexer equipment.

  An inadvertent loopback might also occur if light from a fiber-optic transmitter reflects off a surface and returns to a receiver. To effectively detect inadvertent loopbacks, set RA_X different than TA_X.

➤ The second purpose is to avoid misoperations due to misrouted communications links.

To effectively detect misrouted communications links, set RA_X and TA_X uniquely for each SEL-311M connected to the network. For direct-fiber connections, set RA_X and TA_X uniquely for each SEL-311M with a fiber pair in a bundle, or for each SEL-311M with a fiber pair routed through a patch panel.

Settings RBADXP, RBADYP, AVAXP, and AVAYP (Availability Monitors)

Settings RBADXP and AVAXP (RBADYP and AVAYP for Channel Y) together detect channel loss and degradation. When no acceptable packets have been received for longer than setting RBADXP (in seconds), Relay Word bit RBADX asserts. This asserts Relay Word bit CHXAL and illuminates front-panel LED **87CH FAIL**.

When the number of packets corrupted or lost from the previous 10,000 packets exceeds setting AVAXP, Relay Word bit AVAX asserts. This asserts Relay Word bit CHXAL, and illuminates front-panel LED **87CH FAIL**. Use Relay Word bit CHXAL to assert an alarm, turn on a display point, etc.

Together, AVAXP and RBADXP detect short-term interruptions and long-term degradation of the communications circuit. After the problem is repaired, Relay Word bit AVAX resets itself in less than 15 seconds, and RBADX resets itself instantly. Settings AVAYP and RBADYP and Relay Word bits AVAY and RBADY operate the same for Channel Y.

Settings DBADXP and DBADYP (Channel Delay Monitors)

Setting DBADXP (DBADYP for Channel Y) detects longer than expected channel delays. Such increased delays might be caused by channel reroutes on a switched network. When the estimated one-way channel delay exceeds setting DBADXP (in milliseconds), Relay Word bit DBADX asserts. This asserts Relay Word bit CHXAL, and illuminates front-panel LED **87CH FAIL**.

⚠CAUTION
Longer channel delays result in slower tripping times. The operate speeds shown in Figure 3.7 were measured using a back-to-back connection. One-way channel delay times that exceed the automatic compensation capability of the SEL-311M (35 milliseconds) can result in misoperation.

During installation, inspect the estimated one-way channel delay, using the **COMM X** or **COMM Y** commands described later in this section. Verify that this delay is as expected. Set DBADXP two to five milliseconds higher than the maximum expected or tolerable one-way channel delay. Setting DBADYP and Relay Word bit DBADY operate similarly for Channel Y.

Relay Word Bits CHXAL and CHYAL

The bits described above are combined into a single Relay Word bit for each channel, CHXAL or CHYAL. When any of AVAX, RBADX, or DBADX assert, CHXAL asserts. Similarly for Channel Y, when any of AVAY, RBADY, or DBADY assert, CHYAL asserts. Default factory settings use CHXAL and CHYAL to enable display points, alerting operators to a problem.

Relay Word Bits ROKX and ROKY

ROKX or ROKY assert if both of the previous two received packets on Channel X or Channel Y contain no errors. They are an instantaneous, unfiltered indication of channel health. The relay uses ROKX and ROKY to produce the other Relay Word bits described above. ROKX and ROKY can be useful for testing.

Relay Word Bit 87LPE

87LPE asserts when 87L protection is enabled. The relay monitors the available channels and determines if enough information is available from each remote relay to perform protection in two-terminal mode. When the relay cannot perform 87L protection, Relay Word bit 87LPE deasserts. There are no settings associated with Relay Word bit 87LPE.

Hot Standby

Front-panel LED **87LCH FAIL** illuminates when the relay detects a problem on either 87L Channel X or Y. When the hot-standby feature is enabled, a channel problem on one of the two 87L channels will cause the **87CH FAIL** LED to illuminate in only the relay that cannot receive valid 87L data. In all other cases (two-terminal mode without hot-standby), the **87CH FAIL** LED illuminates in both relays attached to the affected channel.

Use programmable Display Points and 87L Transmit/Receive bits to generate a local indication of a transmit problem in a hot-standby application. Transmit the status of the Channel Y alarm bit, CHYAL, using one of the eight transmit bits of Channel X (T1X, T2X, T3X. . .T8X). Likewise transmit the status of the Channel X alarm bit, CHXAL, using one of the eight transmit bits of Channel Y (T1Y, T2Y, T3Y. . .T8Y). Then use a local display point to signal a problem on either channel in either direction.

For example, assume a two-terminal application has a direct fiber connection on Channel Y, which is the primary protection channel, and a multiplexer connection on Channel X which is the hot-standby channel. The direct fiber connection uses fiber pair A4B79. The multiplexed connection uses Channel 5 in Multiplexer A. In each relay, use the **SET L** command to make the following settings:

T1Y = **CHXAL**

T1X = **CHYAL**

DP1 = **R1Y**

DP2 = **CHXAL**

DP3 = **R1X**

DP4 = **CHYAL**

DP5 = **87LPE**

Using the **SET T** command, make the following text settings:

DP1_1 = **MX A CH5 TX FAIL**

DP1_0 =

DP2_1 = **MX A CH5 RX FAIL**

DP2_0 =

DP3_1 = **A4B79 TX FAIL**

DP3_0 =

DP4_1 = **A4B79 RX FAIL**

DP4_0 =

DP5_1 =

DP5_0 = **87L DISABLED**

The SEL-311M front panel LCD displays the appropriate message when a problem occurs on either channel, in either direction. This alerts operators to the problem, and gives valuable assistance in troubleshooting the problem.

Rear Panel TX/RX LED

Each channel interface has two rear-panel LEDs that help in troubleshooting installation problems. The RX LED illuminates when the channel is enabled and receives valid packets from another SEL-311M. The RX LED extinguishes if the channel is disabled, if there are sufficient data errors to prevent the relay from recognizing the packet boundaries, if the receive data are entirely absent.

The TX LED illuminates when the channel is enabled and transmits valid packets. The TX LED extinguishes if the channel is disabled.

Interface and Channel Testing

The **TST** command temporarily modifies the channel configuration without changing settings. Upon exiting test mode, the relay reconfigures the channels per the channel settings.

The **TST** command enables short term or long term internal or external loopback tests, end-to-end tests, or back-to-back tests. To enter the **TST** command, type **TST X** or **TST Y** for Channel X or Y, respectively. To end the test mode before the duration timer expires, type **TST X C** or **TST Y C**.

After entering the **TST** command, the relay warns that protection and tripping are still enabled. Cut out the 87L trip contacts to avoid misoperations. This enables you to perform channels tests while backup protection remains enabled. All applied faults and load current appear as internal faults when the communications channel is looped back.

All channel monitor functions remain operational during test mode. This allows you to monitor the channel for errors during the test.

```
=>>TST X <Enter>
Entering Test Mode on Channel X.

WARNING!!!  Tripping is enabled in test mode.  !!!WARNING
Press Ctrl X now to abort. Type "TST X C" to end test mode.

  Enable Loop-Back: Internal, External or None (I,E,N)   ? E <Enter>
  Timing Source: Internal or External (I,E)              ? I <Enter>
  Test Mode Duration: 1 - 30 min. or Infinite (1-30,INF) ? 30 <Enter>

Are you sure (Y/N) ? Y <Enter>
Test Mode Enabled on Channel X.
Channel X: Test Mode
Channel Y: Normal Mode

=>>TST C X <Enter>
Channel X: Normal Mode
Channel Y: Normal Mode
=>>
```

Figure 8.1 Example of Test Mode

The **TST** command presents several options.

- The first option enables loopback operation.

  Choose either internal or external loopback operation to disable receive address checking for that channel, regardless of the EADDCX and EADDCY settings.

  - Select internal loopback to test the internal SEL-311M hardware without external connections.

    Internal loopback connects the SEL-311M transmitter to the receiver. While in internal loopback the relay continues to transmit 87L data.

  - Select external loopback to loop the channel anywhere outside the SEL-311M.

Loop the channel back at the SEL-311M connector, at the multiplexer, anywhere in the network, or at the far end.

- Select None to perform end-to-end or back-to-back tests.
- If external or no loopback is selected, the relay prompts for the channel timing source.

  This selection overrides setting TIMRX or TIMRY.
  - Select internal timing if the channel is looped before it reaches the communications equipment.
  - Select external timing if the channel is looped after it reaches the communications equipment.
- Select the duration of the temporary test configuration from 1 to 30 minutes.
  - Enter a duration to prevent accidentally leaving the relay in test mode after the test.

    After the duration timer expires, the relay reconfigures itself per the Channel X and Channel Y settings.
  - For tests longer than 30 minutes, enter INF, and be certain to end the test mode with the **TST X C** or **TST Y C** command after testing is complete.

Communications Report

Like MIRRORED BITS®, the 87L Channel Monitor creates a detailed report containing all of the previous 256 channel problems. The relay maintains a separate report for each active channel. Retrieve a summary of the report by using the **COMM X** or **COMM Y** commands. Retrieve the entire report by using the **COMM X L** or **COMM Y L** commands. Filter both the summary report and the extended report by selecting start and stop dates, or start and stop records. For example, the command **COMM X L 5/26/01 5/30/01 <Enter>** displays and summarizes all of the problems encountered on and between those dates.

Use the **COMM X C** and **COMM Y C** commands to clear the COMM reports.

The screen capture below shows an example COMM report.

```
=>>COMM Y L <Enter>
SEL-311M                          Date: 05/26/01    Time: 09:27:03.269
EXAMPLE: BUS B, BREAKER 3

FID=SEL-311M-R100-V0-Z001001-D20010625       CID=BAFD
Summary for 87L Channel Y

Channel Status Alarms
    ROKY = 1    DBADY = 0    RBADY = 0    AVAY = 0

For 05/24/01 13:37:01.631 to 05/26/01 09:27:04.248

    COMMUNICATION LOG SUMMARY        COMMUNICATION STATISTICS
    # of Error records  29           Last error          Data Error
    Data Error          20           Longest failure            4.685 sec.
    Dropout              9           Lost Packets, prev. 24 hours      407
    Test Mode Entered    0           One Way Delay (Ping-Pong)     0 msec.

Error                  Recovery
#   Date     Time          Date     Time          Duration  Cause
  1 05/26/01 09:23:54.041  05/26/01 09:23:54.042     0.001  Data Error
  2 05/26/01 09:23:53.888  05/26/01 09:23:54.040     0.152  Dropout Error
  3 05/26/01 09:23:53.885  05/26/01 09:23:53.888     0.003  Data Error
  4 05/26/01 09:23:53.882  05/26/01 09:23:53.885     0.003  Dropout Error
  5 05/26/01 09:23:53.870  05/26/01 09:23:53.882     0.011  Data Error
  6 05/26/01 09:23:53.851  05/26/01 09:23:53.870     0.020  Dropout Error
  7 05/26/01 09:23:53.847  05/26/01 09:23:53.851     0.003  Data Error
  8 05/26/01 09:23:53.846  05/26/01 09:23:53.847     0.001  Dropout Error
  9 05/26/01 09:23:53.843  05/26/01 09:23:53.846     0.003  Data Error

.
.
.

 25 05/26/01 09:23:51.554  05/26/01 09:23:51.654     0.100  Dropout Error
 26 05/26/01 09:23:51.550  05/26/01 09:23:51.554     0.003  Data Error
 27 05/24/01 13:37:04.688  05/24/01 13:37:04.689     0.001  Data Error
 28 05/24/01 13:37:00.003  05/24/01 13:37:04.688     4.685  Dropout Error
 29 05/24/01 13:37:00.000  05/24/01 13:37:00.003     0.003  Data Error

=>>
```

Figure 8.2 Example COMM Report

Serial Port Communications and Commands

In addition to the differential communication channel(s) all SEL-311M models have three EIA-232 ports (one front and two rear) and one rear EIA-485 port. The ports are useful for relay settings changes, interrogation, control, and data collection.

Connect the serial port to a computer serial port for local communications or to a modem for remote communications. Other devices useful for communications include the following:

- SEL-2032, SEL-2030, and SEL-2020 Communications Processors
- SEL-2505 Remote I/O Module
- SEL-2100 Logic Processor

You can use a variety of terminal emulation programs on your personal computer to communicate with the relay. For the best display, use VT-100 terminal emulation or the closest variation.

The default settings for all serial ports are:

- Baud Rate = 2400
- Data Bits = 8
- Parity = N
- Stop Bits = 1

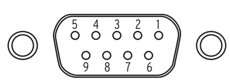
To change the port settings, use the **SET P** command (see *Table 7.1*) or the front-panel {SET} pushbutton (see *Figure 9.3*).

Port Connector and Communications Cables

The relay physical interfaces (DB-9 connectors and screw-terminal connector) support a communications interface, power supply for communications interface converters, and time synchronization source (IRIG-B), as shown in *Table 8.1*. Several optional SEL devices are available to provide alternative physical interfaces, including EIA-485 and fiber-optic cable as shown in *Table 2.1*.

Table 8.1 Alternative Physical Interfaces

Port	Communications Interface	Demodulated IRIG-B	+5 Vdc Power Supply
Port 1	EIA-485	X	X
Port 2	EIA-232	X	X
Port 3	EIA-232		X
Port 4	EIA-232		



(female chassis connector, as viewed from outside)

Figure 8.3 DB-9 Connector Pinout for EIA-232 Serial Ports

IRIG-B

Refer to *Figure 1.5* and *Figure 2.2*. Note that demodulated IRIG-B time code can be input into Serial Port 1 or Serial Port 2 on any of the SEL-311M models. This is easily handled by connecting Serial Port 2 of the SEL-311M to an SEL-2020 with Cable C273A (see cable diagrams that follow in this section).

Note that demodulated IRIG-B time code can be input into the connector for Serial Port 1. If demodulated IRIG-B time code is input into this connector, it should not be input into Serial Port 2, and vice versa.

Table 8.2 Pinout Functions for EIA-232 Serial Ports 2, 3, and F (Sheet 1 of 2)

Pin	Port 2	Port 3	Port F
1	N/C or +5 Vdc[a]	N/C or +5 Vdc[a]	N/C
2	RXD	RXD	RXD
3	TXD	TXD	TXD
4	+IRIG-B	N/C	N/C
5, 9	GND	GND	GND

Table 8.2 Pinout Functions for EIA-232 Serial Ports 2, 3, and F (Sheet 2 of 2)

Pin	Port 2	Port 3	Port F
6	-IRIG-B	N/C	N/C
7	RTS	RTS	RTS
8	CTS	CTS	CTS

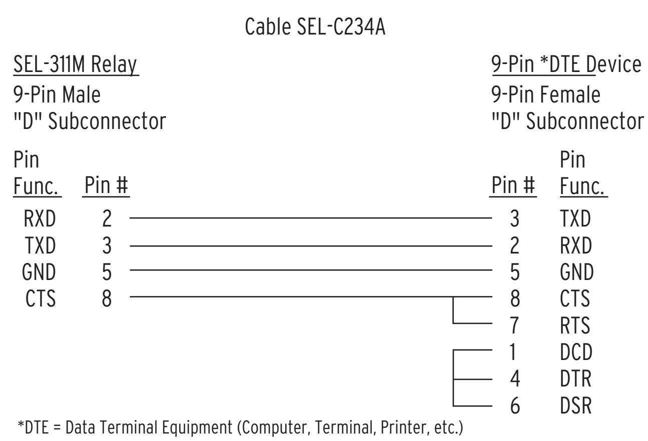
[a] See EIA-232 Serial Port Jumpers in Section 2: Installation.

Table 8.3 Terminal Functions for EIA-485 Serial Port 1

Terminal	Function
1	+TX
2	–TX
3	+RX
4	–RX
5	SHIELD
6	N/C
7	+IRIG-B
8	–IRIG-B

The following cable diagrams show several types of EIA-232 serial communications cables that connect the SEL-311M to other devices. SEL provides fiber-optic transceivers and cable for communications links with improved safety, noise immunity, and distance as compared to copper links. The equivalent fiber cables are listed following each copper cable description. These and other cables are available from SEL. Contact the factory for more information.

SEL-311M to Computer



Cable SEL-C227A

SEL-311M Relay 9-Pin Male "D" Subconnector			25-Pin *DTE Device 25-Pin Female "D" Subconnector	
Pin Func.	Pin #		Pin #	Pin Func.
GND	5	—	7	GND
TXD	3	—	3	RXD
RXD	2	—	2	TXD
GND	9	—	1	GND
CTS	8	—	4	RTS
			5	CTS
			6	DSR
			8	DCD
			20	DTR

*DTE = Data Terminal Equipment (Computer, Terminal, Printer, etc.)

SEL-311M to SEL-2032, SEL-2030, SEL-2020, or SEL-2100

Cable SEL-C273A

SEL-2032/2030/2020 or SEL-2100 9-Pin Male "D" Subconnector			SEL-311M Relay 9-Pin Male "D" Subconnector	
Pin Func.	Pin #		Pin #	Pin Func.
RXD	2	—	3	TXD
TXD	3	—	2	RXD
IRIG+	4	—	4	IRIG+
GND	5	—	5	GND
IRIG-	6	—	6	IRIG-
RTS	7	—	8	CTS
CTS	8	—	7	RTS

SEL-311M to StarComm Modem, 5 Vdc Powered

Cable SEL-C220

StarComm Modem 25-Pin Male "D" Subconnector			SEL-311M Relay 9-Pin Male "D" Subconnector	
Pin Func.	Pin #		Pin #	Pin Func.
GND	72	—	5	GND
TXD (IN)	2	—	3	TXD
DTR (IN)	20	—	7	RTS
RXD (OUT)	3	—	2	RXD
CD (OUT)	8	—	8	CTS
PWR (IN)	10	—	1	+5 VDC
GND	1	—	9	GND

SEL-311M to Modem or Other DCE

Cable SEL-C222

SEL-311M Relay 9-Pin Male "D" Subconnector			**DCE Device 25-Pin Male "D" Subconnector	
Pin Func.	Pin #		Pin #	Pin Func.
GND	5	—	7	GND
TXD	3	—	2	TXD (IN)
RTS	7	—	20	DTR (IN)
RXD	2	—	3	RXD (OUT)
CTS	8	—	8	CD (OUT)
GND	9	—	1	GND

**DCE = Data Communications Equipment (Modem, etc.)

Table 8.4 Serial Communications Port Pin/Terminal Function Definitions

Pin Function	Definition
N/C	No Connection
+5 Vdc (0.5 A limit)	5 Vdc Power Connection
RXD, RX	Receive Data
TXD, TX	Transmit Data
IRIG-B	IRIG-B Time-Code Input
GND	Ground
SHIELD	Grounded Shield
RTS	Request To Send
CTS	Clear To Send
DCD	Data Carrier Detect
DTR	Data Terminal Ready
DSR	Data Set Ready

For communications up to 80 kilometers and for electrical isolation of communications ports, use the SEL-2800 family of fiber-optic transceivers. Contact SEL for more details on these devices.

Communications Protocols

Hardware Protocol

All EIA-232 serial ports support RTS/CTS hardware handshaking. RTS/CTS handshaking is not supported on the EIA-485 Serial Port 1.

To enable hardware handshaking, use the **SET P** command (or front-panel {SET} pushbutton) to set RTSCTS = Y. Disable hardware handshaking by setting RTSCTS = N.

- If RTSCTS = N, the relay permanently asserts the RTS line.
- If RTSCTS = Y, the relay deasserts RTS when it is unable to receive characters.
- If RTSCTS = Y, the relay does not send characters until the CTS input is asserted.

Software Protocols

The SEL-311M provides standard SEL protocols: SEL ASCII, SEL Fast Meter, SEL Compressed ASCII, and MIRRORED BITS. The relay activates protocols on a per-port basis. See *Port Settings (Serial Port Command SET P and Front Panel)* in the *SEL-311M Settings Sheets*.

To select SEL ASCII protocol, set the port PROTO setting to SEL.

SEL Fast Meter and SEL Compressed ASCII commands are active when PROTO is set to SEL. The commands are not active when PROTO is set to MIRRORED BITS.

SEL ASCII Protocol

SEL ASCII protocol is designed for manual and automatic communications.

NOTE: The **<Enter>** key on most keyboards is configured to send the ASCII character 13 (^M) for a carriage return. This manual instructs you to press the **<Enter>** key after commands, which should send the proper ASCII code to the relay.

1. All commands received by the relay must be of the form:

   <command><CR> or <command><CRLF>

   A command transmitted to the relay should consist of the command followed by either a CR (carriage return) or a CRLF (carriage return and line feed). You may truncate commands to the first three characters. For example, **EVENT 1 <Enter>** would become **EVE 1 <Enter>**. Upper- and lowercase characters may be used without distinction, except in passwords.

2. The relay transmits all messages in the following format:

   <STX><MESSAGE LINE 1><CRLF>

   <MESSAGE LINE 2><CRLF>

   •

   •

   •

   <LAST MESSAGE LINE><CRLF>< ETX>

   Each message begins with the start-of-transmission character (ASCII 02) and ends with the end-of-transmission character (ASCII 03). Each line of the message ends with a carriage return and line feed.

3. The relay implements XON/XOFF flow control.

   The relay transmits XON (ASCII hex 11) and asserts the RTS output (if hardware handshaking is enabled) when the relay input buffer drops below 25 percent full.

   The relay transmits XOFF (ASCII hex 13) when the buffer is over 75 percent full. If hardware handshaking is enabled, the relay deasserts the RTS output when the buffer is approximately 95 percent full. Automatic transmission sources should monitor for the XOFF character so they do not overwrite the buffer. Transmission should terminate at the end of the message in progress when XOFF is received and may resume when the relay sends XON.

4. You can use the XON/XOFF protocol to control the relay during data transmission. When the relay receives XOFF during transmission, it pauses until it receives an XON character. If there is no message in progress when the relay receives XOFF, it blocks transmission of any message presented to its buffer. Messages will be accepted after the relay receives XON.

The CAN character (ASCII hex 18) aborts a pending transmission. This is useful in terminating an unwanted transmission.

Control characters can be sent from most keyboards with the following keystrokes:

Control Characters	Keystrokes	Action
XON:	**<Ctrl+Q>**	hold down the Control key and press Q
XOFF:	**<Ctrl+S>**	hold down the Control key and press S
CAN:	**<Ctrl+X>**	hold down the Control key and press X

SEL Fast Meter Protocol

SEL Fast Meter protocol supports binary messages to transfer metering and control messages. The protocol is described in *Appendix C: SEL Communications Processors*.

SEL Compressed ASCII Protocol

SEL Compressed ASCII protocol provides compressed versions of some of the relay ASCII commands. The protocol is described in *Appendix C: SEL Communications Processors*.

MIRRORED BITS Communications

The SEL-311M supports MIRRORED BITS relay-to-relay communications on two ports simultaneously. See *Appendix D: MIRRORED BITS Communications*.

Serial Port Automatic Messages

When the serial port AUTO setting is Y, the relay sends automatic messages to indicate specific conditions. The automatic messages are described in *Table 8.5*.

Table 8.5 Serial Port Automatic Messages

Condition	Description
Power Up	The relay sends a message containing the present date and time, Relay and Terminal Identifiers, and the Access Level 0 prompt when the relay is turned on.
Event Trigger	The relay sends an event summary each time an event report is triggered. See *Section 10: Analyzing Events*.
Group Switch	The relay displays the active settings group after a group switch occurs. See *GRO n Command (Change Active Setting Group) on page 8.43*.
Self-Test Warning or Failure	The relay sends a status report each time a self-test warning or failure condition is detected. See *STA Command (Relay Self-Test Status) on page 8.37*.
Event Playback	The relay sends a message to indicate that event playback has started.

Using and Changing SEL-311M Relay Passwords

Step 1. Connect to one of the serial ports on the SEL-311M.

Step 2. Open a connection.

Step 3. Press a carriage return, **<Enter>**.

Step 4. Verify that a "=" prompt is returned.

The "=" indicates that you are in Access Level 0.

If you do not get a "=" with each carriage return, then something is wrong with your connection.

Step 5. Terminate your serial connection, check your cable connections and your communications parameters, and restart your serial I/O connection.

To change passwords you need to move through Access Level 1 to Access Level 2.

Step 6. Type **ACC <Enter>** to go to Access Level 1.

The SEL-311M will respond with:

Password: ? @@@@@@

Step 7. At the above prompt, enter your existing or default Level 1 password and press **<Enter>**.

The SEL-311M will respond with the Level 1 access notification and the "=>" prompt indicating that you are in Access Level 1.

Step 8. Type **2AC <Enter>** to go to Access Level 2.

The SEL-311M will respond with the same password prompt that you saw for Level 1.

Step 9. At the password prompt, enter your existing or default Level 2 password and press **<Enter>**.

The SEL-311M will respond with the Level 2 access notification and the "=>>" prompt indicating that you are in Access Level 2.

The **PAS** command is used to view and set passwords.

Step 10. Type **PAS <Enter>** to see the existing passwords settings.

Another form of the **PAS** command is used to set passwords. The command **PAS 1** followed by a password string is used to change the Level 1 password. For example, **PAS 1 Ot3579 <Enter>** sets "Ot3579" as the password for Access Level 1. Similarly, the command **PAS B** followed by a password will set the Level B password, and the command **PAS 2** followed by a password will set the Level 2 password.

Step 11. After entering your new passwords, use the **PAS** command to view the new settings.

When setting your six-character passwords, be sure and choose "strong" passwords that cannot be guessed or broken with an automated password cracker. These passwords include special characters, upper- and lowercase letters, and numbers. They also form no recognizable names or words.

Figure 8.4 demonstrates how to change your SEL-311M passwords. It assumes the existing passwords are "BADPAS," "BRAKER," and "TOOEZY" for Access Levels 1, B, and 2, respectively. It changes the passwords to

"Ot3579," "Bkr351," and "Ta2468," respectively. Your default factory password settings can be found under the *Command Explanations on page 8.20*.

```
=ACC <Enter>
Password: ? BADPAS <Enter>

FEEDER 1            Date: 11/27/00    Time: 13:46:38.548       STATION A
Level 1

=>2AC <Enter>
Password: ? TOOEZY <Enter>

FEEDER 1            Date: 11/27/00    Time: 13:46:45.048       STATION A
Level 2

=>>PAS <Enter>
1:BADPAS
B:BRAKER
2:TOOEZY

=>>PAS 1 Ot3579 <Enter>
Set

=>>PAS B Bkr351 <Enter>
Set

=>>PAS 2 Ta2468 <Enter>

Set


=>>PAS <Enter>
1:Ot3579
B:Bkr351
2:Ta2468

=>>QUIT <Enter>
=
```

Figure 8.4 Example of How to Change Passwords

Serial Port Access Levels

Commands can be issued to the relay via the serial port to view metering values, change relay settings, etc. The available serial port commands are listed in *Table 8.6*. The commands can be accessed only from the corresponding access level as shown in *Table 8.6*. The access levels are:

NOTE: In this manual, commands you type appear in bold/uppercase: **STATUS**. Computer keys you press appear in bold/brackets: **<Enter>**.

Access Level	Status
Access Level 0	lowest access level
Access Level 1	general information only
Access Level B	all Level 1 commands plus breaker control commands
Access Level 2	the highest access level; all Level B commands plus setting and test commands

Access Level 0

Once serial port communications are established with the relay, the relay sends the following prompt:

```
=
```

This is referred to as Access Level 0. Enter the **ACC** command at the Access Level 0 prompt:

```
=ACC <Enter>
```

The **ACC** command takes the relay to Access Level 1.

Access Level 1

When the relay is in Access Level 1, the relay sends the following prompt:

```
=>
```

Commands **2AC** through **TRI** in *Table 8.6* are available from Access Level 1. For example, enter the **MET** command at the Access Level 1 prompt to view metering data:

```
=>MET <Enter>
```

The **2AC** command allows the relay to go to Access Level 2. Enter the **2AC** command at the Access Level 1 prompt:

```
=>2AC <Enter>
```

The **BAC** command allows the relay to go to Access Level B. Enter the **BAC** command at the Access Level 1 prompt:

```
=>BAC <Enter>
```

Access Level B

When the relay is in Access Level B, the relay sends the prompt:

```
==>
```

Commands **BRE *n*** through **PUL** in *Table 8.6* are available from Access Level B. For example, enter the **CLO** command at the Access Level B prompt to close the circuit breaker:

```
==>CLO <Enter>
```

While the relay is in Access Level B, any of the Access Level 1 and Access Level 0 commands are also available (commands **ACC** through **TRI** in *Table 8.6*).

The **2AC** command allows the relay to go to Access Level 2. Enter the **2AC** command at the Access Level B prompt:

```
==>2AC <Enter>
```

Access Level 2

When the relay is in Access Level 2, the relay sends the prompt:

```
==>>
```

Commands **CON** through **VER** in *Table 8.6* are available from Access Level 2. For example, enter the **SET** command at the Access Level 2 prompt to make relay settings:

```
==>>SET <Enter>
```

While the relay is in Access Level 2, any of the Access Level 1, Access Level B, and Access Level 0 commands are also available (commands **ACC** through **VER** in *Table 8.6*).

Command Summary

Table 8.6 alphabetically lists the serial port commands within a given access level. Much of the information available from the serial port commands is also available via the front-panel pushbuttons. The correspondence between the serial port commands and the front-panel pushbuttons is also given in *Table 8.6*. See *Section 9: Front-Panel Operations* for more information on the front-panel pushbuttons.

The commands are shown in uppercase letters, but they can also be entered with lowercase letters.

Table 8.6 Serial Port Command Summary (Sheet 1 of 2)

Access Level	Prompt	Serial Port Command	Command Description	Corresponding Front-Panel Pushbutton
0	=	**ACC**	Go to Access Level 1	
0	=	**CAS**	Compressed ASCII configuration data	
0	=>	**QUI**	Quit to Access Level 0	
1	=>	**2AC**	Go to Access Level 2	
1	=>	**BAC**	Go to Access Level B	
1	=>	**BRE**	Breaker monitor data	{OTHER}
1	=>	**CEV**	Compressed event report	
1	=>	**CHIS**	Compressed history	
1	=>	**COM**	MIRRORED BITS communications statistics	
1	=>	**CST**	Compressed status report	
1	=>	**CSU**	Compressed event summary	
1	=>	**DAT**	View/change date	{OTHER}
1	=>	**EVE**	Event reports	
1	=>	**FIL DIR**	Shows filenames from the specified directory	
1	=>	**FIL READ**	Reads specified file from relay	
1	=>	**FIL SHOW**	Displays file contents	

Table 8.6 Serial Port Command Summary (Sheet 2 of 2)

Access Level	Prompt	Serial Port Command	Command Description	Corresponding Front-Panel Pushbutton
1	=>	**GRO**	Display active setting group number	{GROUP}
1	=>	**HELP**	View commands help	
1	=>	**HIS**	Event summaries/histories	{EVENTS}
1	=>	**IRI**	Synchronize to IRIG-B	
1	=>	**MET**	Differential metering data	{METER}
1	=>	**MET B**	Backup metering data	{METER}
1	=>	**MET D**	Demand metering data	{METER}
1	=>	**MET E**	Energy metering data	{METER}
1	=>	**MET M**	Maximum/minimum metering data	{METER}
1	=>	**MET N**	Zero-sequence metering data	{METER}
1	=>	**SER**	Sequential Events Recorder	
1	=>	**SHO**	Show/view settings	{SET}
1	=>	**STA**	Relay self-test status	{STATUS}
1	=>	**SUM**	Display event summary	{EVENTS}
1	=>	**TAR**	Display relay element status	{OTHER}
1	=>	**TIM**	View/change time	{OTHER}
1	=>	**TRI**	Trigger an event report	
B	==>	**BRE *n***	Preload/reset breaker wear	{OTHER}
B	==>	**CLO**	Close breaker	
B	==>	**GRO *n***	Change active setting group	{GROUP}
B	==>	**OPE**	Open breaker	
B	==>	**PUL**	Pulse output contact	{CNTRL}
2	=>>	**CON**	Control remote bit	
2	=>>	**COP**	Copy setting group	
2	=>>	**FIL WRITE**	Transfers file to the relay in the directory specified	
2	=>>	**L_D**	Load new firmware	
2	=>>	**LOO**	Enable loopback testing of MIRRORED BITS channels	
2	=>>	**PAS**	View/change passwords	{SET}
2	=>>	**PLA**	Event playback	
2	=>>	**SET**	Change settings	{SET}
2	=>>	**TST**	Test differential communications channels	
2	=>>	**VER**	Display version and configuration information	

The relay responds with `Invalid Access Level` if a command is entered from an access level lower than the specified access level for the command. The relay responds:

```
Invalid Command
```

to commands not listed above or entered incorrectly.

Many of the command responses display the following header at the beginning:

```
SEL-311M                           Date: 10/12/99    Time: 16:15:39.372
EXAMPLE: BUS B, BREAKER 3
```

The definitions are:

SEL-311M Response	Definition
SEL-311M	This is the RID setting (the relay is shipped with the default setting RID = SEL-311M; see *Identifier Labels on page 7.35*).
EXAMPLE: BUS B, BREAKER 3:	This is the TID setting (the relay is shipped with the default setting TID = EXAMPLE: BUS B, BREAKER 3; see *Identifier Labels on page 7.35*).
Date:	This is the date the command response was given (except for relay response to the **EVE** or **SUM** command, where it is the date the event occurred). You can modify the date display format (Month/Day/Year or Year/Month/Day) by changing the DATE_F relay Global setting.
Time	This is the time the command response was given (except for relay response to the **EVE** or **SUM** command, where it is the time the event occurred).

The serial port command explanations that follow in the *Command Explanations on page 8.20* are in the same order as the commands listed in *Table 8.6*.

Command Explanations

Access Level 0 Commands

ACC Command (Go to Access Level 1)

The **ACC** command provides entry to Access Level 1. Different commands are available at the different access levels as shown in *Table 8.6*.

ACC moves from any access level to Access Level 1.

Password Requirements and Default Passwords

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Passwords are required if the main board Password jumper is not in place (Password jumper = OFF). Passwords are not required if the main board Password jumper is in place (Password jumper = ON). Refer to *Table 2.4* for Password jumper information. See *PAS Command (View/Change Passwords) on page 8.48* for more information on passwords.

The factory default passwords for Access Levels 1, B, and 2 are:

Access Level	Factory Default Password
1	OTTER
B	EDITH
2	TAIL

Access Level Attempt (Password Required)

Assume the following conditions: Password jumper = OFF (not in place), Access Level = 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the Password jumper is not in place, the relay asks for the Access Level 1 password to be entered:

```
Password: ? @@@@@@
```

The relay responds:

```
SEL-311M                         Date: 10/12/99    Time: 16:22:04.372
EXAMPLE: BUS B, BREAKER 3

Level 1
=>
```

The “=>” prompt indicates the relay is now in Access Level 1.

If the entered password is incorrect, the relay asks for the password again (Password: ?). The relay will ask up to three times. If the requested password is incorrectly entered three times, the relay closes the **ALARM** contact for one second, remains at Access Level 0 (“=” prompt), and locks out communications for 30 seconds.

Access Level Attempt (Password Not Required)

Assume the following conditions: Password jumper = ON (in place), Access Level = 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the Password jumper is in place, the relay does not ask for a password; it goes directly to Access Level 1. The relay responds:

```
SEL-311M                          Date: 10/12/99    Time: 16:22:04.372
EXAMPLE: BUS B, BREAKER 3

Level 1
=>
```

The “=>” prompt indicates the relay is now in Access Level 1.

The above two examples demonstrate how to go from Access Level 0 to Access Level 1. The procedure to go from Access Level 1 to Access Level B, Access Level 1 to Access Level 2, or Access Level B to Access Level 2 is much the same, with command **BAC** or **2AC** entered at the access level screen prompt. The relay closes the **ALARM** contact for one second after a successful Level B or Level 2 access. If access is denied, the **ALARM** contact closes for one second, returns to Access Level 0 (“=” prompt), and locks out communications for 30 seconds.

CAS Command

The Compressed ASCII configuration provides data for an external computer to extract data from other Compressed ASCII commands. For details on this and other Compressed ASCII commands see *Appendix C: SEL Communications Processors*.

QUI Command (Quit Access Level)

The **QUI** command returns the relay to Access Level 0.

To return to Access Level 0, enter the command:

```
=>QUI <Enter>
```

The relay sets the port access level to 0 and responds:

```
SEL-311M                          Date: 10/12/99    Time: 16:32:10.747
EXAMPLE: BUS B, BREAKER 3

=
```

The “=” prompt indicates the relay is back in Access Level 0.

Access Level 1 Commands

2AC and BAC Commands

See previous discussion on passwords.

BRE Command (Breaker Monitor Data)

Use the **BRE** command to view the breaker monitor report.

```
=>BRE <Enter>

SEL-311M                         Date: 10/12/99    Time: 16:24:01.623
EXAMPLE: BUS B, BREAKER 3

Rly Trips=      9
 IA=       40.7 IB=       41.4 IC=       53.8 kA

Ext Trips=      3
 IA=        0.8 IB=        0.9 IC=        1.1 kA

Percent wear: A=   4 B=   4 C=   6

LAST RESET 10/12/99 15:32:59
=>
```

See *BRE n Command (Preload/Reset Breaker Wear) on page 8.42* in *Access Level B* commands and *Breaker Monitor on page 6.10* for further details on the breaker monitor.

CEV Command

Displays event report in Compressed ASCII format. For details on this and other Compressed ASCII commands see *Appendix C: SEL Communications Processors*.

CHIS Command

Display history in Compressed ASCII format. For details on this and other Compressed ASCII commands see *Appendix C: SEL Communications Processors*.

COM Command (Communication Data)

The **COM** command displays integral relay-to-relay (MIRRORED BITS) communications performance data. For more information on MIRRORED BITS, see *Appendix D: MIRRORED BITS Communications*. To get a summary report, enter the **COM *n*** command with the channel parameter (*n* = A, B, X, or Y). **COM A** and **COM B** report performance for MIRRORED BITS Channels A and B, respectively. **COM X** and **COM Y** report performance for 87L Channels X and Y. This section describes the MIRRORED BITS reports. See *Communications Report on page 8.7*, for information on **COM X** and **COM Y**.

```
=>COM A <Enter>

SEL-311M                          Date: 10/12/99    Time: 16:24:01.623
EXAMPLE: BUS B, BREAKER 3

FID=SEL-311M-R100-V0-Z001001-D20010625       CID=FF27
Summary for Mirrored Bits channel A

For 10/05/99 18:36:09.279 to 10/10/99 18:36:11.746

    Total failures      1                   Last error
    Relay Disabled      1
    Data error          0                   Longest Failure     2.458 sec.
    Re-Sync             0
    Underrun            0                   Unavailability  0.996200
    Overrun             0
    Parity error        0
    Framing error       0                   Loop-back    0
    Bad Re-Sync         0
=>
```

If only one MIRRORED BITS port is enabled, the channel specifier may be omitted. Use the L parameter to get a summary report, followed by a listing of the COMM records.

```
=>COM A L <Enter>

SEL-311M                          Date: 10/12/99    Time: 16:24:01.623
EXAMPLE: BUS B, BREAKER 3

FID=SEL-311M-R100-V0-Z001001-D20010625       CID=FF27
Summary for Mirrored Bits channel A

For 10/05/99 17:18:12.993 to 10/10/99 18:37:36.123

    Total failures      4                   Last error
    Relay Disabled      2
    Data error          0                   Longest Failure     2.835 sec.
    Re-Sync             0
    Underrun            1                   Unavailability  0.000003
    Overrun             0
    Parity error        1
    Framing error       0                   Loop-back    0
    Bad Re-Sync         0

    Failure                Recovery
#   Date     Time          Date     Time          Duration  Cause
1   10/05/99 18:36:09.279  10/05/9918:37:36.114      2.835
2   10/06/99 13:18:09.236  10/06/99 13:18:09.736     0.499  Parity error
3   10/07/99 11:43:35.547  10/07/99 11:43:35.637     0.089  Underrun
4   10/09/99 17:18:12.993  10/09/99 17:18:13.115     0.121

=>
```

There may be up to 255 records in the extended report. To limit the number of COMM records displayed in the report to the 10 most recent records, type **COM n 10 L <Enter>**. To select lines 10 through 20 of the COMM records for display in the report, type **COM n 10 20 L <Enter>**. To reverse the order of the COMM records in the report, supply a range of row numbers, with the larger number first, i.e., **COM n 40 10 L <Enter>**. To display all the COMM records that started on a particular day, supply that date as a parameter, i.e., **COM n 2/8/98 L <Enter>**. To display all the COMM records that started between a range of dates, supply both dates as parameters, i.e., **COM n 2/21/98 2/7/98 L <Enter>**. Reversing the order of the dates will reverse the order of the records in the report. To receive a summary report for a subset of the records, use one of the above methods while omitting the L parameter.

To clear the COMM records, type **COM n C <Enter>**. The prompting message `Are you sure (Y/N) ?` is displayed. Typing **N <Enter>** aborts the clearing operation with the message `Canceled`. If both MIRRORED BITS channels are enabled, omitting the channel specifier in the clear command will cause both channels to be cleared.

CST Command

Display status data in Compressed ASCII format. For details on this and other Compressed ASCII commands see *Appendix C: SEL Communications Processors*.

CSU Command

Display long summary event report in Compressed ASCII format. For details on this and other Compressed ASCII commands see *Appendix C: SEL Communications Processors*.

DAT Command (View/Change Date)

NOTE: After setting date or time, allow at least 60 seconds before powering down the relay or the new setting may be lost.

DAT displays the date stored by the internal calendar/clock. If the date format setting DATE_F is set to MDY, the date is displayed as month/day/year. If the date format setting DATE_F is set to YMD, the date is displayed as year/month/day.

To set the date, type **DAT mm/dd/yy <Enter>** if the DATE_F setting is MDY. If the DATE_F is set to YMD, **enter DAT yy/mm/dd <Enter>**. To set the date to June 1, 1999, enter when DATE_F = MDY:

```
=>DAT 6/1/99 <Enter>
06/01/99
=>
```

You can separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons.

EVE Command (Event Reports)

Use the **EVE** command to view event reports. See *Section 10: Analyzing Events* for further details on retrieving event reports.

FIL DIR (View File Directory)

FILE DIR [*directory*] initiates a text response containing all of the filenames within the specified *directory* if specified. If [*directory*] is not specified, the file list is taken from the root directory of the SEL-311M. Valid directories are SETTINGS and EVENTS.

XON/XOFF flow control must be suspended during file transfers. Binary transfers (such as Fast Meter and Fast Operate) may only occur between YMODEM packets. Information on file formats is contained in separate specifications.

All text enclosed in [brackets] indicates optional command line parameters.

FIL READ (Transfer Files From Relay)

FILE READ [*directory*] *filename* initiates a file transfer from the relay to the computer, where *directory*, if specified, is the file location and *filename* is the name of the file involved in the transfer. The YModem transfer protocol is used.

The command is commonly used to retrieve files from the SETTINGS directory that can be used to set other SEL-311M relays using the FILE WRITE command.

XON/XOFF flow control must be suspended during file transfers. Binary transfers (such as Fast Meter and Fast Operate) may only occur between YMODEM packets. Information on file formats is contained in separate specifications.

FIL SHOW (Show File Contents)

FILE SHOW [*directory*] *filename* initiates a file transfer from the relay to the computer, where *directory*, if specified, is the file location and *filename* is the name of the file involved in the transfer. This displays the file contents to the computer terminal.

GRO Command (Display Active Setting Group Number)

Use the **GRO** command to display the active settings group number. See *GRO n Command (Change Active Setting Group) on page 8.43* and *Multiple Setting Groups on page 5.14* for further details on settings groups.

HELP Command

Us the **HELP** command to view a list of commands available at the current access level and a description of those commands.

If no parameters are specified with the **HELP** command, the relay displays the commands available at the present access level (Access Level 2, refer to *Figure 8.5*).

```
=>HELP <Enter>
ACC
 .
 .
 .
PLA - Control and/or monitor Event Playback
 .
 .
 .
TRI
=>
```

Figure 8.5 Example Relay Response to HELP Command

The SEL-311M **HELP** command displays a short description only for commands that are supported by the **HELP** command. The SEL-311M only supports the **HELP** command for the **PLAY** command.

If the **PLA** parameter is specified with the **HELP** command, the relay displays a description of the **PLA** command (see *PLA Command (Event Playback) on page 8.48* and *Figure 8.6*).

```
=>HELP PLA <Enter>

NOTE: See the Instruction Manual for further detail on this command.

Use the PLAYBACK command to control and/or monitor Event Playback.
Command format is as follows (ordering of parameters does not matter):

PLAY       - display status of latest Event Playback
PLAY X     - Cancel pending Event Playback so it will not execute
PLAY filename [A] [C] [D] [MA] [MB] [O bbbbbbb] [E ele|T hh:mm:ss]
           - Set up Event Playback to execute based on the given parameters
             filename = Name of COMTRADE DAT file to Play back
             A = Play back Analog data values
             C = Play back Command Bit values
             D = Play back Digital Input values
             MA = Play back Channel A Mirrored Bit values
             MB = Play back Channel B Mirrored Bit values
             O bbbbbbb = Control Output Contacts according to string "bbbbbbb"
               (b = o,c,x,*, where o=Open, c=Close, x=hold, *=drive normally)
               The first 'b' represents the lowest numbered Output Contact
             E ele = trigger Playback to begin on Relay Word element with name ele


T hh:mm:ss = begin Playback at given time (hours:minutes:seconds)
PLAY filename
           - same as "PLAY filename A D" (Play back Analogs and Digitals)

If no trigger condition is provided via the 'E' or 'T' parameter, Event
Playback begins 5 seconds after user verification.

=>
```

Figure 8.6 Description of the PLA Command

HIS Command (Event Summaries/History)

HIS *x* displays event summaries or allows you to clear event summaries (and corresponding event reports and event summaries) from nonvolatile memory.

If no parameters are specified with the **HIS** command:

```
=>HIS <Enter>
```

the relay displays the most recent event summaries in reverse chronological order.

If *x* is the letter E

```
=>HIS E <Enter>
```

the relay displays the most recent event summaries in reverse chronological order. The leading number is a unique event identifier between 1 and 32767 that can be used with the **SUM** or **CSU** commands to view event summaries for that event.

If *x* is a number:

```
=>HIS x <Enter>
```

the relay displays the *x* most recent event summaries. The maximum number of available event summaries is a function of the LER (length of event report) setting.

If *x* is “C” or “c,” the relay clears the event summaries and all corresponding event reports from nonvolatile memory.

If *x* is “A or “a,” the relay displays all the events including user-loaded events stored in nonvolatile memory. The relay stores the events in reverse chronological order.

The event summaries include the date and time the event was triggered, the type of event, the maximum phase current in the event, the power system frequency, the number of the active setting group, and the front-panel targets.

To display the relay event summaries, enter the following command:

```
=>>HIS <Enter>

SEL-311M                          Date: 11/20/03    Time: 13:53:00.995
EXAMPLE: BUS B, BREAKER 3

#      DATE         TIME EVENT   CURR  FREQ GRP TARGETS

1  11/20/03 13:52:47.739 ER         1 60.00  1
2  11/20/03 13:51:57.741 TRIG       1 60.00  1

=>>
```

The event type is listed in the EVENT column:

Table 8.7 Event Types

Event Type	Faulted Phase
AG	A-phase to ground
BG	B-phase to ground
CG	C-phase to ground
AB	A-B phase-to-phase
BC	B-C phase-to-phase
CA	C-A phase-to-phase
ABG	A-B phase-to-phase to ground
BCG	B-C phase-to-phase to ground
CAG	C-A phase-to-phase to ground
ABC	three-phase

If a trip occurs in the same event report, a “T” is appended to the event type (e.g., AG T).

The event type listed in the EVENT column may also be one of the following:

Event Type	Description
TRIP	event report generated by assertion of Relay Word bit TRIP
ER	event report generated by assertion of SELOGIC control equation event report trigger setting ER
PULSE	event report generated by execution of the **PUL** (Pulse) command
TRIG	event report generated by execution of the **TRI** (Trigger) command

The TARGETS column will display any of the following illuminated front-panel target LEDs if the event report is generated by a trip (assertion of TRIP Relay Word bit):

TIME COMM 87 50/51 27 59 32 81

The TARGETS column displays the PLAY Relay Word bit if it is asserted during the event. This allows for easy identification of event playback (see *Section 11: Testing and Troubleshooting*) events.

For more information on front-panel target LEDs, see *Section 4: Trip, Close, and Target Logic*. For more information on event reports, see *Section 10: Analyzing Events*.

For more information on event summaries, see *SUM Command (Long Summary Event Report) on page 8.39*.

IRI Command (Synchronize to IRIG-B Time Code)

IRI directs the relay to read the demodulated IRIG-B time code at the serial port input.

To force the relay to synchronize to IRIG-B, enter the following command:

```
=>IRI <Enter>
```

If the relay successfully synchronizes to IRIG, it sends the following header and access level prompt:

```
SEL-311M                              Date: 10/12/99    Time: 16:22:04.372
EXAMPLE: BUS B, BREAKER 3

=>
```

If no IRIG-B code is present at the serial port input or if the code cannot be read successfully, the relay responds:

```
IRIG-B DATA ERROR

=>
```

If an IRIG-B signal is present, the relay synchronizes its internal clock with IRIG-B. It is not necessary to issue the **IRI** command to synchronize the relay clock with IRIG-B. Use the **IRI** command to determine if the relay is properly reading the IRIG-B signal.

MET Command (Metering Data)

MET k

The numerical modifier *k* is an optional parameter to specify the number of times (1–32767) to repeat the meter display. The **MET** command provides the currents and vector sums and ratios used in the differential calculations. This provides an easily accessible way of checking connections and ensuring no steady-state conditions exist that could cause a relay misoperation. The local I1-phase current is reference-all other current angles are referenced to that.

The vector sum of the currents shows the quality of the CT and communication channels under normal conditions. Under perfect ratio matching and communications, the vector sum would indicate the line charging current. The alpha plane display shows where each phase current plots in the operating characteristic. Both the vector sum and alpha plane values can be used to evaluate the quality of the protection elements.

A typical display of **MET** data follows. Note that currents are displayed in primary values while settings are in secondary values. In this case Channel Y is a standby channel. Channel X is used for calculated values.

```
=>>MET <Enter>

SEL-311M                          Date: 06/05/01    Time: 10:28:50.360
EXAMPLE: BUS B, BREAKER 3

Local              A         B         C         3I0       3I2       I1
I MAG (A Pri)   386.444   385.401   385.597     2.838     1.747   385.813
I ANG (DEG)       -0.10   -119.90    119.80     -2.60    -19.00      0.00

Channel X  PRIM    A         B         C         3I0       3I2       I1
I MAG (A Pri)   385.644   387.077   395.563    32.567    30.969   389.172
I ANG (DEG)      179.60     59.50    -56.10     14.80    133.70   -179.00

Channel Y  STBY    A         B         C         3I0       3I2       I1
I MAG (A Pri)   386.082   385.349   395.433    31.476    32.077   388.685
I ANG (DEG)      179.70     59.80    -55.70     15.20    136.40   -178.70

Vector Sum         A         B         C         3I0       3I2       I1
I MAG (A Pri)     2.173     4.378    29.665    35.285    29.427     7.551
I ANG (DEG)       68.10     -7.60     12.20     13.40    132.10   -115.90

Alpha Plane        A         B         C
RADIUS            0.990     1.000     1.020
ANG (DEG)       179.60    179.40    175.80

=>>
```

MET B k—Instantaneous Local Metering

The **MET B k** command displays local instantaneous magnitudes (and angles if applicable) of the following quantities:

Currents	$I_{A,B,C,N}$	Input currents (A primary)
	I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
Voltages	$V_{A,B,C,S}$	Wye-connected voltage inputs (kV primary)
Power	$MW_{A,B,C}$	Single-phase megawatts
	MW_{3P}	Three-phase megawatts
	$MVAR_{A,B,C}$	Single- and three-phase megavars
	$MVAR_{3P}$	Three-phase megavars
Power Factor	$PF_{A,B,C,3P}$	Single- and three-phase power factor; leading or lagging
Sequence	I_1, $3I_2$, $3I_0$	Positive-, negative-, and zero-sequence currents (A primary)
	V_1, V_2	Positive- and negative-sequence voltages (kV primary)
	$3V_0$	Zero-sequence voltage (kV primary)
Frequency	FREQ (Hz)	Instantaneous power system frequency (measured on voltage channel VA)
Station DC	VDC (V)	Voltage at **POWER** terminals (input into station battery monitor

The angles are referenced to the A-phase voltage if it is greater than 13 V secondary; otherwise, the angles are referenced to A-phase current. The angles range from –179.99 to 180.00 degrees.

To view instantaneous metering values, enter the command:

```
=>MET B k <Enter>
```

where *k* is an optional parameter to specify the number of times (1–32767) to repeat the meter display. If *k* is not specified, the meter report is displayed once. The output from an SEL-311M is shown below.

```
=>MET B <Enter>

SEL-311M                           Date: 10/12/99    Time: 16:22:04.372
EXAMPLE: BUS B, BREAKER 3
                 A         B         C         N         G
I MAG (A)      195.146   192.614   198.090    0.302     4.880
I ANG (DEG)     -8.03   -128.02    111.89     52.98     81.22

                 A         B         C         S

V MAG (KV)      11.691    11.686    11.669    11.695
V ANG (DEG)      0.00   -119.79    120.15      0.05

                 A         B         C         3P
MW               2.259     2.228     2.288     6.774
MVAR             0.319     0.322     0.332     0.973
PF               0.990     0.990     0.990     0.990
                 LAG       LAG       LAG       LAG

                 I1        3I2       3I0       V1        V2        3V0
MAG            195.283     4.630     4.880    11.682     0.007     0.056
ANG   (DEG)     -8.06   -103.93     81.22      0.12    -80.25    -65.83

FREQ (Hz)      60.00               VDC (V)      129.5
=>
```

MET D—Local Demand Metering

The **MET D** command displays the local demand and peak demand values of the following quantities:

Currents	$I_{A,B,C,N}$	Input currents (A primary)
	$3I_2$	Negative-sequence current (A primary)
Power	$MW_{A,B,C}$	Single-phase megawatts
	MW_{3P}	Three-phase megawatts
	$MVAR_{A,B,C}$	Single-phase megavars
	$MVAR_{3P}$	Three-phase megavars
Reset Time	Demand, Peak	Last time the demands and peak demands were reset

To view demand metering values, enter the command:

```
=>MET D <Enter>
```

The output from an SEL-311M is shown:

```
=>MET D <Enter>

SEL-311M                           Date: 10/12/99    Time: 16:22:04.372
EXAMPLE: BUS B, BREAKER 3
            IA         IB         IC          IG         3I2
DEMAND     188.6      186.6      191.8       4.5        4.7
PEAK       188.6      186.6      191.8       4.5        4.7

              MWA      MWB      MWC      MW3P     MVARA    MVARB    MVARC    MVAR3P
DEMAND IN      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
PEAK IN        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DEMAND OUT     2.2      2.2      2.2      6.6      0.3      0.3      0.3      0.9
PEAK OUT       3.1      3.1      3.1      9.3      0.4      0.4      0.4      1.2
LAST DEMAND RESET 01/27/97 15:31:51.238   LAST PEAK RESET 01/27/97 15:31:56.239
=>
```

Reset the accumulated demand values, using the **MET RD** command. Reset the peak demand values, using the **MET RP** command. For more information on demand metering, see *Local Demand Metering on page 6.3*.

MET E—Local Energy Metering

The **MET E** command displays the following local quantities:

Energy	$MWh_{A,B,C}$	Single-phase megawatt hours (in and out)
	MWh_{3P}	Three-phase megawatt hours (in and out)
	$MVARh_{A,B,C}$	Single-phase megavar hours (in and out)
	$MVARh_{3P}$	Three-phase megavar hours (in and out)
Reset Time		Last time the energy meter was reset

To view energy metering values, enter the command:

```
=>MET E <Enter>
```

The output from an SEL-311M is shown:

```
=>MET E <Enter>

SEL-311M                    Date: 03/01/00    Time: 15:11:24.056
EXAMPLE: BUS B, BREAKER 3
        MWhA      MWhB      MWhC     MWh3P    MVARhA    MVARhB    MVARhC    MVARh3P
IN       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
OUT     36.0      36.6      36.7     109.2       5.1       5.2       5.3      15.6
LAST RESET 02/10/00 23:31:28.864

=>
```

Reset the energy values, using the **MET RE** command. For more information on energy metering, see *Local Energy Metering on page 6.8*.

MET M—Local Maximum/Minimum Metering

The **MET M** command displays the local maximum and minimum values of the following quantities:

Currents	$I_{A,B,C,N}$	Input currents (A primary)
	I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
Voltages	$V_{A,B,C,S}$	Wye-connected voltage inputs (kV primary)
Power	MW_{3P}	Three-phase megawatts
	$MVAR_{3P}$	Three-phase megavars
Reset Time		Last time the maximum/minimum meter was reset

To view maximum/minimum metering values, enter the command:

```
=>MET M <Enter>
```

The output from an SEL-311M is shown:

```
=>MET M <Enter>

SEL-311M                          Date: 10/12/99    Time: 16:22:04.372
EXAMPLE: BUS B, BREAKER 3
           Max    Date      Time             Min    Date      Time
IA(A)      196.8  10/01/99  15:00:42.574      30.0  10/01/99  14:51:02.391
IB(A)      195.0  10/01/99  15:05:19.558      31.8  10/01/99  14:50:55.536
IC(A)      200.4  10/01/99  15:00:42.578      52.2  10/01/99  14:51:02.332
IN(A)       42.6  10/01/99  14:51:02.328      42.6  10/01/99  14:51:02.328
IG(A)       42.0  10/01/99  14:50:55.294      42.0  10/01/99  14:50:55.294
VA(kV)      11.7  10/01/99  15:01:01.576       3.4  10/01/99  15:00:42.545
VB(kV)      11.7  10/01/99  15:00:42.937       2.4  10/01/99  15:00:42.541
VC(kV)      11.7  10/01/99  15:00:42.578       3.1  10/01/99  15:00:42.545
VS(kV)      11.7  10/01/99  15:01:01.576       3.4  10/01/99  15:00:42.545
MW3P         6.9  10/01/99  15:00:44.095       0.4  10/01/99  15:00:42.545
MVAR3P       1.0  10/01/99  15:00:42.578       0.1  10/01/99  15:00:42.545
LAST RESET 01/27/99 15:31:41.237
=>
```

Reset the maximum/minimum values using the **MET RM** command. All values will display RESET until new maximum/minimum values are recorded. For more information on maximum/minimum metering, see *Local Maximum/ Minimum Metering on page 6.9*.

MET N n—Instantaneous Zero-Sequence Metering

The **MET N *n*** command outputs the present differential protection analog values. The numerical modifier *n* is an optional parameter to specify the number of times (1–32767) to repeat the meter display. Magnitudes are in primary values. The angles are referenced to the local I1 phase differential current. The angles range from -179.99 to 180.00. If data are not available for a channel, or if Vector Sum current is not calculated, "****.**" or "***.**" is displayed.

```
=>>MET N <Enter>

SEL-311M                          Date: 11/19/03    Time: 17:06:56.479
EXAMPLE: BUS B, BREAKER 3

Local              IG        IN        3V0
MAG            ****.***  ****.***  ****.***
ANG (DEG)        ***.**    ***.**    ***.**

Channel X          IG        IN        3V0
MAG            ****.***  ****.***  ****.***
ANG (DEG)        ***.**    ***.**    ***.**

Vector Sum         IG        IN
MAG            ****.***  ****.***
ANG (DEG)        ***.**    ***.**

=>>
```

SER Command (Sequential Events Recorder Report)

Use the **SER** command to view the Sequential Events Recorder report. For more information on SER reports, see *Section 10: Analyzing Events*.

SHO Command (Show/View Settings)

Use the **SHO** command to view relay settings, SELOGIC control equations, global settings, serial port settings, sequential events recorder (SER) settings, and text label settings. Below are the **SHO** command options.

Table 8.8 SHO Command Options

SHO Commands	Function
SHO *n*	Show relay settings. *n* specifies the setting group (1, 2, 3, 4, 5, or 6); *n* defaults to the active setting group if not listed.
SHO A *n*	Show all settings, even hidden settings. *n* specifies the setting group (1, 2, 3, 4, 5, and 6).
SHO C	Show calibration settings.
SHO L *n*	Show SELOGIC control equation settings. *n* specifies the setting group (1, 2, 3, 4, 5, or 6); *n* defaults to the active setting group if not listed.
SHO G	Show global settings.
SHO P *n*	Show serial port settings. *n* specifies the port (1, 2, 3, or F); *n* defaults to the active port if not listed.
SHO R	Show sequential events recorder (SER) settings.
SHO T	Show text label settings.
SHO X	Show differential Channel X settings.
SHO Y	Show differential Channel Y settings.

You may append a setting name to each of the commands to specify the first setting to display (e.g., **SHO 1 E50P** displays the setting Group 1 relay settings starting with setting E50P). The default is the first setting.

The **SHO** commands display only the enabled settings. To display all settings, including disabled/hidden settings, append an A to the **SHO** command (e.g., **SHO 1 A**).

Below are sample **SHOWSET** commands for the SEL-311M, showing all the factory default settings.

```
=>>SHO <Enter>
Group 1

Relay Settings:
RID   =SEL-311M                        TID   =EXAMPLE: BUS B, BREAKER 3
CTR   = 1000     CTRN  = 1000
PTR   = 20.00    PTRS  = 20.00
VNOM  = 120.00
Z1MAG = 39.00    Z1ANG = 84.00
Z0MAG = 124.00   Z0ANG = 81.50

E87L  = 2        EHST  = 2
87LPP = 1.20     CTALRM= 0.50
87LR  = 6.00     87LANG= 195
50FWP = 0.005    87WP  = 0        W_ANG = -90
E50P  = 1        E50NG = N        E50Q  = N
E51P  = N        E51NG = N        E51Q  = N
E32   = AUTO
ELOAD = Y
ESOTF = Y
EVOLT = N

Press RETURN to continue
E25   = N
E81   = N
ELOP  = Y
ECOMM = N
EPWR  = N
ESV   = N
ELAT  = N
EDP   = 16
EDEM  = THM
50P1P = 11.25
```

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```
67P1D = 0.00
ZLF   = 120.00   ZLR   = 120.00
PLAF  = 50.00    NLAF  =-50.00
PLAR  = 130.00   NLAR  = 230.00
DIR3  = R        DIR4  = F
CLOEND= OFF      52AEND= 10.00    SOTFD = 30.00
DMTC  = 60       PDEMP = OFF      NDEMP = OFF      QDEMP = OFF
TDURD = 9.00     CFD   = 60.00    3POD  = 0.50     50LP  = 0.25

=>>
```

```
=>>SHO L <Enter>
SELogic Group 1

SELogic Control Equations:
TR    =TRIP + OC
TRSOTF=0
DTT   =0
ULTR  =0
52A   =IN101
CL    =CC
ULCL  =TRIP + TRIP87
67P1TC=1
OUT101=0
OUT102=TRIP
OUT103=CLOSE
OUT104=KEY
OUT105=0
OUT106=0
OUT107=87HWAL
OUT201=TRIP + TRIP87
OUT202=TRIP + TRIP87

Press RETURN to continue
OUT203=0
OUT204=0
OUT205=0
OUT206=0
DP1   =52A
DP2   =CHXAL
DP3   =CHYAL
DP4   =0
DP5   =0
DP6   =0
DP7   =0
DP8   =0
DP9   =0
DP10  =0
DP11  =0
DP12  =0
DP13  =0
DP14  =0
DP15  =0
DP16  =0

Press RETURN to continue
SS1   =0
SS2   =0
SS3   =0
SS4   =0
SS5   =0
SS6   =0
ER    =0
FAULT =0
BSYNCH=0
CLMON =0
87WB  =0
E32IV =1
T1X   =0
T2X   =0
T3X   =0
T4X   =0
T5X   =0
T6X   =0
T7X   =0
T8X   =0
```

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```
Press RETURN to continue
T1Y   =0
T2Y   =0
T3Y   =0
T4Y   =0
T5Y   =0
T6Y   =0
T7Y   =0
T8Y   =0
LED_TRP=(/TRIP + TRP) * !TRGTR
LED_TIME=(/TRIP * TFLT + TIME) * !TRGTR
LED_COMM=(COMMT + COMM) * !TRGTR
LED_87=(TRIP87 + 87) * !TRGTR
LED_50_51=(50P1 + 67P1T + 50NG1 + 67NG1T + 50Q1 + 67Q1T + 51PT + 51NGT + 51QT)
        * /TRIP * !TRGTR + (50_51 * !TRGTR)
LED_27=(3P27 * !3PO + 27) * !TRGTR
LED_59=(3P59 + 59) * !TRGTR
LED_32=(3PWR1 + 3PWR2 + 3PWR3 + 3PWR4) * /TRIP * !TRGTR + (32 * !TRGTR)
LED_81=(81D1T + 81D2T + 81D3T + 81D4T + 81D5T + 81D6T) * /TRIP * !TRGTR
        + (81 * !TRGTR)
LED_25=(25A1 + 25A2) * 3PO

Press RETURN to continue
LED_87CHFAIL=CHXAL + CHYAL + 87HWAL + !87LPE

=>>
```

```
=>>SHO G <Enter>

Global Settings:
TGR   = 1800.00  NFREQ = 60       PHROT = ABC
DATE_F= MDY      FP_TO = 15.00    SCROLD= 2
LER   = 15       PRE   = 4        DCLOP = OFF      DCHIP = OFF
IN101D= 0.50     IN102D= 0.50     IN103D= 0.50     IN104D= 0.50
IN105D= 0.50     IN106D= 0.50     FMETER= STANDARD
EBMON = Y        COSP1 = 1000     COSP2 = 150      COSP3 = 12
KASP1 = 1.20     KASP2 = 8.00     KASP3 = 20.00

=>>
```

```
=>>SHO P <Enter>

Port F
PROTO = SEL
SPEED = 2400     BITS  = 8        PARITY= N        STOP  = 1
T_OUT = 15       AUTO  = N        RTSCTS= N        FASTOP= N


=>>
```

```
=>>SHO R <Enter>
Sequential Events Recorder trigger lists:
SER1  =0
SER2  =0
SER3  =0

=>>
```

```
=>>SHO T <Enter>

Text Labels:
NLB1  =               CLB1  =        SLB1  =        PLB1  =
NLB2  =               CLB2  =        SLB2  =        PLB2  =
NLB3  =               CLB3  =        SLB3  =        PLB3  =
NLB4  =               CLB4  =        SLB4  =        PLB4  =
NLB5  =               CLB5  =        SLB5  =        PLB5  =
NLB6  =               CLB6  =        SLB6  =        PLB6  =
NLB7  =               CLB7  =        SLB7  =        PLB7  =
NLB8  =               CLB8  =        SLB8  =        PLB8  =
NLB9  =               CLB9  =        SLB9  =        PLB9  =
NLB10 =               CLB10 =        SLB10 =        PLB10 =
NLB11 =               CLB11 =        SLB11 =        PLB11 =
NLB12 =               CLB12 =        SLB12 =        PLB12 =
NLB13 =               CLB13 =        SLB13 =        PLB13 =
NLB14 =               CLB14 =        SLB14 =        PLB14 =
NLB15 =               CLB15 =        SLB15 =        PLB15 =
NLB16 =               CLB16 =        SLB16 =        PLB16 =
DP1_1 =BREAKER CLOSED   DP1_0 =BREAKER OPEN

Press RETURN to continue
DP2_1 =CHANNEL X ALARM  DP2_0 =
DP3_1 =CHANNEL Y ALARM  DP3_0 =
DP4_1 =                 DP4_0 =
DP5_1 =                 DP5_0 =
DP6_1 =                 DP6_0 =
DP7_1 =                 DP7_0 =
DP8_1 =                 DP8_0 =
DP9_1 =                 DP9_0 =
DP10_1=                 DP10_0=
DP11_1=                 DP11_0=
DP12_1=                 DP12_0=
DP13_1=                 DP13_0=
DP14_1=                 DP14_0=
DP15_1=                 DP15_0=
DP16_1=                 DP16_0=
=>>

=>>
```

```
=>>SHO X <Enter>
EADDCX= Y        TA_X  = 1        RA_X  = 2
RBADXP= 1        AVAXP = 10       DBADXP= 10
TIMRX = E
=>>

=>>
```

```
=>>SHO Y <Enter>
EADDCY= Y        TA_Y  = 3        RA_Y  = 4
RBADYP= 1        AVAYP = 10       DBADYP= 10
TIMRY = E

=>>
```

STA Command (Relay Self-Test Status)

The **STA** command displays the status report, showing the relay self-test information.

To view a status report, enter the command:

```
=>>STA n <Enter>
```

where *n* is an optional parameter to specify the number of times (1–32767) to repeat the status display. If *n* is not specified, the status report is displayed once. The output of an SEL-311M is shown:

```
=>STA <Enter>

SEL-311M                          Date: 06/01/01    Time: 21:43:05.997
EXAMPLE: BUS B, BREAKER 3

FID=SEL-311M-R100-V0-Z001001-D20010625       CID=BAFD

SELF TESTS

W=Warn    F=Fail

       IA      IB      IC      IN      VA      VB      VC      VS      MOF
OS     0       1       0       1       1       1       1      -0       1

       +5V_PS  +5V_REG -5V_REG +12V_PS -12V_PS +15V_PS -15V_PS
PS      4.91    4.98   -5.00    12.00  -12.05   14.80  -14.71

MB     TEMP    RAM     ROM     A/D     CR_RAM  EEPROM
        36.8   OK      OK      OK      OK      OK

87L    RAM     ROM     CHAN X  CHAN Y  FPGA    BOARD
       OK      OK      OK      N/A     OK      OK

 Relay Enabled       Line Current Differential Protection Disabled

=>
```

STA Command Row and Column Definitions

FID	FID is the firmware identifier string. It identifies the firmware revision.
CID	CID is the firmware checksum identifier.
OS	OS = Offset; displays measured dc offset voltages in millivolts for the current and voltage channels. The MOF (master) status is the dc offset in the A/D circuit when a grounded input is selected.
PS	PS = Power Supply; displays power supply voltages in Vdc for the power supply outputs.
TEMP	Displays the internal relay temperature in degrees Celsius.
RAM, ROM, CR_RAM (critical RAM), and EEPROM	These tests verify that the relay memory components are functional. The columns display OK if memory is functioning properly; the columns display FAIL if the memory area has failed.
A/D	Analog to Digital converter status.
CHAN X	Indicates present status of 87L Channel X. FAIL indicates an active channel has a problem. OK indicates an active channel is functional. N/A indicates that channel is not active.
CHAN Y	Indicates present status of 87L Channel Y. FAIL indicates an active channel has a problem. OK indicates an active channel is functional. N/A indicates that channel is not active.
FPGA	Indicates health of the FPGA on the dedicated 87L hardware. FAIL indicates a problem.

BOARD	Indicates the health of the dedicated 87L hardware. FAIL indicates a problem.
Relay Enabled/Relay Disabled	Indicates the status of the backup protection. If backup protection is Disabled, 87L protection is also disabled.
Line Current Differential Protection Disabled/Enabled	Indicates the status of 87L protection. If 87L protection is disabled, backup protection may still be enabled and functional. W (Warning) or F (Failure) is appended to the values to indicate an out-of-tolerance condition.

The relay latches all self-test warnings and failures in order to capture transient out-of-tolerance conditions. To reset the self-test statuses, use the **STA C** command from Access Level 2:

```
=>>STA C <Enter>
```

The relay responds:

```
Reboot the relay and clear status
Are you sure (Y/N) ?
```

If you select "N" or "n," the relay displays:

```
Canceled
```

and aborts the command.

If you select "Y," the relay displays:

```
Rebooting the relay
```

The relay then restarts (just like powering down, then powering up the relay), and all diagnostics are rerun before the relay is enabled.

Refer to *Section 11: Testing and Troubleshooting* for self-test thresholds (in *Table 11.5*) and corrective actions.

SUM Command (Long Summary Event Report)

The **SUM** command displays a long summary event report (see *TRI Command (Trigger Event Report) on page 8.41*). The long summary event report is displayed on all ports with AUTO = Y whenever an event is generated.

To view a summary event report, enter the command

```
=>SUM |ACK| n | N(ext) | <Enter>
```

where:

no parameters	Display the newest chronological summary event.
ACK	Acknowledge the oldest unacknowledged summary event report available on this port, or if a number is supplied, acknowledge the specified summary.
n	Display (or acknowledge if ACK present) the summary event with this corresponding number in the **HIS E** command.
N(ext)	View oldest unacknowledged summary event report.

TAR Command (Display Relay Element Status)

The **TAR** command displays the status of front-panel target LEDs or relay elements, whether they are asserted or deasserted. The elements are represented as Relay Word bits and are listed in rows of eight, called Relay Word rows. The first two rows correspond to *Table 8.9*. All rows of the Relay Word are described in *Section 7: Settings*.

A Relay Word bit is either at a logical 1 (asserted) or a logical 0 (deasserted). Relay Word bits are used in SELOGIC control equations. See *Section 7: Settings* and *Section 5: SELOGIC Control Equation Programming*.

The **TAR** command does not remap the front-panel target LEDs, as is done in some previous SEL relays. But execution of the equivalent **TAR** command via the front-panel display does remap the bottom row of the front-panel target LEDs (see *Figure 9.3*, pushbutton **{OTHER}**).

The **TAR** command options are:

TAR Commands	Function
TAR *n k*	Shows Relay Word row number *n* (0–67). Value *k* is an optional parameter to specify the number of times (1–32767) to repeat the Relay Word row display. If *k* is not specified, the Relay Word row is displayed once.
TAR *name k*	Shows Relay Word row containing Relay Word bit name (e.g., **TAR 50P1** displays Relay Word Row 4). Valid names are shown in *Table 7.5* and *Table 7.6*. The value *k* is an optional parameter to specify the number of times (1–32767) to repeat the Relay Word row display. If *k* is not specified, the Relay Word row is displayed once.
TAR R	Clears front-panel tripping target LEDs; TRIP, TIME, COMM, 87, 50/51, 27, 59, 32, 81. Unlatches the trip logic for testing purposes (see *Figure 4.3*). Shows Relay Word Row 0.

Table 8.9 SEL-311M Relay Word and Its Correspondence to TAR Command

TAR 0 (Front-Panel LEDs)	EN	TRIP	TIME	COMM	87	50_51	27	59
TAR 1 (Front-Panel LEDs)	A	B	C	G	32	81	25	87CH FAIL

Command **TAR 50P1 10** is executed in the following example:

```
=>>TAR 50P1 10

50P1   50P2   50P3   50P4   50NG1  50NG2  50NG3  50NG4
0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0

50P1   50P2   50P3   50P4   50NG1  50NG2  50NG3  50NG4
0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0

=>>
```

Note that the Relay Word row containing the 50P1 bit is repeated 10 times. Command **TAR 4** will report the same data, because the 50P1 bit is in Row 4 of the Relay Word.

TIM Command (View/Change Time)

TIM displays the relay clock. To set the clock, type **TIM** and the desired setting, then press **<Enter>**. Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes. To set the clock to 11:30 PM enter:

NOTE: After setting date or time, allow at least 60 seconds before powering down the relay or the new setting may be lost.

```
=>TIM 23:30:00 <Enter>
23:30:00
=>
```

TRI Command (Trigger Event Report)

Issue the **TRI** command to generate an event report:

```
=>TRI <Enter>
Triggered

=>
```

If the serial port AUTO setting = Y, the relay sends the summary event report:

```
=>>

SEL-311M                          Date: 11/21/03    Time: 10:32:57.994
EXAMPLE: BUS B, BREAKER 3

Event: TRIG                                           Trip Time: --:--:--.---
#: 00005           Freq:  60.00  Group: 1         Close Time: --:--:--.---
Targets:                                                        Breaker: Open

              Local                Channel X               Channel Y
PreFault:   IA    IB    IC   3I2    IA    IB    IC   3I2    IA    IB    IC   3I2
MAG(A)    1028  1028  1030     4  1028  1019  1012    14 XXXXX XXXXX XXXXX XXXXX
ANG(DEG)-160.9  79.0 -40.7-168.2  19.5-100.8 139.5 -74.2 XXX.X XXX.X XXX.X XXX.X
Fault:
MAG(A)    1028  1028  1031     4  1029  1016  1014    10 XXXXX XXXXX XXXXX XXXXX
ANG(DEG)-161.2  78.8 -41.0 125.8  18.9-101.1 139.1 -74.2 XXX.X XXX.X XXX.X XXX.X
```

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```
              Local             Channel X         Channel Y
PreFault:    IN    IG   3V0    IN    IG   3V0    IN    IG   3V0
MAG(kV/A)     0     6     0     0     9     0 XXXXX XXXXX XXXXX
ANG(DEG) -14.22 132.1-135.0-135.0 -3.74-135.0 XXX.X XXX.X XXX.X
Fault:
MAG(kV/A)     1     6     1     0    11     0 XXXXX XXXXX XXXXX
ANG(DEG)  75.78 120.8-159.1-135.0   1.1-158.0 XXX.X XXX.X XXX.X
87L Channel Status
                                                   RX       TX       RY       TY
                                             87654321 87654321 87654321 87654321
TRIG     Channel X:  OK      Channel Y:      00000000 00000000 00000000 00000000

                                         Local
PreFault:     IA     IB     IC     IN     IG    3I2       VA       VB       VC
MAG(A/kV)   1004   1005   1009      0      6      0  131.440  132.280  132.020
ANG(DEG)    0.00-120.20 119.94 -14.22 132.09 -93.22     0.00  -119.98   120.02
Fault:
MAG(A/kV)   1005   1006   1009      1      6      0  131.440  132.280  132.010
ANG(DEG)   -0.24-120.43 119.66  75.78 120.78 -10.22    -0.08  -120.07   119.93

=>>
```

See *Section 10: Analyzing Events* for more information on event reports.

Recall this event summary with the **SUM** command.

Access Level B Commands

BRE n Command (Preload/Reset Breaker Wear)

Use the **BRE W** command to preload breaker monitor data.

```
==>BRE W <Enter>
Breaker Wear Preload

Internal Trips (0-65000)            ITRIP   =     0        ?  11 <Enter>
Internal Current (0.00-99999 kA)    IA      = 0.00         ?  40.7 <Enter>
                                    IB      = 0.00         ?  40.8 <Enter>
                                    IC      = 0.00         ?  40.8 <Enter>

External Trips (0-65000)            EXTRIP  =     0        ?  3 <Enter>
External Current (0.00-99999 kA)    IA      = 0.00         ?  0.8 <Enter>
                                    IB      = 0.00         ?  0.9 <Enter>
                                    IC      = 0.00         ?  1.1 <Enter>

Percent Wear (0-100%)               A-phase = 0            ?  25 <Enter>
                                    B-phase = 0            ?  28 <Enter>
                                    C-phase = 0            ?  24 <Enter>
Are you sure (Y/N) ? Y <Enter>

SEL-311M                        Date: 05/10/02    Time: 13:14:56.631
EXAMPLE: BUS B, BREAKER 3

Rly Trips=     11
 IA=     40.7 IB=     40.8 IC=     40.8 kA
Ext Trips=      3
 IA=      0.8 IB=      0.9 IC=      1.1 kA
Percent wear: A=  25 B=  28 C=  24

LAST RESET 00/00/00 00:00:00
==>
```

Use the **BRE R** command to reset the breaker monitor:

```
==>BRE R <Enter>

Reset Trip Counters and Accumulated Currents/Wear
Are you sure (Y/N) ? Y <Enter>

SEL-311M                        Date: 10/13/99    Time: 10:12:45.627
EXAMPLE: BUS B, BREAKER 3

Rly Trips=      0
 IA=        0.0 IB=        0.0 IC=        0.0 kA
```

(Continued on next page)

(Continued from previous page)

```
Ext Trips=      0
 IA=        0.0 IB=        0.0 IC=        0.0 kA

Percent wear: A=   0 B=   0 C=   0

LAST RESET 02/03/99 05:41:07
==>
```

See *Breaker Monitor on page 6.10* for further details on the breaker monitor.

CLO Command (Close Breaker)

The **CLO** command asserts Relay Word bit CC for 1/4 cycle. Relay Word bit CC can then be programmed into the SELOGIC control equation CL to assert the CLOSE Relay Word bit, which in turn asserts an output contact (e.g., OUT102 = CLOSE) to close a circuit breaker.

See *Close Logic on page 4.25* for more information concerning Relay Word bit CC and its recommended use, as used in the factory settings.

To issue the **CLO** command, enter the following:

```
==>CLO <Enter>
Close Breaker  (Y/N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
==>
```

Typing **N <Enter>** after either of the above prompts will abort the command.

The **CLO** command is supervised by the main board Breaker jumper (see *Table 2.4*). If the Breaker jumper is not in place (Breaker jumper = OFF), the relay does not execute the **CLO** command and responds:

```
Aborted: No Breaker Jumper
```

GRO n Command (Change Active Setting Group)

The **GRO** command displays the active settings group. The **GRO *n*** command changes the active setting group to setting Group *n*. To change to settings Group 2, enter the following:

```
==>GRO 2
Change to Group 2
Are you sure (Y/N) ? Y <Enter>
 Changing
Active Group = 2
==>
```

The relay switches to Group 2 and pulses the **ALARM** contact. If the serial port AUTO setting = Y, the relay sends the group switch report:

```
==>
SEL-311M                         Date: 10/13/99    Time: 10:12:45.627
EXAMPLE: BUS B, BREAKER 3

Active Group = 2
==>
```

If any of the SELOGIC control equations settings SS1–SS6 are asserted to logical 1, the active setting group may not be changed with the **GRO** command. SELOGIC control equations settings SS1–SS6 have priority over the **GRO** command in active setting group control.

For example, assume setting Group 1 is the active setting group and the SS1 setting is asserted to logical 1 (e.g., SS1 = IN101 and optoisolated input IN101 is asserted). An attempt to change to setting Group 3 with the **GRO 3** command will not be accepted:

```
==>GRO 3 <Enter>
Change to Group 3
Are you sure (Y/N) ? Y <Enter>
  Changing
No group change (see manual)
Active Group = 1
==>
```

For more information on setting group selection, see *Multiple Setting Groups on page 5.14*.

OPE Command (Open Breaker)

The **OPE** command asserts Relay Word bit OC for 1/4 cycle when it is executed. Relay Word bit OC can then be programmed into the SELOGIC control equation TR to assert the TRIP Relay Word bit, which in turn asserts an output contact (e.g., OUT101 = TRIP) to trip a circuit breaker. See *Figure 4.14*.

To issue the **OPE** command, enter the following:

```
==>OPE <Enter>
Open Breaker  (Y/N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
==>
```

Typing **N <Enter>** after either of the above prompts will abort the command.

The **OPE** command is supervised by the main board Breaker jumper (see *Table 2.4*). If the Breaker jumper is not in place (Breaker jumper = OFF), the relay does not execute the **OPE** command and responds:

```
Aborted: No Breaker Jumper
```

PUL Command (Pulse Output Contact)

The **PUL** command allows you to pulse any of the output contacts for a specified length of time. The command format is:

PUL *x y*

where:

x = the output name (e.g. OUT101, OUT107, ALARM, OUT206—see *Figure 5.14*).

y = is the pulse duration (1–30 seconds). If *y* is not specified, the pulse duration defaults to 1 second.

To pulse OUT101 for 5 seconds:

```
==>PUL OUT101 5 <Enter>
Are you sure (Y/N) ? Y <Enter>
==>
```

If the response to the `Are you sure (Y/N) ?` prompt is `N` or `n`, the command is aborted.

The **PUL** command is supervised by the main board Breaker jumper (see *Table 2.4*). If the Breaker jumper is not in place (Breaker jumper = OFF), the relay does not execute the **PUL** command and responds:

```
Aborted:  No Breaker Jumper
```

The relay generates an event report if any of the OUT101–OUT107 or OUT201–OUT206 contacts are pulsed. The **PUL** command is primarily used for testing purposes.

Access Level 2 Commands

CON Command (Control Remote Bit)

The **CON** command is a two-step command that allows you to control Relay Word bits RB1–RB16. At the Access Level 2 prompt, type **CON**, a space, and the number of the remote bit you wish to control (1–16). The relay responds by repeating your command followed by a colon. At the colon, type the Control subcommand you want to perform (see *Table 8.10*).

The following example shows the steps necessary to pulse Remote Bit 5 (RB5):

```
=>>CON 5 <Enter>
CONTROL RB5: PRB 5 <Enter>
=>>
```

You must enter the same remote bit number in both steps in the command. If the bit numbers do not match, the relay responds `Invalid Command`.

Table 8.10 SEL-311M CON Subcommands

Subcommand	Description
SRB *n*	Set Remote Bit *n* (“ON” position)
CRB *n*	Clear Remote Bit *n* (“OFF” position)
PRB *n*	Pulse Remote Bit *n* for 1/4 cycle (“MOMENTARY” position)

See *Remote Bits on page 5.13* for more information.

COP m n Command (Copy Setting Group)

Copy relay and SELOGIC control equation settings from setting Group *m* to setting Group *n* with the **COP m n** command. Setting group numbers range from 1 to 6. After entering settings into one setting group with the **SET** and

SET L, commands, copy them to the other groups with the **COP** command. Use the **SET** and **SET L** commands to modify the copied settings. The **ALARM** output pulses if you copy settings into the active group.

For example, to copy settings from Group 1 to Group 3 issue the following command:

```
=>>COP 1 3 <Enter>
Copy 1 to 3
Are you sure (Y/N) ? Y <Enter>

Please wait...
Settings copied
=>>
```

FIL WRITE (Write File to Relay)

FILE WRITE [[*directory*]*filename*] initiates a file transfer from the computer to the relay, where *directory*, if specified, is the file location and *filename* is the name of the file involved in the transfer. The YModem transfer protocol is used.

This command is commonly used in two distinct ways: to upload settings files to the relay (if valid, the relay changes its settings accordingly) and to upload events in IEEE Comtrade format for use with the **PLAY** command.

The **FILE WRITE** command gives a convenient way to enter identical settings into a large number of relays. First, enter the desired settings in one relay using the **SET** command. Then use the **FILE READ** command to retrieve the desired files from the SETTINGS directory:

SET_G.TXT:	global settings
SET_T.TXT:	text settings
SET_R.TXT:	sequential events recorder (SER) settings
SET_X.TXT:	fiber-optic channel X
SET_Y.TXT:	fiber-optic channel Y
SET_P1.TXT:	port one settings
...	
SET_P4.TXT:	port four settings
SET_1.TXT:	group one settings
SET_L1.TXT:	group one logic settings
...	
SET_6.TXT:	group six settings
SET_L6.TXT:	group six logic settings

Once the desired files are downloaded to the computer, connect to another relay and use the **FILE WRITE** command to upload them. The relay will use the new settings if they are valid, or display an error message if they are not.

To upload Comtrade event files for playback, first upload the .CFG file to the EVENTS directory, then upload the corresponding .DAT file. (See the *PLA Command (Event Playback) on page 8.48* for information on file requirements.) One common error is uploading an event file whose length (number of cycles) does not match the relay's global event report length setting (SET G LER).

If an invalid Comtrade .CFG is loaded using the **FILE WRITE** command, the relay will respond with the following:

```
=>>FILE WRITE EVENTS ANA_ERR.CFG <Enter>  Transfer Aborted - Error in file
```

If you then use the **FILE SHOW** command to view the err.txt created by the relay, you will see a description of the invalid file content.

```
=>>FILE SHOW EVENTS ERR.TXT <Enter>
Error at ROW 3, near ITEM 0 ("3"):
Invalid Channel Number - invalid or out of sequence
```

If an err.txt file is not created by the relay, there is a communications error. The relay generates an err.txt file only when the relay is able to begin receiving the Comtrade file.

If the file transfer to the relay is successful, the relay responds as follows:

```
=>>FILE WRITE EVENTS EVENT1.CFG <Enter>  Transfer Complete
```

The Comtrade .CFG file must be loaded before the .DAT file.

The relay only supports baud rates less than or equal to 19200 for writing files to the relay.

L_D (Load New Firmware)

Use the **L_D** command to load new firmware into the relay. See *Appendix B: Firmware Upgrade Instructions* for the use of the **L_D** command.

LOO Command (Enable MIRRORED BITS Loopback Testing)

The **LOO** command is used for testing the MIRRORED BITS communications channel. For more information on MIRRORED BITS, see *Appendix D: MIRRORED BITS Communications*. With the transmitter of the communications channel physically looped back to the receiver, the MIRRORED BITS addressing will be wrong and ROK will be deasserted. The **LOO** command tells the MIRRORED BITS software to temporarily expect to see its own data looped back as its input. In this mode, LBOK will assert if error-free data are received.

The **LOO** command with just the channel specifier, enables looped-back mode on that channel for 5 minutes, while the inputs are forced to the default values.

```
=>>LOO A <Enter>
Loopback will be enabled on Mirrored Bits channel A for the next 5 minutes.
The RMB values will be forced to default values while loopback is enabled
Are you sure (Y/N) ?
```

If only one MIRRORED BITS port is enabled, the channel specifier may be omitted. To enable looped-back mode for other than the default 5 minutes, enter the desired number of minutes (1–5000) as a command parameter. To allow the looped-back data to modify the RMB values, include the DATA parameter.

```
=>>LOO 10 DATA <Enter>
Loopback will be enabled on Mirrored Bits channel A for the next 10 minutes.
The RMB values will be allowed to change while loopback is enabled
Are you sure (Y/N) ? N <Enter>
Canceled
=>>
```

To disable looped-back mode before the selected number of minutes, re-issue the **LOO** command with the R parameter. If both MIRRORED BITS channels are enabled, omitting the channel specifier in the disable command will cause both channels to be disabled.

```
=>>LOO R <Enter>
Loopback is disabled on both channels.
=>>
```

PAS Command (View/Change Passwords)

For details on the **PAS** command, see *Using and Changing SEL-311M Relay Passwords on page 8.15*.

PLA Command (Event Playback)

To configure the relay for event playback, issue the **PLAY** command:

PLAY <filename>[A][C][D][MA][MB][O bbbbbbb][E ele|T time]

where:

filename	name of COMTRADE .DAT file within relay file system
A	include analogs IA, IB, IC, IN, VA, VB, VC, VS, VDC (this includes frequency data)
C	include remote bits (RB1–RB16), local bits (LB1–LB16), and the **OPEN** Command bit (OC) and **CLOSE** Command bit (CC)
D	include digital inputs (IN101–IN106)
MA	include received MIRRORED BITS for MIRRORED BITS channel A (RMB1A–RMB8A, ROKA)
MB	include received MIRRORED BITS for MIRRORED BITS channel B (RMB1B–RMB8B, ROKB)
O *bbbbbbb*	drive outputs during playback according to the string *bbbbbbb*, where the first *b* represents OUT101 and the last OUT107 and *b* can be o, c, x, or * to signify holding contact open, holding contact closed, holding it in its current state, or driving it normally during playback
E ele(ment)	trigger on element ele (with timeout)
T time	trigger at given time (time has same format as **TIME** command parameter: hh:mm:ss, where hh = hours, mm = minutes, ss = seconds)

If both the **E** (element trigger) and **T** (time trigger) parameters are used, the relay responds with the following error message:

```
Conflicting triggers entered (both Element and Time specified)
```

If no trigger is provided via **E** or **T** parameters, playback starts five seconds after verification. If no playback items are specified (**A/C/D/MA/MB/O**), the **PLAY** command defaults to playback analogs and digitals with output contacts driven normally. If no playback parameters are specified (**<filename>/A/C/D/MA/MB/O/E/T**), the **PLAY** command displays the status of last requested event playback.

The relay supports the **PLAY** command at Access Level 1 and above. If you define playback parameters, the relay must be at Access Level 2 or above.

If a trigger time is specified that is prior to the current time, the relay assumes that the trigger time applies to the following day. If the trigger time is more than 30-minutes from current time, the relay displays the following message and aborts the command.

```
Trigger time invalid - already past or too far ahead
```

If a trigger time is specified within five seconds of midnight (before or after), the relay displays the following message and aborts the command.

```
Trigger time invalid - too close to midnight
```

Playback

When a **PLAY** command creates a new playback trigger, the relay responds with status information and a verification prompt as shown in *Figure 8.7*.

```
SEL-311M                          Date: 01/27/04    Time: 18:09:39.455
EXAMPLE: BUS B, BREAKER 3

FILE            DATE       TIME      EVENT  DEVICE
ER_10003.DAT  01/27/04 18:07:25.169 ER     SEL-311M

PLAYBACK TRIGGER: 5 seconds after verification

DATA SOURCES
----------------------------------------
Analogs     Digitals    Cmd Bits    MBits A     MBits B
Playback    Playback    External    External    External

OUTPUT CONTROL
----------------------------------------
OUT101    OUT102    OUT103    OUT104    OUT105    OUT106    OUT107
Normal    Normal    Normal    Normal    Normal    Normal    Normal


Perform Event Playback as described above.  Are you sure (Y/N)?
```

Figure 8.7 Event Playback Verification Prompt

If the **PLAY** command is issued and a playback trigger is already set up or playback is already executing, the relay displays the following message and aborts the command.

```
Playback already pending or executing (Cancel current Playback or wait for
    completion)
```

Canceling Playback

Canceling playback clears the trigger associated with the data. If event playback is in progress, the cancel does not stop currently executing playback.

Use the **PLA X** command to cancel pending event playback. The relay responds to a cancel request with the following validation prompt.

```
Cancel any pending Event Playback.  Are you sure (Y/N)?
```

After your verification, if there is no event playback pending (Playback never set up or Playback already completed or canceled), the relay responds with the following message.

```
No Event Playback pending
```

After the cancel actions are completed (regardless of whether any Playback was actually canceled), the relay displays basic playback status information as shown in *Figure 8.8*.

```
SEL-311M                          Date: 01/27/04    Time: 18:08:17.245
EXAMPLE: BUS B, BREAKER 3

Event Playback Status: CANCELED

FILE            DATE       TIME      EVENT  DEVICE

ER_10003.DAT  01/27/04 18:07:25.169 ER     SEL-311M

PLAYBACK TRIGGER: 01/27/04 18:08:00.000
```

Figure 8.8 Canceled Playback Status Information

Playback Status

The **PLAY** status command displays the current playback status as shown in *Figure 8.9*.

```
SEL-311M                          Date: 01/27/04    Time: 18:09:52.616
EXAMPLE: BUS B, BREAKER 3

Event Playback Status: PENDING

FILE            DATE       TIME      EVENT  DEVICE
ER_10003.DAT  01/27/04 18:07:25.169 ER     SEL-311M

PLAYBACK TRIGGER: 01/27/04 18:08:00.000

DATA SOURCES
----------------------------------------
Analogs     Digitals    Cmd Bits    MBits A     MBits B
Playback    Playback    External    External    External

OUTPUT CONTROL
----------------------------------------
OUT101    OUT102    OUT103    OUT104    OUT105    OUT106    OUT107
Normal    Normal    Normal    Normal    Normal    Normal    Normal
```

Figure 8.9 Playback Status Information

The `Event Playback Status` has possible values of `NONE`, `PENDING`, `ACTIVE`, `COMPLETE`, `TIMED-OUT`, and `CANCELED`. When `Event Playback Status` is `NONE`, no other information is displayed.

The `PLAYBACK TRIGGER` field has two possible forms:

- element trigger with timeout
- time trigger

Examples are shown in *Figure 8.10*.

```
PLAYBACK TRIGGER: element RB2 with time-out at 07/07/03 16:09:40.864

(Playback is initiated by Relay Word bit RB2 time-out)

PLAYBACK TRIGGER: 07/07/03 11:45:00.000
(Playback is initiated at 11:45:00.000 on 7/7/03)
```

Figure 8.10 Playback Trigger Examples

As shown in a previous example, a third form of playback trigger display is possible during the **PLAY** command. If you do not specify a trigger condition, the `PLAYBACK TRIGGER` field display appears as shown below. This form will not occur during the PLAY status display because a fixed trigger time is in place, resulting in the date/time display format shown above.

```
PLAYBACK TRIGGER: 5 seconds after verification
```

Within the Playback Status display, the `Event` field value displays as `$$$$$$` in the case of user-loaded events.

When event playback completes, the relay returns to normal operation without any required actions.

SET Command (Change Settings)

The **SET** command allows the user to view or change the relay settings—see *Section 7: Settings*.

TST Command (Differential Channel Testing)

The **TST** command is used for configuring the differential channels for testing. By itself, the **TST** command will give normal or test mode status of the differential channels, as shown below.

NOTE: Because the current from the local relay will be looped back into the relay, it is important to remove the relay from trip circuits prior to putting it into the TST mode.

```
=>>TST <Enter>
Channel X: Test Mode
Channel Y: Test Mode
```

When followed by the channel designation (**TST X** or **TST Y**), a dialog will begin to put the channel into a loopback back-to-back or end-to-end test, as shown below.

```
=>>TST X <Enter>
Entering Test Mode on Channel X.

WARNING!!!  Tripping is enabled in test mode.  !!!WARNING
Press Ctrl X now to abort. Type "TST X C" to end test mode.

  Enable Loop-Back: Internal, External or None (I,E,N)   ? I <Enter>
  Test Mode Duration: 1 - 30 min. or Infinite (1-30,INF) ? 20 <Enter>

Are you sure (Y/N) ? Y <Enter>
Test Mode Enabled on Channel X.
Channel X: Test Mode
Channel Y: Normal Mode
=>>
```

VER Command (View Version Information)

Use the **VER** command to display version information about the relay.

```
=>>VER <Enter>
Partnumber: 0311M0HC035A4XX

Mainboard: 0311
Appearance: Horizontal, Conventional
Data FLASH Size:  1024 KBytes
Analog Input Voltage (PT): 300 Vac, wye-connected
Analog Input Current (CT): 1 Amp Phase, 0.2 Amp Pol
Channel X Configuration: IEEE C37.94
Channel Y Configuration: None
Extended Relay Features:
  Power Elements
  Mirrored Bits

  Enhanced Integration Bits

SELboot checksum F267 OK
FID=SEL-311M-R100-V0-Z003002-D20031117

SELboot-311M-R100

If above information is unexpected. . .
contact SEL for assistance
=>>
```

SEL-311M Relay Command Summary

Command	Description
2AC	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 2 password in order to enter Access Level 2.
ACC	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 1 password in order to enter Access Level 1.
BAC	Enter Breaker Access Level (Access Level B). If the main board password jumper is not in place, the relay prompts for entry of the Access Level B password.
BRE	Display breaker monitor data (trips, interrupted current, wear).
BRE *n*	Enter **BRE W** to preload breaker wear. Enter **BRE R** to reset breaker monitor data.
CAS	Compressed ASCII configuration data.
CEV [n Sx Ly L R C]	Compressed event report (parameters in [ ] are optional)
where: ***n***	event number (1–39 if LER = 15; 1–15 if LER = 30; defaults to 1).
S*x*	*x* samples per cycle (4 or 16); defaults to 4. If S*x* parameter is present, it overrides the L parameter.
L*y*	*y* cycles event report length (1–LER) for filtered event reports, (1–LER + 1) for raw event reports, defaults to 15 if not specified.
L	16 samples per cycle; overridden by the S*x* parameter, if present.
R	specifies raw (unfiltered) data; defaults to 16 samples per cycle unless overridden by the S*x* parameter. Defaults to 16 cycles in length unless overridden with the L*y* parameter.
C	specifies 16 samples per cycle, 15-cycle length.
CHIS	Compressed history.
CLO	Close the circuit breaker. The **CLO** command asserts Relay Word bit CC for 1/4 cycle. Relay Word bit CC can then be programmed into the SELOGIC control equation CL to assert the CLOSE Relay Word bit, which in turn asserts an output contact (e.g., OUT102 = CLOSE) to close a circuit breaker. See *Figure 4.14*. See *Set Close on page 4.26* for more information concerning Relay Word bit CC and its recommended use, as used in the factory settings.
COM *p* L	Show a long format communications summary report for all events on MIRRORED BITS® or Differential Channel *p*.
COM *p n*	Show a communications summary for latest *n* events on MIRRORED BITS or Differential Channel *p*.
COM *p m n*	Show a communications summary report for events *n–m* on MIRRORED BITS or Differential Channel *p*.
COM *p d1*	Show a communications summary report for events occurring on date *d1* on MIRRORED BITS or Differential Channel *p*.
COM *p d1 d2*	Show a communications summary report for events occurring between dates *d1* and *d2* on MIRRORED BITS or Differential Channel *p*. Entry of dates is dependent on the Global Date Format setting DATE_F (= MDY or YMD).
COM C *p*	Clears the communications summary report for Channel *p*.
CON *n*	Control Remote Bit RB*n* (Remote Bit *n*; *n* = 1–16). Execute **CON *n*** and the relay responds: `CONTROL RBn`. Reply with one of the following: **SRB *n*** [set Remote Bit *n* (assert RB*n*)]. **CRB *n*** [clear Remote Bit *n* (deassert RB*n*)]. **PRB *n*** [pulse Remote Bit *n* (assert RB*n* for 1/4 cycle)].
COP *m n*	Copy relay and logic settings from Group *m* to Group *n*.
CST	Compressed status report.
CSU	Compressed event summary.
DAT	Set/show relay date.

Command	Description
DAT m/d/y	Enter date in this manner if Date Format setting DATE_F = MDY.
DAT y/m/d	Enter date in this manner if Date Format setting DATE_F = YMD.
EVE *n*	Show event report number *n* with 1/4-cycle resolution.
EVE L *n*	Show event report number *n* with 1/16-cycle resolution.
EVE R *n*	Show raw event report number *n* with 1/16-cycle resolution.
EVE B *n*	Show event report number *n* for backup elements (not including differential) with 1/4-cycle resolution.
EVE C *n*	Show compressed event report number *n*.
EVE N *n*	Show event report number *n* 87W differential report with 1/4-cycle resolution.
FIL DIR	Initiate a text response containing all of the filenames within a specified directory.
FIL READ	Initiate a file transfer from the relay to the computer for display on the computer.
FIL SHOW	Initiate a file transfer from the relay to the computer.
FIL WRITE	Initiate a file transfer from the computer to the relay.
GRO	Display the active group number.
GRO *n*	Change active group to Group *n*.
HELP	View commands help.
HIS *n*	Show brief summary of the *n* latest event reports.
HIS C	Clear the brief summary and corresponding event reports.
IRI	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
L_D	Load new firmware.
LOO	Set Mirrored Bits port to loopback.
MET *k*	Display instantaneous metering data (currents and alpha plane) for local and remote terminals. Enter *k* for repeat count.
MET B *k*	Display instantaneous metering data for local terminal including voltage. Enter *k* for repeat count.
MET D	Display demand and peak demand data. Enter **MET RD** or **MET RP** to reset.
MET E	Display energy metering data. Enter **MET RE** to reset.
MET M	Display maximum/minimum metering data. Enter **MET RM** to reset.
MET N	Display instantaneous metering data (currents and voltages) for local and remote zero-sequence data.
OPE	Open the circuit breaker. The **OPE** command asserts Relay Word bit OC for 1/4 cycle when it is executed. Relay Word bit OC can then be programmed into the SELogic control equation TR to assert the TRIP Relay Word bit, which in turn asserts an output contact (e.g., OUT101 = TRIP) to trip a circuit breaker. See *Figure 4.3*. See *OPE Command (Open Breaker) on page 8.44* for more information concerning Relay Word bit OC and its recommended use, as used in the factory settings.
PAS	Show existing Access Level 1, B, and 2 passwords.
PAS 1 xxxxxx	Change Access Level 1 password to xxxxxx.
PAS B xxxxxx	Change Access Level B password to xxxxxx.
PAS 2 xxxxxx	Change Access Level 2 password to xxxxxx.
PLA <filename>[A C D MA MB O bbbbbb E ele T Time]	
where: **filename**	name of COMTRADE DAT file within relay file system.
A	include analogs (this includes frequency data).
C	include command bits.
D	include digital inputs.
MA	include Mirrored Bits channel A.

Command	Description
MB	include MIRRORED BITS channel B.
O bbbbbb	drive outputs during playback according to the “binary” string bbbbbb, where the first b represents IN101 and the last IN106, and b can be o, c, x, or * to signify holding contact open, holding contact closed, holding it in its current state, or driving it normally during playback.
E element	trigger on element ele (with timeout).
T Time	trigger at given time (time has same format as **TIME** command parameter: hh:mm:ss, where hh = hours, mm = minutes, ss = seconds). If no trigger is provided via E or T parameters, playback starts five seconds after your verification. If no playback items are specified (A/C/D/MA/MB/O), the command defaults to playback analogs and digitals with output contacts driven to their default (de-energized) state
PUL *n k*	Pulse output contact *n* (OUT101–OUT107, ALARM, OUT201–OUT212) for *k* (1–30) seconds. Parameter *n* must be specified; *k* defaults to 1 if not specified.
QUI	Quit. Returns to Access Level 0. Available in all access levels.
SER *n*	Show the latest *n* rows in the Sequential Events Recorder (SER) event report.
SER *m n*	Show rows *m* through *n* in the Sequential Events Recorder (SER) event report.
SER *d1*	Show rows in the Sequential Events Recorder (SER) event report from *date d1*.
SER *d1 d2*	Show rows in the Sequential Events Recorder (SER) event report from *date d1* to *date d2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY or YMD).
SER C	Clears the Sequential Events Recorder (SER).
SET *n*[a]	Change relay settings (overcurrent, differential, timers, etc.) for Group *n*.
SHO *n*[a]	Show relay settings (overcurrent, differential, timers, etc.) for Group *n*.
STA	Show relay self-test status.
STA C	Resets self-test warnings/failures and reboots relay.
SUM	Show newest event summary.
SUM A	Acknowledge oldest event summary.
SUM N	View oldest unacknowledged event report.
SUM N [A]	Display or acknowledge event summary number “N.”
TAR R	Reset the front-panel tripping targets.
TAR *n k*	Display Relay Word row. If *n* = 0 through 67, display row *n*. If *n* is an element name (e.g., 50NG1) display the row containing element *n*. Enter *k* for repeat count.
TIM	Show or set time (24-hour time). Show time presently in the relay by entering just **TIM**. Example time 22:47:36 is entered with command **TIM 22:47:36**.
TRI	Trigger an event report.
TST {chn}	Test the differential communication channel. If channel (X or Y) is specified, a question string will follow to configure the channel for testing. With no channel identifier, the command will return each channel status.
VER	Display the relay hardware and software configurations

[a] See the table below for **SET/SHOW** options.

SET/SHOW Command Options

Option	Setting Type	Description
G	Global settings	Relay-wide settings
L *n*	Protection Logic Group 1–6	Protection SELOGIC® control equations
P *n*	Port *n*	Communications port settings
R	Report	Event report and SER settings
T	Text	Text label settings
{Blank}	Relay Group 1–6	Group settings

Section 9

Front-Panel Operations

Overview

This section describes how to get information, make settings, and execute control operations from the relay front panel. It also describes the default displays.

Front-Panel Pushbutton Operation

Overview

Note in *Figure 9.1* that most of the pushbuttons have dual functions (primary/secondary).

A primary function is selected first (e.g., **{METER}** pushbutton).

After a primary function is selected, the pushbuttons revert to operating on their secondary functions (**{CANCEL}**, **{SELECT}**, left/right arrows, up/down arrows, **{EXIT}**). For example, after the **{METER}** pushbutton is pressed, the up/down arrows are used to scroll through the front-panel metering screens. The primary functions are activated again when the present selected function (e.g. metering) is exited (press **{EXIT}** pushbutton) or the display goes back to the default display after no front-panel activity for a settable time period (see *Global Settings* ***(Serial Port Command SET G and Front Panel)*** at the end of *Section 7: Settings*; the relay is shipped with FP_TO = 15 minutes).

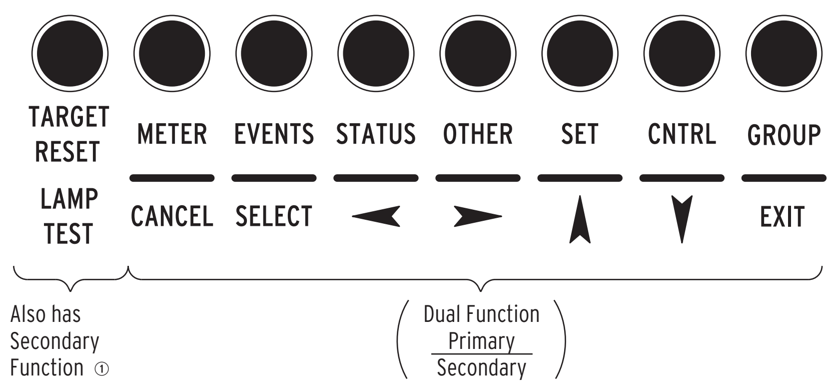


Figure 9.1 SEL-311M Front-Panel Pushbuttons—Overview

① See Figure 9.4.

Primary Functions

Note in *Figure 9.2* and *Figure 9.3* that the front-panel pushbutton primary functions correspond to serial port commands—both retrieve the same information or perform the same function. To get more detail on the information provided by the front-panel pushbutton primary functions, refer to the corresponding serial port commands in *Table 8.6*. For example, to get more information on the metering values available via the front-panel **{METER}** pushbutton, refer to the *MET Command (Metering Data) on page 8.29*.

Some of the front-panel primary functions do not have serial port command equivalents. These are discussed in *Functions Unique to the Front-Panel Interface on page 9.5*.

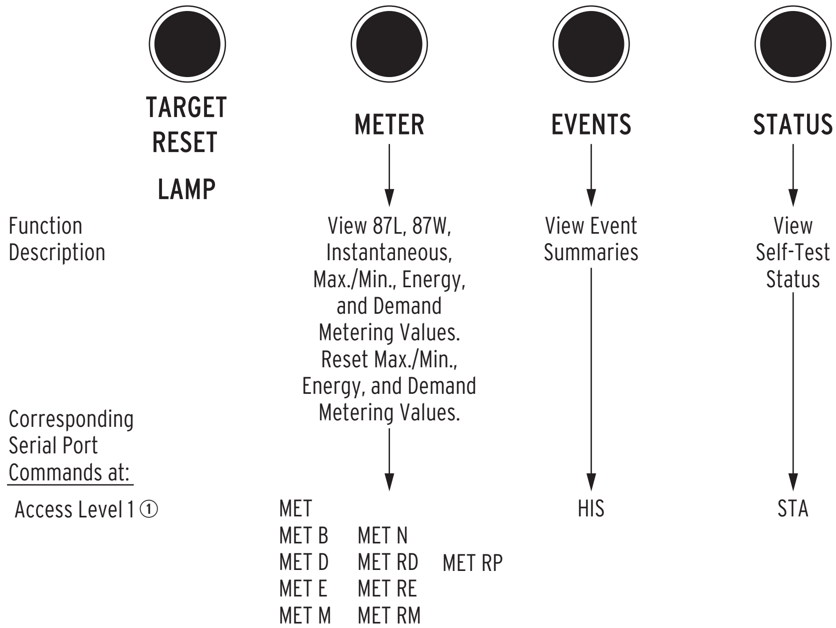


Figure 9.2 SEL-311M Front-Panel Pushbuttons—Primary Functions

① Front-panel pushbutton functions that correspond to Access Level 1 serial port commands do not require the entry of the Access Level 1 password through the front panel.

Front-Panel Password Security

Refer to the comments at the bottom of *Figure 9.3* concerning Access Level B and Access Level 2 passwords. See *PAS Command (View/Change Passwords) on page 8.48* for the list of default passwords and for more information on changing passwords.

To enter the Access Level B and Access Level 2 passwords from the front panel (if required), use the left/right arrow pushbuttons to underscore a password digit position. Then use the up/down arrow pushbuttons to change the digit. Press the **{SELECT}** pushbutton once the correct Access Level B or Access Level 2 password is ready to enter.

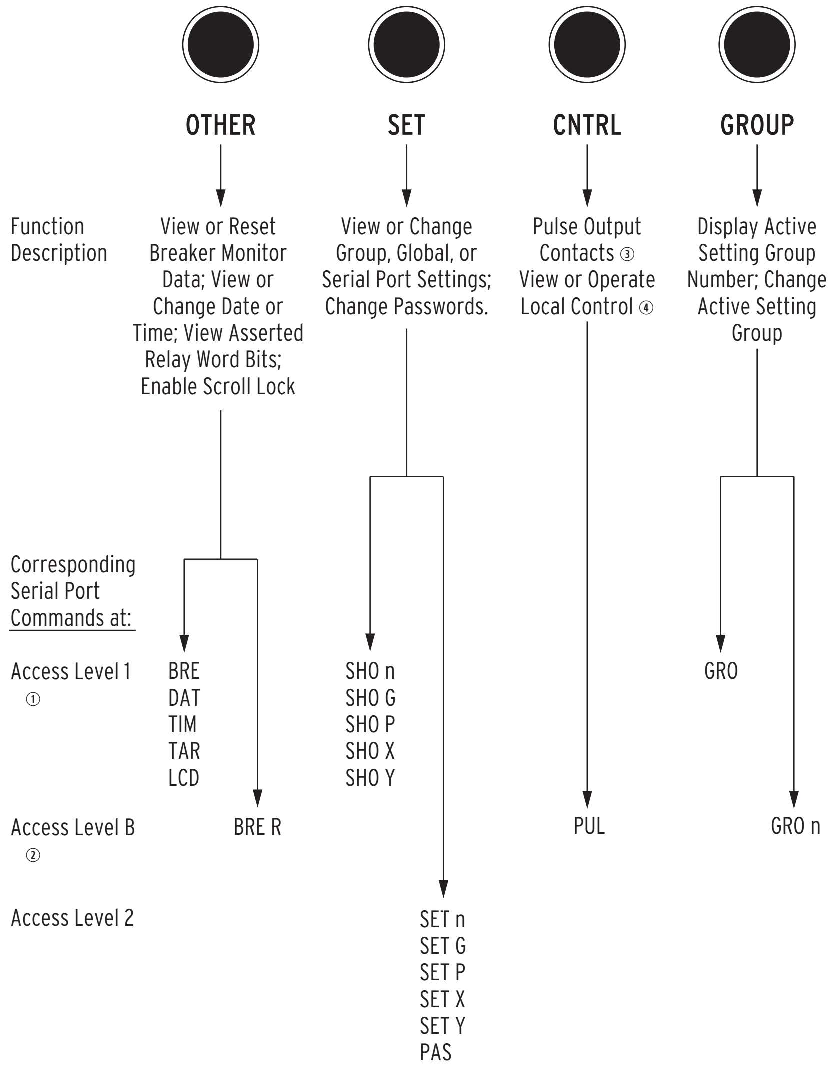


Figure 9.3 SEL-311M Front-Panel Pushbuttons—Primary Functions (Continued)

① Front-panel pushbutton functions that correspond to Access Level 1 serial port commands do not require the entry of the Access Level 1 password through the front panel.

② Front-panel pushbutton functions that correspond to Access Level B or Access Level 2 serial port commands do require the entry of the Access Level B or Access Level 2 passwords through the front panel if the main board Password jumper is not in place (see Table 2.4).

③ Output contacts are pulsed for only one second from the front panel.

④ Local control is not available through the serial port and does not require the entry of a password.

Secondary Functions

After a primary function is selected (see *Figure 9.2* and *Figure 9.3*), the pushbuttons then revert to operating on their secondary functions (see *Figure 9.4*).

When changing settings, use the left/right arrows to underscore a desired function. Then press the **{SELECT}** pushbutton to select the function.

Use left/right arrows to underscore a desired setting digit. Then use the up/down arrows to change the digit. After the setting changes are complete, press the **{SELECT}** pushbutton to select/enable the setting.

Press the {CANCEL} pushbutton to abort a setting change procedure and return to the previous display. Press the {EXIT} pushbutton to return to the default display and have the primary pushbutton functions activated again (see *Figure 9.2* and *Figure 9.3*).

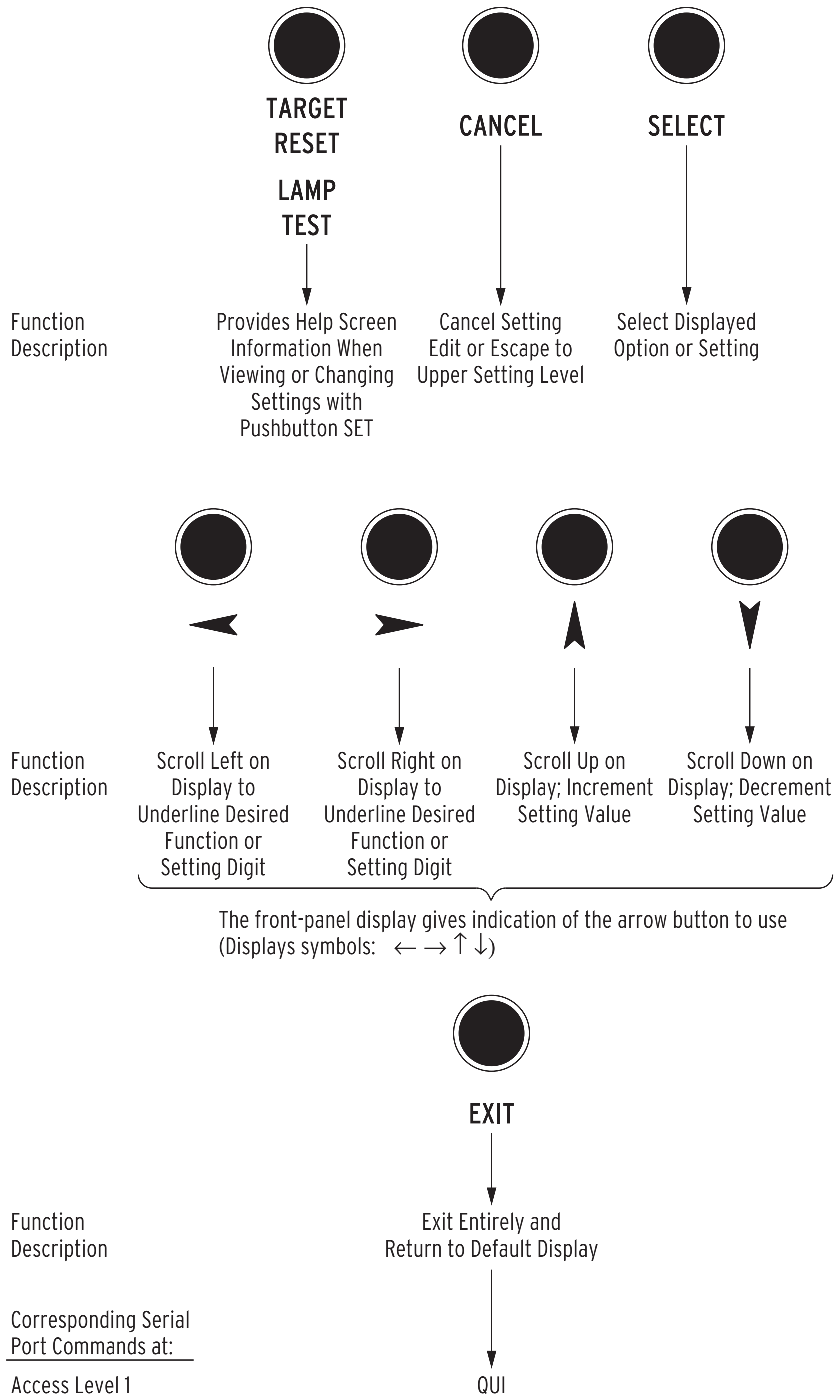


Figure 9.4 SEL-311M Front-Panel Pushbuttons—Secondary Functions

Functions Unique to the Front-Panel Interface

Two front-panel primary functions do not have serial port command equivalents. These are:

- Local control (accessed via the **{CNTRL}** pushbutton)
- Modified rotating display with scroll lock control (accessed via the **{OTHER}** pushbutton)

Local Control

Use local control to enable/disable schemes, trip/close breakers, etc., via the front panel.

In more specific terms, local control asserts (sets to logical 1) or deasserts (sets to logical 0) what are called local bits LB1–LB16. These local bits are available as Relay Word bits and are used in SELOGIC® control equations (see *Table 7.5* and *Table 7.6*).

Local control can emulate the switch types shown in *Figure 9.5*–*Figure 9.7*.

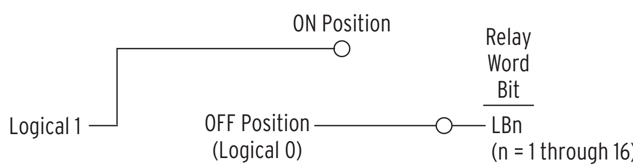


Figure 9.5 Local Control Switch Configured as an ON/OFF Switch

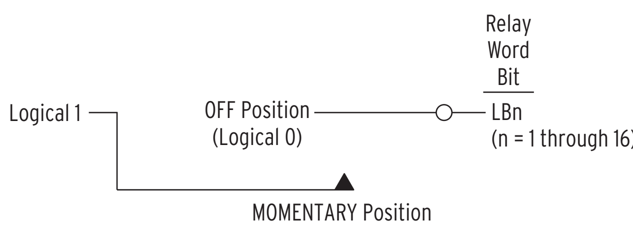


Figure 9.6 Local Control Switch Configured as an OFF/MOMENTARY Switch

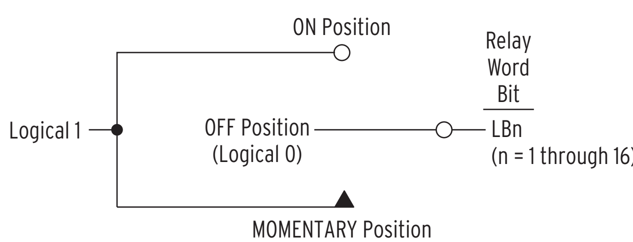


Figure 9.7 Local Control Switch Configured as an ON/OFF/MOMENTARY Switch

Local control switches are created by making corresponding switch position label settings. These text label settings are set with the **SET T** command or viewed with the **SHO T** command via the serial port (see *Section 7: Settings* and *SHO Command (Show/View Settings) on page 8.33*).

View Local Control (with Example Settings)

Access local control via the **{CNTRL}** pushbutton. If local control switches exist (i.e., corresponding switch position label settings were made), the following message displays with the rotating default display messages.

```
Press CNTRL for
Local Control
```

Assume the following settings:

TR = **...+LB3 +...** (Trip setting includes LB3)

CL = **...+ LB4 +...** (Close setting includes LB4)

NLB3 = **MANUAL TRIP**

CLB3 = **RETURN**

PLB3 = **TRIP**

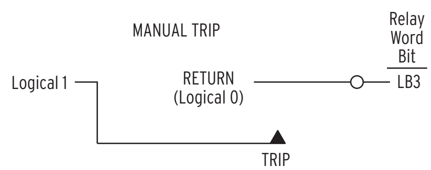
NLB4 = **MANUAL CLOSE**

CLB4 = **RETURN**

PLB4 = **CLOSE**

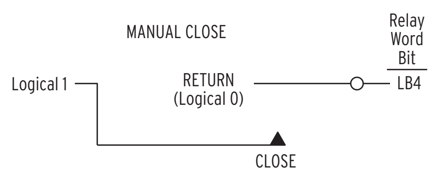
Press the **{CNTRL}** pushbutton, and the first set local control switch displays

```
MANUAL TRIP    ←→
Position: RETURN
```



Press the right arrow pushbutton, and scroll to the next set local control switch:

```
MANUAL CLOSE  ←→
Position: RETURN
```



The `MANUAL TRIP: RETURN/TRIP` and `MANUAL CLOSE: RETURN/CLOSE` switches are both OFF/MOMENTARY switches (see *Figure 9.6*).

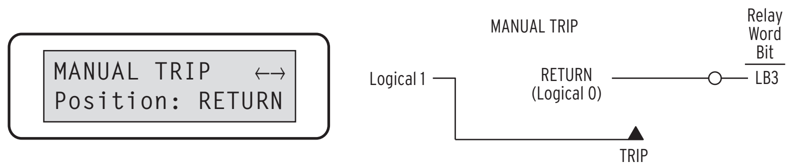
There are no more local control switches in the example setting. Press the right arrow pushbutton, and scroll to the `OUTPUT CONTACT TESTING` function:

```
Output Contact←→
Testing
```

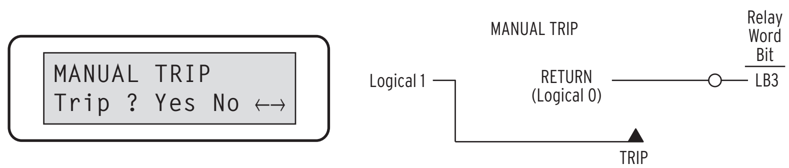
This front-panel function provides the same function as the serial port **PUL** command (see *Figure 9.3*).

Operate Local Control (With Example Settings)

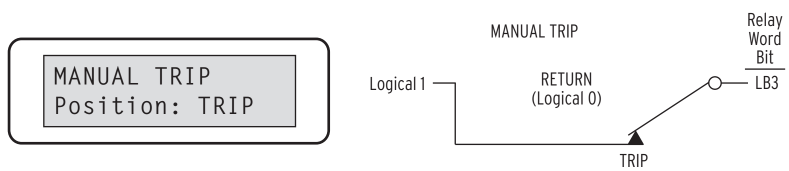
Press the right arrow pushbutton, and scroll back to the first set local control switch in the example settings:



Press the **{SELECT}** pushbutton, and the operate option for the displayed local control switch displays:

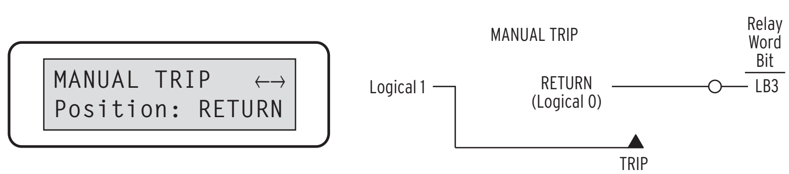


Scroll left with the left arrow button and then select `Yes`. The display then shows the new local control switch position:



Because this is an OFF/MOMENTARY type switch, the `MANUAL TRIP` switch returns to the `RETURN` position after momentarily being in the `TRIP` position. Technically, the `MANUAL TRIP` switch (being an OFF/MOMENTARY type switch) is in the `TRIP` position for one processing interval (1/4 cycle; long enough to assert the corresponding local bit LB3 to logical 1) and then returns to the `RETURN` position (local bit LB3 deasserts to logical 0 again).

On the display, the `MANUAL TRIP` switch is shown to be in the `TRIP` position for two seconds (long enough to be seen), and then it returns to the `RETURN` position:

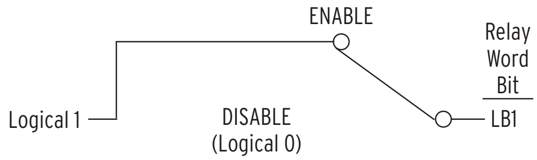


The `MANUAL CLOSE` switch is an OFF/MOMENTARY type switch, like the `MANUAL TRIP` switch, and operates similarly.

Local Control State Retained When Relay De-energized

Local bit states are stored in nonvolatile memory, so when power to the relay is turned off, the local bit states are retained.

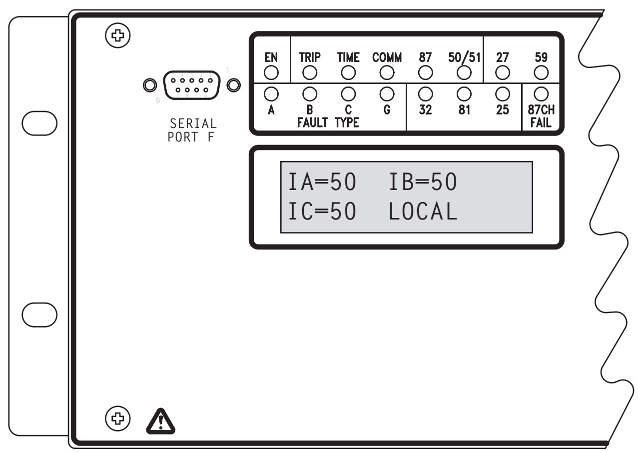
For example, suppose the local control switch with local bit output LB1 is configured as an ON/OFF type switch (see *Figure 9.5*). Additionally, suppose it is used to enable/disable the zero-sequence differential element via setting. If local bit LB1 is at logical 0, 87WB is enabled:



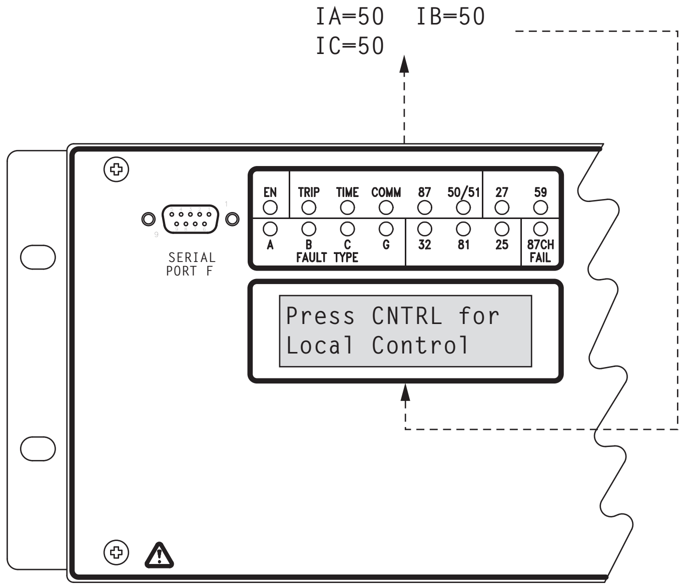
If power to the relay is turned off and then turned on again, local bit LB1 remains at logical 0, and the zero-sequence differential protection is still enabled.

Rotating Default Display

The local and remote channel `IA`, `IB`, and `IC` current values (in primary Amps) display continually if no local control is operational (i.e., no corresponding switch position label settings were made) and no display point labels are enabled for display.



The `Press CNTRL for Local Control` message displays in rotation (display time = SCROLD) with the default metering screen if at least one local control switch is operational. It is a reminder of how to access the local control function. See *Local Control on page 9.5* for more information on local control.



If display point labels (e.g., CHANNEL X ALARM and CHANNEL Y ALARM) are enabled for display, they also enter into the display rotation (display time = SCROLD).

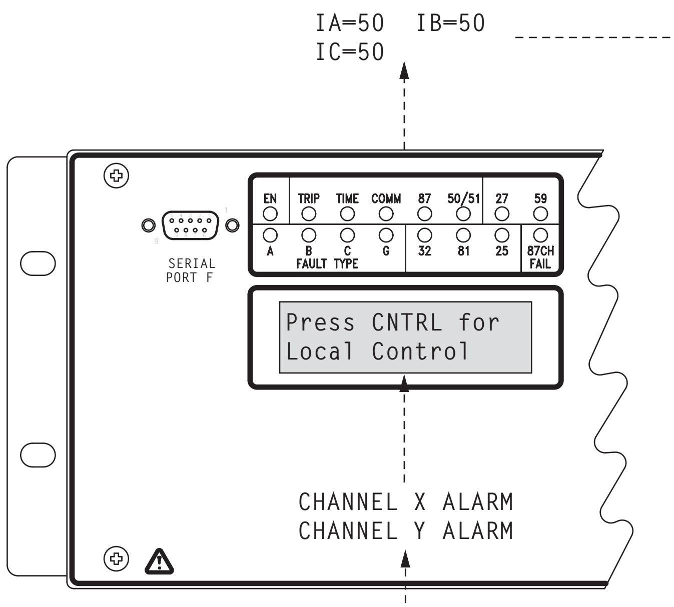


Figure 9.8 demonstrates the correspondence between changing display point states (e.g., DP2 and DP3) and enabled display point labels (DP2_1/DP2_0 and DP3_1/DP3_0, respectively). The display time is equal to global setting SCROLD for each screen.

The display point example settings are:

DP2 = **CHXAL** (alarm condition on Channel X)

DP3 = **CHYAL** (alarm condition on Channel Y)

Display Points 2 and 3 are used to help diagnostics when the **87CH FAIL** LED illuminates.

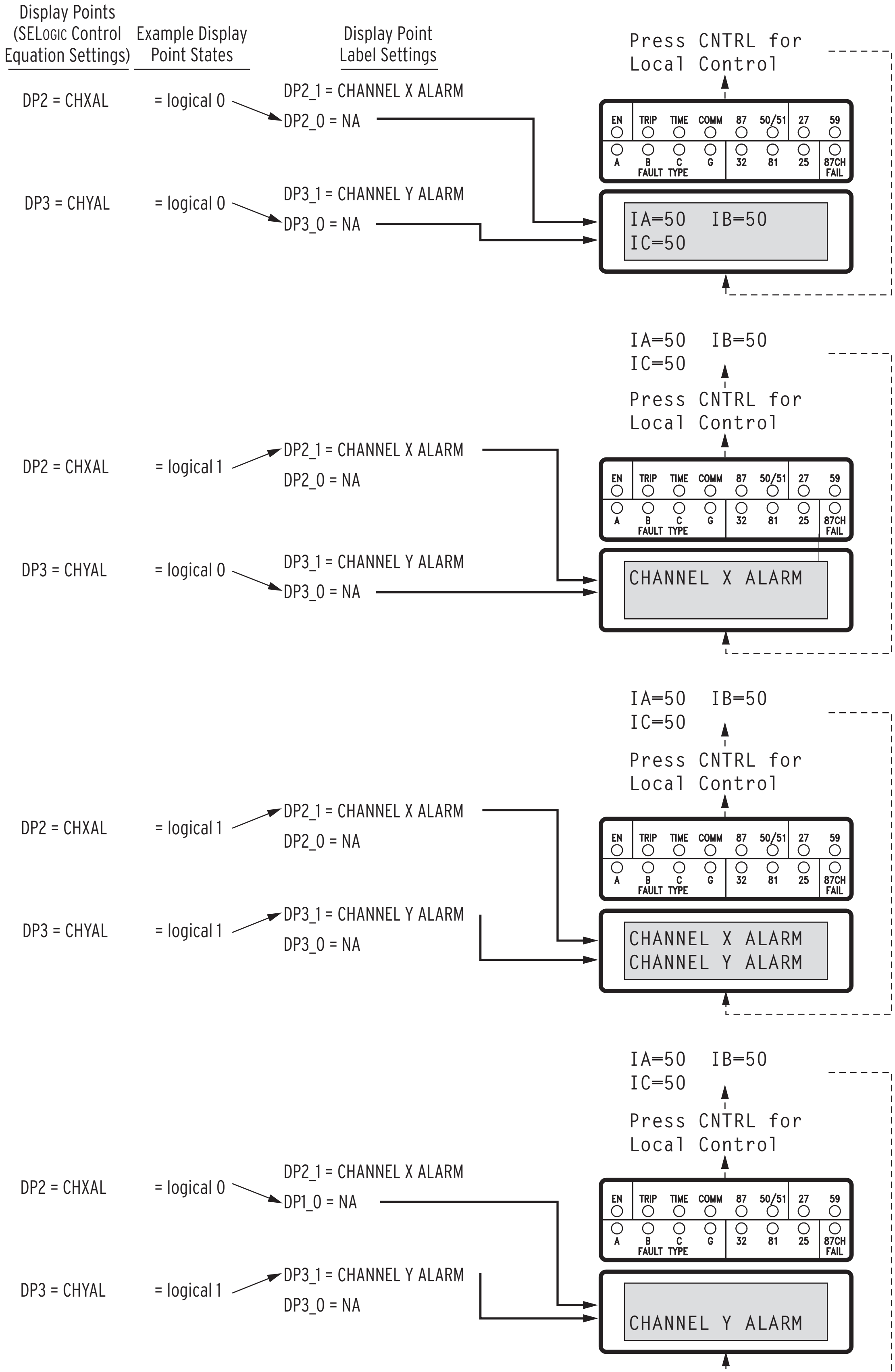


Figure 9.8 Correspondence Between Changing Display Point States and Enabled Display Point Labels

In the preceding example, only two display points (DP2 and DP3) and their corresponding display point labels are set. If additional display points and corresponding display point labels are set, the additional enabled display point labels join the rotation (display time = SCROLD) on the front-panel display. The SCROLD setting is made with the **SET G** command and reviewed with the **SHO G** command.

Display point label settings are set with the **SET T** command or viewed with the **SHO T** command via the serial port (see *Section 7: Settings* and *SHO Command (Show/View Settings) on page 8.33*).

For more detailed information on the logic behind the rotating default display, see *Rotating Default Display on page 5.25*.

Scroll Lock Control of Front Panel LCD

The rotating default display can be locked on a single screen. (See *Rotating Default Display on page 5.25*). Access the scroll lock control with the **{OTHER}** pushbutton.

```
DATE   TIME
TAR BRK_MON  LCD
```

Select LCD for Scroll Lock Control mode. The rotating display will then appear, and the scroll mode reminder screen will appear every eight seconds for one second as a reminder that the display is in Scroll Lock Control mode.

```
Scroll lock OFF
SELECT to Lock
```

Stop Scrolling (Lock)

When in the Scroll Lock Control mode, press the **{SELECT}** key to stop display rotation. Scrolling can be stopped on any of the display point screens, or on the current-meter display screen. While rotation is stopped, the active display is updated continuously so that current or display point changes can be seen. If no button is pressed for eight seconds, the reminder message will appear for one second, followed by the active screen.

```
Scroll lock ON
SELECT to Unlock
```

Restart Scrolling (Unlock)

The **{SELECT}** key unlocks the LCD and resumes the rotating display.

Single Step

From the Scroll Locked state, single-step through the display screens, by pressing the **{SELECT}** key twice. Wait for the first press to display the next screen as the active display, then press the **{SELECT}** key a second time to freeze scrolling.

Exit

Press the **{EXIT}** key to leave Scroll Lock Control and return the rotating display to normal operation.

Cancel

Press the **{CANCEL}** key to return to the OTHER menu.

```
DATE   TIME
TAR BRK_MON  LCD
```

Additional Rotating Default Display Example

See *Figure 4.15* and accompanying text in *Section 4: Trip, Close, and Target Logic* for an example of resetting a rotating default display with the **{TARGET RESET}** pushbutton.

Section 10
Analyzing Events

Overview

The SEL-311M Relay provides three separate event reports:

- ➤ Standard 15/30-cycle oscillographic event reports for backup protection
- ➤ Standard 15/30-cycle oscillographic event reports for line current differential protection
- ➤ Standard 15/30-cycle oscillographic event reports from 87W protection

In addition, the SEL-311M also provides Sequential Events Recorder (SER) reports.

The standard event reports contain date, time, current, voltage, frequency, relay element, optoisolated input, and output contact information.

The relay generates (triggers) 15/30-cycle event reports simultaneously by both fixed and programmable conditions. These reports show information for 15 or 30 continuous cycles. At least thirty-nine 15-cycle or fifteen 30-cycle reports are maintained. If more reports are triggered, the latest event report overwrites the oldest event report. See *Figure 10.4* for an example standard 15-cycle backup event report, *Figure 10.5* for an example standard 15-cycle differential event report, and *Figure 10.6* for an example standard 15-cycle ground differential event report.

The relay adds lines in the sequential events recorder (SER) report for a change of state of a programmable condition. The SER lists date and time-stamped lines of information each time a programmed condition changes state. The relay stores the latest 512 lines of the SER report in nonvolatile memory. If the report fills up, newer rows overwrite the oldest rows in the report. See *Figure 10.9* for an example SER report.

Standard 15/30-Cycle Event Reports

NOTE: Figure 10.4, Figure 10.5, and Figure 10.6 are on multiple pages.

See *Figure 10.4*, *Figure 10.5*, and *Figure 10.6* for example event reports.

Event Report Length (Settings LER and PRE)

The SEL-311M provides user-programmable event report length and prefault length. Event report length is 15 or 30 cycles. Prefault length ranges from 1 to 29 cycles. Prefault length is the first part of the event report that precedes the event report triggering point.

Set the event report length with the SET G LER setting. Set the prefault length with the SET G PRE setting. See the **SET G** command in *SEL-311M Settings Sheets* in *Section 7: Settings* for instructions on setting the LER and PRE settings.

Changing the LER setting erases all events stored in nonvolatile memory. Changing the PRE setting has no effect on the nonvolatile reports.

Standard Event Report Triggering

The relay triggers (generates) a standard event report when any of the following occur:

- Relay Word bit TRIP asserts
- Programmable SELOGIC® control equation setting ER asserts
- **TRI** (Trigger Event Reports) serial port command executed
- Output contacts OUT101–OUT107 and OUT201–OUT206 pulsed via the serial port or front-panel **PUL** (Pulse output contact) command

Relay Word Bit TRIP

Refer to *Figure 4.3*. If Relay Word bits TRIP asserts to logical 1, an event report is automatically generated. Thus, any condition that causes a trip does not have to be entered in SELOGIC control equation setting ER.

For example, SELOGIC control equation trip setting TR is unsupervised. Any trip condition that asserts in setting TR causes the TRIP Relay Word bit to assert immediately. The Relay Word bit TRIP asserts, and an event report is automatically generated. Thus, any element in setting TR does not have to be entered in SELOGIC control equation setting ER.

Relay Word bits TRIP is usually assigned to an output contact for tripping a circuit breaker (e.g., SELOGIC control equation setting OUT201 = TRIP).

TRIP87 also asserts Relay Word bit TRIP when high-speed tripping is enabled (EHST ≠ 000000).

Programmable SELOGIC Control Equation Setting ER

The programmable SELOGIC control equation event report trigger setting ER is set to trigger standard event reports for conditions other than trip conditions. When setting ER sees a logical 0 to logical 1 transition, it generates an event report (if the SEL-311M is not already generating a report that encompasses the new transition). For example, set ER to the following elements:

ER = **/51NG + /51Q + /50P1 + /LOP**

The elements in this example setting are:

51NG	Ground current above pickup setting 51NGP for residual ground time-overcurrent element 51NGT (see *Figure 3.20*).
51Q	Negative-sequence current above pickup setting 51QP for negative-sequence time-overcurrent element 51QT (see *Figure 3.21*).
50P1	Phase current above pickup setting 50P1P for phase overcurrent element 50P1 (see *Figure 3.14*).
LOP	Loss-of-potential (LOP) asserts (see *Figure 3.32*).

Note the rising edge operator / in front of each of these elements. See *Section 5: SELogic Control Equation Programming* for more information on rising edge operators and SELogic control equations in general.

Rising edge operators are especially useful in generating an event report at fault inception and then generating another later if for example a breaker failure condition occurs. If at the inception of a ground fault, pickup indicator 51NG asserts and an event report is generated, include /51NG in the ER setting:

ER = **... + /51NG + ... = logical 1** (for one processing interval)

Even though the 51NG pickup indicator remains asserted for the duration of the ground fault, the rising edge operator / in front of 51NG (/51NG) causes setting ER to be asserted for only one processing interval. Other operators in the setting ER SELogic control equation can trigger event reports while 51NG is still asserted.

Falling edge operators \ are also used to generate event reports. See *Section 5: SELogic Control Equation Programming* for more information on falling edge operators.

TRI (Trigger Event Report) and PUL (Pulse Output Contact) Commands

The sole function of the **TRI** serial port command is to generate standard event reports, primarily for testing purposes.

The **PUL** command asserts the output contacts for testing purposes or for remote control. If output contacts OUT101–OUT107 or OUT201–OUT206 assert via the **PUL** command, the relay triggers a standard event report. The **PUL** command is available at the serial port and the relay front-panel **{CNTRL}** pushbutton.

See *Section 8: Communications* and *Section 9: Front-Panel Operations* (*Figure 9.3*) for more information on the **TRI** (Trigger Event Report) and **PUL** (Pulse Output Contact) commands.

Event Summary

Each time the relay generates a standard event report, it also generates a corresponding event summary (see *Figure 10.1*). Event summaries contain the following information:

- Relay and terminal identifiers (settings RID and TID)
- Date and time when the event was triggered
- Event type
- Breaker Trip Time
- System frequency at trigger time

- ➤ Active Settings Group
- ➤ Breaker Close Time
- ➤ Front-panel fault type targets at the time of trip
- ➤ Breaker Status (Open or closed)
- ➤ Phase (**IA**, **IB**, **IC**, **IN**, **VA**, **VB**, **VC**), calculated residual ground (I_G = $3I_0$), calculated zero-sequence voltage ($3V_0$), and negative-sequence ($3I_2$) currents, along with phase angles for prefault and fault quantities.
- ➤ Differential currents.
- ➤ MIRRORED BITS® status if MIRRORED BITS are enabled.
- ➤ Differential channel transmit and receive bit status.

The relay includes event summary information in the standard event report. The identifiers, date, and time information are at the top of the standard event report, and the other information follows as channel row data and summary data at the end. See *Figure 10.4*.

NOTE: Figure 10.4, Figure 10.5, and Figure 10.6 are on multiple pages.

Figure 10.1 corresponds to the full-length standard 15-cycle event reports in *Figure 10.4* and *Figure 10.5*.

```
=>>SUM <Enter>

SEL-311M                          Date: 11/20/03    Time: 15:31:09.187
EXAMPLE: BUS B, BREAKER 3

Event: BCG T                                       Trip Time: 10:25:24.810
#: 00085          Freq:  60.00  Group: 1          Close Time: --:--:--.---
Targets: 87                                                       Breaker: Open

                  Local                Channel X              Channel Y
PreFault:    IA    IB    IC   3I2    IA    IB    IC   3I2    IA    IB    IC   3I2
MAG(A)      224   225   227     4   226   224   230     2 XXXXX XXXXX XXXXX XXXXX
ANG(DEG)-149.4  90.6 -28.8 118.4  30.4 -89.3 154.8  19.4 XXX.X XXX.X XXX.X XXX.X
Fault:
MAG(A)      224  1640  1485  2234   226  1510  1647  1630 XXXXX XXXXX XXXXX XXXXX
ANG(DEG)-149.8  25.0-127.8 -58.6  30.1   9.1-140.1-160.6 XXX.X XXX.X XXX.X XXX.X

              Local              Channel X         Channel Y
PreFault:     IN    IG   3V0    IN    IG   3V0    IN    IG   3V0
MAG(kV/A)      0     3     0 XXXXX XXXXX XXXXX XXXXX XXXXX XXXXX
ANG(DEG)   79.37 165.9 -91.1 XXX.X XXX.X XXX.X XXX.X XXX.X XXX.X
Fault:
MAG(kV/A)      0   684    84 XXXXX XXXXX XXXXX XXXXX XXXXX XXXXX
ANG(DEG)   79.37  94.3  -4.7 XXX.X XXX.X XXX.X XXX.X XXX.X XXX.X

87L Channel Status
                                                   RX       TX       RY       TY
                                             87654321 87654321 87654321 87654321
TRIG     Channel X:  Bad     Channel Y:      00000000 00000000 00000000 00000000
TRIP     Channel X:  Bad     Channel Y:      00000000 00000000 00000000 00000000

                                         Local
PreFault:     IA      IB      IC      IN      IG     3I2       VA       VB       VC
MAG(A/kV)    220     221     223       0       2       2  129.410  129.600  129.540
ANG(DEG)    2.20-117.67  122.55   79.37  169.37-121.63     0.00  -119.91   120.01
Fault:
MAG(A/kV)    219    1584    1429       0     684    2188  148.480   65.200   65.180
ANG(DEG)    1.44  176.15   23.53   79.37   94.17   90.37    -1.24  -116.75   123.20

=>>
```

Figure 10.1 Example Event Summary

The relay sends event summaries to all serial ports with port setting of AUTO = Y each time an event triggers.

The latest event summaries are stored in nonvolatile memory and are accessed by the **SUM** and **HIS** (Event Summaries/History) commands.

Event Type

The `Event:` field shows the event type. The possible event types and their descriptions are shown in *Table 10.1*. Note the correspondence to the preceding event report triggering conditions (see *Standard Event Report Triggering on page 10.2*).

Table 10.1 Event Types

Event Type	Description
AG, BG, CG	Single phase-to-ground faults. Appends T if TRIP asserted.
ABC	Three-phase faults. Appends T if TRIP asserted.
AB, BC, CA	Phase-to-phase faults. Appends T if TRIP asserted.
ABG, BCG, CAG	Two phase-to-ground faults. Appends T if TRIP asserted.
TRIP	Assertion of Relay Word bit TRIP (relay could not determine phase involvement, so just TRIP is displayed).
ER	SELOGIC control equation setting ER. Phase involvement is indeterminate.
TRIG	Execution of **TRIGGER** command.
PULSE	Execution of **PULSE** command.

(Event Summary Number)

Unique event identifier of the event summary found in the **HIS E** command. See *Section 8: Communications*.

Frequency

System frequency at trigger time.

Group

Active settings group at trigger time.

Trip and Close Times

Trip and close times follow 52A Relay Word bit contact changes during the event. A blank value indicates that a trip or close did not occur.

Targets

The relay reports the targets at the rising edge of TRIP (or TRIP87). The targets include the following:

- TIME
- COMM
- 87
- 50/51
- 27
- 59

- 32
- 81

If there is no rising edge of TRIP (or TRIP87) in the report, the Targets field is blank. See *Front-Panel Target LEDs on page 4.28*.

Currents and Voltages

Prefault current and voltage magnitudes and phase angles are selected from the first cycle of the event report.

Retrieving Full-Length Standard Event Reports

The latest event reports for both backup, zero-sequence current differential, and line current differential protection are stored in nonvolatile memory. Each event report includes five sections:

- Analog information, such as current, voltage, station battery, and V1Mem
- Protection and control elements, contact outputs, and optoisolated inputs
- Communications and MIRRORED BITS elements
- Event summary
- Group, SELOGIC control equations, and global settings

Use the **EVE** command to retrieve line current differential reports. Use the **EVE N** command to retrieve the 87W differential reports. Use the **EVE B** command to retrieve backup protection event reports. There are several options to customize the report format. The general command format is:

EVE [B] [*n* S*x* L*y* L R A D C M N]

n	Event number (1 to number of events stored), corresponding to the number displayed in the HIS report. Defaults to 1 if not listed, where 1 is the most recent event.
S*x*	Display *x* samples per cycle (4 or 16); defaults to 4 if not listed.
L*y*	Display *y* cycles of data (1 to LER). Defaults to LER value if not listed. Unfiltered reports (R parameter) display an extra cycle of data.
L	Display 16 samples per cycle; same as the S16 parameter.
R	Specifies the unfiltered (raw) event report. Defaults to 16 samples per cycle unless overridden with the S*x* parameter.
A	Specifies that only the analog section of the event is displayed (current, voltage, station battery, polarizing voltage).
D	Specifies that only the digital section (protection and control elements) of the event is displayed.
C	Display the report in Compressed ASCII format.
M	Specifies only that the communication elements section of the event is displayed.
N	Displays the 87W differential protection analogs in the event.
B	Display backup protection event report. If switch B is not present, the line current differential event report will be displayed.

Table 10.2 presents example uses of the **EVE** command.

Table 10.2 Example EVE Commands

Serial Port Command	Description
EVE	Display the most recent event report at 1/4-cycle resolution.
EVE 2	Display the second event report at 1/4-cycle resolution.
EVE S16 L10	Display 10 cycles of the most recent report at 1/16-cycle resolution.
EVE C 2	Display the second report in Compressed ASCII format at 1/4-cycle resolution.
EVE L	Display most recent report at 1/16-cycle resolution.
EVE R	Display most recent report at 1/16-cycle resolution; analog and digital data are unfiltered (raw).
EVE 2 D L10	Display 10 cycles of the protection and control elements section of the second event report at 1/4-cycle resolution.
EVE 2 A R S4	Display the unfiltered analog section of the second event report at 1/4-cycle resolution.
EVE N	Display the most recent event report for 87W differential protection at 1/4-cycle resolution.
EVE B	Display the most recent event report for backup protection at 1/4-cycle resolution.

If an event report is requested that does not exist, the relay responds `Invalid Event.`

Compressed ASCII Event Reports

The SEL-311M provides Compressed ASCII event reports to facilitate event report storage and display. The SEL-2030 Communications Processor takes advantage of the Compressed ASCII format. Use the **EVE C** command or **CEV** command to capture Compressed ASCII event reports. The Compressed ASCII event report contains both the backup and differential event report information.

See the **CEVENT** command discussion in *Appendix C: SEL Communications Processors* for further information.

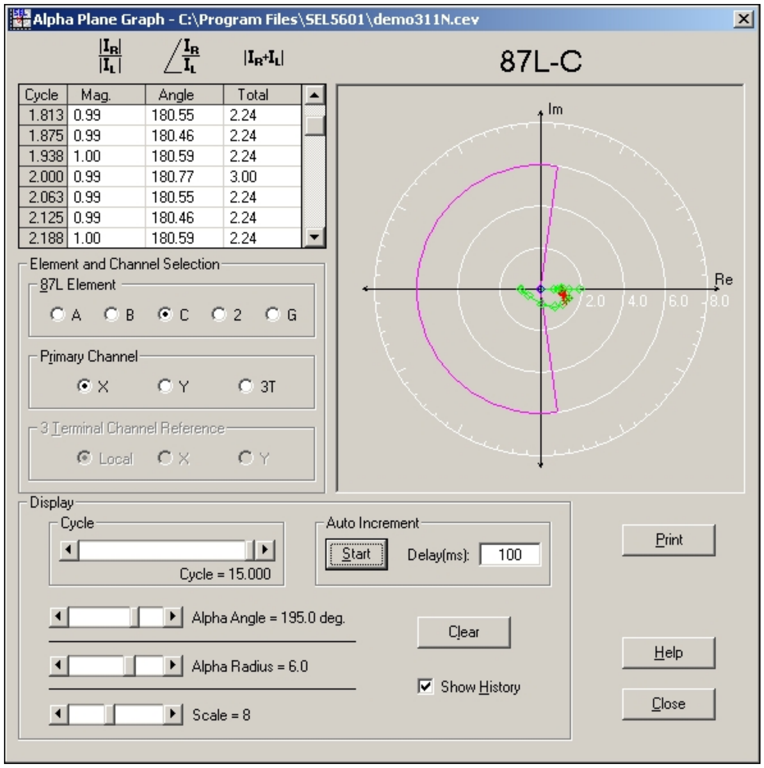


Figure 10.2 Internal Fault

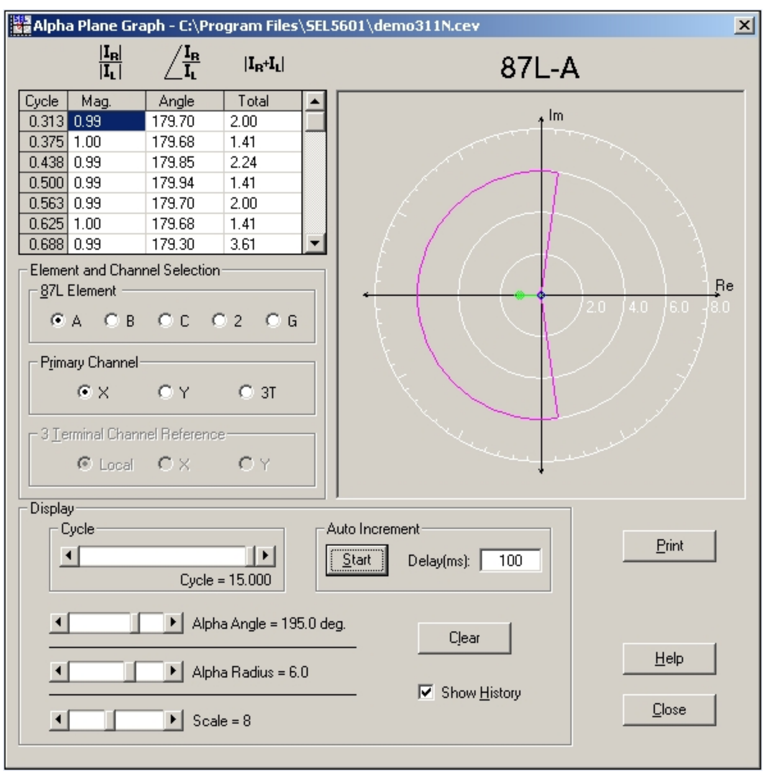


Figure 10.3 External Fault

Filtered and Unfiltered Event Reports

The SEL-311M samples the basic power system measurements (ac voltage, ac current, station battery, and optoisolated inputs) 16 times per power system cycle. The relay filters the measurands to remove transient signals. The relay operates on the filtered values and reports them in the event report.

To view the raw inputs to the relay, select the unfiltered event report (e.g., **EVE R, EVE N R,** or **EVE B R**). Use the unfiltered event reports to observe:

- Power system harmonics on the voltage and current channels
- Decaying dc offset during fault conditions on current channels
- Optoisolated input contact bounce
- Transients on the station dc battery channel Vdc (power input terminals Z25 and Z26)

The filters for ac current and voltage and station battery are fixed. You can adjust the optoisolated input debounce via debounce settings (see *Figure 5.6* in *Section 5: SELOGIC Control Equation Programming*).

Raw event reports display one extra cycle of data at the beginning of the report.

Clearing Standard Event Report Buffer

The **HIS C** command clears the event summaries and corresponding standard event reports from nonvolatile memory. *Section 8: Communications* for more information on the **HIS** (Event Summaries/History) command.

Standard Event Report Column Definitions for Backup Protection

Refer to the example event report in *Figure 10.4* to view event report columns (Note: *Figure 10.4* is on multiple pages). This example event report displays rows of information each 1/4 cycle and was retrieved with the **EVE B** command.

The columns contain ac current, ac voltage, station dc battery voltage, and directional polarizing voltage (V1Mem).

Current, Voltage, and Frequency Columns in the Backup Protection Event Report

Table 10.3 summarizes the backup event report current, voltage, and frequency columns.

Table 10.3 Standard Event Report Current, Voltage, and Frequency Columns (Backup Protection) (Sheet 1 of 2)

Column Heading	Definition
IA	Current measured by channel IA (primary A)
IB	Current measured by channel IB (primary A)
IC	Current measured by channel IC (primary A)
IN	Current measured by channel IN (primary A)
IG	Calculated residual current IG = 3I0 = IA + IB + IC (primary A)
VA	Voltage measured by channel VA (primary kV)
VB	Voltage measured by channel VB (primary kV)
VC	Voltage measured by channel VC (primary kV)
VS	Voltage measured by channel VS (primary kV)
V1Mem	Positive-sequence memory voltage (primary kV)

Table 10.3 Standard Event Report Current, Voltage, and Frequency Columns (Backup Protection) (Sheet 2 of 2)

Column Heading	Definition
FREQ	Frequency of Channel VA
Vdc	Voltage measured at power input terminals Z25 and Z26 (Vdc)

Note that the ac values change from positive to negative in *Figure 10.4*, indicating the sinusoidal nature of the waveforms.

Other figures help in understanding the information available in the event report current or voltage columns:

- *Figure 10.7* shows how event report current column data relate to the actual sampled waveform and rms values.
- *Figure 10.8* shows how event report column data can be converted to phasor rms values.

Output, Input, Protection, and Control Columns

Table 10.4, *Table 10.5*, and *Table 10.7* summarize the event report output, input, protection, and control columns for backup and differential protection, respectively. See *Table 7.5* in *Section 7: Settings* for more information on the Relay Word bits shown in *Table 10.4*, *Table 10.5*, and *Table 10.7*.

Table 10.4 Output, Input, Protection, and Control Element Event Report Columns (Backup Protection) (Sheet 1 of 5)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
All columns		.	Element/input/output not picked up or not asserted, unless otherwise stated.
VPOL	VPOLV	V	VPOLV asserted
51 P	51P, 51PT, 51PR	p	Time-overcurrent element picked up and timing
51 NG	51NG, 51NGT, 51NGR	T	Time-overcurrent element timed out
51 Q	51Q, 51QT, 51QR	r	Time-overcurrent element timing to reset
		1	Time-overcurrent element timing to reset after having timed out (when element reset is set for 1 cycle, not electromechanical reset)
50P 1 2	50P1, 50P2	1	50P1 asserted
		2	50P2 asserted
		b	both 50P1 and 50P2 asserted
50P 3 4	50P3, 50P4	3	50P3 asserted
		4	50P4 asserted
		b	both 50P3 and 50P4 asserted
50Q 1 2	50Q1, 50Q2	1	50Q1 asserted
		2	50Q2 asserted
		b	both 50Q1 and 50Q2 asserted
50Q 3 4	50Q3, 50Q4	3	50Q3 asserted
		4	50Q4 asserted
		b	both 50Q3 and 50Q4 asserted

Table 10.4 Output, Input, Protection, and Control Element Event Report Columns (Backup Protection) (Sheet 2 of 5)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
50NG 1 2	50NG1, 50NG2	1 2 b	50NGQ1 asserted 50NG2 asserted both 50NG1 and 50NG2 asserted
50NG 3 4	50NG3, 50NG4	3 4 b	50NG3 asserted 50NG4 asserted both 50NG3 and 50NG4 asserted
32 P Q	F32P R32P F32Q R32Q	P R Q q	F32P asserted R32P asserted Forward negative-sequence directional element F32Q picked up. Reverse negative-sequence directional element R32Q picked up.
32 N	F32N R32N	N n	F32N asserted R32N asserted
Zld	ZLIN, ZLOUT	i o	Load encroachment “load in” element ZLIN picked up. Load encroachment “load out” element ZLOUT picked up.
67P 1 2	67P1, 67P2	1 2 b	67P1 asserted 67P2 asserted both 67P1 and 67P2 asserted
67P 3 4	67P3, 67P4	3 4 b	67P3 asserted 67P4 asserted both 67P3 and 67P4 asserted
67NG 1 2	67NG1, 67NG2	1 2 b	67NG1 asserted 67NG2 asserted both 67NG1 and 67NG2 asserted
67NG 3 4	67NG3, 67NG4	3 4 b	67NG3 asserted 67NG4 asserted both 67NG3 and 67NG4 asserted
67Q 1 2	67Q1, 67Q2	1 2 b	67Q1 asserted 67Q2 asserted both 67Q1 and 67Q2 asserted
67Q 3 4	67Q3, 67Q4	3 4 b	67Q3 asserted 67Q4 asserted both 67Q3 and 67Q4 asserted
DM P Q	PDEM, QDEM	P Q b	Phase demand ammeter element PDEM picked up. Negative-sequence demand ammeter element QDEM picked up. Both PDEM and QDEM picked up.
DM N	NDEM	*	Ground demand ammeter element NDEM picked up.
27 P 1 2	27A1, 27B1, 27C1 27A2, 27B2, 27C2	1 2 b	27A1 + 27B1 + 27C1 27A2 + 27B2 + 27C2 (27A1 + 27B1 + 27C1) and (27A2 + 27B2 + 27C2)
27 P 3 4	27A3, 27B3, 27C3 27A4, 27B4, 27C4	3 4 b	27A3 + 27B3 + 27C3 27A4 + 27B4 + 27C4 (27A3 + 27B3 + 27C3) and (27A4 + 27B4 +27C4)
27 PP 1 2	27AB1, 27BC1, 27CA1 27AB2, 27BC2, 27CA2	1 2 b	27AB1 + 27BC1 + 27CA1 27AB2 + 27BC2 + 27CA2 (27AB1 + 27BC1 + 27CA1) and (27AB2 + 27BC2 + 27CA2)

Table 10.4 Output, Input, Protection, and Control Element Event Report Columns (Backup Protection) (Sheet 3 of 5)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
27 PP 3 4	27AB3, 27BC3, 27CA3 27AB4, 27BC4, 27CA4	3 4 b	27AB3 + 27BC3 + 27CA3 27AB4 + 27BC4 + 27CA4 (27AB3 + 27BC3 + 27CA3) and (27AB4 + 27BC4 + 27CA4)
59 P 1 2	59A1, 59C1, 59C1 59A2, 59C2, 59C2	1 2 b	59A1 + 59B1 + 59C1 59A2 + 59B2 + 59C2 (59A1 + 59B1 + 59C1) and (59A2 + 59B2 + 59C2)
59 P 3 4	59A3, 59C3, 59C3 59A4, 59C4, 59C4	3 4 b	59A3 + 59B3 + 59C3 59A4 + 59B4 + 59C4 (59A3 + 59B3 + 59C3) and (59A4 + 59B4 + 59C4)
59 PP 1 2	59AB1, 59BC1, 59CA1 59AB2, 59BC2, 59CA2	1 2 b	59AB1 + 59BC1 + 59CA1 59AB2 + 59BC2 + 59CA2 (59AB1 + 59BC1 + 59CA1) and (59AB2 + 59BC2 + 59CA2)
59 PP 3 4	59AB3, 59BC3, 59CA3 59AB4, 59BC4, 59CA4	3 4 b	59AB3 + 59BC3 + 59CA3 59AB4 + 59BC4 + 59CA4 (59AB3 + 59BC3 + 59CA3) and (59AB4 + 59BC4 + 59CA4)
59 N 1 2	59N1, 59N2	1 2 b	First ground instantaneous overvoltage element 59N1 picked up Second ground instantaneous overvoltage element 59N2 picked up. Both 59N1 and 59N2 picked up.
59 N 3 4	59N3, 59N4	3 4 b	First ground instantaneous overvoltage element 59N3 picked up Second ground instantaneous overvoltage element 59N4 picked up. Both 59N3 and 59N4 picked up.
59 Q 1 2	59Q1, 59Q2	1 2 b	First ground instantaneous overvoltage element 59Q1 picked up Second ground instantaneous overvoltage element 59Q2 picked up. Both 59Q1 and 59Q2 picked up.
59 Q 3 4	59Q3, 59Q4	3 4 b	First ground instantaneous overvoltage element 59Q3 picked up Second ground instantaneous overvoltage element 59Q4 picked up. Both 59Q3 and 59Q4 picked up.
59 V1	59V1	*	Positive-sequence instantaneous overvoltage element 59V1 picked up.
25 59 V	59VP, 59VS	P S b	Phase voltage window element 59VP picked up (used in synchronism check). Channel VS voltage window element 59VS picked up (used in synchronism check). Both 59VP and 59VS picked up.
25 SF	SF	*	Slip frequency element SF picked up (used in synchronism check).
25 A	25A1, 25A2	1 2 b	First synchronism check element 25A1 picked up. Second synchronism check element 25A2 picked up. Both 25A1 and 25A2 picked up.
27B	27B81	*	Undervoltage element for frequency element blocking (any phase) asserted.
81 1 2	81D1, 81D2	1 2 b	Level 1 instantaneous frequency element asserted. Level 2 instantaneous frequency element asserted. Level 1 and 2 instantaneous frequency elements asserted.
81 3 4	81D3, 81D4	3 4 b	Level 3 instantaneous frequency element asserted. Level 4 instantaneous frequency element asserted. Level 3 and 4 instantaneous frequency elements asserted.

Table 10.4 Output, Input, Protection, and Control Element Event Report Columns (Backup Protection) (Sheet 4 of 5)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
81 5 6	81D5, 81D6	5 6 b	Level 5 instantaneous frequency element asserted. Level 6 instantaneous frequency element asserted. Level 5 and 6 instantaneous frequency elements asserted.
Pwr 1	PWRA1, PWRB1, PWRC1	A B C * 3	PWRA1 asserted PWRB1 asserted PWRC1 asserted PWRA1 * PWR1 + PWRB1 * PWRC1 + PWRC1 * PWRA1 PWRA1 * PWRB1 * PWRC1
Pwr 2	PWRA2, PWRB2, PWRC2	A B C * 3	PWRA2 asserted PWRB2 asserted PWRC2 asserted PWRA2 * PWR2 + PWRB2 * PWRC2 + PWRC2 * PWRA2 PWRA2 * PWRB2 * PWRC2
Pwr 3	PWRA3, PWRB3, PWRC3	A B C * 3	PWRA3 asserted PWRB3 asserted PWRC3 asserted PWRA3 * PWR3 + PWRB3 * PWRC3 + PWRC3 * PWRA3 PWRA3 * PWRB3 * PWRC3
Pwr 4	PWRA4, PWRB4, PWRC4	A B C * 3	PWRA4 asserted PWRB4 asserted PWRC4 asserted PWRA4 * PWR4 + PWRB4 * PWRC4 + PWRC4 * PWRA4 PWRA4 * PWRB4 * PWRC4
LOP	LOP	*	Loss-of-potential element LOP picked up.
Vdc	DCHI, DCLO	H L b	Station battery instantaneous overvoltage element DCHI picked up. Station battery instantaneous undervoltage element DCLO picked up. Both DCHI and DCLO asserted.
Out1 1 2[a]	OUT101, OUT102	1 2 b	Output contact OUT101 asserted. Output contact OUT102 asserted. Both OUT101 and OUT102 asserted.
Out1 3 4[a]	OUT103, OUT104	3 4 b	Output contact OUT103 asserted. Output contact OUT104 asserted. Both OUT103 and OUT104 asserted.
Out1 5 6[a]	OUT105, OUT106	5 6 b	Output contact OUT105 asserted. Output contact OUT106 asserted. Both OUT105 and OUT106 asserted.
Out1 7 A[a]	OUT107, ALARM	7 A b	Output contact OUT107 asserted. Output contact ALARM asserted. Both OUT107 and ALARM asserted.
Out2 1 2	OUT201, OUT202	1 2 b	Output contact OUT201 asserted. Output contact OUT202 asserted. Both OUT201 and OUT202 asserted.
Out2 3 4	OUT203, OUT204	3 4 b	Output contact OUT203 asserted. Output contact OUT204 asserted. Both OUT203 and OUT204 asserted.

Table 10.4 Output, Input, Protection, and Control Element Event Report Columns (Backup Protection) (Sheet 5 of 5)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
Out2 5 6	OUT205, OUT206	5 6 b	Output contact OUT205 asserted. Output contact OUT206 asserted. Both OUT205 and OUT206 asserted.
In1 1 2	IN101, IN102	1 2 b	Optoisolated input IN101 asserted. Optoisolated input IN102 asserted. Both IN101 and IN102 asserted.
In1 3 4	IN103, IN104	3 4 b	Optoisolated input IN103 asserted. Optoisolated input IN104 asserted. Both IN103 and IN104 asserted.
In1 5 6	IN105, IN106	5 6 b	Optoisolated input IN105 asserted. Optoisolated input IN106 asserted. Both IN105 and IN106 asserted.

[a] Output contacts can be A or B type contacts (see Table 2.4 and Figure 5.13–Figure 5.14).

Table 10.5 Communication Elements Event Report Columns (Backup Protection) (Sheet 1 of 3)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
3PO	3PO	*	Three pole open condition 3PO asserted.
SOTF	SOTF	*	Switch-onto-fault condition SOTF asserted.
PT	PT	*	Permissive trip signal to POTT logic PT asserted.
PTRX	PTRX	*	Permissive trip signal from DCUB logic PTRX asserted.
Z3RB	Z3RB	*	Zone /Level 3 reverse block Z3RB asserted.
KEY	KEY	*	Key permissive trip signal KEY asserted.
EKEY	EKEY	*	Echo key EKEY asserted.
ECTT	ECTT	*	Echo conversion to trip condition ECTT asserted.
WFC	WFC	*	Weak-infeed condition WFC asserted.
UBB	UBB	*	Unblocking block from DCUB logic UBB asserted.
Z3XT	Z3XT	*	Logic output from Zone/Level 3 extension timer Z3XT asserted.
DSTR	DSTRT	*	Directional carrier start DSTRT asserted.
NSTR	NSTRT	*	Nondirectional carrier start NSTRT asserted.
STOP	STOP	*	Carrier stop STOP asserted.
BTX	BTX	*	Block trip input extension BTX asserted.
TMB A 1 2	TMB1A, TMB2A	1 2 b	MIRRORED BITS channel A transmit bit 1 TMB1A asserted. MIRRORED BITS channel A transmit bit 2 TMB2A asserted. Both TMB1A and TMB2A asserted.
TMB A 3 4	TMB3A, TMB4A	3 4 b	MIRRORED BITS channel A transmit bit 3 TMB3A asserted. MIRRORED BITS channel A transmit bit 4 TMB4A asserted. Both TMB3A and TMB4A asserted.

Table 10.5 Communication Elements Event Report Columns (Backup Protection) (Sheet 2 of 3)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
TMB A 5 6	TMB5A, TMB6A	5	MIRRORED BITS channel A transmit bit 5 TMB5A asserted.
		6	MIRRORED BITS channel A transmit bit 6 TMB6A asserted.
		b	Both TMB5A and TMB6A asserted.
TMB A 7 8	TMB7A, TMB8A	7	MIRRORED BITS channel A transmit bit 7 TMB7A asserted.
		8	MIRRORED BITS channel A transmit bit 8 TMB8A asserted.
		b	Both TMB7A and TMB8A asserted.
RMB A 1 2	RMB1A, RMB2A	1	MIRRORED BITS channel A receive bit 1 RMB1A asserted.
		2	MIRRORED BITS channel A receive bit 2 RMB2A asserted.
		b	Both RMB1A and RMB2A asserted.
RMB A 3 4	RMB3A, RMB4A	3	MIRRORED BITS channel A receive bit 3 RMB3A asserted.
		4	MIRRORED BITS channel A receive bit 4 RMB4A asserted.
		b	Both RMB3A and RMB4A asserted.
RMB A 5 6	RMB5A, RMB6A	5	MIRRORED BITS channel A receive bit 5 RMB5A asserted.
		6	MIRRORED BITS channel A receive bit 6 RMB6A asserted.
		b	Both RMB5A and RMB6A asserted.
RMB A 7 8	RMB7A, RMB8A	7	MIRRORED BITS channel A receive bit 7 RMB7A asserted.
		8	MIRRORED BITS channel A receive bit 8 RMB8A asserted.
		b	Both RMB7A and RMB8A asserted.
TMB B 1 2	TMB1B, TMB2B	1	MIRRORED BITS channel B transmit bit 1 TMB1B asserted.
		2	MIRRORED BITS channel B transmit bit 2 bit TMB2B asserted.
		b	Both TMB1B and TMB2B asserted.
TMB B 3 4	TMB3B, TMB4B	3	MIRRORED BITS channel B transmit bit 3 TMB3B asserted.
		4	MIRRORED BITS channel B transmit bit 4 TMB4B asserted.
		b	Both TMB3B and TMB4B asserted.
TMB B 5 6	TMB5B, TMB6B	5	MIRRORED BITS channel B transmit bit 5 TMB5B asserted.
		6	MIRRORED BITS channel B transmit bit 6 TMB6B asserted.
		b	Both TMB5B and TMB6B asserted.
TMB B 7 8	TMB7B, TMB8B	7	MIRRORED BITS channel B transmit bit 7 TMB7B asserted.
		8	MIRRORED BITS channel B transmit bit 8 TMB8B asserted.
		b	Both TMB7B and TMB8B asserted.
RMB B 1 2	RMB1B, RMB2B	1	MIRRORED BITS channel B receive bit 1 RMB1B asserted.
		2	MIRRORED BITS channel B receive bit 2 RMB2B asserted.
		b	Both RMB1B and RMB2B asserted.
RMB B 3 4	RMB3B, RMB4B	3	MIRRORED BITS channel B receive bit 3 RMB3B asserted.
		4	MIRRORED BITS channel B receive bit 4 RMB4B asserted.
		b	Both RMB3B and RMB4B asserted.
RMB B 5 6	RMB5B, RMB6B	5	MIRRORED BITS channel B receive bit 5 RMB5B asserted.
		6	MIRRORED BITS channel B receive bit 6 RMB6B asserted.
		b	Both RMB5B and RMB6B asserted.

Table 10.5 Communication Elements Event Report Columns (Backup Protection) (Sheet 3 of 3)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
RMB B 7 8	RMB7B, RMB8B	7 8 b	MIRRORED BITS channel B receive bit 7 RMB7B asserted. MIRRORED BITS channel B receive bit 8 RMB8B asserted. Both RMB7B and RMB8B asserted.
ROK	ROKA, ROKB	A B b	MIRRORED BITS channel A receive OK ROKA asserted. MIRRORED BITS channel B receive OK ROKB asserted. Both ROKA and ROKB asserted.
RBAD	RBADA, RBADB	A B b	MIRRORED BITS channel A extended. outage RBADA asserted. MIRRORED BITS channel B extended outage RBADB asserted. Both RBADA and RBADB asserted.
CBAD	CBADA, CBADB	A B b	MIRRORED BITS channel A unavailability CBADA asserted. MIRRORED BITS channel B unavailability CBADB asserted. Both CBADA and CBADB asserted.
LBOK	LBOKA, LBOKB	A B b	MIRRORED BITS channel A loop back OK LBOKA asserted. MIRRORED BITS channel A loop back OK LBOKB asserted. Both LBOKA and LBOKB asserted.
OC	OC, CC	o c	**OPE** (Open) command executed. **CLO** (Close) command executed.
Lcl RW 27	LB8–LB1	00–FF Hex[a]	Hex value of Relay Word 27, LB8–LB1, Local Bits
Lcl RW 28	LB16–LB9	00–FF Hex[a]	Hex value of Relay Word 28, LB16–LB9, Local Bits
Rem RW 29	RB8–RB1	00–FF Hex[a]	Hex value of Relay Word 29, RB8–RB1, Remote Bits
Rem RW 30	RB16–RB9	00–FF Hex[a]	Hex value of Relay Word 30, RB16–RB9, Remote Bits
Ltch RW 31	LT8–LT1	00–FF Hex[a]	Hex value of Relay Word 31, LT8–LT1, Latch Bits
Ltch RW 32	LT16–LT9	00–FF Hex[a]	Hex value of Relay Word 32, LT16–LT9, Latch Bits
SELOGIC 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	 SV1, SV1T SV2, SV2T SV3, SV3T SV4, SV4T SV5, SV5T SV6, SV6T SV7, SV7T SV8, SV8T SV9, SV9T SV10, SV10T SV11, SV11T SV12, SV12T SV13, SV13T SV14, SV14T SV15, SV15T SV16, SV16T	 p T d	 SELOGIC control equation variable timer input SV_ asserted; timer timing on pickup time; timer output SV_T not asserted. SELOGIC control equation variable timer input SV_ asserted; timer timed out on pickup time; timer output SV_T asserted. SELOGIC control equation variable timer input SV_ not asserted; timer previously timed out on pickup time; timer output SV_T remains asserted while timer timing on dropout time.

[a] Hexadecimal values are constructed with the lowest numbered bit (e.g., LB1) being the least significant, as follows:

LB8	LB7	LB6	LB5	LB4	LB3	LB2	LB1	
1	0	0	0	1	0	1	0	= 8A Hex

Example Standard 15-Cycle Event Report (Backup Protection)

The following example standard 15-cycle event report in *Figure 10.4* also corresponds to the example sequential events recorder (SER) report in *Figure 10.9*. The circled numbers in *Figure 10.4* correspond to the SER row numbers in *Figure 10.9*. The row explanations follow *Figure 10.9*.

In *Figure 10.4*, the arrow (>) in the column following the Vdc column identifies the "trigger" row. This is the row that corresponds to the Date and Time values at the top of the event report.

The asterisk (*) in the column following the Vdc column identifies the row corresponding to the "fault" values listed in the event summary report. See *Currents and Voltages on page 10.6*. The phase current is calculated from the row identified with the asterisk and the row one quarter-cycle previous (see *Figure 10.4* and *Table 10.1*). These currents are listed at the end of the event report in the event summary. If the "trigger" row (>) and the faulted phase current row (*) are the same row, the * symbol takes precedence.

```
=>>EVE B <Enter>

SEL-311M                             Date: 11/20/03    Time: 15:31:09.187
EXAMPLE: BUS B, BREAKER 3

FID=SEL-311M-R101-V0-Z003002-D20031117       CID=EDED

      Currents (Amps Pri)            Voltages (kV Pri)         V1
    IA     IB     IC     IN     IG     VA     VB     VC     VS     Mem  FREQ Vdc
[1]
    49   -212    163      0      0   23.9 -122.3   98.3    0.0   24.2 60.00  23
   215    -65   -153      0     -3  127.2  -42.8  -84.3   -0.0  127.2 60.00  23
   -50   -211   -164     -1     -3  -23.8  122.3   98.4   -0.0  -24.1 60.00  23
  -216     65    152     -1      1 -127.2   42.9   84.3    0.0 -127.3 60.00  23
[2]
    48   -212    163      0     -1   23.9 -122.3   98.4    0.0   24.1 60.00  23
   215    -65   -153      0     -4  127.2  -43.0  -84.3   -0.0  127.3 60.00  23
   -48   -211   -164      0     -1  -23.8  122.2   98.5   -0.0  -24.0 60.00  23
  -216     65    152     -1      1 -127.2   43.1   84.2    0.0 -127.3 60.00  23
[3]
    47   -212    163     -1     -2   23.5 -122.3   98.4    0.0   24.1 60.00  23
   215    -66   -152      0     -3  127.3  -43.0  -84.3   -0.0  127.3 60.00  23
   -48   -211   -164      0     -1  -23.4  122.2   98.5   -0.0  -24.0 60.00  23
  -216     66    151      0      1 -127.3   43.1   84.2    0.0 -127.3 60.00  23
[4]
    47   -212    163      0     -2   23.2 -122.1   98.7    0.0   23.7 60.00  23
   215    -72   -156      0    -13  128.8  -41.3  -81.6   -0.0  127.3 60.00  23
   -48    381   -524     -1   -191  -20.8  110.9  -80.0   -0.0  -23.7 60.00  23
  -216    744   -433     -1     95 -138.4   28.5   62.4    0.0 -124.6 60.00  23>
[5]
    47   -445    918      0    520   21.5  -81.2   54.1    0.0   23.1 60.00  23
   215  -1555   1164      0   -176  146.4  -18.0  -45.3   -0.0  118.0 60.00  23
   -48    216   -834      0   -666  -24.6   62.7  -46.9   -0.0  -22.1 60.00  23
  -216   1594  -1205     -1    173 -146.5   17.9   45.3    0.0 -111.3 60.00  23
[6]
    47   -183    798     -1    662   24.5  -62.7   46.9    0.0   21.2 60.00  23
   215  -1567   1176      0   -176  146.5  -18.0  -45.2   -0.0  106.2 60.00  23
   -48    205   -823      0   -666  -24.4   62.6  -47.0   -0.0  -20.5 60.00  23
  -216   1586  -1198     -1    172 -146.5   18.0   45.2    0.0 -102.4 60.00  23
[7]
    46   -187    803      0    662   24.3  -62.6   47.0    0.0   20.0 60.00  23
   215  -1573   1183      0   -175  146.5  -18.1  -45.1   -0.0   99.6 60.00  23*
   -47    197   -816     -1   -666  -24.1   62.6  -47.1   -0.0  -19.6 60.00  23
  -216   1582  -1195     -1    171 -146.5   18.2   45.1    0.0  -97.4 60.00  23
.
.
.
.
[11]
    22    -48    318      0    292   35.1  -91.3   88.7    0.0   18.2 60.00  23
    45   -365    182      0   -138  130.6  -42.5  -76.4   -0.0   99.2 60.00  23
     0     -8     -1     -1     -9  -31.1  123.3  -95.7   -0.0  -19.9 60.00  23
     0      0      0     -1      0 -126.7   37.1   89.6    0.0 -106.1 60.00  23
                                                         (Continued on next page)
```

(Continued from previous page)

```
[12]
    -1     0      0     0    -1   30.0 -125.0   94.8    0.0   22.5 60.00  23
    -1    -1     -1     0    -3  126.7  -37.2  -89.5   -0.0  111.3 60.00  23
     0     0     -1     0    -1  -29.9  124.9  -94.9   -0.0  -24.4 60.00  23
     0     0      0    -1     0 -126.8   37.3   89.4    0.0 -115.2 60.00  23
[13]
    -1    -1      0    -1    -2   29.8 -124.9   95.0    0.0   25.8 60.00  23
    -1    -1     -1     0    -3  126.8  -37.5  -89.3   -0.0  118.1 60.00  23
     0    -1     -1    -1    -2  -29.7  124.9  -95.1   -0.0  -26.8 60.00  23
     0     0      0    -1     0 -126.8   37.6   89.2    0.0 -120.3 60.00  23
[14]
    -1     0      0     0    -1   29.6 -124.9   95.1    0.0   27.5 60.00  23
    -1    -1     -2     0    -4  126.8  -37.6  -89.2   -0.0  121.9 60.00  23
     0    -1     -1     0    -2  -29.5  124.8  -95.2   -0.0  -28.1 60.00  23
     0     0      0    -1     0 -126.9   37.7   89.1    0.0 -123.2 60.00  23
[15]
     0     0      0    -1     0   29.4 -124.8   95.2    0.0   28.4 60.00  23
    -1    -1     -1     0    -3  126.9  -37.8  -89.1   -0.0  124.1 60.00  23
     0    -1      0     0    -1  -29.3  124.8  -95.3   -0.0  -28.7 60.00  23
     1     0      0    -1     1 -126.9   37.9   89.0    0.0 -124.9 60.00  23

Protection and Contact I/O Elements

V 51  50     32  67     Dm 27   59        25   81
P     P Q NG   Z P Q NG    P PP P P V      5   2          LV Out1 Out2 In1
O  N  131313 P l 131313 P  1313 13131313V 9S  7135 Pwr  Od 1357 135  135
L PGQ 242424 QNd 242424 QN 2424 242424241 VFA B246 1234 Pc 246A 246  246
[1]
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
[2]
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
[3]
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
V ... ...... ..o ...... .. .... ......... ... *... .... .. .... ...  ...
[4]
V ... ...... ..o ...... .. .... ......... ... .... .... .. .... ...  ...
V ... ...... ..o ...... .. .... ......... ... .... .... .. .... ...  ...
V .p. ...... ..o ...... .. .... ......... ... .... .... .. .... ...  ...
V .pp ...... ..o ...... .. .... ......... ... .... .... .. .... ...  ... >
[5]                                                                           ⑧
V .pp ...... Q.. ...... .. .... ......... ... .... .... .. .... ...  ...
V .pp ...... Q.. ...... .. .... ......... ... .... .... .. b4.. b..  ...      ⑦
V .pp ...... Q.. ...... .. .... ......... ... .... .... .. b4.. b..  ...
V .pp ...... Q.. ...... .. .... ......... ... .... .... .. b4.. b..  ...      ⑫
[6]
V .pp ...... Q.. ...... .. .... ......... ... .... .... .. b4.. b..  ...
V .pp ...... Q.. ...... .. .... ......... ... .... .... .. b4.. b..  ...
V .pp ...... Q.. ...... .. .... ......... ... .... .... .. b4.. b..  ...
V .pp ...... Q.. ...... .. .... ......... ... .... .... .. b4.. b..  ...
.
.
.                                                                             ⑥
[11]
V .pp ...... Q.. ...... .. .... ......... ... .... .... .. b4.. b..  ...
V .pp ...... Q.. ...... .. .... ......... ... .... .... .. b... b..  ...
V .rp ...... Q.. ...... .. .... ......... ... .... .... .. b... b..  ...
V .rr ...... Q.. ...... .. .... ......... ... .... .... .. b... b..  ...
[12]
V .rr ...... ... ...... .. .... ......... ... .... .... .. b... b..  ...
V .rr ...... ... ...... .. .... ......... ... .... .... .. b... b..  ...
V .rr ...... ... ...... .. .... ......... ... .... .... .. b... b..  ...
V .r. ...... ... ...... .. .... ......... ... .... .... .. b... b..  ...
[13]
V .r. ...... ... ...... .. .... ......... ... .... .... .. b... b..  ...
V .r. ...... ... ...... .. .... ......... ... .... .... .. b... b..  ...
V .r. ...... ... ...... .. .... ......... ... .... .... .. b... b..  ...      ①
V .r. ...... ... ...... .. .... ......... ... .... .... .. b... b..  ...
[14]
V .r. ...... ... ...... .. .... ......... ... .... .... .. b... b..  ...
V .r. ...... ... ...... .. .... ......... ... .... .... .. .... b..  ...      ②
V .r. ...... ... ...... .. .... ......... ... .... .... .. .... b..  ...
V .r. ...... ... ...... .. .... ......... ... .... .... .. .... ...  ...
```

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[15]
V .r. ...... ... ...... .. .... ......... ... .... .... .. .... ...  ...
V .r. ...... ... ...... .. .... ......... ... .... .... .. .... ...  ...
V .r. ...... ... ...... .. .... ......... ... .... .... .. .... ...  ...
V .r. ...... ... ...... .. .... ......... ... .... .... .. .... ...  ...

Communication Elements                     Control Elements

 S  PZ EE   ZDNS  TMB  RMB  TMB  RMB  RRCL   Lcl   Rem   Ltch  SELogic
3O  T3KKCWU 3SSTB A    A    B    B    OBBB
PT PRREETFB XTTOT 1357 1357 1357 1357 KAAO O RW RW RW RW RW RW          1111111
OF TXBYYTCB TRRPX 2468 2468 2468 2468  DDK C 27 28 29 30 31 32 1234567890123456
[1]
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[2]
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[3]
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[4]
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[5]                                                                                  7
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.* ...*.... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.* ...*.... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.* ...*.... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[6]
.* ...*.... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.* ...*.... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.* ...*.... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.* ...*.... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.
.
.                                                                                    6
[11]
.* ...*.... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[12]
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[13]
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[14]
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[15]
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
*. ........ ..... .... .... .... .... .... . 00 00 00 00 00 00 ................

Event: BCG T     Frequency:  60.00
Targets: 87
Currents (A Pri), ABCNGQ:    219  1584  1429     0   684  2188

Group 1

Relay Settings:
RID   =SEL-311M                        TID   =EXAMPLE: BUS B, BREAKER 3
CTR   = 200      CTRN  = 200      PTR   = 2000.00  PTRS  = 2000.00  VNOM  = 120.00
Z1MAG = 7.80     Z1ANG = 84.00
Z0MAG = 24.80    Z0ANG = -81.50
```

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```
E87L  = 2         EHST  = 000011
CTR_X = 200
87LPP = 6.00      CTALRM= 0.50
87LR  = 6.0       87LANG= 195
50FWP = 0.005     87WP  = 50.00    W_ANG= -90

E50P  = 1         E50NG = N        E50Q  = N
E51P  = N         E51NG = Y        E51Q  = Y
E32   = AUTO      ELOAD = Y        ESOTF = Y        EVOLT = N        E25   = N
E81   = N         ELOP  = Y        ECOMM = POTT     EPWR  = N        ESV   = N
ELAT  = N         EDP   = 3        EDEM  = THM      50P1P = 2.25     67P1D = 0.00
51NGP = 0.250     51QP  = 0.44
ZLF   = 9.22      ZLR   = 9.22
PLAF  = 30.00     NLAF  =-30.00    PLAR  = 150.00   NLAR  = 210.00   DIR3  = R
DIR4  = F
CLOEND= OFF       52AEND= 10.00    SOTFD = 30.00
Z3RBD = 5.00      EBLKD = 10.00    ETDPU = 2.00
EDURD = 4.00      EWFC  = N
DMTC  = 60        PDEMP = OFF      NDEMP = OFF      QDEMP = OFF      TDURD = 9.00
CFD   = 60.00     3POD  = 0.50
50LP  = 0.25

SELogic Group 1

SELogic Control Equations:
TR    =51NGT + 51QT + OC
TRCOMM=TRIP87
TRSOTF=50P1
DTT   =0
ULTR  =!(50L + 50NG1)
PT    =IN102
52A   =IN101
CL    =CC
ULCL  =TRIP + TRIP87
67P1TC=1
51NGTC=1
51QTC =1
OUT101=TRIP
OUT102=TRIP
OUT103=CLOSE
OUT104=KEY
OUT105=0
OUT106=0
OUT107=87HWAL
OUT201=TRIP + TRIP87
OUT202=TRIP + TRIP87
OUT203=0
OUT204=0
OUT205=0
OUT206=0
DP1   =52A
DP2   =CHXAL
DP3   =CHYAL
SS1   =0
SS2   =0
SS3   =0
SS4   =0
SS5   =0
SS6   =0
ER    =+ /51NG + /51Q + /50P1 + /LOP
FAULT =51NG + 51Q
BSYNCH=0
CLMON =0
87WB  =0
E32IV =1
T1X   =0
T2X   =0
T3X   =0
T4X   =0
T5X   =0
T6X   =0
T7X   =0
T8X   =0
T1Y   =0
T2Y   =0
T3Y   =0
T4Y   =0
T5Y   =0
T6Y   =0
T7Y   =0
T8Y   =0
```

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```
TGR    = 1800.00  NFREQ = 60       PHROT = ABC
DATE_F= MDY       FP_TO = 15.00    SCROLD= 5
LER    = 15       PRE    = 4       DCLOP = OFF      DCHIP = OFF
IN101D= 0.00      IN102D= 0.00     IN103D= 0.00     IN104D= 0.00
IN105D= 0.00      IN106D= 0.00     FMETER= STANDARD
EBMON = N

=>>
```

Figure 10.4 Example Standard 15-Cycle Event Report 1/4-Cycle Resolution (Backup Protection)

Table 10.6 Standard Event Report Current and Frequency Columns (Line Current Differential)

Column Heading		Definition
Local	IA	Local Phase A current
	IB	Local Phase B current
	IC	Local Phase C current
Channel X	IA	IA current received at Channel X
	IB	IB current received at Channel X
	IC	IC current received at Channel X
Channel Y	IA	IA current received at Channel Y
	IB	IB current received at Channel Y
	IC	IC current received at Channel Y
Total	IA	Sum of all Phase A terminal currents.
	IB	Sum of all Phase B terminal currents.
	IC	Sum of all Phase C terminal currents.
FREQ		Frequency measured by the relay

Table 10.7 Output, Input and Protection, and Control Element Event Report Columns (Line Current Differential) (Sheet 1 of 4)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
87LA	87LA	*	87LA asserted
87LB	87LB	*	87LB asserted
87LC	87LC	*	87LC asserted
87LL	87L	*	87L asserted
87WF	87WF	*	87WF asserted
3POR		X	3POX asserted
		Y	3POY asserted
		b	Both 3POX and 3POY asserted
B87W		*	B87W asserted
GNDS		L	Local ground switch indicating that the zero-sequence calculations are to use calculated zero-sequence currents instead of those measured by the IN channel (GNDSWL Relay Word bit)

Table 10.7 Output, Input and Protection, and Control Element Event Report Columns (Line Current Differential) (Sheet 2 of 4)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
		R	Remote channel GNDSWL Relay Word bit
		b	Both local and remote GNDSWL asserted
Restr A	R87LA	*	R87LA asserted
Restr B	R87LB	*	R87LB asserted
Restr C	R87LC	*	R87LC asserted
Restr G	R87LG	*	R87LG asserted
Restr 2	R87L2	*	R87L2 asserted
FTSA	FTSA	*	FTAG or FTAB or FTCA or FTABC asserted
FTSB	FTSB	*	FTBG or FTAB or FTBC or FTABC asserted
FTSC	FTSC	*	FTCG or FTBC or FTCA or FTABC asserted
R1	R1X, R1Y	b	Receive bit 1 on both Channels X and Y asserted
		X	Receive bit 1 on Channel X asserted
		Y	Receive bit 1 on Channel Y asserted
R2	R2X, R2Y	b	Receive bit 2 on both Channels X and Y asserted
		X	Receive bit 2 on Channel X asserted
		Y	Receive bit 2 on Channel Y asserted
R3	R3X, R3Y	b	Receive bit 3 on both Channels X and Y asserted
		X	Receive bit 3 on Channel X asserted
		Y	Receive bit 3 on Channel Y asserted
R4	R4X, R4Y	b	Receive bit 4 on both Channels X and Y asserted
		X	Receive bit 4 on Channel X asserted
		Y	Receive bit 4 on Channel Y asserted
R5	R5X, R5Y	b	Receive bit 5 on both Channels X and Y asserted
		X	Receive bit 5 on Channel X asserted
		Y	Receive bit 5 on Channel Y asserted
R6	R6X, R6Y	b	Receive bit 6 on both Channels X and Y asserted
		X	Receive bit 6 on Channel X asserted
		Y	Receive bit 6 on Channel Y asserted
R7	R7X, R7Y	b	Receive bit 7 on both Channels X and Y asserted
		X	Receive bit 7 on Channel X asserted
		Y	Receive bit 7 on Channel Y asserted

Table 10.7 Output, Input and Protection, and Control Element Event Report Columns (Line Current Differential) (Sheet 3 of 4)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
R8	R8X, R8Y	b	Receive bit 8 on both Channels X and Y asserted
		X	Receive bit 8 on Channel X asserted
		Y	Receive bit 8 on Channel Y asserted
T1	T1X, T1Y	b	Transmit bit 1 on both Channels X and Y asserted
		X	Transmit bit 1 on Channel X asserted
		Y	Transmit bit 1 on Channel Y asserted
T2	T2X, T2Y	b	Transmit bit 2 on both Channels X and Y asserted
		X	Transmit bit 2 on Channel X asserted
		Y	Transmit bit 2 on Channel Y asserted
T3	T3X, T3Y	b	Transmit bit 3 on both Channels X and Y asserted
		X	Transmit bit 3 on Channel X asserted
		Y	Transmit bit 3 on Channel Y asserted
T4	T4X, T4Y	b	Transmit bit 4 on both Channels X and Y asserted
		X	Transmit bit 4 on Channel X asserted
		Y	Transmit bit 4 on Channel Y asserted
T5	T5X, T5Y	b	Transmit bit 5 on both Channels X and Y asserted
		X	Transmit bit 5 on Channel X asserted
		Y	Transmit bit 5 on Channel Y asserted
T6	T6X, T6Y	b	Transmit bit 6 on both Channels X and Y asserted
		X	Transmit bit 6 on Channel X asserted
		Y	Transmit bit 6 on Channel Y asserted
T7	T7X, T7Y	b	Transmit bit 7 on both Channels X and Y asserted
		X	Transmit bit 7 on Channel X asserted
		Y	Transmit bit 7 on Channel Y asserted
T8	T8X, T8Y	b	Transmit bit 8 on both Channels X and Y asserted
		X	Transmit bit 8 on Channel X asserted
		Y	Transmit bit 8 on Channel Y asserted
ROK	ROKX, ROKY	b	ROK for both Channels X and Y asserted
		X	ROK for Channel X asserted
		Y	ROK for Channel Y asserted
Out1 1 2	OUT101, OUT102	1	OUT101 asserted
		2	OUT102 asserted
		b	Both OUT101 and OUT102 asserted

Table 10.7 Output, Input and Protection, and Control Element Event Report Columns (Line Current Differential) (Sheet 4 of 4)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
Out1 3 4	OUT103, OUT104	1	OUT103 asserted
		2	OUT104 asserted
		b	Both OUT103 and OUT104 asserted
Out1 5 6	OUT105, OUT106	1	OUT105 asserted
		2	OUT106 asserted
		b	Both OUT105 and OUT106 asserted
Out1 7 A	OUT107, ALARM	7	OUT107 asserted
		A	ALARM deasserted (relay failure or ALARM pulsed)
		b	OUT107 asserted and ALARM deasserted
Out2 1 2	OUT201, OUT202	1	OUT201 asserted
		2	OUT202 asserted
		b	Both OUT201 and OUT202 asserted
Out2 3 4	OUT203, OUT204	1	OUT203 asserted
		2	OUT204 asserted
		b	Both OUT203 and OUT204 asserted
Out2 5 6	OUT205, OUT206	1	OUT205 asserted
		2	OUT206 asserted
		b	Both OUT205 and OUT206 asserted
In1 1 2	IN101, IN102	1	IN101 asserted
		2	IN102 asserted
		b	Both IN101 and IN102 asserted
In1 3 4	IN103, IN104	1	IN103 asserted
		2	IN104 asserted
		b	Both IN103 and IN104 asserted
In1 5 6	IN105, IN106	1	IN105 asserted
		2	IN106 asserted
		b	Both IN105 and IN106 asserted

Example Standard 15-Cycle Event Report (Differential Protection)

The example standard 15-cycle event report in *Figure 10.5* also corresponds to the example sequential events recorder (SER) report in *Figure 10.9*. The boxed numbers in *Figure 10.5* correspond to the SER row numbers in *Figure 10.9*. The row explanations follow *Figure 10.9*.

```
=>>EVE <Enter>

SEL-311M                          Date: 11/20/03    Time: 15:31:09.187
EXAMPLE: BUS B, BREAKER 3

FID=SEL-311M-R101-V0-Z003002-D20031117        CID=EDED

                  Terminal Currents (Amps Pri)
         Local             Channel X           Total
   IA    IB    IC    IA    IB    IC    IA    IB    IC
[1]
  -148   221   -71   149  -220    58     1     1   -13
  -169   -44   216   171    44  -223     2     0    -7
   148  -221    71  -150   221   -58    -2     0    13
   169    45  -215  -169   -44   223     0     1     8
[2]
  -148   221   -72   149  -221    59     1     0   -13
  -169   -45   216   171    44  -223     2    -1    -7
   147  -221    71  -149   220   -57    -2    -1    14
   169    44  -215  -172   -43   221    -3     1     6
[3]
  -147   221   -71   149  -220    58     2     1   -13
  -169   -44   215   170    43  -222     1    -1    -7
   146  -222    72  -148   221   -59    -2    -1    13
   169    44  -216  -170   -43   223    -1     1     7
[4]
  -146   221   -72   148  -220    58     2     1   -14
  -170   -43   215   171    42  -222     1    -1    -7
   147  -221    72  -149   220   -59    -2    -1    13
   170    34  -266  -170   -51   162     0   -17  -104>
.
.
.
[7]
  -147   957 -1321   148   510 -1271     1  1467 -2592
  -170  1333  -679   172  1422 -1048     2  2755 -1727*
   146  -939  1304  -148  -491  1255    -2 -1430  2559
   171 -1318   663  -171 -1402  1025     0 -2720  1688
[8]                                                         Figure 10.7 and Figure 10.8
  -146   946 -1313   148   499 -1264     2  1445 -2577
  -171  1328  -673   171  1417 -1042     0  2745 -1715
   146  -937  1304  -148  -492  1256    -2 -1429  2560
   171 -1324   671  -171 -1408  1041     0 -2732  1712
[9]
  -146   944 -1311   147   496 -1263     1  1440 -2574
  -171  1328  -674   171  1410 -1037     0  2738 -1711
   145  -937  1305  -147  -486  1250    -2 -1423  2555
   171 -1324   671  -171 -1413  1036     0 -2737  1707
[10]
  -146   943 -1311   147   495 -1254     1  1438 -2565
  -171  1329  -677   171  1416 -1041     0  2745 -1718
   146  -940  1308  -147  -490  1252    -1 -1430  2560
   170 -1326   674  -171 -1408  1030    -1 -2734  1704
[11]
  -129   805  -1073  130   416 -1069     1  1221 -2142
  -108   890   -395  109  1000  -635     1  1890 -1030
    56  -336    418  -57  -173   443    -1  -509   861
    22  -224     55  -23  -293   117    -1  -517   172
[12]
     0     1      0    1     0     0     1     1     0
     0     0      0    0     0     0     0     0     0
     0     0      0    0     0     0     0     0     0
     0     0      0    0     0     0     0     0     0
```

(Continued on next page)

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```
[13]
     0     0      0    0     1     0     0     1     0
     0     0      0    0     0     0     0     0     0
     0     0      0    0     0     0     0     0     0
     0     0     -1    0     0     0     0     0    -1
[14]
     0     0      0    0     0     0     0     0     0
     0     0      0    0     0     0     0     0     0
     0     0      0    0     0     0     0     0     0
     0     0      0    0     0     0     0     0     0
[15]
     0     0      0    0     0     0     0     0     0
     0     0      0    0     0     0     0     0     0
     0     0      0    0     0     0     0     0     0
     0     0      0    0     0     0     0     0     0

      87L Protection and Contact I/O Elements

     83B8G
87L  7P87N Rstr FTS R        T          R Out1 Out2 In1
     WO7WD                              O 1357 135  135
ABCL FRWBS ABC  ABC 12345678 12345678   K 246A 246  246
[1]
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...
[2]
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...
[3]
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...        9  11
.... .... ***  ... ........ ........   X .... ...  ...
[4]
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...
.... .... ***  ... ........ ........   X .... ...  ...>
[5]
.... .... ***  ... ........ ........   X .... ...  ...
.*** .... *..  .** ........ ........   X b4.. b..  ...           10
.*** .... *..  .** ........ ........   X b4.. b..  ...
.*** .... *..  .** ........ ........   X b4.. b..  ...           12
[6]                                                              7
.*** .... *..  .** ........ ........   X b4.. b..  ...
.*** .... *..  .** ........ ........   X b4.. b..  ...           8
.*** .... *..  .** ........ ........   X b4.. b..  ...
.*** .... *..  .** ........ ........   X b4.. b..  ...
.                                                                6
.
.
[11]
.*** .... *..  .** ........ ........   X b4.. b..  ...
.*** .... *..  .** ........ ........   X b... b..  ...           5
.*** .... *..  .** ........ ........   X b... b..  ...
.*.* .... *..  .*. ........ ........   X b... b..  ...           4
[12]
...* .... *..  *** ........ ........   X b... b..  ...
...* .... ...  ... ........ ........   X b... b..  ...           3
.... .... ...  ... ........ ........   X b... b..  ...
.... .... ...  ... ........ ........   X b... b..  ...
[13]
.... .... ...  ... ........ ........   X b... b..  ...
.... .... ...  ... ........ ........   X b... b..  ...
.... .... ...  ... ........ ........   X b... b..  ...           1
.... .... ...  ... ........ ........   X b... b..  ...
[14]
.... .... ...  ... ........ ........   X b... b..  ...
.... .... ...  ... ........ ........   X .... b..  ...           2
.... .... ...  ... ........ ........   X .... b..  ...
.... .... ...  ... ........ ........   X .... ...  ...
[15]
.... .... ...  ... ........ ........   X .... ...  ...
```

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```
Event: BCG T     Frequency:  60.00
Targets: 87
Currents (A Pri), ABCNGQ:    219  1584  1429     0   684  2188

Group 1

Relay Settings:
RID   =SEL-311M                       TID   =EXAMPLE: BUS B, BREAKER 3
CTR   = 200       CTRN  = 200       PTR   = 2000.00  PTRS  = 2000.00  VNOM  = 120.00
Z1MAG = 7.80      Z1ANG = 84.00
Z0MAG = 24.80     Z0ANG = -81.50

E87L  = 2         EHST  = 000011
CTR_X = 200
87LPP = 6.00      CTALRM= 0.50
87LR  = 6.0       87LANG= 195
50FWP = 0.005     87WP  = 50.00     W_ANG = -90

E50P  = 1         E50NG = N         E50Q  = N
E51P  = N         E51NG = Y         E51Q  = Y
E32   = AUTO      ELOAD = Y         ESOTF = Y         EVOLT = N         E25   = N
E81   = N         ELOP  = Y         ECOMM = POTT      EPWR  = N         ESV   = N
ELAT  = N         EDP   = 3         EDEM  = THM       50P1P = 2.25      67P1D = 0.00
51NGP = 0.250     51QP  = 0.44
ZLF   = 9.22      ZLR   = 9.22
PLAF  = 30.00     NLAF  =-30.00     PLAR  = 150.00    NLAR  = 210.00    DIR3  = R
DIR4  = F
CLOEND= OFF       52AEND= 10.00     SOTFD = 30.00
Z3RBD = 5.00      EBLKD = 10.00     ETDPU = 2.00
EDURD = 4.00      EWFC  = N
DMTC  = 60        PDEMP = OFF       NDEMP = OFF       QDEMP = OFF       TDURD = 9.00
CFD   = 60.00     3POD  = 0.50
50LP  = 0.25

SELogic Group 1

SELogic Control Equations:
TR    =51NGT + 51QT + OC
TRCOMM=TRIP87
TRSOTF=50P1
DTT   =0
ULTR  =!(50L + 50NG1)
PT    =IN102
52A   =IN101
CL    =CC
ULCL  =TRIP + TRIP87
67P1TC=1
51NGTC=1
51QTC =1
OUT101=TRIP
OUT102=TRIP
OUT103=CLOSE
OUT104=KEY
OUT105=0
OUT106=0
OUT107=87HWAL
OUT201=TRIP + TRIP87
OUT202=TRIP + TRIP87
OUT203=0
OUT204=0
OUT205=0
OUT206=0
DP1   =52A
DP2   =CHXAL
DP3   =CHYAL
SS1   =0
SS2   =0
SS3   =0
SS4   =0
SS5   =0
SS6   =0
ER    =/51NG + /51Q + /50P1 + /LOP
FAULT =51NG + 51Q
BSYNCH=0
CLMON =0
87WB  =0
E32IV =1
```

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```
T1X   =0
T2X   =0
T3X   =0
T4X   =0
T5X   =0
T6X   =0
T7X   =0
T8X   =0
T1Y   =0
T2Y   =0
T3Y   =0
T4Y   =0
T5Y   =0
T6Y   =0
T7Y   =0
T8Y   =0


Global Settings:
TGR    = 1800.00  NFREQ = 60        PHROT = ABC
DATE_F= MDY       FP_TO = 15.00     SCROLD= 5
LER    = 15       PRE    = 4        DCLOP = OFF       DCHIP = OFF
IN101D= 0.00      IN102D= 0.00      IN103D= 0.00      IN104D= 0.00
IN105D= 0.00      IN106D= 0.00      FMETER= STANDARD
EBMON = N


=>>
```

Figure 10.5 Example Standard 15-Cycle Event Report 1/4-Cycle Resolution (Differential Protection)

Example Standard 15-Cycle Event Report (87W Differential Protection)

The example standard 15-cycle event report in *Figure 10.6* is an example 87W differential protection report. See *EVE Command (Event Reports) on page 8.25*.

```
=>>EVE N <Enter>

SEL-311M                          Date: 12/08/03    Time: 10:42:50.872
EXAMPLE: BUS B, BREAKER 3

FID=SEL-311M-R101-V0-Z003002-D20031204       CID=98FB

   Terminal Currents (Amps Pri) &  Voltages (Volts Pri)
        Local             Channel X      Total
    IN    IG    3V0    IN    IG    3V0   IN    IG
[1]
  -216   236   -33  -215   469   -33  -432   706
    92   736    14    91  1469    14   183  2205
   216  -241    33   215  -475    33   432  -716
   -92  -732   -14   -91 -1469   -14  -183 -2201
[2]
  -216   242   -33  -216   463   -33  -433   706
    93   733    14    91  1478    14   184  2211
   216  -237    33   217  -473    33   433  -710
   -93  -737   -14   -91 -1471   -14  -184 -2208
[3]
  -216   241   -33  -216   484   -33  -432   726
    92   732    14    91  1466    14   183  2198
   216  -243    33   216  -469    33   432  -712
   -93  -733   -14   -91 -1474   -14  -184 -2207
[4]
  -216   238   -33  -217   470   -33  -433   708
    93   737    14    91  1470    14   183  2207
   216  -242    33   217  -480    33   432  -723
   -92  -733   -14   -91 -1467   -14  -183 -2200>
```

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```
[5]
  -216   244   -33  -217   469   -33  -433   712
    92   733    14    92  1473    14   184  2206
   216  -238    33   217  -467    33   433  -705
   -92  -735   -14   -92 -1473   -14  -184 -2207
[6]
  -216   238   -33  -216   483   -33  -432   721*
    92   733    14    92  1471    14   184  2204
   216  -240    33   216  -473    33   433  -714
   -92  -733   -14   -92 -1475   -14  -184 -2207
[7]
  -216   238   -33  -216   465   -33  -432   704
    92   735    14    91  1474    14   183  2209
   216  -237    33   216  -476    33   432  -713
   -92  -734   -14   -91 -1473   -14  -182 -2206
[8]
  -216   239   -33  -217   470   -33  -433   710
    92   732    14    92  1478    14   184  2210
   216  -238    33   216  -465    33   433  -704
   -92  -734   -14   -91 -1478   -14  -184 -2212
[9]
  -216   235   -33  -216   479   -33  -432   714
    92   734    14    91  1472    14   183  2206
   216  -238    33   217  -473    33   433  -711
   -92  -732   -14   -91 -1478   -14  -183 -2210
[10]
  -216   239   -33  -217   464   -33  -433   703
    92   733    14    91  1478    14   183  2212
   216  -234    33   217  -477    33   433  -711
   -92  -735   -14   -91 -1476   -14  -183 -2210
[11]
  -216   238   -33  -218   481   -33  -434   719
    92   731    14    92  1478    14   184  2208
   217  -240    33   217  -474    33   434  -714
   -93  -732   -14   -92 -1473   -14  -185 -2206
[12]
  -216   234   -33  -216   484   -33  -433   718
    92   736    14    91  1467    14   182  2202
   216  -238    33   217  -482    33   434  -719
   -91  -733   -14   -91 -1473   -14  -183 -2206
[13]
  -216   239   -33  -217   467   -33  -434   706
    92   734    14    91  1480    14   183  2214
   216  -234    33   217  -473    33   433  -707
   -92  -736   -14   -90 -1476   -14  -182 -2212
[14]
  -216   239   -33  -217   477   -33  -433   716
    92   732    14    91  1475    14   183  2208
   216  -241    33   216  -469    33   433  -710
   -92  -734   -14   -91 -1475   -14  -184 -2208
[15]
  -216   235   -33  -215   473   -33  -432   708
    92   737    14    91  1468    14   183  2204
   216  -239    33   216  -475    33   433  -715
   -92  -732   -14   -92 -1469   -14  -183 -2202

      87L Protection and Contact I/O Elements

     83BG
87L  7P8N Rstr FTS R        T        RT R Out1 Out2 In1
     WO7D                            DD O 1357 135  135
ABCL FRWS ABC  ABC 12345678 12345678 TT K 246A 246  246
[1]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[2]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[3]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[4]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...>
```

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```
[5]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[6]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[7]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[8]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[9]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[10]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[11]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[12]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[13]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[14]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
[15]
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...
**** .... ...  *** ........ ........ .. X .4.. b..  ...

Communication Elements                     Control Elements

 S  PZ EE   ZDNS  TMB  RMB  TMB  RMB  RRCL   Lcl   Rem   Ltch  SELogic
30  T3KKCWU 3SSTB A    A    B    B    OBBB
PT PRREETFB XTTOT 1357 1357 1357 1357 KAAO O RW RW RW RW RW RW         1111111
OF TXBYYTCB TRRPX 2468 2468 2468 2468  DDK C 27 28 29 30 31 32 1234567890123456
[1]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[2]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[3]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[4]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................>
```

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(Continued from previous page)

```
[5]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[6]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[7]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[8]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[9]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[10]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[11]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[12]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
[13]
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.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
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[14]
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
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.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
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[15]
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.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................
.. *..**... ..... .... .... .... .... .... . 00 00 00 00 00 00 ................

Event: TRIG  Location: $$$$$$$  Shot:    Frequency:  59.99
Targets:
Currents (A Pri), ABCPGQ:    500   499   500   230   752  1196

Group 1

Relay Settings:
RID   =SEL-311M                     TID   =EXAMPLE: BUS B, BREAKER 3
CTR   = 100      CTRN  = 200      PTR   = 1000.00  PTRS  = 2000.00  VNOM  = 0.00
Z1MAG = 78.00    Z1ANG = 84.00
Z0MAG = 248.00   Z0ANG = -81.50

E87L  = 2
EHST  = 000011   PCHAN = X        EHSC  = N
87LPP = 0.00     CTALRM= 0.00
87LR  = 6.0      87LANG= 195
50FWP = 0.005    87WP  = 50.00    W_ANG = -90

E50P  = 1        E50NG = N        E50Q  = N
E51P  = N        E51NG = Y        E51Q  = Y
E32   = AUTO     ELOAD = Y        ESOTF = Y        EVOLT = N        E25   = N
E81   = N        ELOP  = Y        ECOMM = POTT     EPWR  = N        ESV   = N
ELAT  = 16       EDP   = 16       EDEM  = THM      50P1P = 0.07     67P1D = 0.00
51NGP = 0.075    51QP  = 0.44
ZLF   = 92.19    ZLR   = 92.19
PLAF  = 30.00    NLAF  =-30.00    PLAR  = 150.00   NLAR  = 210.00   DIR3  = R
DIR4  = F
```

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```
CLOEND= OFF      52AEND= 10.00    SOTFD = 30.00
Z3RBD = 5.00     EBLKD = 10.00    ETDPU = 2.00
EDURD = 4.00     EWFC  = N
DMTC  = 60       PDEMP = OFF      NDEMP = 1.50     QDEMP = OFF      TDURD = 9.00
CFD   = 60.00    3POD  = 0.50
50LP  = 0.00

SELogic Group 1

SELogic Control Equations:
TR    =TRIP + OC
TRCOMM=TRIP87
TRSOTF=0
DTT   =0
ULTR  =0
PT    =IN102
52A   =IN101
CL    =CC
ULCL  =TRIP + TRIP87
SET1  =0
RST1  =0
SET2  =0
RST2  =0
SET3  =0
RST3  =0
SET4  =0
RST4  =0
SET5  =0
RST5  =0
SET6  =0
RST6  =0
SET7  =0
RST7  =0
SET8  =0
RST8  =0
SET9  =0
RST9  =0
SET10 =0
RST10 =0
SET11 =0
RST11 =0
SET12 =0
RST12 =0
SET13 =0
RST13 =0
SET14 =0
RST14 =0
SET15 =0
RST15 =0
SET16 =0
RST16 =0
67P1TC=1
51NGTC=1
51QTC =1
OUT101=0
OUT102=TRIP
OUT103=CLOSE
OUT104=KEY
OUT105=0
OUT106=0
OUT107=87HWAL
OUT201=TRIP + TRIP87
OUT202=TRIP + TRIP87
OUT203=0
OUT204=0
OUT205=0
OUT206=0
DP1   =52A
DP2   =CHXAL
DP3   =CHYAL
DP4   =0
DP5   =0
DP6   =0
DP7   =0
DP8   =0
DP9   =0
DP10  =0
DP11  =0
DP12  =0
DP13  =0
DP14  =0
DP15  =0
DP16  =0
```

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```
SS1   =0
SS2   =0
SS3   =0
SS4   =0
SS5   =0
SS6   =0
ER    =0
FAULT =0
BSYNCH=0
CLMON =0
87WB  =0
E32IV =1

T1X   =0
T2X   =0
T3X   =0
T4X   =0
T5X   =0
T6X   =0
T7X   =0
T8X   =0
T1Y   =0
T2Y   =0
T3Y   =0
T4Y   =0
T5Y   =0
T6Y   =0
T7Y   =0
T8Y   =0

Global Settings:
TGR    = 1800.00  NFREQ = 60       PHROT = ABC
DATE_F= MDY       FP_TO = 15.00    SCROLD= 2
LER    = 15       PRE   = 4        DCLOP = OFF      DCHIP = OFF
IN101D= 0.50      IN102D= 0.50     IN103D= 0.50     IN104D= 0.50
IN105D= 0.50      IN106D= 0.50
EBMON = N

=>>
```

Figure 10.6 Example Standard 15-Cycle Event Report 1/4-Cycle Resolution (87W Differential Protection)

Table 10.8 Standard Event Report Current (87W Line Current Differential)

Column Heading		Definition
Local	IN	Local IN channel current
	IG	Local residual ground current ($I_G = 3I_0 = I_A + I_B + I_C$)
	3V0	Local zero-sequence voltage ($3V_0 = V_A + V_B + V_C$)
Channel X	IN	IN channel current received via Channel X
	IG	Residual ground current received via Channel X
	3V0	Zero-sequence voltage received via Channel X
Channel Y	IN	IN channel current via Channel Y
	IG	Residual ground current via Channel Y
	3V0	Zero-sequence voltage received via Channel Y
Total	IN	Sum of all IN channel currents (Local + Channel X or Y)
	IG	Sum of all residual ground currents (Local + Channel X or Y)

Analyzing Analog Data Columns of Event Reports

See *Table 10.7* for the output, input, protection, and control elements in the 87W line current differential event report columns.

Figure 10.7 and *Figure 10.8* look in detail at one cycle of B-phase total current (column Total IB) identified in *Figure 10.5*. *Figure 10.7* shows how the event report ac current column data relate to the actual filtered waveform and rms values. *Figure 10.8* shows how the event report current column data can be converted to phasor rms values. Voltages are processed similarly.

Refer to cycle 11 of the analog section of *Figure 10.4* and *Figure 10.5*. Notice that the currents decrease to about 0 at row 3 of cycle 11 in the backup event report, and not until row 1 of cycle 12 in the line current differential report. The currents in the line current differential report are delayed by approximately one-half cycle plus channel delay by the data alignment processing algorithms.

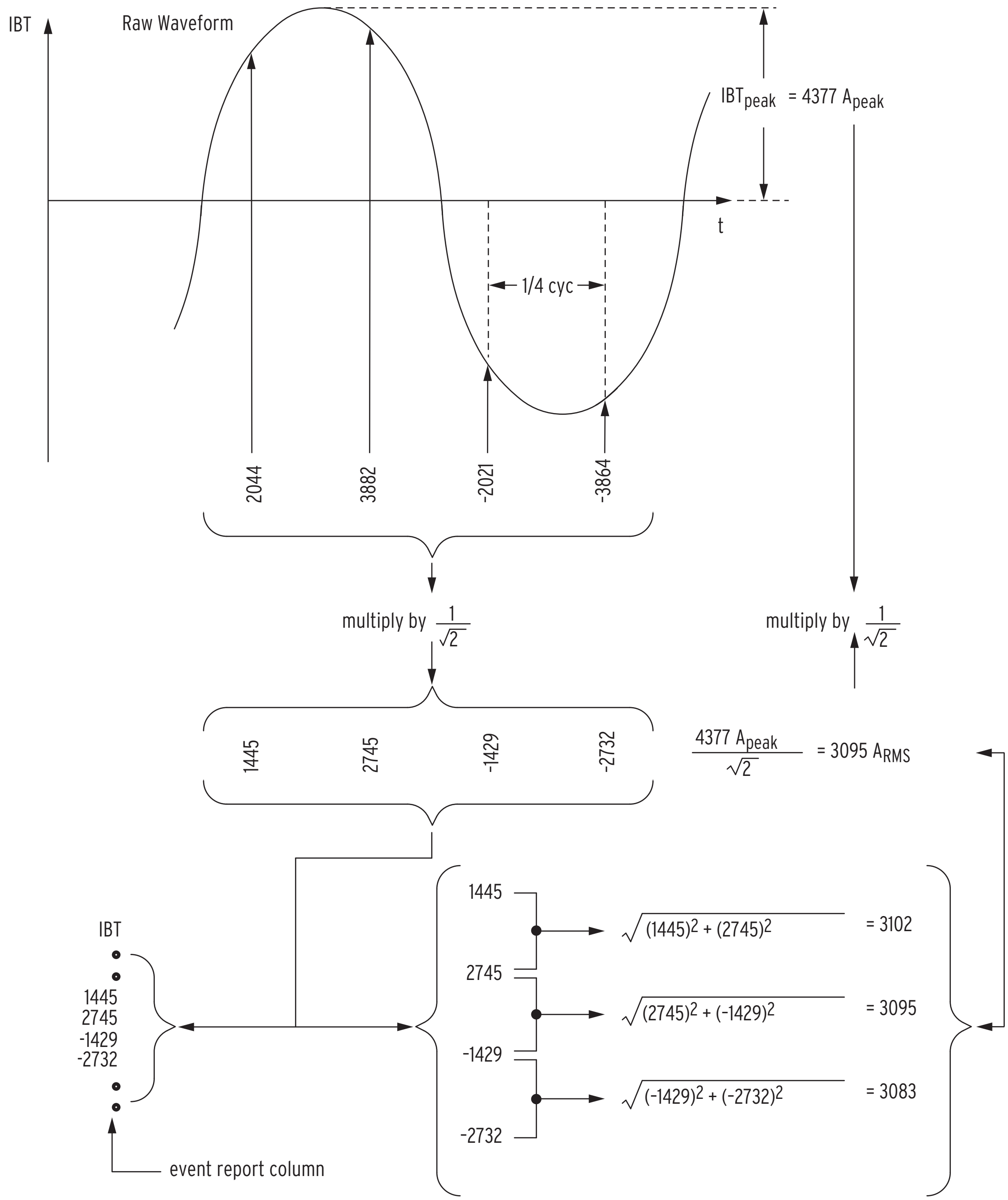

Figure 10.7 Derivation of Event Report Current Values and RMS Current Values From Sampled Current Waveform

In *Figure 10.7*, note that any two rows of current data from the event report in *Figure 10.5*, 1/4-cycle apart, can be used to calculate rms current values.

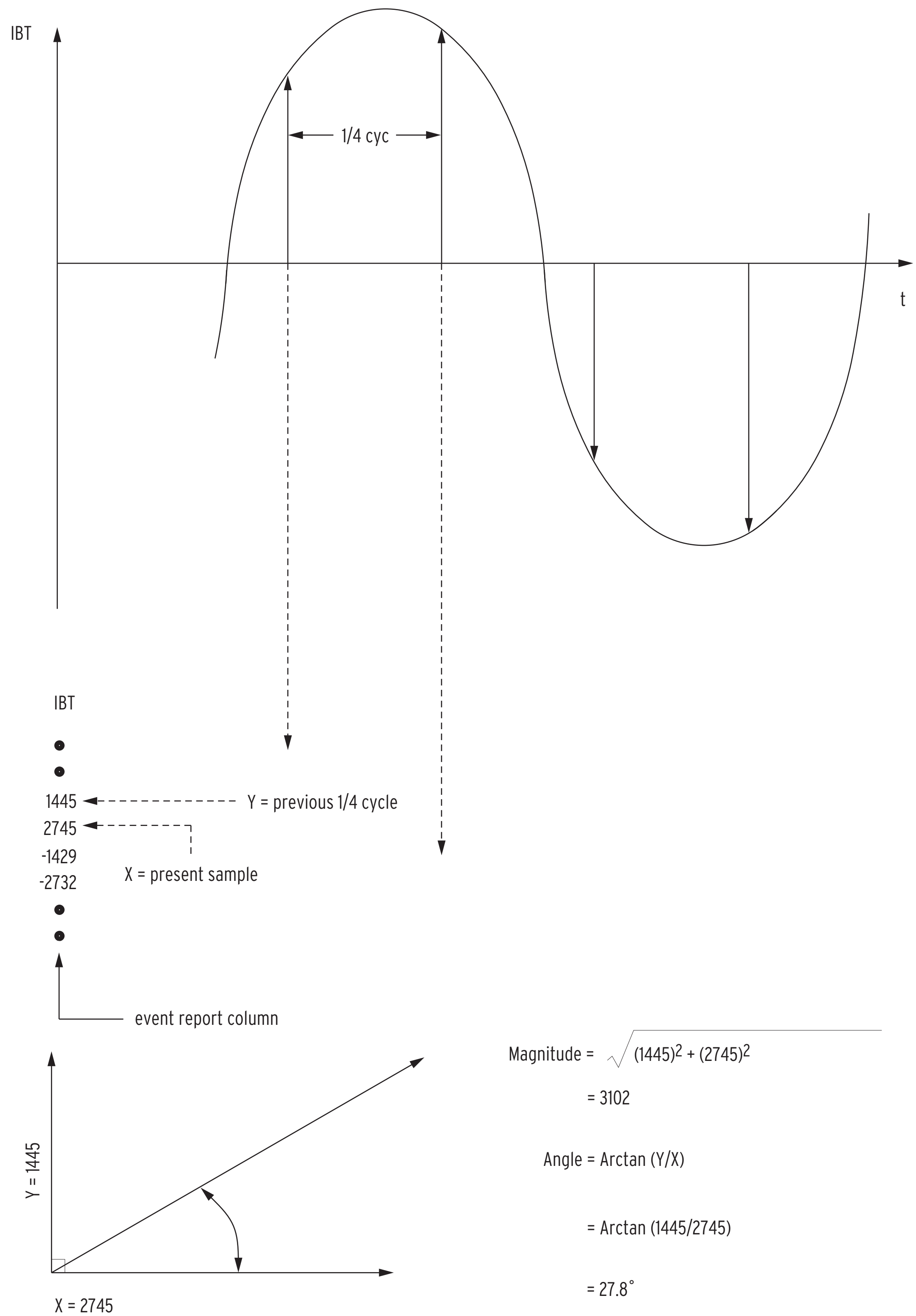

Figure 10.8 Derivation of Phasor RMS Current Values From Event Report Current Values

In *Figure 10.8*, note that two rows of current data from the event report in *Figure 10.5*, 1/4 cycle apart, can be used to calculate phasor rms current values. In *Figure 10.8*, at the present sample, the phasor rms current value is:

IBT = 3102 A ∠ 27.8°

The present sample (IBT = 2745 A) is the real part of the rms current value that relates to the phasor RMS current value:

3102 A • cos(27.8°) = 2745 A

Sequential Events Recorder Report

See *Figure 10.9* for an example Sequential Events Recorder (SER) report.

SER Triggering

The relay triggers (generates) an entry in the SER report for a change of state of any one of the elements listed in the SER1, SER2, and SER3 trigger settings. The factory default settings are:

SER1 = **0**

SER2 = **0**

SER3 = **0**

Use any of the elements in Relay Word bits in *Table 7.5*. The relay monitors each element in the SER lists every 1/4-cycle for backup elements and every 1/16-cycle for differential elements. If an element changes state, the relay time-tags the changes in the SER. For example, setting SER3 to contain time-overcurrent element pickups. Thus, any time one of these elements picks up or drops out, the relay time-tags the change in the SER.

The relay adds a message to the SER to indicate power up, event playback, or settings change (to active setting group) conditions:

`Relay newly powered up` or `Relay settings changed or PLAY`

Each entry in the SER includes SER row number, date, time, element name, and element state.

Making SER Trigger Settings

Enter up to 24 element names in each of the SER settings via the **SET R** command. See *Table 7.5* and *Table 7.6* for references to valid relay element (Relay Word bit) names. See the *Sequential Events Recorder Settings* ***(Serial Port Command SET R)*** *on page SETSET.30* at the end of *Section 7: Settings*. Use commas to delimit the elements. For example, if you enter setting SER1 as:

SER1 = **51P,51NG,51PT,51NGT,50P1,50P2**

The relay displays the setting as:

SER1 = **51P,51NG,51PT,51NGT,50P1,50P2**

The relay can monitor up to 72 elements in the SER (24 in each of SER1, SER2, and SER3).

Retrieving SER Reports

The relay saves the latest 512 rows of the SER in nonvolatile memory. Row 1 is the most recently triggered row, and row 512 is the oldest. View the SER report by date or SER row number as outlined in *Table 10.9*.

Table 10.9 Example SER Serial Port Commands and Results

Example SER Serial Port Commands	Format
SER	If **SER** is entered with no numbers following it, all available rows are displayed (up to row number 512). They display with the oldest row at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 17	If **SER** is entered with a single number following it (**17** in this example), the first 17 rows are displayed, if they exist. They display with the oldest row (row 17) at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 10 33	If **SER** is entered with two numbers following it (**10** and **33** in this example; 10 < 33), all the rows between (and including) rows 10 and 33 are displayed, if they exist. They display with the oldest row (row 33) at the beginning (top) of the report and the latest row (row 10) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 47 22	If **SER** is entered with two numbers following it (**47** and **22** in this example; 47 > 22), all the rows between (and including) rows 47 and 22 are displayed, if they exist. They display with the newest row (row 22) at the beginning (top) of the report and the oldest row (row 47) at the end (bottom) of the report. Reverse chronological progression through the report is down the page and in ascending row number.
SER 3/30/97	If **SER** is entered with one date following it (date **3/30/97** in this example), all the rows on that date are displayed, if they exist. They display with the oldest row at the beginning (top) of the report and the latest row at the end (bottom) of the report, for the given date. Chronological progression through the report is down the page and in descending row number.
SER 2/17/97 3/23/97	If **SER** is entered with two dates following it (date **2/17/97** chronologically precedes date **3/23/97** in this example), all the rows between (and including) dates 2/17/97 and 3/23/97 are displayed, if they exist. They display with the oldest row (date 2/17/97) at the beginning (top) of the report and the latest row (date 3/23/97) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 3/16/97 1/5/97	If **SER** is entered with two dates following it (date **3/16/97** chronologically follows date **1/5/97** in this example), all the rows between (and including) dates 1/5/97 and 3/16/97 are displayed, if they exist. They display with the latest row (date 3/16/97) at the beginning (top) of the report and the oldest row (date 1/5/97) at the end (bottom) of the report. Reverse chronological progression through the report is down the page and in ascending row number.

The date entries in the above example **SER** commands are dependent on the Date Format setting DATE_F. If setting DATE_F = MDY, then the dates are entered as in the above examples (Month/Day/Year). If setting DATE_F = YMD, then the dates are entered Year/Month/Day.

If the requested SER event report rows do not exist, the relay responds: `No SER Data.`

Clearing SER Report

Clear the SER report from nonvolatile memory with the **SER C** command as shown in the following example:

```
=>>SER C <Enter>
Clear the SER
Are you sure (Y/N) ? Y <Enter>
Clearing Complete
```

Example SER Report

An example SER report is shown in *Figure 10.9*.

```
=>SER <Enter>

SEL-311M Date: 11/20/03 Time: 16:13:43.271
EXAMPLE: BUS B, BREAKER 3

FID=SEL-311M-R100-V0-Z001001-D20010625 CID=396E

#      DATE       TIME            ELEMENT      STATE
12     11/20/03   15:31:24.816    TRIP87       Asserted
11     11/20/03   15:31:24.816    87LC         Asserted
10     11/20/03   15:31:24.816    87L          Asserted
9      11/20/03   15:31:24.819    87LB         Asserted
8      11/20/03   15:31:24.818    TRIP         Asserted
7      11/20/03   15:31:24.818    KEY          Asserted
6      11/20/03   15:31:24.918    KEY          Deasserted
5      11/20/03   15:31:24.924    87LC         Deasserted
4      11/20/03   15:31:24.925    87LB         Deasserted
3      11/20/03   15:31:24.934    87L          Deasserted
2      11/20/03   15:31:24.966    TRIP87       Deasserted
1      11/20/03   15:31:24.969    TRIP         Deasserted

=>
```

Figure 10.9 Example SER Event Report

Give special attention to the time stamps associated with SER 9 and 8. SER 9 has an “older” time stamp than SER 8. This is not an error. The time stamp is accurate and correct. The differential elements are processed 16 times per power system cycle. This means they are also time stamped and written to the SER buffer every millisecond. However, the backup protection elements are only processed four times per power system cycle. They are then written to the SER buffer at the end of the quarter-cycle processing interval. This is the most accurate way to show the relative time stamps of the elements with a high-speed differential processing interval and a quarter-cycle backup protection-processing interval. Note that this occasional discrepancy between the sequence number order and the relative time stamps will never be greater than 3 ms.

The SER event report rows in *Figure 10.9* are explained in *Table 10.10*, numbered in correspondence to the # column. The circled numbered comments in *Figure 10.4* and *Figure 10.5* also correspond to the # column numbers in *Figure 10.9*.

Table 10.10 Explanation of Row Entries for Figure 10.9

SER Row No.	Explanation
12, 11, 10	Differential element 87LC asserts which calls for a differential trip, TRIP87. Element 87L, which is 87LA + 87LB + 87LC, also asserts.
9	B-phase differential element 87LB asserts.
8	TRIP asserts.
7	The POTT scheme asserts Relay Word bit KEY, which closes OUT104.
6–3	Protection elements deassert as the breaker opens and fault is interrupted.
2, 1	TRIP and TRIP87 deassert. At first glance, SER records 1 and 2 do not appear to correspond to the event report (*Figure 10.5*) with OUT101 = TRIP and OUT201 = TRIP + TRIP87. In *Figure 10.5*, OUT201 deasserts 1/2-cycle after OUT101. This is because the dedicated line current differential hardware controls outputs **OUT201–OUT206**. The 1/2-cycle delay reflects the time necessary for the result of the OUT201 equation to be passed to the line current differential hardware and for the contact status to be passed back to the backup protection processor where the event report is created. Refer to *Use of High-Speed Contacts OUT201-OUT206 With Fast, Sensitive Loads on page 5.23* for an in-depth explanation of the TRIP and TRIP87 logic.

Section 11
Testing and Troubleshooting

Overview

This section provides guidelines for determining and establishing test routines for the SEL-311M Relay. Included are discussions on testing philosophies, methods, and tools. Relay self-tests and troubleshooting procedures are shown at the end of the section.

This section also provides guidance on event playback in the SEL-311M.

Testing Philosophy

Protective relay testing may be divided into three categories:

- acceptance
- commissioning
- maintenance

The categories are differentiated by when they take place in the life cycle of the relay as well as by the test complexity.

The paragraphs below describe when to perform each type of test, the goals of testing at that time, and the relay functions that you need to test at each point. This information is intended as a guideline for testing SEL relays.

Acceptance Testing

1. When:
   a. When qualifying a relay model to be used on the utility system.
2. Goals:
   a. Ensure that the relay meets published critical performance specifications such as operating speed and element accuracy.
   b. Ensure that the relay meets the requirements of the intended application.
   c. Gain familiarity with relay settings and capabilities.
3. What to test:
   a. All protection elements and logic functions critical to the intended application.

SEL performs detailed acceptance testing on all new relay models and versions. We are certain the relays we ship meet their published specifications. It is important for you to perform acceptance testing on a relay if you are unfamiliar with its operating theory, protection scheme logic, or settings. This helps ensure the accuracy and correctness of the relay settings when you issue them.

Commissioning Testing

1. When:
    a. When installing a new protection system.
2. Goals:
    a. Ensure that all system ac and dc connections are correct.
    b. Ensure that the relay functions as intended using your settings.
    c. Ensure that all auxiliary equipment operates as intended.
3. What to test:
    a. All connected or monitored inputs and outputs, polarity and phase rotation of ac connections, simple check of protection elements.

SEL performs a complete functional check and calibration of each relay before it is shipped. This helps ensure that you receive a relay that operates correctly and accurately.

Step 1. Commissioning tests should verify that the relay is properly connected to the power system and all auxiliary equipment.

Step 2. Verify control signal inputs and outputs.

Step 3. Check breaker auxiliary inputs, SCADA control inputs, and monitoring outputs.

Step 4. Use an ac connection check to verify that the relay current and voltage inputs are of the proper magnitude and phase rotation.

Step 5. Brief fault tests ensure that the relay settings are correct.

It is not necessary to test every relay element, timer, and function in these tests.

Step 6. At commissioning time, use the relay **METER** command to verify the ac current and voltage magnitude and phase rotation.

Step 7. Use the **PULSE** command to verify relay output contact operation.

Step 8. Use the **TARGET** command to verify optoisolated input operation.

Maintenance Testing

1. When:
    a. At regularly scheduled intervals or when there is an indication of a problem with the relay or system.
2. Goals:
    a. Ensure that the relay is measuring ac quantities accurately.
    b. Ensure that scheme logic and protection elements are functioning correctly.
    c. Ensure that auxiliary equipment is functioning correctly.

3. What to test:
   a. Anything not shown to have operated during an actual fault within the past maintenance interval.

SEL relays use extensive self-testing capabilities and feature detailed metering and event reporting functions that lower the dependence on routine maintenance testing.

Use the SEL relay reporting functions as maintenance tools.

Step 1. Periodically verify that the relay is making correct and accurate current and voltage measurements by comparing the relay METER output to other meter readings on that line.

Step 2. Review relay event reports in detail after each fault.

Step 3. Using the event report current, voltage, and relay element data, you can determine that the relay protection elements are operating properly.

Step 4. Using the event report input and output data, you can determine that the relay is asserting outputs at the correct instants and that auxiliary equipment is operating properly.

At the end of your maintenance interval, the only items that need testing are those that have not operated during the maintenance interval.

The basis of this testing philosophy is simple: If the relay is correctly set and connected, is measuring properly, and no self-test has failed, there is no reason to test it further.

Each time a fault occurs, the protection system is tested. Use event report data to determine areas requiring attention. Slow breaker auxiliary contact operations and increasing or varying breaker operating time can be detected through detailed analysis of relay event reports.

Because SEL relays are microprocessor based, their operating characteristics do not change over time. Time-overcurrent operating times are affected only by the relay settings and applied signals. It is not necessary to verify operating characteristics as part of maintenance checks.

At SEL, we recommend that maintenance tests on SEL relays be limited under the guidelines provided above. The time saved may be spent analyzing event data and thoroughly testing those systems that require more attention.

Testing Methods and Tools

Test Features Provided by the Relay

Use the features listed in *Table 11.1* to assist you during relay testing.

Table 11.1 Features Useful for Relay Testing

Commands	Description
MET, **MET N**, and **MET B**	The **MET** command shows local and remote currents (magnitude and phase angle) referenced to the local I1 current. The vector sum and the vector ratio in the Alpha protection plane will be displayed. Use this information, with load applied to the protected line, to validate the ac current connections at all terminals. The **MET N** command shows local and remote zero-sequence currents and voltages (magnitude and phase angle) referenced to the local I1 current. Use this information to validate connections at all current terminals. The **MET B** command displays the local current and voltage (if applied) magnitude and phase angle, as well as metering data. In addition, the command shows power system frequency and the dc voltage applied to the relay power supply terminals. See *Section 8: Communications* and *Section 9: Front-Panel Operations*.
TST	Use the **TST** command from Access Level 2 to display the protection status of the differential communication channels. Use the **TST X** or **TST Y** commands to place the channel in a loopback or end-to-end test mode. Use this feature to check the integrity and quality of the differential channels.
EVENT	The relay generates a 15- or 30-cycle event report in response to faults or disturbances. Each report contains current and voltage information, relay element states, and input/output contact information. If you question the relay response or your test method, use the event report for more information. The **EVENT** (**EVE**) command is available at the serial ports. See *Section 10: Analyzing Events*.
SUM	The relay generates an event summary for each oscillographic event report. Use the **SUM** command to view and acknowledge the event summaries. Use the event summary to quickly verify proper relay operation. Compare the reported fault current and voltage magnitudes and angles against the reported fault location and fault type. If you question the relay response, or your test method, obtain the oscillographic event report for a more detailed analysis. See *Section 10: Analyzing Events* for more information on the event summary.
SER	The relay provides a Sequential Events Recorder (SER) event report that time-tags changes in relay element and input/output contact states. The SER provides a convenient means to verify the pickup/dropout of any element in the relay. The **SER** command is available at the serial ports. See *Section 10: Analyzing Events*.
TARGET	Use the **TARGET** (**TAR**) command to view the state of relay control inputs, relay outputs, and relay elements individually during a test. The **TARGET** command is available at the serial ports and the front panel. See *Section 8: Communications* and *Section 9: Front-Panel Operations*.
PULSE	Use the **PULSE** (**PUL**) command to test the contact output circuits. The **PULSE** command is available at the serial ports and the front panel. See *Section 8: Communications*.

NOTE: In loopback mode the received current is the same as the local current. This condition may be interpreted by the relay as an internal fault, so care should be taken to disable trip outputs.

Low-Level Test Interface

The SEL-311M has a low-level test interface between the calibrated input module and the separately calibrated processing module. You may test the relay in either of two ways:

- ➤ by using secondary injection testing
- ➤ by applying low magnitude ac voltage signals to the low-level test interface

Access the test interface by removing the relay front panel.

Figure 11.1 shows the low-level interface connections. Remove the ribbon cable between the two modules to access the outputs of the input module and the inputs to the processing module (relay main board).

⚠CAUTION
The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.

You can test the relay processing module, using signals from the SEL-RTS Low-Level Relay Test System. Never apply voltage signals greater than 9 volts peak-peak to the low-level test interface. *Figure 11.1* shows the signal scaling factors.

You can test the input module two different ways:

- ➤ Measure the outputs from the input module with an accurate voltmeter (measure signal pin to **GND** pin), and compare the readings to accurate instruments in the relay input circuits.
- ➤ Replace the ribbon cable, press the front-panel **{METER}** pushbutton, and compare the relay readings to other accurate instruments in the relay input circuits.

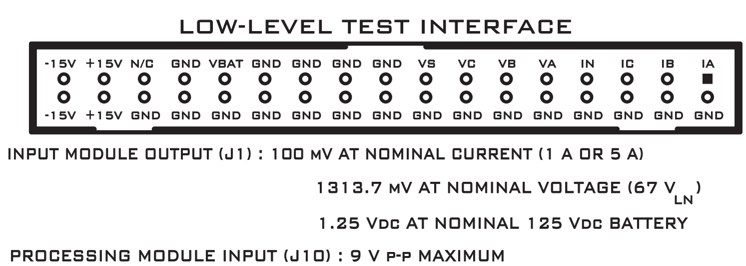

Figure 11.1 Low-Level Test Interface

Test Methods

Test the pickup and dropout of relay elements, using one of three methods:

- ➤ target command indication
- ➤ output contact closure
- ➤ sequential events recorder (SER)

The examples below show the settings necessary to route the phase time-overcurrent element 51PT to the output contacts and the SER. The 51PT element, like many in the SEL-311M, is controlled by enable settings and/or torque control SELOGIC® control equations. To enable the 51PT element, set the E51P enable setting and 51PTC torque control settings to the following:

E51P = **Y** (via the **SET** command)

51PTC = **1** (set directly to logical 1, via the **SET L** command)

Testing Via Front-Panel Indicators

Display the state of relay elements, inputs, and outputs using the front-panel or serial port **TAR** commands. Use this method to verify the pickup settings of protection elements.

Access the front-panel **TAR** command from the front-panel **{OTHER}** pushbutton menu.

Step 1. To display the state of the 51PT element on the front-panel display, press the **{OTHER}** pushbutton.

Step 2. Cursor to the `TAR` option, and press **{SELECT}**.

Step 3. Press the up arrow pushbutton until `TAR 2` is displayed on the top row of the LCD.

The bottom row of the LCD displays all elements asserted in Relay Word Row 2. The relay maps the state of the elements in Relay Word Row 2 on the bottom row of LEDs. The 51PT element state is reflected on the LED. See *Table 7.6* for the correspondence between the Relay Word elements and the **TAR** command.

Step 4. To view the 51PT element status from the serial port, issue the **TAR 51PT** or **TAR2** command.

The relay will display the state of all elements in the Relay Word row containing the 51PT element.

Review **TAR** command descriptions in *Section 8: Communications* and *Section 9: Front-Panel Operations* for further details on displaying element status via the **TAR** commands.

Testing Via Output Contacts

You can set the relay to operate an output contact for testing a single element.

Use the **SET L** command (SELOGIC control equations) to set an output contact (e.g., **OUT101–OUT206**) to the element under test.

The available elements are the Relay Word bits referenced in *Table 7.6*.

Use this method especially for time testing time-overcurrent elements. For example, to test the phase time-overcurrent element 51PT via output contact OUT104, make the following SELOGIC setting:

OUT104 = **51PT**

Time-overcurrent curve and time-dial information can be found in *Section 7: Settings*. Do not forget to reenter the correct relay settings when you are finished testing and are ready to place the relay in service.

Testing Via Sequential Events Recorder

You can set the relay to generate an entry in the Sequential Events Recorder (SER) for testing relay elements. Use the **SET R** command to include the element(s) under test in any of the SER trigger lists (SER1–SER3). See *Section 10: Analyzing Events*.

To test the phase time-overcurrent element 51PT with the SER, make the following setting:

SER1 = **51P, 51PT**

Element 51P asserts when phase current is above the pickup of the phase time-overcurrent element. Element 51PT asserts when the phase time-overcurrent element times out. The assertion and deassertion of these elements is time-stamped in the SER report. Use this method to verify timing associated with time-overcurrent elements, etc. Do not forget to reenter the correct relay settings when you are ready to place the relay in service.

Event Playback

Event Playback allows the relay to recreate events by using the data from an event report (see *Section 10: Analyzing Events*) or from user-loaded Comtrade files to replace the external inputs. Event playback supports the playback of the analog and digital signals shown in *Table 11.2*.

Table 11.2 Playback Signal Categories and Signals

Category	Signal	Description
Analog Data	IA	A-phase input current
	IB	B-phase input current
	IC	C-phase input current
	IN	Channel IN input current
	VA	A-phase input voltage
	VB	B-phase input voltage
	VC	C-phase input voltage
	VS	Channel VS input voltage
	VDC	Station battery voltage
Digital Data	IN101–IN106	Contact input Relay Word bits
MIRRORED BITS®	RMB1A–RMB8A RMB1B–RMB8B ROKA, ROKB	MIRRORED BITS Relay Word bits
Control Bits	RB1–RB16	Remote bits
	LB1–LB16	Local bits
	OC, CC	Open and Close bits

The basic steps required for Event Playback are as follows:

Step 1. Generate a relay COMTRADE Event file by either:

a. applying a fault to the relay, or

b. loading 1999 format COMTRADE files (.CFG and .DAT files) into the relay via the **FILE WRITE** command.

See *Section 8: Communications* for more information on the **FILE** command and writing COMTRADE Event files.

NOTE: The Comtrade .CFG file must be loaded before the .DAT file.

Step 2. Use the **HIS A** command to view COMTRADE Event files that are available for Playback.

See *Section 8: Communications* for more information on the **HISTORY** command.

Step 3. Use the **PLAY** command to set up the desired Event for playback and check Playback status.

See *Section 8: Communications* for more information on the **PLAY** command.

Step 4. Use any or all of the **HIS**, **EVE**, and **SER** commands to view the results of the Event Playback just executed.

When event playback completes, the relay returns to normal operation without any required actions.

The example below demonstrates the Event Playback process.

Event Playback

NOTE: To playback an event stored in the SEL-311M, it is not necessary to download the event report to the computer, however, these steps are included for demonstration purposes.

In the example, we want to playback an event stored in the SEL-311M.

The **FILE SHOW EVENTS** command is first used to view the events stored in the relay.

```
=>>FILE SHOW EVENTS <Enter>
ER_10002.CFG                    R
ER_10002.DAT                    R
ER_10001.CFG                    R
ER_10001.DAT                    R
ERR.TXT                         R

=>>
```

Event report ER_10002 is then downloaded to the computer using the **FILE READ** command.

```
=>>FILE READ EVENTS ER_10002.CFG <Enter> Ready to send file
Transfer Complete

=>>FILE READ EVENTS ER_10002.DAT <Enter> Ready to send file
Transfer Complete
=>>
```

If you experience trouble downloading the events from the relay to the computer see *Relay Troubleshooting on page 11.17*. The filenames must change as the relay will not receive files with the ER_xxxx naming. In this example, the filenames are changed to example.cfg and example.dat. The renamed example files are then reloaded into the relay using the **FILE WRITE** command.

```
=>>FILE WRITE EVENTS EXAMPLE.CFG <Enter> Transfer Complete

=>>FILE WRITE EVENTS EXAMPLE.DAT <Enter> Transfer Complete

=>>
```

The Comtrade .CFG file must be loaded before the .DAT file.

If you experience trouble using the **FILE WRITE** command see the *FIL WRITE (Write File to Relay) on page 8.46*.

The **HIS A** command is then used to verify files loaded and are available for playback as shown in *Figure 11.2*.

```
=>>HIS A <Enter>

SEL-311M                          Date: 01/20/04    Time: 10:33:27.387
EXAMPLE: BUS B, BREAKER 3

FILE             DATE       TIME      EVENT   FREQ     TARGETS

EXAMPLE.DAT   01/19/04 14:05:48.253 $$$$$$ 60.0 NOM

=>>
```

Figure 11.2 HIS A Response During Example Event Playback

Event playback is then initiated using the **PLAY** command and responding **Y** at the prompt as shown in *Figure 11.3*.

```
=>>PLAY EXAMPLE.DAT <Enter>

SEL-311M                          Date: 01/20/04    Time: 10:34:06.756
EXAMPLE: BUS B, BREAKER 3

FILE            DATE       TIME      EVENT  DEVICE

ER_10003.DAT  01/20/04 09:07:25.169 ER     SEL-311M

PLAYBACK TRIGGER: 01/20/04 10:33:06.756

DATA SOURCES
----------------------------------------
Analogs     Digitals    Cmd Bits    MBits A     MBits B
Playback    Playback    External    External    External

OUTPUT CONTROL
----------------------------------------
OUT101    OUT102    OUT103    OUT104    OUT105    OUT106    OUT107
Normal    Normal    Normal    Normal    Normal    Normal    Normal

Perform Event Playback as described above.  Are you sure (Y/N)? Y <Enter>
```

Figure 11.3 Playback Initiation During Example Event Playback

Completion of the event playback can be verified via both the **PLA** command and the **SER** command as shown in *Figure 11.4*.

```
=>>PLAY <Enter>

SEL-311M                          Date: 01/20/04    Time: 10:34:37.113
EXAMPLE: BUS B, BREAKER 3

Event Playback Status: COMPLETE

FILE            DATE       TIME      EVENT  DEVICE
ER_10003.DAT  01/20/04 09:07:25.169 ER     SEL-311M

PLAYBACK TRIGGER: 01/20/04 10:33:37.113

DATA SOURCES
----------------------------------------
Analogs     Digitals    Cmd Bits    MBits A     MBits B
External    External    External    External    External

OUTPUT CONTROL
----------------------------------------
OUT101    OUT102    OUT103    OUT104    OUT105    OUT106    OUT107
Normal    Normal    Normal    Normal    Normal    Normal    Normal

=>>SER <Enter>

SEL-311M                          Date: 01/20/04    Time: 10:35:41.529
EXAMPLE: BUS B, BREAKER 3

FID=SEL-311M-X108-V0-Z003002-D20040116       CID=0DB2

#     DATE       TIME            ELEMENT           STATE

2     01/20/04   10:34:18.720    PLAY              Asserted
1     01/20/04   10:34:18.970    PLAY              Deasserted

=>>
```

Figure 11.4 Event Playback Status During Example Event Playback

Additional Details About Event Playback

Auto Messages

Set AUTO=Y in the Port Settings on your serial port to get an Automatic Message each time Event Playback begins. See *Serial Port Automatic Messages on page 8.14* for more information on the AUTO setting.

PLAY Relay Word Element

The PLAY Relay Word bit asserts each time Event Playback begins and de-asserts upon Playback completion. The PLAY Relay Word bit is ALWAYS monitored by the relay SER, regardless of the content of the SER settings. See *Section 10: Analyzing Events* for more information about SER.

Date/Time Changes

Changing the Date or Time via the **DATE/TIME** commands will automatically cancel any pending Event Playback.

Multiple Playback Triggers

Event Playback can trigger only one time. In order to execute Playback again, you must enter another **PLAY** command.

Disabling of Protection Algorithms

The relay protection algorithms are disabled for two cycles at the start of Event Playback as the relay transitions from live data to the Playback data. Similarly, the relay protection is disabled for a time period between two cycles and one full second as the relay transitions from Playback to normal operation.

Prefault Data

Due to the disabling of relay protection algorithms described above, the COMTRADE Event to be played back must include at least two cycles of data prior to its fault condition. Otherwise, the relay will not see at least part of the fault and the re-creation of the Event may not be accurate.

System Frequency

When analog data values are played back, system frequency is also played back. However, it is simply forced to the Nominal Frequency value (NFREQ setting within Global Settings) for all channels, regardless of what the system frequency may have been during the original Event. The Analog magnitudes that are present in the COMTRADE file are injected at a rate such that each new sample is applied 1/16th of a power cycle (at nominal frequency) after the previous sample. Since the frequency is treated as nominal, all samples are injected at equally spaced intervals.

Testing Alpha Plane 87L Elements

Introduction

Test alpha plane 87L elements for operation speed and security, and for element accuracy. To test for operation speed and security, optionally apply prefault load current, then switch to an internal or external fault. Because the SEL-311M often trips in less than one cycle, transient effects in the fault currents do impact operation speed. In some instances, it may be necessary to test using Comtrade files from an EMTP simulation or a real time simulator. The operate speeds depicted in *Figure 3.7* are from fault inception to closure of high-speed output contacts OUT201–OUT206, using setting EHST. The tests used symmetrical fault currents only, so they can be easily reproduced.

To test element accuracy, test the operate elements 87LOPA, 87LOPB, and 87LOPC and also test the alpha plane restraint elements R87LA, R87LB, and R87LC. The relay trips when the restraint element deasserts to indicate that the alpha plane ratio falls outside the restraint region, and the operate element asserts to indicate that the differential current is above the differential current pickup setting.

This section details a test procedure suitable for testing the accuracy of the 87L elements in the SEL-311M.

The test procedure outlined below assumes the following factory default settings:

E87L = **2** Two terminal protection

87LPP = **1.2** 1.2 A secondary phase line current differential pickup setting

87LANG = **195** Restraint region subtends 195 degrees

87LR = **6** Restraint region outside radius is six; inside radius is 1/6

The test procedure alters those settings for the operate element tests to isolate the element under test.

SEL-311M 87L Element Test Procedure

1. Purpose:
   a. Test the accuracy of phase 87L elements.
2. Test Outline:
   a. Test the phase 87L element accuracy for A-phase. (B- and C-phase optional)

Test Phase 87L Element Accuracy

Test the phase operate element 87LOPA.

Step 1. To test the operate element, apply a low-current internal three-phase fault.

Step 2. Then increase the differential current until the relay trips.

Test the phase restraint element R87LA.

Step 1. To test the restraint element, apply currents at the local relay, with zero current applied to the remote relay.

This simulates a weak-infeed internal fault, deasserts restraint element R87LA, and causes both relays to trip.

Step 2. Increase the magnitude of the currents at the remote relay until the restraint bit R87LA asserts.

Step 3. Continue to increase the magnitude of the remote currents until restraint bit R87LA deasserts.

Step 4. Repeat with various phase angles applied between local and remote currents.

Step 5. Finally, apply an internal fault with equal current at each relay.

Step 6. Change the angle of the current on the remote relay until restraint element R87LA in the local relay solidly asserts.

This approach is graphically depicted in *Figure 11.5*.

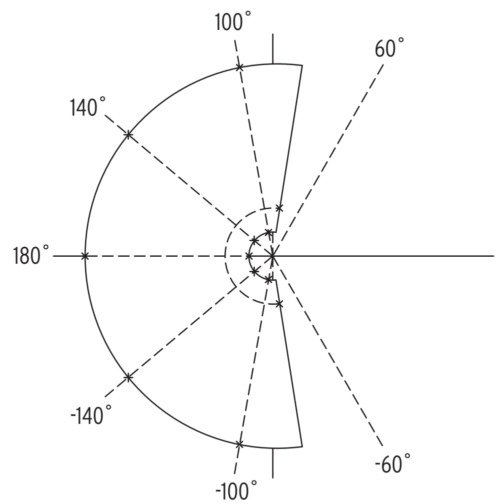

Figure 11.5 Alpha Plane Element Accuracy Test Points

Phase operate elements 87LOPB and 87LOPC, and phase restraint elements R87LB and R87LC are identical to the A-phase elements, and are not tested here. They may be tested with an identical procedure.

Required Equipment

- ➤ Two SEL-311M Relays with established 87L communications interface
- ➤ Three-phase secondary injection test equipment, or low-level test equipment such as the SEL-AMS Adaptive Multichannel Source
- ➤ PC with terminal emulation software
- ➤ SEL cable C234A

Test Setup

Step 1. Ensure the relay is set appropriately.

Step 2. Connect three-phase secondary injection current sources or low-level test sources to the relays.

Step 3. Connect the PC to the relays with an SEL C234A cable.

Step 4. Establish communications.

Test Procedure

Phase 87L Element Tests

Step 1. Make setting 87LPP = 1.2.

Step 2. Apply the following currents:

Local Relay: IA = 0.5 A < 0 degrees
IB = 0.5 A < –120 degrees
IC = 0.5 A < 120 degrees

Remote Relay: IA = 0.5 A < 0 degrees
IB = 0.5 A < –120 degrees
IC = 0.5 A < 120 degrees

Step 3. Increase IA in the remote relay at 0 degrees until the relay trips.

Step 4. Record the remote A-phase current that causes the relay to trip.

Step 5. Ensure that the current is within the range indicated.

0.68 A < _________ < 0.72 A

Step 6. Return A-phase current to 0.5 A.

Step 7. Repeat with the B- and C-phase currents if desired.

Expect similar results.

Step 8. Apply the following currents:

Local Relay: IA = 0.466 A ∠0 degrees
Remote Relay: IA = 0 A ∠180 degrees

Step 9. In the local relay, use the **TAR R87LA 10000** command to display the R87LA Relay Word bit 10,000 times, or use the front panel **TAR** command to display Relay Word row 55.

Step 10. Ensure bit R87LA is deasserted.

Step 11. Increase the remote A-phase current at 180 degrees until the R87LA bit solidly asserts.

Step 12. Record the remote A-phase current required to solidly assert R87LA in *Table 11.3*.

Step 13. Ensure that the current is within the expected range indicated.

Table 11.3 Phase Restraint Element Pickup Test Results (Inner Radius)

Remote Current Angle	Remote Current at Which R87LA Asserts		
	Min.	Actual	Max.
180	0.075		0.080
140	0.075		0.080
100	0.075		0.080
60	No assertion		No assertion
0	No assertion		No assertion
–60	No assertion		No assertion
–100	0.075		0.080
–140	0.075		0.080

Step 14. Apply the following currents:

Local Relay: IA = 0.466 A ∠0 degrees

Remote Relay: IA = 2.6 A ∠180 degrees[a]

[a] The SEL-311M is rated to withstand 3 • I_{NOM} indefinitely.

Step 15. In the local relay, use the **TAR R87LA 10000** command to display the R87LA Relay Word bit 10,000 times, or use the front-panel **TAR** command to display Relay Word row 55.

Step 16. Ensure bit R87LA is asserted.

Step 17. Increase the remote A-phase current at 180 degrees until the R87LA bit is no longer solidly asserted (until it begins to deassert).

Step 18. Record the remote A-phase current required to begin to deassert R87LA in *Table 11.4*.

Step 19. Ensure that the current is within the expected range indicated in the table.

Step 20. Repeat *Step 8* though *Step 19* for each remote current angle shown in *Table 11.3* and *Table 11.4*.

Table 11.4 Phase Restraint Element Dropout Test Results (Outer Radius)

Remote Current Angle	Remote Current at Which R87LA Deasserts		
	Min.	Actual	Max.
180	2.72		2.88
140	2.72		2.88
100	2.72		2.88
–100	2.72		2.88
–140	2.72		2.88

Step 21. Apply the following currents:

Local Relay: IA = 1 A ∠0 degrees

Remote Relay: IA = 1 A ∠0 degrees

Step 22. In the local relay, use the **TAR R87LA 10000** command to display the R87LA Relay Word bit 10,000 times, or use the front-panel **TAR** command to display Relay Word row 55.

Step 23. Ensure bit R87LA is deasserted.

Step 24. Increase the angle of the remote IA from zero until Relay Word bit R87LA is solidly asserted.

Step 25. Record the angle of IA required to solidly assert R87LA.

Step 26. Ensure that the angle is within the range expected:

80 degrees < __________ < 85 degrees

Step 27. Decrease the angle of the remote IA from zero (more negative) until Relay Word bit R87LA is solidly asserted.

Step 28. Record the angle of IA required to solidly assert R87LA.

Step 29. Ensure that the angle is within the range expected:

–85 degrees < __________ < –80 degrees

Relay Self-Tests

The relay runs a variety of self-tests. The relay takes the following corrective actions for out-of-tolerance conditions (see *Table 11.5*):

- ➤ Protection Disabled: The relay disables overcurrent elements and trip/close logic. All output contacts are de-energized. The **EN** front-panel LED is extinguished.
- ➤ ALARM Output: The **ALARM** output contact signals an alarm condition by going to its de-energized state.
  - ➢ If the **ALARM** output contact is a b contact (normally closed), it closes for an alarm condition or if the relay is de-energized.
  - ➢ If the **ALARM** output contact is an a contact (normally open), it opens for an alarm condition or if the relay is de-energized.

  Alarm condition signaling can be a single 5-second pulse (Pulsed) or permanent (Latched).
- ➤ Line Current Differential Protection Disabled: The relay disables 87L protection and de-energizes outputs **OUT201**–**OUT206**. Relay Word bit 87LPE deasserts and Relay Word bit 87HWAL asserts.
- ➤ The relay generates automatic STATUS reports at the serial port for warnings and failures.
- ➤ The relay displays failure messages on the relay LCD display for failures.

Use the serial port **STATUS** command or front-panel **{STATUS}** pushbutton to view relay self-test status.

Table 11.5 Relay Self Tests (Sheet 1 of 2)

Self-Test	Condition	Limits	Protection Disabled	ALARM Output	Description
IA, IB, IC, IN, VA, VB, VC, VS Offset	Warning	30 mV	No	Pulsed	Measures the dc offset at each of the input channels every 10 seconds.
Master Offset	Warning	20 mV	No	Pulsed	Measures the dc offset at the A/D every 10 seconds.
	Failure	30 mV	Yes	Latched	
+5 V PS	Warning	+4.80 V +5.20 V	No	Pulsed	Measures the +5 V power supply every 10 seconds.
	Failure	+4.65 V +5.40 V	Yes	Latched	
+5 V REG	Warning	+4.75 V +5.20 V, –4.75 V –5.25 V	No	Pulsed	Measures the regulated 5 V power supply every 10 seconds.
	Failure	+4.50 V +5.40 V, –4.50 V –5.50 V	Yes	Latched	

Table 11.5 Relay Self Tests (Sheet 2 of 2)

Self-Test	Condition	Limits	Protection Disabled	ALARM Output	Description
+12 V PS	Warning Failure	+11.50 V +12.50 V +11.20 V +14.00 V	No Yes	Pulsed Latched	Measures the 12 V power supply every 10 seconds.
+15 V PS	Warning Failure	+14.40 V +15.60 V +14.00 V +16.00 V	No Yes	Pulsed Latched	Measures the 15 V power supply every 10 seconds.
TEMP	Warning Failure	–40° C +85° C –50° C +100° C	No Yes	 Latched	Measures the temperature at the A/D voltage reference every 10 seconds.
RAM	Failure		Yes	Latched	Performs a read/write test on system RAM every 60 seconds.
ROM	Failure	checksum	Yes	Latched	Performs a checksum test on the relay program memory every 10 seconds.
A/D	Failure		Yes	Latched	Validates proper number of conversions each 1/4 cycle.
CR_RAM	Failure	checksum	Yes	Latched	Performs a checksum test on the active copy of the relay settings every 10 seconds.
EEPROM	Failure	checksum	Yes	Latched	Performs a checksum test on the nonvolatile copy of the relay settings every 10 seconds.
87L RAM	Failure		87L only disabled	87HWAL asserted; ALARM pulsed	Periodically performs a read/write test at each RAM location.
87L ROM	Failure	checksum	87L only disabled	87HWAL asserted; ALARM pulsed	Performs a checksum test on program storage ROM.
CHAN X CHAN Y	Failure		Determined by 87LPE	None	See *87L Communications Monitoring on page 8.3*.
FPGA	Failure		87L only disabled	87HWAL asserted; ALARM pulsed	Ensures FPGA configures properly.
BOARD	Failure		87L only disabled	87HWAL asserted; ALARM pulsed	Checks each processing interval to ensure dedicated 87L hardware responds and the watchdog timer has not expired.
The following self-tests are performed by dedicated circuitry in the microprocessor and the SEL-311M main board. Failures in these tests shut down the microprocessor and are not shown in the STATUS report.					
Microprocessor Crystal	Failure		Yes	Latched	The relay monitors the microprocessor crystal. If the crystal fails, the relay displays `CLOCK STOPPED` on the LCD display. The test runs continuously.
Microprocessor	Failure		Yes	Latched	The microprocessor examines each program instruction, memory access, and interrupt. The relay displays `VECTOR nn` on the LCD upon detection of an invalid instruction, memory access, or spurious interrupt. The test runs continuously.

Relay Troubleshooting

Inspection Procedure

Complete the following procedure before disturbing the relay. After you finish the inspection, proceed to the *Troubleshooting Procedure*.

Step 1. Measure and record the power supply voltage at the power input terminals.

Step 2. Check to see that the power is on.

Step 3. Do not turn the relay off.

Step 4. Measure and record the voltage at all control inputs.

Step 5. Measure and record the state of all output relays.

Troubleshooting Procedure

All Front-Panel LEDs Dark

1. Input power not present or fuse is blown.
2. Self-test failure.

Cannot See Characters on Relay LCD Screen

1. Relay is de-energized.

   Check to see if the **ALARM** contact is closed.

2. LCD contrast is out of adjustment.

   Use the steps below to adjust the contrast.

Step 1. Remove the relay front panel by removing the six front-panel screws.

Step 2. Press any front-panel button.

The relay should turn on the LCD back lighting.

Step 3. Locate the contrast adjust potentiometer adjacent to the serial port connector.

Step 4. Use a small screwdriver to adjust the potentiometer.

Step 5. Replace the relay front panel.

Relay Does Not Respond to Commands From Device Connected to Serial Port

Step 1. Ensure that the communications device is connected to the relay.

Step 2. Verify relay or communications device baud rate setting and other communications parameters.

Step 3. Check for a cabling error.

Relay serial port may have received an XOFF, halting communications.

Step 4. Type **<Ctrl+Q>** to send relay an XON and restart communications.

Step 5. View the port setting, using the front-panel **{SET}** buttons.

Relay Does Not Respond to Faults

Step 1. Verify that the **87CH FAIL** front-panel LED is extinguished.

Step 2. Verify that the relay is properly set.

Step 3. Verify that the test source is properly set.

Step 4. Verify that the test connections are correct by using the **MET** command.

Step 5. Ensure that the analog input cable between transformer secondary and main board is not loose or defective.

Step 6. Inspect the relay self-test status with the **STA** command or with the front-panel **{STATUS}** pushbutton.

87CH FAIL LED Is Illuminated

The **87CH FAIL** LED illuminates when the relay detects a problem with any enabled 87L communications channel. The following steps isolate the problem to one channel, to either the transmit or receive direction on that channel, and then further isolate the problem if possible based on the channel interface type. The **87CH FAIL** LED can take up to 15 seconds to extinguish after the problem is resolved.

Step 1. Determine which channel has a problem, and verify channel configuration.

a. If the relay is equipped with two channel interfaces, determine if both channel interfaces are being used.

b. Inspect Relay Word Bits CHXAL and CHYAL with the front panel **TAR** command, or with the serial port **TAR CHXAL** or **TAR CHYAL** commands. CHXAL asserts when the relay detects a problem on Channel X. CHYAL asserts when the relay detects a problem on Channel Y.

c. Inspect the channel settings by using **SHO X** or **SHO Y** commands, and verify the settings are as intended.

This is very important. If more than one setting is in error, or if there is a setting error combined with some other problem, it can be very difficult to diagnose problems with the troubleshooting steps outlined below.

Step 2. Determine if there is channel delay problem.

a. Inspect Relay Word bit DBADX or DBADY.

DBADX asserts if half the round trip channel delay on Channel X exceeds the DBADXP setting. DBADY asserts if half the round trip channel delay on Channel Y exceeds the DBADYP setting.

b. Either increase setting DBADXP or DBADYP to exceed the delay reported by the **COM X** or **COM Y** commands, or rectify the excessive channel delay.

Step 3. Determine if there is a transmit or receive problem.

a. Inspect Relay Word bits AVAX and RBADX for Channel X, or AVAY and RBADY for Channel Y.

   If either bit is asserted, that channel has a problem in the receive direction. If neither bit is asserted, go to *Step p*.

   If the RX LED is illuminated, the local relay is receiving valid packets from the remote relay. If the RX LED is not illuminated, go to *Step i*.

b. Verify that the associated address settings are correct in remote and local relays. (RA_X, TA_X when using the **SET X** command, or RA_Y and TA_Y when using the **SET Y** command.)

   The Last Error field in the report generated by the **COMM X** or **COMM Y** commands indicates Address Error if the address settings in both relays are not correct.

c. If the address settings are correct (as verified by the **COMM X** or **COMM Y** commands), issue the **COMM X C** or **COMM Y C** commands.

d. Wait a few minutes and issue the **COMM X** or **COMM Y** command again.

   If the report logs new errors, the communications link is probably unreliable or noisy. However, the new errors may also be caused by incorrect timer source or clock polarity settings in the relay.

e. Ensure settings TIMRX or TIMRY are correct.

f. If channel X is connected to a multiplexer, or to any DCE, verify that setting TIMRX = E.

g. If channel X is connected directly to another relay, ensure TIMRX = E in one relay, and TIMRX = I in the other relay.

h. Likewise, ensure that setting TIMRY is correct for channel Y.

   If the problem persists, the communications link is probably noisy or unreliable.

i. If the RX LED is extinguished, the local relay is not receiving valid packets from the remote relay.

j. Verify setting E87L is not OFF.

k. If E87L is 2 and the relay is equipped with two channel interfaces, verify that hot-standby enable setting EHSC = Y if appropriate.

l. Verify that the relay-to-multiplexer cable is fully seated at both the relay and the multiplexer, and that it has the proper pinout.

m. For fiber interfaces, swap the transmit and receive fibers at the rear panel of the relay.

n. If this does not rectify the problem, verify with an optical power meter that received power is more than –32 dBm for an IEEE Standard C37.94 interface.

o. Verify that the remote relay channel settings are correct and that the rear panel **TX** LED is illuminated on the remote relay.

If the remote relay **TX** LED is illuminated, and the local relay **RX** LED is extinguished, the transmit data that leave the remote relay do not arrive at the local relay.

p. If AVAX, RBADX, and DBADX are all deasserted, then there is a receive problem in the remote relay. Repeat *Step 3* for the remote relay.

Step 4. If the problem persists, contact the factory for assistance.

Relay Calibration

The SEL-311M is factory calibrated. If you suspect that the relay is out of calibration, please contact the factory.

Factory Assistance

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 USA
Phone: +1.509.332.1890
Fax: +1.509.332.7990
Internet: www.selinc.com
E-mail: info@selinc.com

Appendix A
Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Relay

To find the firmware revision number in your relay, view the status report by using the serial port **STATUS** (**STA**) command or the front-panel **STATUS** pushbutton. The status report displays the Firmware Identification (FID) label:

FID=SEL-311M-R102-V0-Z003003-D20100122

The SEL-311M Relay provides a means of interpreting Firmware Identification Data (FID). The FID string is included near the top of each long event report. The string format follows:

FID = SEL-311M - R[RN] - V[VS] - Z[ES] - D[RD]

where:

[RN] = Revision Number (e.g., 102)
[VS] = Version Specification
[ES] = External Software Version (e.g., 003003)
[RD] = Release Date (e.g., YYYYMMDD=20100122)

Table A.1 lists the firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.1 Firmware Revision History

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-311M-R102-V0-Z003003-D20100122	➤ Initial version.	20100122

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.2 lists the instruction manual release dates and a description of modifications. The most recent instruction manual revisions are listed at the top.

Table A.2 Instruction Manual Revision History

Revision Date	Summary of Revisions
20100122	➤ Initial version.

Appendix B
Firmware Upgrade Instructions

Overview

From time to time, SEL issues firmware upgrades for this relay. The instructions which follow explain how you can install new firmware in your SEL-300 series relay. In addition, SEL issues firmware upgrades for the optional Ethernet ports (see *Ethernet Port Firmware Upgrade Instructions on page B.17*).

Relay Firmware Upgrade Instructions

Introduction

These firmware upgrade instructions apply to all SEL-300 series relays except the SEL-321 series relays (which use EPROM instead of Flash).

SEL occasionally offers firmware upgrades to improve the performance of your relay. Changing physical components is unnecessary because the relay stores firmware in Flash memory.

A firmware loader program called SELBOOT resides in the relay. To upgrade firmware, use the SELBOOT program to download an SEL-supplied file from a personal computer to the relay via any communications port. This procedure is described in the following steps.

NOTE: SEL strongly recommends that you upgrade firmware at the location of the relay and with a *direct connection* from the personal computer to one of the relay serial ports. Do not load firmware from a remote location; problems can arise that you will not be able to address from a distance. When upgrading at the substation, do not attempt to load the firmware into the relay through an SEL communications processor.

Perform the firmware upgrade process in the following sequence:

A. Prepare the Relay
B. Establish a Terminal Connection
C. Save Settings and Other Data
D. Start SELBOOT
E. Download Existing Firmware
F. Upload New Firmware
G. Check Relay Self-Tests
H. Verify Settings, Calibration, Status, Breaker Wear, and Metering
I. Return the Relay to Service

Required Equipment

Gather the following equipment before starting this firmware upgrade:

- Personal computer
- Terminal emulation software that supports 1K Xmodem or Xmodem (these instructions use HyperTerminal® from a Microsoft® Windows® operating system)
- Serial communications cable (SEL Cable C234A or equivalent)
- Disk containing the firmware upgrade file
- Firmware Upgrade Instructions (these instructions)

Optional Equipment

These items help you manage relay settings and understand firmware upgrade procedures:

- SEL-5010 Relay Assistant software or ACSELERATOR® QuickSet™ SEL-5030 software

  The SEL-5010 Relay Assistant software has a feature that guides you through the conversion process. This upgrade guide will assist you with steps C, D, E, F, and G of these upgrade instructions. If you do not have the latest SEL-5010 software, please contact your customer service representative or the factory for details on getting the SEL-5010 Relay Assistant software.
- Your relay instruction manual

Upgrade Procedure

A. Prepare the Relay

Step 1. If the relay is in use, follow your company practices for removing a relay from service.

Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

Step 3. From the relay front panel, press the **{SET}** pushbutton.

Step 4. Use the arrow pushbuttons to navigate to `PORT`.

Step 5. Press the **{SELECT}** pushbutton.

Step 6. Use the arrow pushbuttons to navigate to the relay serial port you plan to use (usually the front port).

Step 7. Press the **{SELECT}** pushbutton.

Step 8. With `SHOW` selected, press the **{SELECT}** pushbutton.

Step 9. Press the **{Down Arrow}** pushbutton to scroll through the port settings; write down the value for each setting.

Step 10. At the `EXIT SETTINGS?` prompt, select `Yes` and press the **{SELECT}** pushbutton.

Step 11. Connect an SEL Cable C234A (or equivalent) serial communications cable to the relay serial port selected in *Step 6* above.

B. Establish a Terminal Connection

To establish communication between the relay and a personal computer, you must be able to modify the computer serial communications parameters (i.e., data transmission rate, data bits, parity) and set the file transfer protocol to 1K Xmodem or Xmodem protocol.

Step 1. Connect a serial communications cable to the computer serial port:

a. Check the computer for a label identifying the serial communications ports.

b. Choose a port and connect an SEL Cable C234A (or equivalent) serial communications cable to the personal computer serial port.

If there is no identification label, connect the cable to any computer serial port. Note that you might later change this computer serial port to a different port in order to establish communication between the relay and the computer.

Step 2. Disconnect any other serial port connection(s).

Step 3. From the computer, open **HyperTerminal**.

On a personal computer running Windows, you would typically click **Start > Programs > Accessories**.

Step 4. Enter a name, select any icon, and click **OK** (*Figure B.1*).

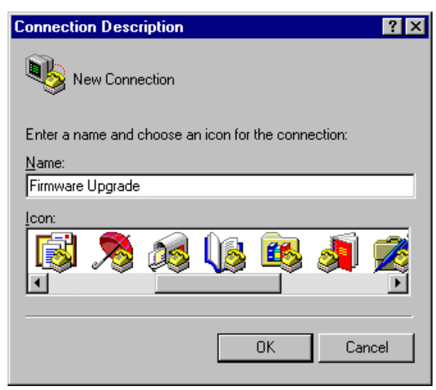

Figure B.1 Establishing a Connection

Step 5. Select the computer serial port you are using to communicate with the relay (*Figure B.2*) and click **OK**. This port matches the port connection that you made in *Step 1* under *B. Establish a Terminal Connection*.

Figure B.2 Determining the Computer Serial Port

Step 6. Establish serial port communications parameters.

The settings for the computer (*Figure B.3*) must match the relay settings you recorded earlier.

a. Enter the serial port communications parameters (*Figure B.3*) that correspond to the relay settings you recorded in *Step 9 on page B.2*.

If the computer settings do not match the relay settings, change the computer settings to match the relay settings.

b. Click **OK**.

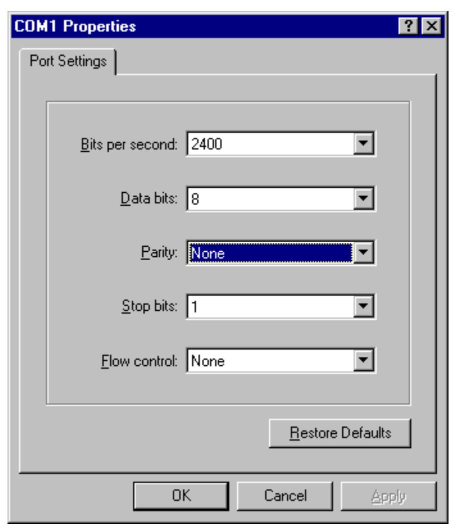

Figure B.3 Determining Communications Parameters for the Computer

Step 7. Set the terminal emulation to VT100:

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Firmware Upgrade Properties** dialog box (*Figure B.4*).

c. Select **VT100** from the **Emulation** list box and click **OK**.

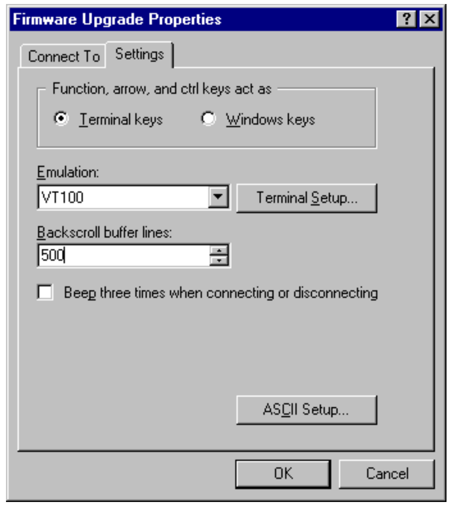

Figure B.4 Setting Terminal Emulation

Step 8. Confirm serial communication.

Press **<Enter>**. In the terminal emulation window, you should see the Access Level 0 = prompt, similar to that in *Figure B.5*.

If this is successful, proceed to *C. Save Settings and Other Data on page B.6*.

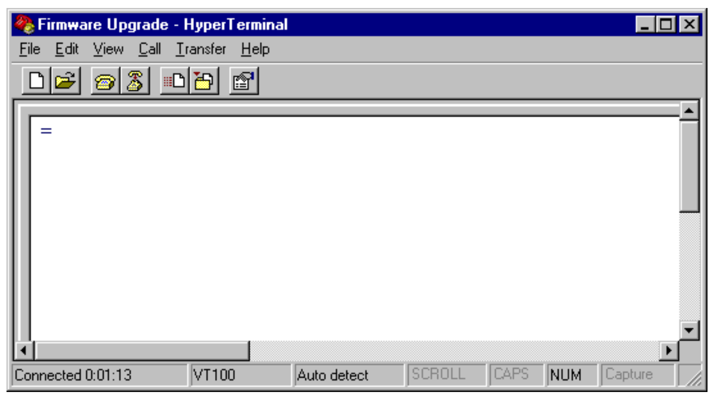

Figure B.5 Terminal Emulation Startup Prompt

Failure to Connect

If you do not see the Access Level 0 = prompt, press **<Enter>** again. If you still do not see the Access Level 0 = prompt, you have either selected the incorrect serial communications port on the computer, or the computer speed setting does not match the data transmission rate of the relay. Perform the following steps to reattempt a connection.

Step 9. From the **Call** menu, choose **Disconnect** to terminate communication.

Step 10. Correct the port setting.

a. From the **File** menu, choose **Properties**.

You should see a dialog box similar to *Figure B.6*.

b. Select a different port in the **Connect using** list box.

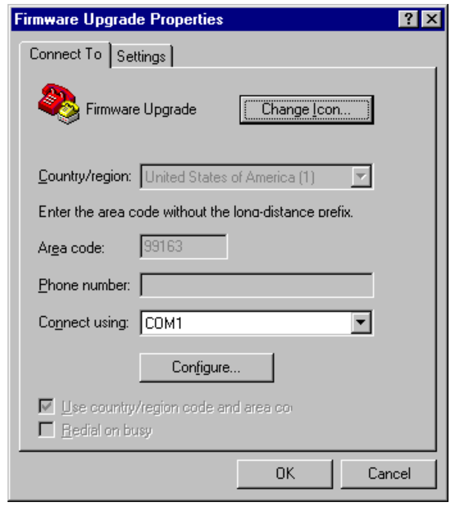

Figure B.6 Correcting the Port Setting

Step 11. Correct the communications parameters.

a. From the filename **Properties** dialog box shown in *Figure B.6*, click **Configure**.

You will see a dialog box similar to *Figure B.7*.

b. Change the settings in the appropriate list boxes to match the settings you recorded in *Step 9 on page B.2* and click **OK** twice to return to the terminal emulation window.

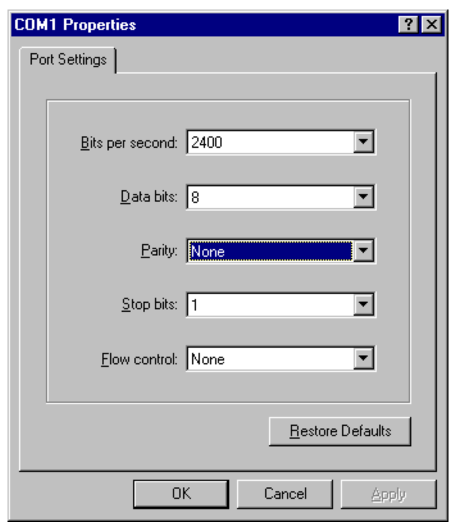

Figure B.7 Correcting the Communications Parameters

Step 12. Press **<Enter>**. In the terminal emulation window, you should see the Access Level 0 = prompt, similar to that in *Figure B.5*.

C. Save Settings and Other Data

Before upgrading firmware, retrieve and record any History (**HIS**), Event (**EVE**), Metering (**MET**), Breaker Wear Monitor (**BRE**), Communications Log Summary (**COM X** or **COM Y**), or Sequential Events Recorder (**SER**) data that you want to retain (see the relay instruction manual for these procedures).

Enter Access Level 2

NOTE: If the relay does not prompt you for Access Level 1 and Access Level 2 passwords, check whether the relay has a password jumper in place. With this jumper in place, the relay is unprotected from unauthorized access (see the relay instruction manual).

Step 1. Type **ACC <Enter>** at the Access Level 0 = prompt.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Type **2AC <Enter>**.

Step 4. Type the Access Level 2 password and press **<Enter>**.

You will see the Access Level 2 =>> prompt.

Backup Relay Settings

The relay preserves settings and passwords during the firmware upgrade process. However, interruption of relay power during the upgrade process can cause the relay to lose settings. Make a copy of the original relay settings in case you need to reenter the settings. Use either the SEL-5010 Relay Assistant software or ACSELERATOR QuickSet to record the existing relay settings and proceed to *D. Start SELBOOT*. Otherwise, perform the following steps.

Step 1. From the **Transfer** menu in **HyperTerminal**, select **Capture Text**.

Step 2. Enter a directory and filename for a text file where you will record the existing relay settings.

Step 3. Click **Start**.

The **Capture Text** command copies all the information you retrieve and all the keystrokes you type until you send the command to stop capturing text. The terminal emulation program stores these data in the text file.

Step 4. Execute the Show Calibration (**SHO C**) command to retrieve the relay calibration settings.

Use the following Show commands to retrieve the relay settings: **SHO G**, **SHO 1**, **SHO L 1**, **SHO 2**, **SHO L 2**, **SHO 3**, **SHO L 3**, **SHO 4**, **SHO L 4**, **SHO 5**, **SHO L 5**, **SHO 6**, **SHO L 6**, **SHO P 1**, **SHO P 2**, **SHO P 3**, **SHO P F**, **SHO R**, and **SHO T**.

NOTE: Settings classes can vary among SEL relays. See the relay instruction manual for a listing.

Step 5. From the **Transfer** menu in **HyperTerminal**, select **Capture Text** and click **Stop**.

The computer saves the text file you created to the directory you specified in *Step 2* under *Backup Relay Settings*.

Step 6. Write down the present relay data transmission setting (SPEED).

This setting is SPEED in the **SHO P** relay settings output. The SPEED value should be the same as the value you recorded in *A. Prepare the Relay on page B.2*.

D. Start SELBOOT

Step 1. Find and record the firmware identification string (FID):

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Properties** dialog box (*Figure B.4*).

c. Click **ASCII Setup**.

You should see a dialog box similar to *Figure B.8*.

d. Under **ASCII Receiving**, select the check box to **Append line feeds to incoming line ends**.

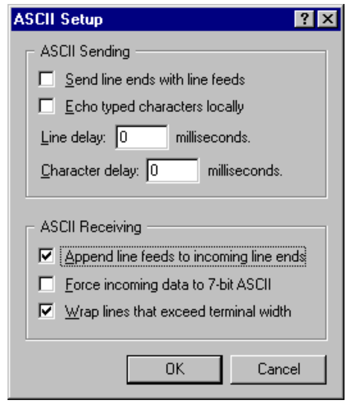

Figure B.8 Preparing HyperTerminal for ID Command Display

e. Click **OK** twice to go back to the terminal emulation window.

f. Type **ID <Enter>** and record the FID number the relay displays.

g. Repeat *Step a* through *Step c*, then uncheck the **Append line feeds to incoming line ends** check box. (This feature can cause problems when uploading firmware to the relay.)

Step 2. From the computer, start the SELBOOT program.

a. From the Access Level 2 =>> prompt, type **L_D <Enter>**.

The relay responds with the following:

```
Disable relay to send or receive firmware
(Y/N)?
```

b. Type **Y <Enter>**.

The relay responds with the following:

```
Are you sure (Y/N)?
```

c. Type **Y <Enter>**.

The relay responds with the following:

```
Relay Disabled
```

Step 3. Wait for the SELBOOT program to load.

The front-panel LCD screen displays the SELBOOT firmware number (e.g., `SLBT-3xx-R100`). The number following the R is the SELBOOT revision number. This number is different from the relay firmware revision number.

After SELBOOT loads, the computer will display the SELBOOT !> prompt.

Step 4. Press **<Enter>** to confirm that the relay is in SELBOOT.

You will see another SELBOOT !> prompt.

Commands Available in SELBOOT

For a listing of commands available in SELBOOT, type **HELP <Enter>**. You should see a screen similar to *Figure B.9*.

```
!>HELP <Enter>

SELboot-3xx-R100

bau "rate"  ; Set baud rate to 300, 1200, 2400, 4800, 9600, 19200, or 38400 baud

era         ; Erase the existing relay firmware

exi         ; Exit this program and restart the device

fid         ; Print the relays firmware id

rec         ; Receive new firmware for the relay using xmodem

sen         ; Send the relays firmware to a pc using xmodem

hel         ; Print this list
FLASH Type : 040         Checksum = 370E  OK
```

Figure B.9 List of Commands Available in SELBOOT

Establish a High-Speed Connection

Step 5. Type **BAU 38400 <Enter>** at the SELBOOT !> prompt.

Match Computer Communications Speed to the Relay

Step 6. From the **Call** menu, choose **Disconnect** to terminate communication.

Step 7. Correct the communications parameters:

a. From the **File** menu, choose **Properties**.

b. Choose **Configure**.

c. Change the computer communications speed to match the new data transmission rate in the relay (*Figure B.10*).

d. Click **OK** twice.

Step 8. Press **<Enter>** to check for the SELBOOT !> prompt indicating that serial communication is successful.

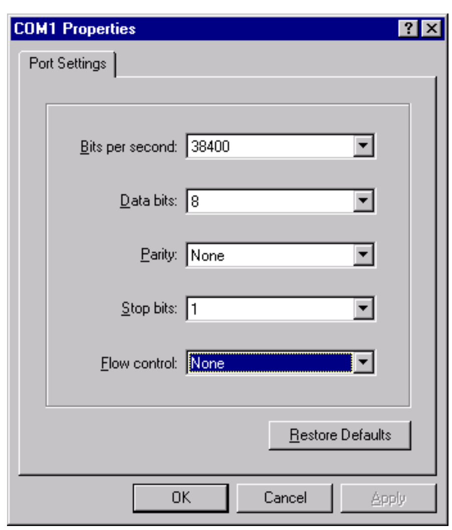

Figure B.10 Matching Computer to Relay Parameters

E. Download Existing Firmware

Copy the firmware presently in the relay, in case the new firmware upload is unsuccessful. To make a backup of the existing firmware, the computer will need as much as 3 MB of free disk space. This backup procedure takes 5–10 minutes at 38400 bps.

Step 1. Type **SEN <Enter>** at the SELBOOT !> prompt to initiate the firmware transfer from the relay to the computer.

Step 2. From the **Transfer** menu in **HyperTerminal**, select **Receive File**.

You should see a dialog box similar to *Figure B.11*.

Step 3. Enter the pathname of a folder on the computer hard drive where you want to record the existing relay firmware.

Step 4. Select **1K Xmodem** if this protocol is available on the PC.

If the computer does not have **1K Xmodem**, choose **Xmodem**.

Step 5. Click **Receive**.

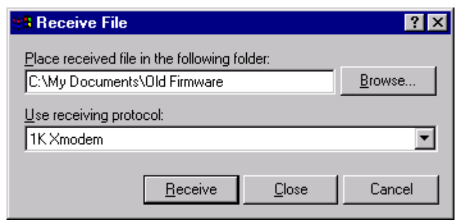

Figure B.11 Example Receive File Dialog Box

Step 6. Enter a filename that clearly identifies the existing firmware version (*Figure B.12*), using the version number from the FID you recorded earlier in *Step 1 on page B.7* and click **OK**.

SEL lists the firmware revision number first, then the product number.

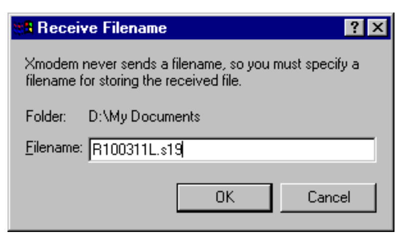

Figure B.12 Example Filename Identifying Old Firmware Version

If Xmodem times out before the download completes, repeat the process from *Step 1*.

NOTE: HyperTerminal stored any pathname you entered in Step 3 and any filename you entered in Step 6 during the earlier download attempt; this saves you from reentering these on a subsequent attempt.

For a successful download, you should see a dialog box similar to *Figure B.13*. After the transfer, the relay responds with the following:

```
Download completed successfully!
```

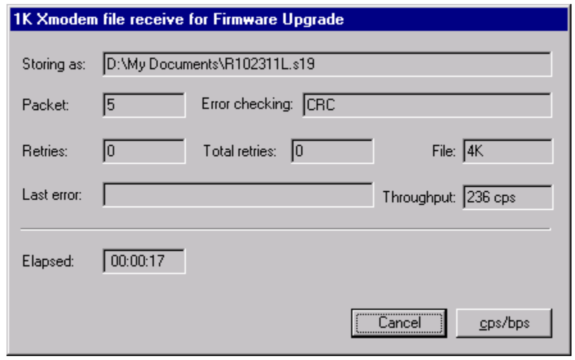

Figure B.13 Downloading Old Firmware

F. Upload New Firmware

Step 1. Prepare to load the firmware:

a. Insert the disk containing the new firmware into the appropriate disk drive on the computer.

NOTE: This example shows uploading new firmware directly from a disk. For a faster upload (and less potential for file corruption), copy the new firmware to the local hard drive and upload the new firmware from the hard drive.

b. Some firmware is in self-extracting compressed files (files with .exe extensions). For firmware in such files, from Windows Explorer double-click on the file and select the directory on the hard drive where you want to access the uncompressed files. Verify that these uncompressed files have an .s19 extension.

Step 2. Type **REC <Enter>** at the SELBOOT !> prompt to command the relay to receive new firmware.

```
!>REC <Enter>

Caution! -  This command erases the relays firmware.

If you erase the firmware, new firmware must be loaded into the relay
before it can be put back into service.
```

The relay asks whether you want to erase the existing firmware.

```
Are you sure you wish to erase the existing firmware? (Y/N) Y <Enter>
```

Step 3. Type **Y** to erase the existing firmware and load new firmware. (To abort, type **N** or press **<Enter>**).

The relay responds with the following:

```
Erasing

Erase successful
Press any key to begin transfer, then start transfer at the PC <Enter>
```

Step 4. Press **<Enter>** to start the file transfer routine.

Step 5. Send new firmware to the relay.

a. From the **Transfer** menu in **HyperTerminal**, choose **Send File** (*Figure B.14*).

b. In the **Filename** text box, type the location and filename of the new firmware or use the **Browse** button to select the firmware file.

c. In the **Protocol** text box, select **1K Xmodem** if this protocol is available.

If the computer does not have **1K Xmodem**, select **Xmodem**.

d. Click **Send** to send the file containing the new firmware.

You should see a dialog box similar to *Figure B.14*. Incrementing numbers in the **Packet** box and a bar advancing from left to right in the **File** box indicate that a transfer is in progress.

Receiving software takes 10–15 minutes at 38400 bps, depending on the relay. If you see no indication of a transfer in progress within a few minutes after clicking **Send**, use the **REC** command again and reattempt the transfer.

NOTE: Unsuccessful uploads can result from Xmodem time-out, a power failure, loss of communication between the relay and the computer, or voluntary cancellation. Check connections, reestablish communication, and start again at Step 2 on page B.11.

If you want to reload the previous firmware, begin at Step 2 on page B.11 and use the firmware you saved in E. Download Existing Firmware on page B.10. Contact the factory for assistance in achieving a successful firmware upgrade.

After the transfer completes, the relay displays the following:

```
Upload completed successfully. Attempting a restart.
```

A successful restart sequence can take as long as two minutes, after which time the relay leaves SELBOOT. You will see no display on your PC to indicate a successful restart.

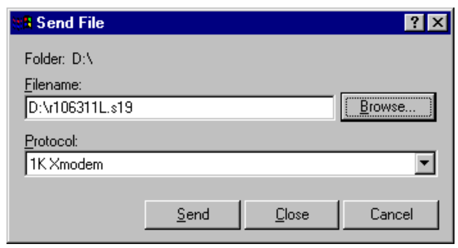

Figure B.14 Selecting New Firmware to Send to the Relay

NOTE: The relay restarts in SELBOOT if relay power fails while receiving new firmware. Upon power-up, the relay serial port will be at the default 2400 baud. Perform the steps beginning in B. Establish a Terminal Connection on page B.3 to increase the serial connection data speed. Then resume the firmware upgrade process at F. Upload New Firmware on page B.11.

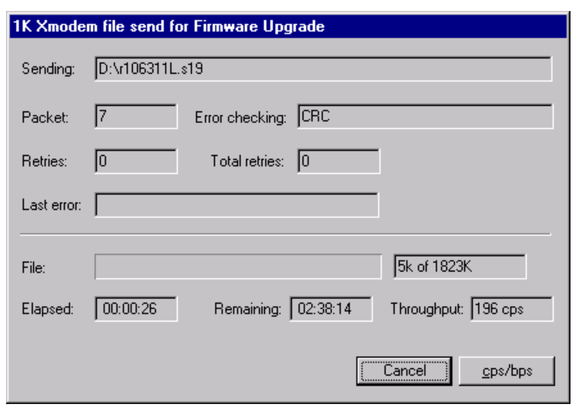

Figure B.15 Transferring New Firmware to the Relay

Step 6. Press **<Enter>** and confirm that the Access Level 0 = prompt appears on the computer screen.

Step 7. If you see the Access Level 0 = prompt, proceed to *G. Check Relay Self-Tests on page B.13*.

No Access Level 0 = Prompt

If no Access Level 0 = prompt appears in the terminal emulation window, one of three things could have occurred. Refer to *Table B.1* to determine the best solution:

Table B.1 Troubleshooting New Firmware Upload

Problem	Solution
The restart was successful, but the relay data transmission rate reverted to the rate at which the relay was operating prior to entering SELBOOT (the rate you recorded in *A. Prepare the Relay on page B.2*).	Change the computer terminal speed to match the relay data transmission rate you recorded in *A. Prepare the Relay on page B.2* (see *Match Computer Communications Speed to the Relay on page B.9*): Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication. Step 2. Change the communications software settings to the values you recorded in *A. Prepare the Relay*. Step 3. From the **Call** menu, choose **Connect** to reestablish communication. Step 4. Press **<Enter>** to check for the Access Level 0 = prompt indicating that serial communication is successful. Step 5. If you get no response, proceed to *Match Computer Communications Speed to the Relay*.
The restart was successful, but the relay data transmission rate reverted to 2400 bps (the settings have been reset to default).	Match the computer terminal speed to a relay data transmission rate of 2400 bps: Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication. Step 2. Change the communications software settings to 2400 bps, 8 data bits, no parity, and 1 stop bit (see *Match Computer Communications Speed to the Relay*). Step 3. From the **Call** menu, choose **Connect** to reestablish communication. Step 4. Press **<Enter>** to check for the Access Level 0 = prompt indicating successful serial communication. If you see a SELBOOT !> prompt, type **EXI <Enter>** to exit SELBOOT. Check for the Access Level 0 = prompt. If you see the Access Level 0 = prompt, proceed to *G. Check Relay Self-Tests on page B.13*.
The restart was unsuccessful, in which case the relay is in SELBOOT.	Reattempt to upload the new firmware (beginning at *Step 5* under *Establish a High-Speed Connection on page B.9*) or contact the factory for assistance.

G. Check Relay Self-Tests

The relay can display various self-test fail status messages. The troubleshooting procedures that follow depend upon the status message the relay displays.

Step 1. Type **ACC <Enter>**.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Enter the **STATUS** command (**STA <Enter>**) to view relay status messages.

If the relay displays no fail status message, proceed to *H. Verify Settings, Calibration, Status, Breaker Wear, and Metering on page B.15*.

IO_BRD Fail Status Message

Perform this procedure only if you have only an IO_BRD Fail Status message; for additional fail messages, proceed to *CR_RAM, EEPROM, and IO_BRD Fail Status Messages on page B.14*.

Step 1. From Access Level 2, type **INI <Enter>** to reinitialize the I/O board(s). If this command is unavailable, go to *CR_RAM, EEPROM, and IO_BRD Fail Status Messages*.

The relay asks the following:

```
Are the new I/O board(s) correct (Y/N)?
```

a. Type **Y <Enter>**.

b. After a brief interval (as long as a minute), the **EN** LED will illuminate.

If the **EN** LED does not illuminate and you see a SELBOOT !> prompt, type **EXI <Enter>** to exit SELBOOT. After a brief interval, the **EN** LED will illuminate. Check for Access Level 0 = prompt.

c. Use the **ACC** and **2AC** commands and type the corresponding passwords to reenter Access Level 2.

NOTE: Depending upon the relay, n can be 1–6, G, P, L, T, R, X, or Y.

d. Enter the **SHO *n*** command to view relay settings and verify that these match the settings you saved (see *Backup Relay Settings on page B.7*).

Step 2. If the settings do not match, reenter the settings you saved earlier.

a. If you have SEL-5010 Relay Assistant software or ACSELERATOR QuickSet, restore the original settings by following the instructions for the respective software.

b. If you do not have the SEL-5010 Relay Assistant software or ACSELERATOR QuickSet, restore the original settings by issuing the necessary **SET *n*** commands, where *n* can be 1–6, G, P, L, T, R, X, or Y (depending upon the settings classes in the relay).

Step 3. Use the **PAS** command to set the relay passwords.

For example, type **PAS 1 <Enter>** to set the Access Level 1 password.

Use a similar format for other password levels. SEL relay passwords are case sensitive, so the relay treats lowercase and uppercase letters as different letters.

Step 4. Go to *H. Verify Settings, Calibration, Status, Breaker Wear, and Metering on page B.15*.

CR_RAM, EEPROM, and IO_BRD Fail Status Messages

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

The factory default passwords are in effect; use the default relay passwords listed in the **PAS** command description in the relay instruction manual.

NOTE: If the relay prompts you to enter a part number, use either the number from the firmware envelope label or the number from the new part number sticker (if supplied).

Step 2. Type **R_S <Enter>** to restore factory default settings in the relay (type **R_S 1 <Enter>** for a 1 A SEL-387 or 1 A SEL-352 relay).

The relay asks whether to restore default settings. If the relay does not accept the **R_S** (or **R_S 1**) command, contact your customer service representative or the factory for assistance.

Step 3. Type **Y <Enter>**.

The relay can take as long as two minutes to restore default settings. The relay then reinitializes, and the EN LED illuminates.

Step 4. Press **<Enter>** to check for the Access Level 0 = prompt indicating that serial communication is successful.

Step 5. Use the **ACC** and **2AC** commands and type the corresponding passwords to reenter Access Level 2.

Step 6. Restore the original settings:

a. If you have SEL-5010 Relay Assistant software or ACSELERATOR QuickSet, restore the original settings by following the instructions for the respective software.

b. If you do not have the SEL-5010 Relay Assistant software or ACSELERATOR QuickSet, restore the original settings by issuing the necessary **SET *n*** commands, where *n* can be 1–6, G, P, L, T, R, X, or Y (depending upon the settings classes available in the relay).

Step 7. Use the **PAS** command to set the relay passwords.

For example, type **PAS 1 <Enter>** to set the Access Level 1 password.

Use a similar format for other password levels. SEL relay passwords are case sensitive, so the relay treats lowercase and uppercase letters as different letters.

Step 8. If any failure status messages still appear on the relay display, see *Section 13: Testing and Troubleshooting* or contact your customer service representative or the factory for assistance.

H. Verify Settings, Calibration, Status, Breaker Wear, and Metering

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

Step 2. Use the **SHO** command to view the relay settings and verify that these match the settings you saved earlier (see *Backup Relay Settings on page B.7*).

If the settings do not match, reenter the settings you saved earlier (see *Step 6* under *CR_RAM, EEPROM, and IO_BRD Fail Status Messages on page B.14*).

Step 3. Type **SHO C <Enter>** to verify the relay calibration settings.

If the settings do not match the settings contained in the text file you recorded in *C. Save Settings and Other Data on page B.6*, contact your customer service representative or the factory for assistance.

Step 4. Use the firmware identification string (FID) to verify download of the correct firmware:

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Firmware Upgrade Properties** dialog box (*Figure B.4*).

c. Click **ASCII Setup**.

You should see a dialog box similar to *Figure B.16*.

d. Under **ASCII Receiving**, select the check box to **Append line feeds to incoming line ends**.

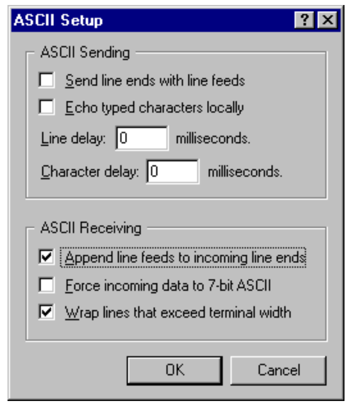

Figure B.16 Preparing HyperTerminal for ID Command Display

e. Click **OK** twice to return to the terminal emulation window.

f. Type **ID <Enter>** and compare the number the relay displays against the number from the firmware envelope label.

g. If the label FID and part number match the relay display, proceed to *Step 5*.

h. For a mismatch between a displayed FID or part number, and the firmware envelope label, reattempt the upgrade or contact the factory for assistance.

Step 5. Type **STA <Enter>** and verify that all relay self-test parameters are within tolerance.

Step 6. If you use the Breaker Wear Monitor, type **BRE <Enter>** to check the data and see if the relay retained breaker wear data through the upgrade procedure.

If the relay did not retain these data, use the **BRE W*n*** command to reload the percent contact wear values for each pole of Circuit Breaker *n* (*n* = 1, 2, 3, or 4) you recorded in *C. Save Settings and Other Data on page B.6*.

Step 7. Apply current and voltage signals to the relay.

Step 8. Type **MET <Enter>** and verify that the current and voltage signals are correct.

Step 9. Use the **TRIGGER** and **EVENT** commands to verify that the magnitudes of the current and voltage signals you applied to the relay match those displayed in the event report.

If these values do not match, check the relay settings and wiring.

I. Return the Relay to Service

Step 1. Follow your company procedures for returning a relay to service.

Step 2. Autoconfigure the SEL communications processor port if you have an SEL communications processor connected to the relay.

This step reestablishes automatic data collection between the SEL communications processor and the relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

The relay is now ready for your commissioning procedure.

Ethernet Port Firmware Upgrade Instructions

Introduction

Perform the firmware upgrade process in the following sequence:

A. Prepare the Relay

B. Establish an FTP Connection

C. Transfer New Firmware

D. Establish a Telnet Connection

E. Verify Firmware Transfer

F. Verify IEC 61850 Operation (Optional)

Required Equipment

Gather the following equipment before starting this firmware upgrade:

- Personal computer
- FTP client software (e.g., Microsoft Internet Explorer)
- Disk containing the communications card firmware upgrade (.s19) file
- Firmware upgrade instructions (these instructions)

Upgrade Procedure

A. Prepare the Relay

Step 1. If the relay is in use, follow your company practices for removing a relay from service. Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

Step 3. These instructions assume that the Ethernet port (**PORT 5**) settings are set as follows:

IPADDR = 10.201.0.213

SUBNETM = 255.255.0.0

DEFRTR = 10.201.0.1

ETELNET = Y

TPORTC = 1024

EFTPSERV = Y

FTPUSER = 2AC

B. Establish an FTP Connection

The following instructions use Internet Explorer operating on Microsoft Windows XP as the FTP client to establish communication between the relay and a personal computer. The instructions assume both devices are on the same side of any firewalls.

Step 1. Connect an Ethernet communications cable between the relay Ethernet port (PORT 5) and the computer Ethernet port.

Alternatively, connect an Ethernet communications cable from the relay Ethernet port to an Ethernet network and another cable from the personal computer Ethernet port to the same Ethernet network.

Step 2. From the computer, open Internet Explorer.

On a personal computer running Windows, you would typically click **Start > Programs > Internet Explorer**.

Step 3. In the **Address** bar, enter the user name (default for FTPUSER setting is 2AC, **2AC** password, and the FTP IP address of the relay (*Figure B.17*) at the same time (ftp://user:password@host:port/path), and press **<Enter>**.

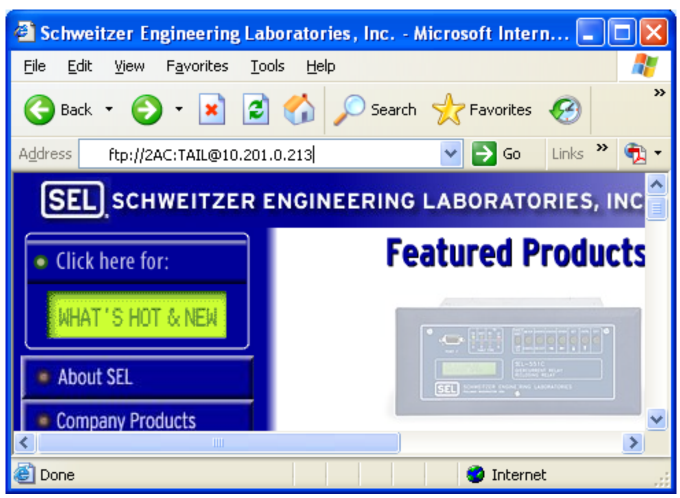

Figure B.17 Establishing an FTP Connection

You can omit the user name and the password if you want to enter the user name and password using the following form. Ensure there is no trailing forward slash (/).

Step 4. Enter the user name and the **2AC** password when the window shown in *Figure B.18* appears.

Step 5. Click the **Log On** button.

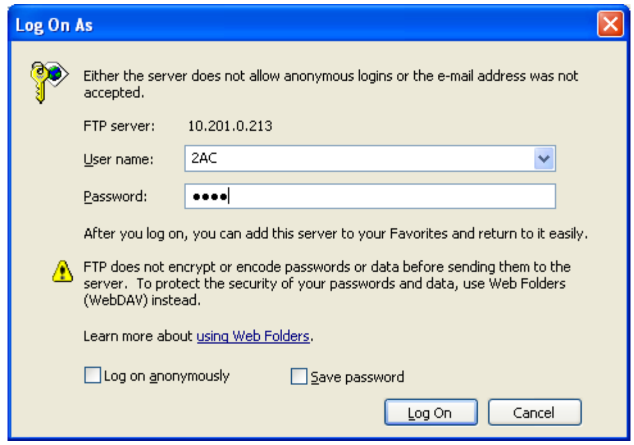

Figure B.18 Alternate Method of Establishing an FTP Connection

Step 6. Right-click on the file that you would like to copy.

Step 7. Click **Copy to Folder** (*Figure B.19*).

Step 8. Browse for folder.

Step 9. Click **OK**.

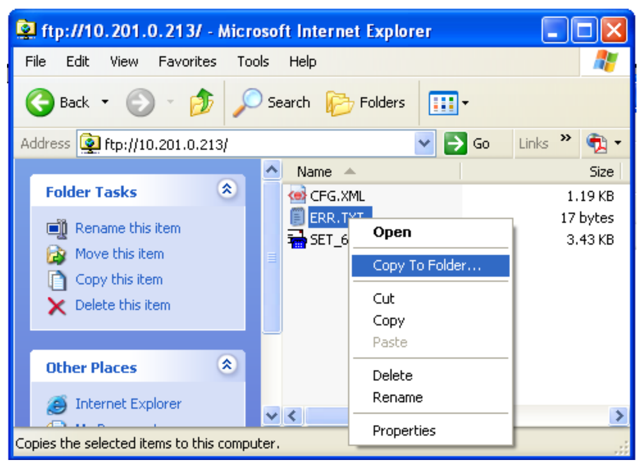

Figure B.19 Read (Open) File

If a window opens with the message, “The page cannot be displayed,” as shown in *Figure B.20*, you might have logged on improperly. Retry the login process described in the steps above.

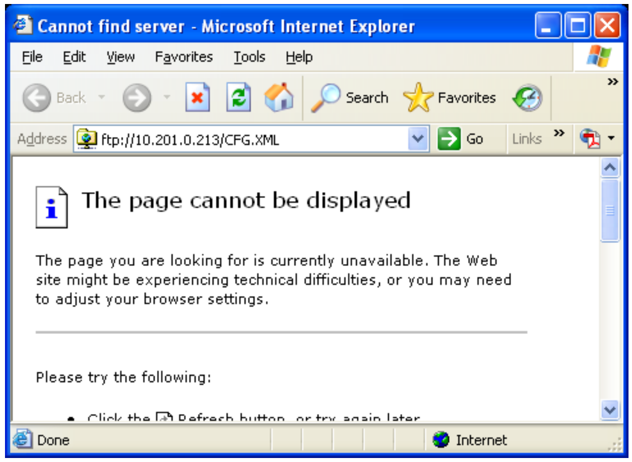

Figure B.20 Page Cannot Be Displayed Window

C. Transfer New Firmware

Following the file transfer process, Ethernet communications will be halted, and the relay will reboot. The relay will take up to a minute to reinitialize after rebooting.

Step 1. Right-click on **Start** and click on **Explore** to launch Windows Explorer.

Step 2. Locate the folder containing the new firmware (e.g., e3r120.s19).

Step 3. Click and drag the file to the Internet Explorer window.

The **Copying** dialog box appears until the upload is complete.

If the **Confirm File Replace** dialog box appears, click on **Yes** and the file will transfer.

D. Establish a Telnet Connection

To establish a Telnet-to-card connection, perform the following steps.

Step 1. Click **Start > Run**.

Step 2. Type **cmd** in the dialog box, and press **<Enter>** to launch a DOS command window.

Step 3. Type **Telnet <IP Address> port** at the prompt (e.g., **Telnet 10.201.0.213 1024**).

Step 4. Press **<Enter>** several times until you see the = prompt.

E. Verify Firmware Transfer

To verify the firmware transfer completed properly, perform the following steps after establishing a Telnet connection.

Step 1. Issue a Status (**STA**) command.

Step 2. Verify that the Status report does not include any warnings or failures.

Step 3. Verify that the Status report includes `Device Enabled` at the end of the report.

Step 4. Verify that the Status report FID matches the FID of the firmware you transferred.

F. Verify or Restart IEC 61850 Operation (Optional)

SEL-300 series relays with optional IEC 61850 protocol require the presence of one valid CID file to enable the protocol. You should only transfer a CID file to the relay if you want to implement a change in the IEC 61850 configuration or if new Ethernet port firmware does not support the current CID file version. If you transfer an invalid CID file, the relay will disable the IEC 61850 protocol, as it no longer has a valid configuration. To restart IEC 61850 protocol operation, you must transfer a valid CID file to the relay.

Perform the following steps to verify that the IEC 61850 protocol is still operational after an Ethernet port firmware upgrade and if not, re-enable it. This procedure assumes that IEC 61850 was operational with a valid CID file immediately before initiating the Ethernet port firmware upgrade.

Step 1. Establish an FTP connection to the relay Ethernet port (see *B. Establish an FTP Connection on page B.18*).

Step 2. Open the ERR.TXT file for reading.

If the ERR.TXT file contains error messages relating to CID file parsing, this indicates that the relay has disabled the IEC 61850 protocol. If this file is empty, the relay found no errors during CID file processing and IEC 61850 should remain enabled. Skip to *Step 3* if ERR.TXT is empty.

If the IEC 61850 protocol has been disabled because of an upgrade-induced CID file incompatibility, you can use ACSELERATOR Architect to convert the existing CID file and make it compatible again.

a. Install the ACSELERATOR Architect software upgrade that supports your required CID file version.

b. Run ACSELERATOR Architect and open the project that contains the existing CID file for the relay.

c. Download the CID file to the relay.

Upon connecting to the relay, ACSELERATOR Architect will detect the upgraded Ethernet port firmware and prompt you to allow it to convert the existing CID file to a supported version. Once converted, downloaded, and processed, the valid CID file allows the relay to re-enable the IEC 61850 protocol.

Step 3. In the Telnet session, type **GOO <Enter>**.

Step 4. View the GOOSE status and verify that the transmitted and received messages are as expected.

Factory Assistance

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 USA
Telephone: +1.509.332.1890
Fax: +1.509.332.7990
Internet: www.selinc.com
Email: info@selinc.com

Appendix C
SEL Communications Processors

SEL Communications Protocols

The SEL-311M Relay supports the protocols and command sets shown in *Table C.1*.

Table C.1 Supported Serial Command Sets

Command Set	Description
SEL ASCII	Use this protocol to send ASCII commands and receive ASCII responses that are human-readable with an appropriate terminal emulation program.
SEL Compressed ASCII	Use this protocol to send ASCII commands and receive Compressed ASCII responses that are comma delimited for use with spreadsheet and database programs or for use by intelligent electronic devices.
SEL Fast Meter	Use this protocol to send binary commands and receive binary meter and target responses.
SEL Fast Operate	Use this protocol to send binary control commands.
SEL Fast SER	Use this protocol to receive binary Sequential Events Recorder unsolicited responses.

SEL ASCII Commands

We originally designed SEL ASCII commands for communication between the relay and a human operator via a keyboard and monitor or a printing terminal. A computer with a serial port can also use the SEL ASCII protocol to communicate with the relay, collect data, and issue commands.

SEL Compressed ASCII Commands

The relay supports a subset of SEL ASCII commands identified as Compressed ASCII commands. Each of these commands results in a comma-delimited message that includes a checksum field. Most spreadsheet and database programs can directly import comma-delimited files. Devices with embedded processors connected to the relay can execute software to parse and interpret comma-delimited messages without expending the customization and maintenance labor needed to interpret nondelimited messages. The relay calculates a checksum for each line by numerically summing all of the bytes that precede the checksum field in the message. The program that uses the data can detect transmission errors in the message by summing the characters of the received message and comparing this sum to the received checksum.

Most commands are available only in SEL ASCII or Compressed ASCII format. Selected commands have versions in both standard SEL ASCII and Compressed ASCII formats. Compressed ASCII reports generally have fewer characters than conventional SEL ASCII reports, because the compressed reports reduce blanks, tabs, and other “white space” between data fields to a single comma.

Table C.2 lists the Compressed ASCII commands and contents of the command responses.

Table C.2 Compressed ASCII Commands

Command	Response	Access Level
BNAME	ASCII names of Fast Meter status bits	0
CASCII	Configuration data of all Compressed ASCII commands available at access levels > 0	0
CEVENT	Event report	1
CHISTORY	List of events	1
CSTATUS	Relay self-test status results	1
CSUMMARY	Summary of an event report	1
DNAME	ASCII names of digital I/O reported in Fast Meter	0
ID	Relay identification	0
SNS	ASCII names for SER data reported in Fast Meter	0

Interleaved ASCII and Binary Messages

SEL relays have two separate data streams that share the same physical serial port. Human data communications with the relay consist of ASCII character commands and reports that you view using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information; the ASCII data stream continues after the interruption. This mechanism uses a single communications channel for ASCII communication (transmission of an event report, for example) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. However, you do not need a device to interleave data streams in order to use the binary or ASCII commands. Note that XON, XOFF, and CAN operations operate on only the ASCII data stream.

An example of using these interleaved data streams is when the SEL-311M communicates with an SEL communications processor. These SEL communications processors perform auto-configuration by using a single data stream and SEL Compressed ASCII and binary messages. In subsequent operations, the SEL communications processor uses the binary data stream for Fast Meter, and Fast Operate messages to populate a local database and to perform SCADA operations. At the same time that a binary data stream is in progress, you can connect transparently to the SEL-311M and use the ASCII data stream for commands and responses.

SEL Fast Meter, Fast Operate, and Fast SER

SEL Fast Meter is a binary message that you solicit with binary commands. Fast Operate is a binary message for control. The relay can also send unsolicited Fast SER messages automatically. If the relay is connected to an SEL communications processor, these messages provide the mechanism that the communications processor uses for SCADA or DCS functions that occur simultaneously with ASCII interaction.

The SEL-311M can be configured to send one of two types of Fast Meter messages: standard or simple. Standard messages contain the status of all relay target bits, plus the following quantities: IA, IB, IC, IN, VA, VB, VC, VS, Freq, Vbatt, IAX, IBX, ICX, INX, IGX, 3V0X, IAT, IBT, ICT, INT, and IGT. Simple messages contain all relay target bits and the following quantities: IA, IB, IC, IN, VA, VB, VC, VS, Freq, and Vbatt. The relay generally responds to a request for a simple Fast Meter message within 50 ms. The Fast Meter message type is selected in the Global Settings dialog (SET G).

SEL Communications Processors

SEL offers SEL communications processors, the SEL-2032, the SEL-2030, and the SEL-2020, powerful tools for system integration and automation. These devices provide a single point of contact for integration networks with a star topology as shown in *Figure C.1*.

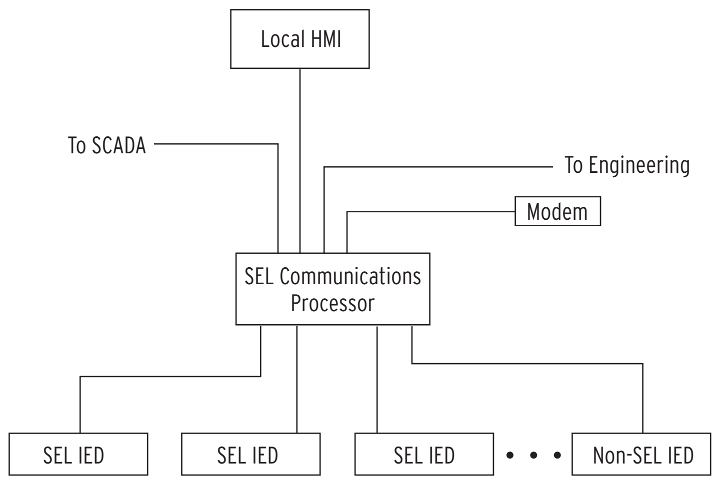

Figure C.1 SEL Communications Processor Star Integration Network

In the star topology network in *Figure C.1* the SEL communications processor offers the following substation integration functions:

- Collection of real-time data from SEL and non-SEL IEDs
- Calculation, concentration, and aggregation of real-time IED data into databases for SCADA, HMI, and other data consumers
- Access to the IEDs for engineering functions including configuration, report data retrieval, and control through local serial, remote dial-in, and Ethernet network connections
- Simultaneous collection of SCADA data and engineering connection to SEL IEDs over a single cable
- Distribution of IRIG-B time synchronization signal to IEDs based on external IRIG-B input, internal clock, or protocol interface
- Automated dial-out on alarms

SEL communications processors have 16 serial ports plus a front port. This port configuration does not limit the size of a substation integration project, because you can create a multitiered solution as shown in *Figure C.2*. In this multitiered system, the lower-tier SEL communications processors forward data to the upper-tier SEL communications processor that serves as the central point of access to substation data and station IEDs.

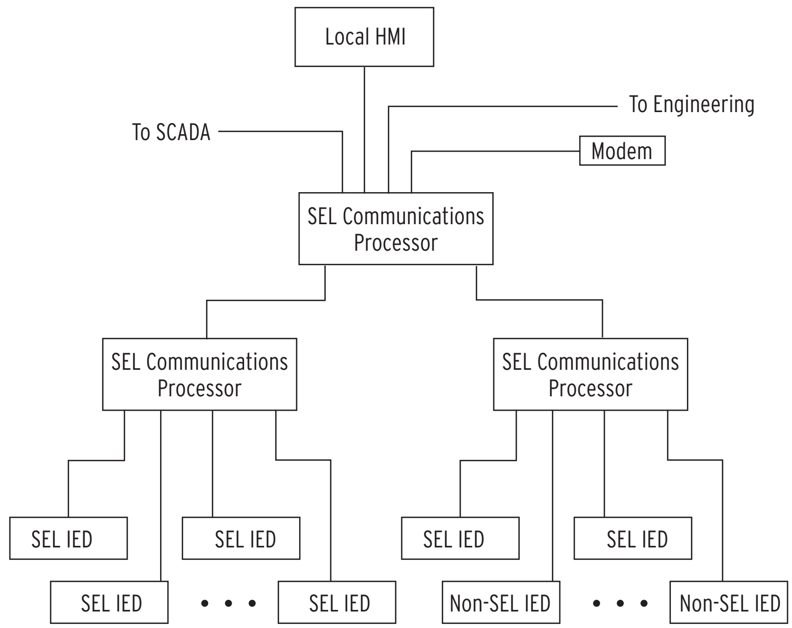

Figure C.2 Multitiered SEL Communications Processor Architecture

You can add additional communications processors to provide redundancy and eliminate possible single points of failure. SEL communications processors provide an integration solution with a reliability comparable to that of SEL relays. In terms of MTBF (mean time between failures), SEL communications processors are 100 to 1000 times more reliable than computer-based and industrial technology-based solutions.

Configuration of an SEL communications processor is different from other general-purpose integration platforms. You can configure SEL communications processors with a system of communication-specific keywords and data movement commands rather than programming in C or another general-purpose computer language. SEL communications processors offer the protocol interfaces listed in *Table C.3*.

Table C.3 SEL Communications Processors Protocol Interfaces

Protocol	Connect to
DNP 3.0 Level 2 Slave	DNP 3.0 masters
Modbus® RTU	Modbus masters
SEL ASCII/Fast Message Slave	SEL protocol masters
SEL ASCII/Fast Message Master	SEL protocol slaves including other communications processors and SEL relays
ASCII and Binary auto messaging	SEL and non-SEL IED master and slave devices
Modbus Plus[a]	Modbus Plus peers with global data and Modbus Plus masters
FTP (File Transfer Protocol)[b]	FTP clients
Telnet[b]	Telnet servers and clients
UCA2 GOMSFE[b]	UCA2 protocol masters
UCA2 GOOSE[b]	UCA2 protocol and peers

[a] Requires SEL-2711 Modbus Plus protocol card.
[b] Requires SEL-2701 Ethernet Processor.

SEL Communications Processor and Relay Architecture

You can apply SEL communications processors and SEL relays in a limitless variety of applications that integrate, automate, and improve station operation. Most system integration architectures using SEL communications processors involve either developing a star network or enhancing a multidrop network.

Developing Star Networks

The simplest architecture using both the SEL-311M and an SEL communications processor is shown in *Figure C.1*. In this architecture, the SEL communications processor collects data from the SEL-311M and other station IEDs. The SEL communications processor acts as a single point of access for local and remote data consumers (local HMI, SCADA, engineers). The communications processor also provides a single point of access for engineering operations including configuration and the collection of report-based information.

By configuring a data set optimized to each data consumer, you can significantly increase the usage efficiency on each link. A system that uses an SEL communications processor to provide a protocol interface to an RTU will have a shorter lag time (data latency); communication overhead is much less for a single data exchange conversation to collect all substation data (from a communications processor) than for many conversations required to collect data directly from each individual IED. You can further reduce data latency by connecting an SEL communications processor directly to the SCADA master and eliminating redundant communication processing in the RTU.

The SEL communications processor is responsible for the protocol interface, so you can install, test, and even upgrade the system in the future without disturbing protective relays and other station IEDs. This insulation of the protective devices from the communications interface assists greatly in situations where different departments are responsible for SCADA operation, communication, and protection.

SEL communications processors equipped with an SEL-2701 can provide a UCA2 interface to SEL-311M relays and other serial IEDs. The SEL-311M data appear in models in a virtual device domain. The combination of the SEL-2701 with an SEL communications processor offer a significant cost savings because you can use existing IEDs or purchase less expensive IEDs. For full details on applying the SEL-2701 with an SEL communications processor, see the SEL-2701 *Ethernet Processor Instruction Manual*.

The engineering connection can use either an Ethernet network connection through the SEL-2701 or a serial port connection. This versatility will accommodate the channel that is available between the station and the engineering center. SEL software, including the ACSELERATOR® SEL-5030 Software Program, can use either a serial port connection or an Ethernet network connection from an engineering workstation to the relays in the field.

Enhancing Multidrop Networks

You can also use an SEL communications processor to enhance a multidrop architecture similar to the one shown in *Figure C.3*. In this example, the SEL communications processor enhances a system that uses the SEL-2701 with an Ethernet HMI multidrop network. In the example, there are two Ethernet networks, the SCADA LAN and the Engineering LAN. The SCADA LAN provides real-time data directly to the SCADA Control Center via a protocol gateway and to the HMI (Human Machine Interface).

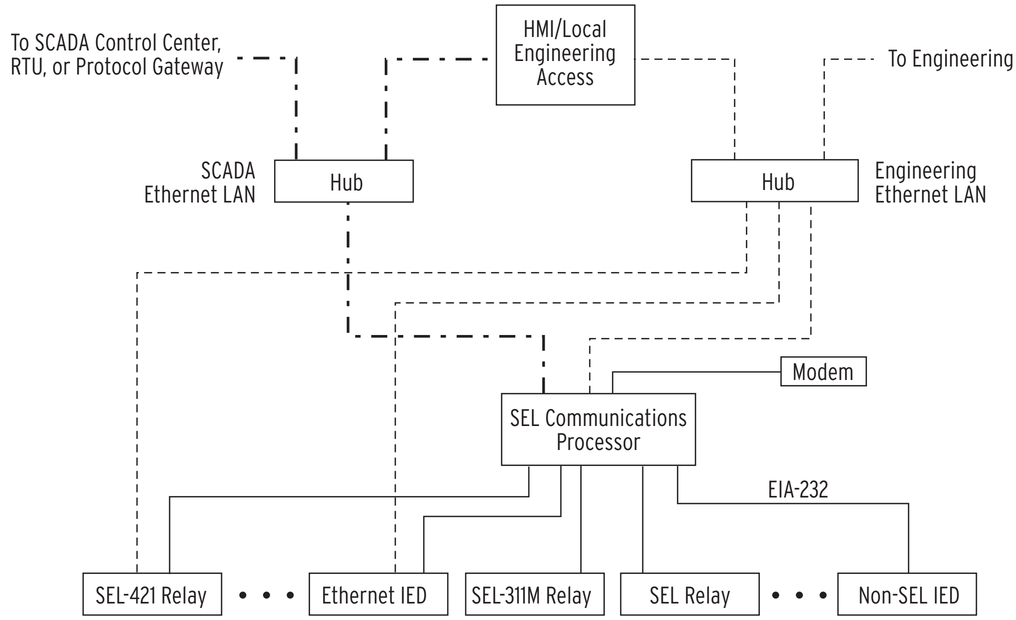

Figure C.3 Enhancing Multidrop Networks With SEL Communications Processors

In this example, the SEL communications processor provides the following enhancements when compared to a system that employs only the multidrop network:

- Ethernet access for IEDs with serial ports
- Backup engineering access through the dial-in modem
- IRIG-B time signal distribution to all station IEDs
- Integration of IEDs without Ethernet
- Single point of access for real-time data for SCADA, HMI, and other uses
- Significant cost savings by use of existing IEDs with serial ports

Control Points

The SEL Communications Processor can pass control messages, called Fast Operate messages, to the SEL-311M.

When Fast Operate functions are enabled, the SEL Communications Processor automatically sends messages to the relay in response to changes in remote bits RB1–RB16 or breaker bits BR1–BR4 on the corresponding SEL Communications Processor port. For example, if you set RB1 on Port 1 in the SEL Communications Processor, it automatically sets RB1 in the SEL-311M connected to that serial port. *Table C.4* shows the relationship between the SEL Communications Processor Remote Bits and the SEL-311M Remote Bits.

Follow these steps to enable Fast Operate messages that set or clear remote bits or breaker bits.

Step 1. Set the FASTOP setting equal to Y in the SEL-311M port settings for the port connected to the SEL Communications Processor.

The SEL-311M breaker jumper must be in the proper position; see *Table 2.4*.

Step 2. Enable Fast Operate messages in the communications processor by setting the auto-message setting SEND_OPER equal to Y.

Step 3. Toggle the corresponding Set and Clear elements SRB1–16, CRB1–16, SBR1–4, and CBR1–4.

To pulse, instead of set or clear, remote bits, set auto-message setting SEND_OPER equal to YP instead of Y. Note that SEND_OPER equal to YP applies to remote bits only; breaker bit operation is the same for both SEND_OPER = Y and SEND_OPER = YP.

Table C.4 Remote Bit Correspondence to the SEL-311M

Remote bit in SEL-20xx Communications Processor:	Corresponding SEL-311M Relay Word bit:
RB1	RB1
RB2	RB2
RB3	RB3
RB4	RB4
...	...
RB15	RB15
RB16	RB16

Fast Operate breaker bits operate differently from remote bits. For example, when you set BR1 on Serial Port 1 of the SEL Communications Processor, the SEL Communications Processor sends a message to the SEL-311M that asserts the open command bit OC for one processing interval. Likewise, if you clear BR1, the SEL Communications Processor sends a message to the SEL-311M that asserts the close command bit CC for one processing interval.

Table C.5 shows how the breaker bits in the SEL Communications Processor are mapped to the Open Command and Close Command Relay Word bits in the SEL-311M. For tripping and closing applications, use BR1 only.

The factory settings for the SEL-311M only use the OC and CC Relay Word bits.

Table C.5 Breaker Bit Correspondence to the SEL-311M

Breaker bits in SEL-20xx Communications Processor:	Corresponding SEL-311M Relay Word bit:	
	When BRn is set:	When BRn is cleared:
BR1	Pulse OC	Pulse CC

See *OPE Command (Open Breaker) on page 8.44*, and *CLO Command (Close Breaker) on page 8.43*, for more information on the Open and Close Command Relay Word bits in the SEL-311M.

SEL Communications Processor Example

This example demonstrates some of the data and control points available in the SEL communications processor when you connect an SEL-311M. The physical configuration used in this example is shown in *Figure C.4*.

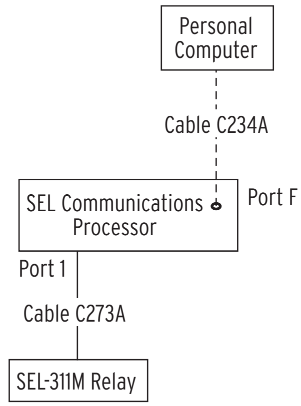

Figure C.4 Example SEL Relay and SEL Communications Processor Configuration

Table C.6 shows the Port 1 settings for the SEL communications processor.

Table C.6 SEL Communications Processor Port 1 Settings

Setting Name	Setting	Description
DEVICE	S	Connected device is an SEL device
CONFIG	Y	Allow autoconfiguration for this device
PORTID	"Relay 1"	Name of connected relay[a]
BAUD	19200	Channel speed of 19200 bits per second[a]
DATABIT	8	Eight data bits[a]
STOPBIT	1	One stop bit
PARITY	N	No parity
RTS_CTS	Y	Hardware flow control enabled
TIMEOUT	5	Idle timeout that terminates transparent connections of 5 minutes

[a] Automatically collected by the SEL communications processor during autoconfiguration.

Data Collection

Table C.7 lists the automatic messages that are available in the SEL-311M.

Table C.7 SEL Communications Processor Data Collection Automessages

Message	Data Collected
20METER	Power system metering data
20DEMAND	Demand and peak demand metering data
20TARGET	Selected Relay Word bit elements
20HISTORY	History Command (ASCII)
20STATUS	Status Command (ASCII)
20EVENT	Standard 4 sample/cycle event report (data only)
20EVENTS	Standard 4 sample/cycle event report (data with settings)
20EVENTL	Long 16 sample/cycle event report (data with settings)

Table C.8 shows the automessage (Set A) settings for the SEL communications processor. In this example the SEL communications processor is configured to collect metering and target data from the SEL-311M via the three automatic messages: 20TARGET, 20 METER, and 20DEMAND.

Table C.8 SEL Communications Processor Port 1 Automatic Messaging Settings

Setting Name	Setting	Description
AUTOBUF	Y	Save unsolicited messages
STARTUP	“ACC\nOTTER\n”	Automatically log-in at Access Level 1
SEND_OPER	Y	Send Fast Operate messages for remote bit and breaker bit control
REC_SER	N	Automatic sequential event recorder data collection disabled
NOCONN	NA	No SELOGIC control equation entered to selectively block connections to this port
MSG_CNT	3	Three automessages
ISSUE1	P00:00:01.0	Issue Message 1 every second
MESG1	20METER	Collect metering data
ISSUE2	P00:00:01.0	Issue Message 2 every second
MESG2	20TARGET	Collect Relay Word bit data
ISSUE3	P00:01:00.0	Issue Message 3 every minute
MESG3	20DEMAND	Collect demand metering data
ARCH_EN	N	Archive memory disabled
USER	0	No USER region registers reserved

Table C.9 shows the map of regions in the SEL communications processor for data collected from the SEL-311M in the example.

Table C.9 SEL Communications Processor Port 1 Region Map

Region	Data Collection Message Type	Region Name	Description
D1	Binary	METER	Relay metering data
D2	Binary	TARGET	Relay Word bit data
D3	Binary	DEMAND	Demand metering data
D4–D8	n/a	n/a	Unused
A1–A3	n/a	n/a	Unused
USER	n/a	n/a	Unused

SEL-311M Metering Data

Table C.10 shows the list of meter data available in the SEL communications processor and the location and data type for the memory area within D1 (Data Region 1). The type field indicates the data type and size. The type "int" is a 16-bit integer. The type "float" is a 32-bit IEEE floating point number. Use the communications processor map **PORT D1** command to view this information.

Table C.10 Communications Processor METER Region Map (Sheet 1 of 2)

Data Item	Starting Address	Type
_YEAR	2000h	int
DAY_OF_YEAR	2001h	int
TIME(ms)	2002h	int[2]
MONTH	2004h	char
DATE	2005h	char
YEAR	2006h	char
HOUR	2007h	char
MIN	2008h	char
SECONDS	2009h	char
MSEC	200Ah	int
IA	200Bh	float[2]
IB	200Fh	float[2]
IC	2013h	float[2]
IN	2017h	float[2]
VA	201Bh	float[2]
VB	201Fh	float[2]
VC	2023h	float[2]
VS	2027h	float[2]
FREQ	202Bh	float[2]
VBAT	202Fh	float[2]
IAX[a]	2033h	float[2]
IBX[a]	2037h	float[2]
ICX[a]	203Bh	float[2]
INX[a]	203Fh	float[2]

Table C.10 Communications Processor METER Region Map (Sheet 2 of 2)

Data Item	Starting Address	Type
IGX[a]	2043h	float[2]
3V0X[a]	2047h	float[2]
IAT[a]	204Bh	float[2]
IBT[a]	204Fh	float[2]
ICT[a]	2053h	float[2]
INT[a]	2057h	float[2]
IGT[a]	205Bh	float[2]
IAB(A)	205Fh	float[2]
IBC(A)	2063h	float[2]
ICA(A)	2067h	float[2]
VAB(V)	206Bh	float[2]
VBC(V)	206Fh	float[2]
VCA(V)	2073h	float[2]
PA(MW)	2077h	float
QA(MVAR)	2079h	float
PB(MW)	207Bh	float
QB(MVAR)	207Dh	float
PC(MW)	207Fh	float
QC(MVAR)	2081h	float
P(MW)	2083h	float
Q(MVAR)	2085h	float
I0(A)	2087h	float[2]
I1(A)	208Bh	float[2]
I2(A)	208Fh	float[2]
V0(V)	2093h	float[2]
V1(V)	2097h	float[2]
V2(V)	209Bh	float[2]

[a] Removed if global setting FMETER = SIMPLE

Relay Word Bit Information

Table C.11 lists the Relay Word bit data available in the SEL communications processor for the memory area within D2 (Data Region 2).

Table C.11 Communications Processor TARGET Region (Sheet 1 of 2)

Address	Relay Word Bits (in Bits 7–0)							
	7	6	5	4	3	2	1	0
2804h	*	*	*	STSET	*	*	*	*
2805h	See *Table 7.5*, Row 0							
2806h	See *Table 7.5*, Row 1							
2807h	See *Table 7.5*, Row 2							
2808h	See *Table 7.5*, Row 3							
2809h	See *Table 7.5*, Row 4							
280Ah	See *Table 7.5*, Row 5							

Table C.11 Communications Processor TARGET Region (Sheet 2 of 2)

Address	Relay Word Bits (in Bits 7–0)							
	7	6	5	4	3	2	1	0
280Bh	See *Table 7.5*, Row 6							
280Ch	See *Table 7.5*, Row 7							
280Dh	See *Table 7.5*, Row 8							
280Eh	See *Table 7.5*, Row 9							
280Fh	See *Table 7.5*, Row 10							
2810h	See *Table 7.5*, Row 11							
. . .	. . .							
2849h	See *Table 7.5*, Row 67							

SEL-311M Demand Data

Table C.12 shows the list of demand data available in the SEL communications processor and the location and data type for the memory areas within D3 (Data Region 3). The type field indicates the data type and size. The type “int” is a 16-bit integer. The type “float” is a 32-bit IEEE floating point number. Use the communications processor map **PORT:33** command to view this information

Table C.12 Communications Processor DEMAND Region Map (Sheet 1 of 2)

Data Item	Starting Address	Type
_YEAR	3000h	int
DAY_OF_YEAR	3001h	int
TIME(ms)	3002h	int[2]
MONTH	3004h	char
DATE	3005h	char
YEAR	3006h	char
HOUR	3007h	char
MIN	3008h	char
SECONDS	3009h	char
MSEC	300Ah	int
IA	300Bh	float
IB	300Dh	float
IC	300Fh	float
IG	3011h	float
3I2	3013h	float
PA+	3015h	float
PB+	3017h	float
PC+	3019h	float
P3+	301Bh	float
QA+	301Dh	float
QB+	301Fh	float
QC+	3021h	float
Q3+	3023h	float
PA–	3025h	float

Table C.12 Communications Processor DEMAND Region Map (Sheet 2 of 2)

Data Item	Starting Address	Type
PB–	3027h	float
PC–	3029h	float
P3–	302Bh	float
QA–	302Dh	float
QB–	302Fh	float
QC–	3031h	float
Q3–	3033h	float

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Appendix D

MIRRORED BITS Communications

Overview

NOTE: Configure the port before connecting it to another MIRRORED BITS device. Otherwise, the relay will appear to be locked out.

MIRRORED BITS™ communications is a direct relay-to-relay communications protocol, which allows protective relays to exchange information quickly and securely, and with minimal expense. Use MIRRORED BITS communications for remote control and remote sensing or communications-assisted protection schemes.

SEL products support several variations of MIRRORED BITS communications protocols. Through port settings, you can set the SEL-311M Relay for compatible operation with SEL-300 series relays, SEL-400 series relays, SEL-600 series relays, the SEL-2505 Remote I/O Modules, and the SEL-2100 Logic Processors. These devices use MIRRORED BITS communications to exchange the states of eight logic bits.

The PROTO = MB*c* option (*c* = A or B) is provided for compatibility with older SEL products that only support this version of MIRRORED BITS. Use PROTO = MB8*c* if each relay supports this MIRRORED BITS version. Use the RTSCTS = MBT*c* option if your application includes Pulsar MBT9600 modems.

SEL Application Guide *AG 2002-23, Applying Two* SEL-*351S Relays to Provide Automatic Source Transfer for Critical Loads*, provides an example of how to use MIRRORED BITS in the SEL-351S Relay. These same principles may be used with the SEL-311M.

Figure D.1 shows this example with the SEL-311M.

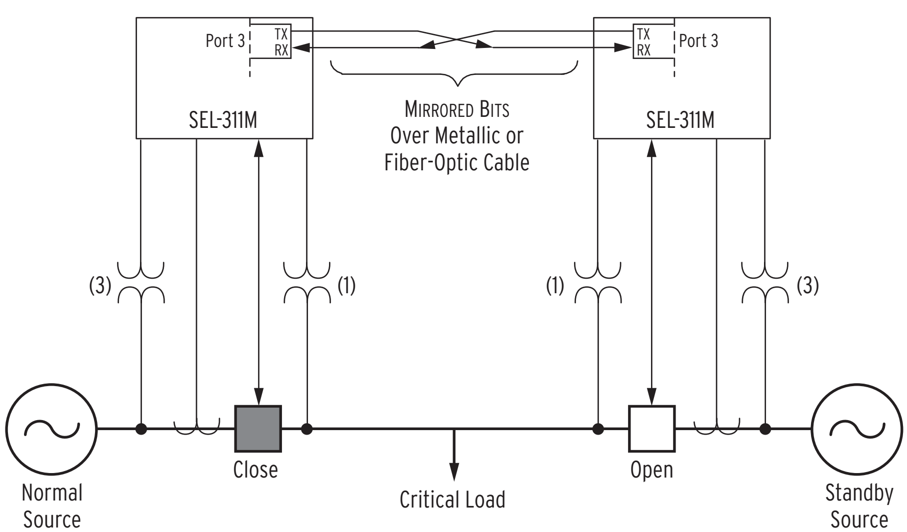

Figure D.1 Automatic Source Transfer Application

Communications Channels and Logical Data Channels

The SEL-311M supports two MIRRORED BITS communications channels, designated A and B. Use the port setting PROTO to assign one of the MIRRORED BITS communications channels to a serial port; PROTO = MBA for MIRRORED BITS communications Channel A or PROTO = MBB for MIRRORED BITS communications Channel B.

Transmitted bits include TMB1A–TMB8A and TMB1B–TMB8B. The last letter (A or B) designates with which channel the bits are associated. These bits are controlled by SELOGIC® control equations. Received bits include RMB1A–RMB8A and RMB1B–RMB8B. You can use received bits as operands in SELOGIC control equations. The channel status bits are ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, and LBOKB. You can also use these bits as operands in SELOGIC control equations. Use the COM command for additional channel status information.

Within each MIRRORED BITS communications message for a given channel (A or B), there are eight logical data channels (1–8). In operation compatible with other SEL products, you can use the eight logical data channels for TMB1 through TMB8, as shown in *Figure D.2*.

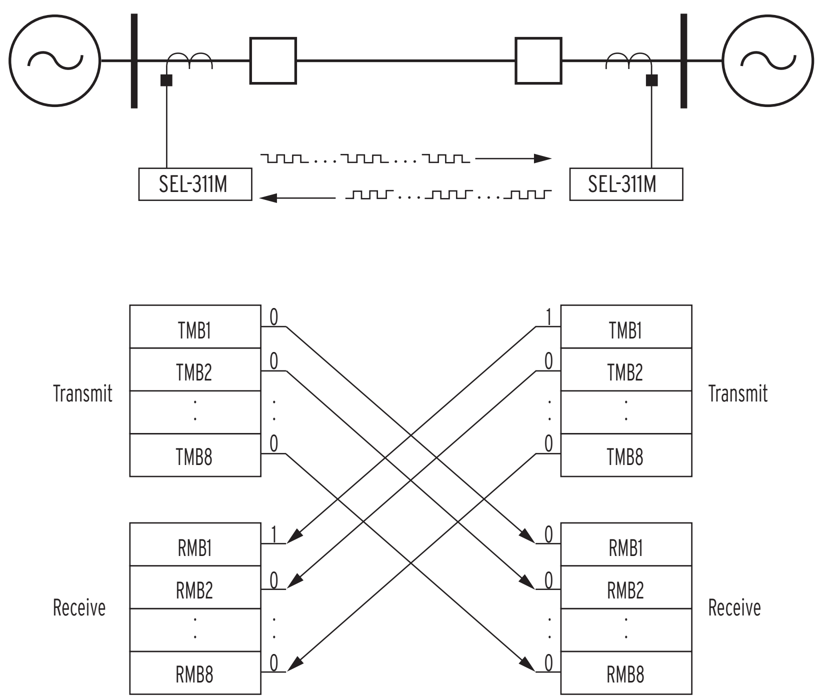

Figure D.2 Relay-to-Relay Logic Communication

Operation

Message Transmission

Depending on the settings, the SEL-311M transmits a MIRRORED BITS communications message every 1/8 to 1/2 of an electrical cycle (see *Table D.2*). Each message contains the most recent values of the transmit bits. All messages are transmitted without idle bits between characters. Idle bits are allowed between messages.

Message Reception

When the devices are synchronized and the MIRRORED BITS communications channel is in a normal state, the relay decodes and checks each received message. If the message is valid, the relay sends each received logic bit (RMB*nc*, where *n* = 1–8, *c* = A or B) to the corresponding pickup and dropout security counters, that in turn set or clear the RMB*nc* relay element bits.

Message Decoding and Integrity Checks

The relay provides indication of the status of each MIRRORED BITS communications channel, with element bits ROKA and ROKB. During normal operation, the relay sets the ROK*c* bit. The relay clears the bit upon detecting any of the following conditions:

- Parity, framing, or overrun errors.
- Receive data redundancy error.
- Receive message identification error.
- No message received in the time three messages have been sent.

The relay will assert ROK*c* only after successful synchronization as described below and two consecutive messages pass all of the data checks described above. After ROK*c* is reasserted, received data may be delayed while passing through the security counters described below.

While ROK*c* is not set, the relay does not transfer new RMB data to the pickup-dropout security counters described below. Instead, the relay sends one of the user-definable default values to the security counter inputs. For each RMB*n*, specify the default value with setting RXDFLT, as follows:

- 1
- 0
- *X* (to use the last valid value)

Pickup/dropout security counters supervise the transfer of received data to RMB1*c*–RMB8*c*. Set these counters between 1 (allow every occurrence to pass) and at least eight (require eight consecutive occurrences to pass). The pickup and dropout security count settings are separate.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that the counter uses units counted received messages instead of time. An SEL-311M communicating with another SEL-311M sends and receives MIRRORED BITS messages four times per power system cycle. Therefore, a security counter set to two counts will delay a bit by about 1/2 power system cycle. You must consider the impact of the security counter settings in the receiving device to determine the channel timing performance.

Things become slightly more complicated when two relays of different processing rates are connected via MIRRORED BITS (for instance, an SEL-321 talking to an SEL-311M). The SEL-321 processes power system information each 1/8 power system cycle but processes the pickup/dropout security counters as messages are received. Since the SEL-321 is receiving messages from the SEL-311M, it will receive a message each 1/4 cycle processing interval. So, a counter set to two will again delay a bit by about 1/2 cycle. However, in that same example, a security counter set to two on the SEL-311M will delay a bit by 1/4 cycle, because the SEL-311M is receiving new MIRRORED BITS messages each 1/8 cycle from the SEL-321.

Channel Synchronization

When an SEL-311M detects a communications error, it deasserts ROKA or ROKB. If a node detects two consecutive communications errors, it transmits an attention message, which includes its TX_ID setting.

When a node receives an attention message, it checks to see if its TX_ID is included.

If its own TX_ID is included and at least one other TX_ID is included, the node transmits data.

If its own TX_ID is not included, the node deasserts ROK*c*, includes its TX_ID in the attention message, and transmits the new attention message.

If its own TX_ID is the only TX_ID included, the relay assumes the message is corrupted unless the loop back mode has been enabled. If loop back is not enabled, the node deasserts ROK*c* and transmits the attention message with its TX_ID included. If loop back is enabled, the relay transmits data.

In summary, when a node detects two consecutive errors, it transmits attention until it receives an attention with its own TX_ID included. If three or four relays are connected in a ring topology, then the attention message will go all the way around the loop, and eventually will be received by the originating node. It will then be killed and data transmission will resume. This method of synchronization allows the relays to determine reliably which byte is the first byte of the message. It also forces mis-synchronized UARTs to become re-synchronized. On the down side, this method takes down the entire loop for a receive error at any node in the loop. This decreases availability. It also makes one-way communications impossible.

Loop-Back Testing

Use the **LOOP** command to enable loop-back testing. While in loop-back mode, ROK*c* is deasserted, and LBOK*c* asserts and deasserts based on the received data checks.

Channel Monitoring

Based on the results of data checks described above, the relay will collect information regarding the 255 most recent communications errors. Each record contains at least the following fields:

- Dropout Time/Date
- Pickup Time/Date
- Time elapsed during dropout
- Reason for dropout (see *Message Decoding and Integrity Checks*)

Use the **COMM** command to generate a long or summary report of the communications errors.

There is a single record for each outage, but an outage can evolve. For example, the initial cause could be a data disagreement, but framing errors can extend the outage. If the channel is presently down, the **COMM** record will only show the initial cause, but the **COMM** summary will display the present cause of failure.

When the duration of an outage on Channel A or B exceeds a user-definable threshold, the relay will assert a user-accessible flag, RBADA or RBADB.

When channel unavailability exceeds a user-settable threshold, the relay will assert a user accessible flag, hereafter called CBAD*c*.

MIRRORED BITS Protocol for the Pulsar 9600 Baud Modem

To use a Pulsar MBT-9600 modem, set setting PROTO = MB8A or MB8B, SPEED = 9600, and RTSCTS = MBT. The PROTO setting enables MIRRORED BITS communications protocol Channel A or B on this port. The relay also injects a delay (idle time) of one processing interval between messages. The SEL-311M port settings associated with MIRRORED BITS communications are shown in *Table D.1*.

With one of these options set, the relay will transmit a message every 1/2 power system cycle and the relay will deassert the RTS signal on the EIA-232 connector. Also, the relay will monitor the CTS signal on the EIA-232 connector, which the modem will deassert if the channel has too many errors. The modem uses the relay RTS signal to determine whether the new (MB8*c*) or old (MB*c*) MIRRORED BITS protocol is in use.

Settings

The SEL-311M port settings associated with MIRRORED BITS communications are shown in *Table D.1*. Set PROTO = MB8A or MBA to enable the MIRRORED BITS communications protocol Channel A on this port. Set PROTO = MB8B or MBB to enable the MIRRORED BITS communications protocol Channel B on this port.

Table D.1 MIRRORED BITS (Sheet 1 of 2)

Name	Description	Range	Default
PROTO	Protocol	SEL, MBA, MBB, MB8A, MB8B	SEL
SPEED	Baud Rate	300, 1200, 2400, 4800, 9600, 19200, 38400	9600
RBADPU	MIRRORED BITS RX Bad Pickup Time	1–10000 s	60
CBADPU	PPM MIRRORED BITS Channel Bad Pickup	1–10000 s	1000
TXID	MIRRORED BITS Transmit Identifier	1–4	2
RXID	MIRRORED BITS Receive Identifier	1–4	1
RXDFLT	MIRRORED BITS Receive Default State	8 character string of 1s, 0s, or *X*s	XXXXXXXX
RMB1PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB1DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB2PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB2DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB3PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB3DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1

Table D.1 MIRRORED BITS (Sheet 2 of 2)

Name	Description	Range	Default
RMB4PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB4DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB5PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB5DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB6PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB6DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB7PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB7DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB8PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB8DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1

As a function of the settings for SPEED, the message transmission periods are shown in *Table D.2*.

Table D.2 Message Transmission Periods

SPEED	SEL-321	SEL-311M
38400	1 message per 1/8 cycle	1 message per 1/4 cycle
19200	1 message per 1/8 cycle	1 message per 1/4 cycle
9600	1 message per 1/4 cycle	1 message per 1/4 cycle
4800	1 message per 1/2 cycle	1 message per 1/2 cycle

Use the RBADPU setting to determine how long a channel error must last before the relay element RBADA is asserted. RBADA is deasserted when the channel error is corrected. RBADPU is accurate to ±1 second.

Use the CBADPU setting to determine the ratio of channel down time to the total channel time before the relay element CBADA is asserted. The times used in the calculation are those that are available in the **COMM** records. See the *COM Command (Communication Data) on page 8.23* for a description of the **COMM** records.

Set the RX_ID of the local relay to match the TX_ID of the remote relay. For example, in the three-terminal case, where Relay X transmits to Relay Y, Relay Y transmits to Relay Z, and Relay Z transmits to Relay X:

	TX_ID	RX_ID
Relay X	1	3
Relay Y	2	1
Relay Z	3	2

Use the RXDFLT setting to determine the default state the MIRRORED BITS should use in place of received data if an error condition is detected. The setting is a mask of 1s, 0s and/or *X*s, for RMB1A–RMB8A, where *X* represents the most recently received valid value.

Supervise the transfer of received data (or default data) to RMB1A–RMB8A with the MIRRORED BITS pickup and dropout security counters. Set the pickup and dropout counters individually for each bit.

SEL-311M Relay Command Summary

Command	Description
2AC	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 2 password in order to enter Access Level 2.
ACC	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 1 password in order to enter Access Level 1.
BAC	Enter Breaker Access Level (Access Level B). If the main board password jumper is not in place, the relay prompts for entry of the Access Level B password.
BRE	Display breaker monitor data (trips, interrupted current, wear).
BRE *n*	Enter **BRE W** to preload breaker wear. Enter **BRE R** to reset breaker monitor data.
CAS	Compressed ASCII configuration data.
CEV [n Sx Ly L R C]	Compressed event report (parameters in [ ] are optional)
where: ***n***	event number (1–39 if LER = 15; 1–15 if LER = 30; defaults to 1).
S*x*	*x* samples per cycle (4 or 16); defaults to 4. If S*x* parameter is present, it overrides the L parameter.
L*y*	*y* cycles event report length (1–LER) for filtered event reports, (1–LER + 1) for raw event reports, defaults to 15 if not specified.
L	16 samples per cycle; overridden by the S*x* parameter, if present.
R	specifies raw (unfiltered) data; defaults to 16 samples per cycle unless overridden by the S*x* parameter. Defaults to 16 cycles in length unless overridden with the L*y* parameter.
C	specifies 16 samples per cycle, 15-cycle length.
CHIS	Compressed history.
CLO	Close the circuit breaker. The **CLO** command asserts Relay Word bit CC for 1/4 cycle. Relay Word bit CC can then be programmed into the SELOGIC control equation CL to assert the CLOSE Relay Word bit, which in turn asserts an output contact (e.g., OUT102 = CLOSE) to close a circuit breaker. See *Figure 4.14*. See *Set Close on page 4.26* for more information concerning Relay Word bit CC and its recommended use, as used in the factory settings.
COM *p* L	Show a long format communications summary report for all events on MIRRORED BITS® or Differential Channel *p*.
COM *p n*	Show a communications summary for latest *n* events on MIRRORED BITS or Differential Channel *p*.
COM *p m n*	Show a communications summary report for events *n*–*m* on MIRRORED BITS or Differential Channel *p*.
COM *p d1*	Show a communications summary report for events occurring on date *d1* on MIRRORED BITS or Differential Channel *p*.
COM *p d1 d2*	Show a communications summary report for events occurring between dates *d1* and *d2* on MIRRORED BITS or Differential Channel *p*. Entry of dates is dependent on the Global Date Format setting DATE_F (= MDY or YMD).
COM C *p*	Clears the communications summary report for Channel *p*.
CON *n*	Control Remote Bit RB*n* (Remote Bit *n*; *n* = 1–16). Execute **CON *n*** and the relay responds: `CONTROL RBn`. Reply with one of the following: **SRB *n*** [set Remote Bit *n* (assert RB*n*)]. **CRB *n*** [clear Remote Bit *n* (deassert RB*n*)]. **PRB *n*** [pulse Remote Bit *n* (assert RB*n* for 1/4 cycle)].
COP *m n*	Copy relay and logic settings from Group *m* to Group *n*.
CST	Compressed status report.
CSU	Compressed event summary.
DAT	Set/show relay date.

Command	Description
DAT m/d/y	Enter date in this manner if Date Format setting DATE_F = MDY.
DAT y/m/d	Enter date in this manner if Date Format setting DATE_F = YMD.
EVE *n*	Show event report number *n* with 1/4-cycle resolution.
EVE L *n*	Show event report number *n* with 1/16-cycle resolution.
EVE R *n*	Show raw event report number *n* with 1/16-cycle resolution.
EVE B *n*	Show event report number *n* for backup elements (not including differential) with 1/4-cycle resolution.
EVE C *n*	Show compressed event report number *n*.
EVE N *n*	Show event report number *n* 87W differential report with 1/4-cycle resolution.
FIL DIR	Initiate a text response containing all of the filenames within a specified directory.
FIL READ	Initiate a file transfer from the relay to the computer for display on the computer.
FIL SHOW	Initiate a file transfer from the relay to the computer.
FIL WRITE	Initiate a file transfer from the computer to the relay.
GRO	Display the active group number.
GRO *n*	Change active group to Group *n*.
HELP	View commands help.
HIS *n*	Show brief summary of the *n* latest event reports.
HIS C	Clear the brief summary and corresponding event reports.
IRI	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
L_D	Load new firmware.
LOO	Set MIRRORED BITS port to loopback.
MET *k*	Display instantaneous metering data (currents and alpha plane) for local and remote terminals. Enter *k* for repeat count.
MET B *k*	Display instantaneous metering data for local terminal including voltage. Enter *k* for repeat count.
MET D	Display demand and peak demand data. Enter **MET RD** or **MET RP** to reset.
MET E	Display energy metering data. Enter **MET RE** to reset.
MET M	Display maximum/minimum metering data. Enter **MET RM** to reset.
MET N	Display instantaneous metering data (currents and voltages) for local and remote zero-sequence data.
OPE	Open the circuit breaker. The **OPE** command asserts Relay Word bit OC for 1/4 cycle when it is executed. Relay Word bit OC can then be programmed into the SELOGIC control equation TR to assert the TRIP Relay Word bit, which in turn asserts an output contact (e.g., OUT101 = TRIP) to trip a circuit breaker. See *Figure 4.3*. See *OPE Command (Open Breaker) on page 8.44* for more information concerning Relay Word bit OC and its recommended use, as used in the factory settings.
PAS	Show existing Access Level 1, B, and 2 passwords.
PAS 1 xxxxxx	Change Access Level 1 password to xxxxxx.
PAS B xxxxxx	Change Access Level B password to xxxxxx.
PAS 2 xxxxxx	Change Access Level 2 password to xxxxxx.
PLA <filename>[A C D MA MB O bbbbbb E ele T Time]	
where: **filename**	name of COMTRADE DAT file within relay file system.
A	include analogs (this includes frequency data).
C	include command bits.
D	include digital inputs.
MA	include MIRRORED BITS channel A.

Command	Description
MB	include MIRRORED BITS channel B.
O bbbbbb	drive outputs during playback according to the “binary” string bbbbbb, where the first b represents IN101 and the last IN106, and b can be o, c, x, or * to signify holding contact open, holding contact closed, holding it in its current state, or driving it normally during playback.
E element	trigger on element ele (with timeout).
T Time	trigger at given time (time has same format as **TIME** command parameter: hh:mm:ss, where hh = hours, mm = minutes, ss = seconds). If no trigger is provided via E or T parameters, playback starts five seconds after your verification. If no playback items are specified (A/C/D/MA/MB/O), the command defaults to playback analogs and digitals with output contacts driven to their default (de-energized) state
PUL *n k*	Pulse output contact *n* (OUT101–OUT107, ALARM, OUT201–OUT212) for *k* (1–30) seconds. Parameter *n* must be specified; *k* defaults to 1 if not specified.
QUI	Quit. Returns to Access Level 0. Available in all access levels.
SER *n*	Show the latest *n* rows in the Sequential Events Recorder (SER) event report.
SER *m n*	Show rows *m* through *n* in the Sequential Events Recorder (SER) event report.
SER *d1*	Show rows in the Sequential Events Recorder (SER) event report from *date d1*.
SER *d1 d2*	Show rows in the Sequential Events Recorder (SER) event report from *date d1* to *date d2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY or YMD).
SER C	Clears the Sequential Events Recorder (SER).
SET *n*[a]	Change relay settings (overcurrent, differential, timers, etc.) for Group *n*.
SHO *n*[a]	Show relay settings (overcurrent, differential, timers, etc.) for Group *n*.
STA	Show relay self-test status.
STA C	Resets self-test warnings/failures and reboots relay.
SUM	Show newest event summary.
SUM A	Acknowledge oldest event summary.
SUM N	View oldest unacknowledged event report.
SUM N [A]	Display or acknowledge event summary number “N.”
TAR R	Reset the front-panel tripping targets.
TAR *n k*	Display Relay Word row. If *n* = 0 through 67, display row *n*. If *n* is an element name (e.g., 50NG1) display the row containing element *n*. Enter *k* for repeat count.
TIM	Show or set time (24-hour time). Show time presently in the relay by entering just **TIM**. Example time 22:47:36 is entered with command **TIM 22:47:36**.
TRI	Trigger an event report.
TST {chn}	Test the differential communication channel. If channel (X or Y) is specified, a question string will follow to configure the channel for testing. With no channel identifier, the command will return each channel status.
VER	Display the relay hardware and software configurations

[a] See the table below for **SET/SHOW** options.

SET/SHOW Command Options

Option	Setting Type	Description
G	Global settings	Relay-wide settings
L *n*	Protection Logic Group 1–6	Protection SELOGIC® control equations
P *n*	Port *n*	Communications port settings
R	Report	Event report and SER settings
T	Text	Text label settings
{Blank}	Relay Group 1–6	Group settings

SEL-311M Relay Command Summary

Command	Description
2AC	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 2 password in order to enter Access Level 2.
ACC	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 1 password in order to enter Access Level 1.
BAC	Enter Breaker Access Level (Access Level B). If the main board password jumper is not in place, the relay prompts for entry of the Access Level B password.
BRE	Display breaker monitor data (trips, interrupted current, wear).
BRE *n*	Enter **BRE W** to preload breaker wear. Enter **BRE R** to reset breaker monitor data.
CAS	Compressed ASCII configuration data.
CEV [n Sx Ly L R C]	Compressed event report (parameters in [ ] are optional)
where: ***n***	event number (1–39 if LER = 15; 1–15 if LER = 30; defaults to 1).
S*x*	*x* samples per cycle (4 or 16); defaults to 4. If S*x* parameter is present, it overrides the L parameter.
L*y*	*y* cycles event report length (1–LER) for filtered event reports, (1–LER + 1) for raw event reports, defaults to 15 if not specified.
L	16 samples per cycle; overridden by the S*x* parameter, if present.
R	specifies raw (unfiltered) data; defaults to 16 samples per cycle unless overridden by the S*x* parameter. Defaults to 16 cycles in length unless overridden with the L*y* parameter.
C	specifies 16 samples per cycle, 15-cycle length.
CHIS	Compressed history.
CLO	Close the circuit breaker. The **CLO** command asserts Relay Word bit CC for 1/4 cycle. Relay Word bit CC can then be programmed into the SELOGIC control equation CL to assert the CLOSE Relay Word bit, which in turn asserts an output contact (e.g., OUT102 = CLOSE) to close a circuit breaker. See *Figure 4.14*. See *Set Close on page 4.26* for more information concerning Relay Word bit CC and its recommended use, as used in the factory settings.
COM *p* L	Show a long format communications summary report for all events on MIRRORED BITS® or Differential Channel *p*.
COM *p n*	Show a communications summary for latest *n* events on MIRRORED BITS or Differential Channel *p*.
COM *p m n*	Show a communications summary report for events *n–m* on MIRRORED BITS or Differential Channel *p*.
COM *p d1*	Show a communications summary report for events occurring on date *d1* on MIRRORED BITS or Differential Channel *p*.
COM *p d1 d2*	Show a communications summary report for events occurring between dates *d1* and *d2* on MIRRORED BITS or Differential Channel *p*. Entry of dates is dependent on the Global Date Format setting DATE_F (= MDY or YMD).
COM C *p*	Clears the communications summary report for Channel *p*.
CON *n*	Control Remote Bit RB*n* (Remote Bit *n*; *n* = 1–16). Execute **CON *n*** and the relay responds: `CONTROL RBn`. Reply with one of the following: **SRB *n*** [set Remote Bit *n* (assert RB*n*)]. **CRB *n*** [clear Remote Bit *n* (deassert RB*n*)]. **PRB *n*** [pulse Remote Bit *n* (assert RB*n* for 1/4 cycle)].
COP *m n*	Copy relay and logic settings from Group *m* to Group *n*.
CST	Compressed status report.
CSU	Compressed event summary.
DAT	Set/show relay date.

Command	Description
DAT m/d/y	Enter date in this manner if Date Format setting DATE_F = MDY.
DAT y/m/d	Enter date in this manner if Date Format setting DATE_F = YMD.
EVE *n*	Show event report number *n* with 1/4-cycle resolution.
EVE L *n*	Show event report number *n* with 1/16-cycle resolution.
EVE R *n*	Show raw event report number *n* with 1/16-cycle resolution.
EVE B *n*	Show event report number *n* for backup elements (not including differential) with 1/4-cycle resolution.
EVE C *n*	Show compressed event report number *n*.
EVE N *n*	Show event report number *n* 87W differential report with 1/4-cycle resolution.
FIL DIR	Initiate a text response containing all of the filenames within a specified directory.
FIL READ	Initiate a file transfer from the relay to the computer for display on the computer.
FIL SHOW	Initiate a file transfer from the relay to the computer.
FIL WRITE	Initiate a file transfer from the computer to the relay.
GRO	Display the active group number.
GRO *n*	Change active group to Group *n*.
HELP	View commands help.
HIS *n*	Show brief summary of the *n* latest event reports.
HIS C	Clear the brief summary and corresponding event reports.
IRI	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
L_D	Load new firmware.
LOO	Set MIRRORED BITS port to loopback.
MET *k*	Display instantaneous metering data (currents and alpha plane) for local and remote terminals. Enter *k* for repeat count.
MET B *k*	Display instantaneous metering data for local terminal including voltage. Enter *k* for repeat count.
MET D	Display demand and peak demand data. Enter **MET RD** or **MET RP** to reset.
MET E	Display energy metering data. Enter **MET RE** to reset.
MET M	Display maximum/minimum metering data. Enter **MET RM** to reset.
MET N	Display instantaneous metering data (currents and voltages) for local and remote zero-sequence data.
OPE	Open the circuit breaker. The **OPE** command asserts Relay Word bit OC for 1/4 cycle when it is executed. Relay Word bit OC can then be programmed into the SELOGIC control equation TR to assert the TRIP Relay Word bit, which in turn asserts an output contact (e.g., OUT101 = TRIP) to trip a circuit breaker. See *Figure 4.3*. See *OPE Command (Open Breaker) on page 8.44* for more information concerning Relay Word bit OC and its recommended use, as used in the factory settings.
PAS	Show existing Access Level 1, B, and 2 passwords.
PAS 1 xxxxxx	Change Access Level 1 password to xxxxxx.
PAS B xxxxxx	Change Access Level B password to xxxxxx.
PAS 2 xxxxxx	Change Access Level 2 password to xxxxxx.
PLA <filename>[A C D MA MB O bbbbbb E ele T Time]	
where: **filename**	name of COMTRADE DAT file within relay file system.
A	include analogs (this includes frequency data).
C	include command bits.
D	include digital inputs.
MA	include MIRRORED BITS channel A.

Command	Description
MB	include MIRRORED BITS channel B.
O bbbbbb	drive outputs during playback according to the “binary” string bbbbbb, where the first b represents IN101 and the last IN106, and b can be o, c, x, or * to signify holding contact open, holding contact closed, holding it in its current state, or driving it normally during playback.
E element	trigger on element ele (with timeout).
T Time	trigger at given time (time has same format as **TIME** command parameter: hh:mm:ss, where hh = hours, mm = minutes, ss = seconds). If no trigger is provided via E or T parameters, playback starts five seconds after your verification. If no playback items are specified (A/C/D/MA/MB/O), the command defaults to playback analogs and digitals with output contacts driven to their default (de-energized) state
PUL *n k*	Pulse output contact *n* (OUT101–OUT107, ALARM, OUT201–OUT212) for *k* (1–30) seconds. Parameter *n* must be specified; *k* defaults to 1 if not specified.
QUI	Quit. Returns to Access Level 0. Available in all access levels.
SER *n*	Show the latest *n* rows in the Sequential Events Recorder (SER) event report.
SER *m n*	Show rows *m* through *n* in the Sequential Events Recorder (SER) event report.
SER *d1*	Show rows in the Sequential Events Recorder (SER) event report from *date d1*.
SER *d1 d2*	Show rows in the Sequential Events Recorder (SER) event report from *date d1* to *date d2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY or YMD).
SER C	Clears the Sequential Events Recorder (SER).
SET *n*[a]	Change relay settings (overcurrent, differential, timers, etc.) for Group *n*.
SHO *n*[a]	Show relay settings (overcurrent, differential, timers, etc.) for Group *n*.
STA	Show relay self-test status.
STA C	Resets self-test warnings/failures and reboots relay.
SUM	Show newest event summary.
SUM A	Acknowledge oldest event summary.
SUM N	View oldest unacknowledged event report.
SUM N [A]	Display or acknowledge event summary number “N.”
TAR R	Reset the front-panel tripping targets.
TAR *n k*	Display Relay Word row. If *n* = 0 through 67, display row *n*. If *n* is an element name (e.g., 50NG1) display the row containing element *n*. Enter *k* for repeat count.
TIM	Show or set time (24-hour time). Show time presently in the relay by entering just **TIM**. Example time 22:47:36 is entered with command **TIM 22:47:36**.
TRI	Trigger an event report.
TST {chn}	Test the differential communication channel. If channel (X or Y) is specified, a question string will follow to configure the channel for testing. With no channel identifier, the command will return each channel status.
VER	Display the relay hardware and software configurations

[a] See the table below for SET/SHOW options.

SET/SHOW Command Options

Option	Setting Type	Description
G	Global settings	Relay-wide settings
L *n*	Protection Logic Group 1–6	Protection SELOGIC® control equations
P *n*	Port *n*	Communications port settings
R	Report	Event report and SER settings
T	Text	Text label settings
{Blank}	Relay Group 1–6	Group settings