SEL-851

Feeder Protection Relay

Instruction Manual

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SEL SCHWEITZER ENGINEERING LABORATORIES

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Preface

Manual Overview

The SEL-851 Feeder Protection Relay Instruction Manual describes common aspects of feeder relay application and use. It includes the necessary information to install, set, test, and operate the relay.

An overview of each manual section and topics follows:

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

Section 1: Introduction and Specifications. Describes the basic features and functions of the SEL-851; lists the relay specifications.

Section 2: Installation. Describes how to mount and wire the SEL-851; illustrates wiring connections for various applications.

Section 3: PC Interface. Describes the built-in web server and its features, including settings, metering and monitoring, reports, and firmware upgrade. Also describes the features, installation methods, and types of help available with SEL Grid Configurator Software.

Section 4: Protection and Logic Functions. Describes the operating characteristic of each protection element, using logic diagrams and text, and explains how to calculate element settings; describes contact output logic, automation, and report settings.

Section 5: Metering and Monitoring. Describes the operation of each metering function; describes the monitoring functions.

Section 6: Settings. Describes how to view, enter, and record settings for protection, control, communications, logic, and monitoring.

Section 7: Communications. Describes how to connect the SEL-851 to a PC for communication; shows serial port pinouts; lists and defines the serial port commands. Describes the communications port interfaces and protocols supported by the relay for serial and Ethernet.

Section 8: HMI. Explains the features and use of the front panel, including the front-panel command menu, default displays, and automatic messages. Describes in detail the graphical monochrome LCD (4 lines, 21 characters) HMI.

Section 9: Analyzing Events. Describes event types, messages, event summary data, standard event reports, and the Sequential Events Recorder (SER) report.

Section 10: Testing and Troubleshooting. Describes relay test procedures, relay self-test, and relay troubleshooting.

Appendix A: Firmware, ICD, and Manual Versions. Lists the present relay firmware version and details differences between the present 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. Provides examples of how to use the SEL-851 with SEL communications processors for total substation automation solutions.

Appendix D: DNP3 Communications. Describes the DNP3 protocol support provided by the SEL-851.

Appendix E: Modbus Communications. Describes the Modbus protocol support provided by the SEL-851.

Appendix F: IEC 61850 Communications. Describes IEC 61850 implementation in the SEL-851.

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

Appendix H: Relay Word Bits. Lists and describes the Relay Word bits (outputs of protection and control elements).

Appendix I: Analog Quantities. Lists and describes the analog quantities (outputs of analog elements).

Appendix J: Cybersecurity Features. Describes a number of features to help meet cybersecurity design requirements.

SEL-851 Command Summary. Briefly describes the serial port commands that are fully described in *Section 7: Communications*.

Safety Information

Dangers, Warnings, and Cautions

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

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

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

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

Safety Symbols

The following symbols are often marked on SEL products.

	CAUTION Refer to accompanying documents.	**ATTENTION** Se reporter à la documentation.
	Earth (ground)	Terre
	Protective earth (ground)	Terre de protection
	Direct current	Courant continu
	Alternating current	Courant alternatif
	Both direct and alternating current	Courant continu et alternatif
	Instruction manual	Manuel d'instructions

Safety Marks

The following statements apply to this device.

General Safety Marks

CAUTION To ensure proper safety and operation, the equipment ratings, installation instructions, and operating instructions must be checked before commissioning or maintenance of the equipment. The integrity of any protective conductor connection must be checked before carrying out any other actions. It is the responsibility of the user to ensure that the equipment is installed, operated, and used for its intended function in the manner specified in this manual. If misused, any safety protection provided by the equipment may be impaired.	**ATTENTION** Pour assurer la sécurité et le bon fonctionnement, il faut vérifier les classements d'équipement ainsi que les instructions d'installation et d'opération avant la mise en service ou l'entretien de l'équipement. Il faut vérifier l'intégrité de toute connexion de conducteur de protection avant de réaliser d'autres actions. L'utilisateur est responsable d'assurer l'installation, l'opération et l'utilisation de l'équipement pour la fonction prévue et de la manière indiquée dans ce manuel. Une mauvaise utilisation pourrait diminuer toute protection de sécurité fournie par l'équipement.
For use in Pollution Degree 2 environment.	Pour l'utilisation dans un environnement de Degré de Pollution 2.
For use on a flat surface of a Type 1 enclosure.	Destiné à l'utilisation sur une surface plane d'un boîtier de Type 1.
Terminal Ratings Wire Material Use 75°C (167°F) copper conductors only. Tightening Torque CT Terminal Blocks: 0.9–1.4 Nm (8–12 in-lb) Compression Plug: 0.5–1.0 Nm (4.4–8.8 in-lb) Compression Plug Mounting Ear Screw: 0.18–0.25 Nm (1.6–2.2 in-lb)	Spécifications des bornes Type de filage Utiliser seulement des conducteurs en cuivre spécifiés à 75°C (167°F). Couple de serrage CT bornes : 0,9–1,4 Nm (8–12 livres-pouce) Fiche à compression : 0,5–1,0 Nm (4,4–8,8 livres-pouce) Vis à oreille de montage de la fiche à compression : 0,18–0,25 Nm (1,6–2,2 livres-pouce)

Other Safety Marks (Sheet 1 of 2)

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 blessures ou la mort.
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.

Other Safety Marks (Sheet 2 of 2)

WARNING Before working on a CT circuit, first apply a short to the secondary winding of the CT.	**AVERTISSEMENT** Avant de travailler sur un circuit TC, placez d'abord un court-circuit sur l'enroulement secondaire du TC.
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 accès non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accès non-autorisé.
WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	**AVERTISSEMENT** Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
WARNING Overtightening the mounting nuts may permanently damage the relay chassis.	**AVERTISSEMENT** Une pression excessive sur les écroux de montage peut endommager de façon permanente le chassis du relais.
WARNING Contact I/O terminals are considered HAZARDOUS at any rated voltage level. External equipment connected to contact I/O terminals shall provide additional electrical isolation based on the maximum rated contact I/O voltage.	**AVERTISSEMENT** Les borniers d'entrée/sortie sont considérés DANGEREUX quel que soit le niveau de tension nominale. Un appareil externe branché aux borniers doit fournir une isolation électrique supplémentaire en fonction de la tension d'entrée/sortie nominale maximale.
CAUTION The equipment shall be isolated or disconnected from hazardous live voltage before access to potentially hazardous live parts is affected.	**ATTENTION** L'appareil doit être isolé ou mis hors tension avant d'accéder à des pièces sous tension potentiellement dangereuse.
CAUTION Protective earth connections should not be removed when the equipment is energized.	**ATTENTION** Les connexions de protection de mise à la terre ne devraient pas être enlevées lorsque l'appareil est sous tension.
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 Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	**ATTENTION** Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.

General Information

Typographic Conventions

There are many ways to communicate with the SEL-851. The three primary methods are:

- Using a command line interface on a PC terminal emulation window.
- Using the built-in four-line LCD HMI front-panel menus and pushbuttons.
- Using SEL Grid Configurator Software.

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 dialog boxes and menu selections. The > character indicates submenus.
ENABLE	Relay front- or rear-panel labels and pushbuttons.
`Main > Meters`	Relay front-panel LCD menus and relay responses. The > character indicates submenus.

Logic Diagram Conventions and Abbreviations

The following icons are used in the logic diagrams to represent corresponding variable types identified in the description.

Icons	Description
⚙	Represents all settings with the exception of SELOGIC control equation type settings (e.g., pickup settings of overcurrent function).
1 0 0 1	Represents Relay Word bits (e.g., the outputs of most protection functions).
∿	Represents analog quantities (e.g., currents, voltages, power, etc.).
⚙ 1 0	Represents SELOGIC control equation Boolean type settings. These setting types are also available as Relay Word bits (e.g., torque control type settings).
No icon	Represents intermediate quantities (Relay Word bits or analog quantities) not accessible to the user.

The pickup (PU) and dropout (DO) settings associated with timers are represented as shown below.

Abbreviation	Description
IPos	Positive-sequence current (IPos = I1)
INeg	Negative-sequence current (INeg = 3I2)
IGnd	Zero-sequence or residual ground current (IGnd = 3I0)
VPos	Positive-sequence voltage (VPos = V1)
VNeg	Negative-sequence voltage (VNeg = 3V2)
VGnd	Zero-sequence or residual ground voltage (VGnd = 3V0)

Trademarks

All brand or product names appearing in this document are the trademark or registered trademark of their respective holders. No SEL trademarks may be used without written permission.

SEL trademarks appearing in this manual are shown in the following table.

ACSELERATOR Architect®	SYNCHROWAVE®
MIRRORED BITS®	time-overlight®
SELOGIC®	

Examples

This instruction manual uses several example illustrations and instructions to explain how to effectively operate the SEL-851. 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 present version of your SEL-851.

LED Emitter

⚠CAUTION
Use of controls, adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure.

The following table shows LED information specific to the SEL-851.

SEL-851 LED Information

Item	Arc-Flash Channel 1-4
Mode	Multimode
Wavelength	640 nm
Source	LED
Connector type	V-pin
Typical output power	–12 dBm

The following figure shows the LED location specific to the SEL-851 (see *Figure 2.15* for the complete rear-panel view).

SEL-851 LED Locations

LED Safety Warnings and Precautions

- Do not look into the end of an optical cable connected to an optical output.
- Do not perform any procedures or adjustments that are not described in this manual.
- During installation, maintenance, or testing of the optical ports only use test equipment classified as Class 1 laser products.
- Incorporated components, such as transceivers and laser/LED emitters, are not user serviceable. Units must be returned to SEL for repair or replacement.

Environmental Conditions and Voltage Information

The following table lists important environmental and voltage information.

Condition	Range/Description
Indoor/outdoor use	Indoor
Altitude[a]	As high as 2000 m
Temperature	
IEC Performance Rating (per IEC/EN 60068-2-1 and IEC/EN 60068-2-2)	–40° to +85°C
UL Applications (per IEC/EN/UL 61010-1)	–20° to +40°C
Relative humidity	5% to 95%
Main supply voltage fluctuations	As high as ±10% of nominal voltage
Overvoltage	Category III
Insulation	Class 1
Pollution	Degree 2
Atmospheric pressure	80 to 110 kPa

[a] Consult the factory for derating specifications for higher altitude applications.

Instructions for Cleaning and Decontamination

Use a mild soap or detergent solution and a damp cloth to carefully clean the SEL-851 chassis when necessary. Avoid using abrasive materials, polishing compounds, and harsh chemical solvents (such as xylene or acetone) on any surface of the relay.

Technical Support

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 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

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Section 1

Introduction and Specifications

Overview

The SEL-851 Feeder Protection Relay is designed to protect three-phase feeders. The base relay includes phase overcurrent, inverse time-overcurrent, breaker failure, reclosing, and over- and underfrequency protection elements. Voltage-based protection and arc-flash detection elements are available as options. All relay models provide monitoring functions.

This manual contains the information necessary to install, set, test, operate, and maintain any SEL-851. You need not review the entire manual to perform specific tasks.

Features

Protection Features

The SEL-851 protection features depend on the model and options selected. *Table 1.1* lists the protection features available in different models.

Table 1.1 SEL-851 Protection Elements (Sheet 1 of 2)

Protection Element		Current Only Model	Current and Voltage Model
50P	Max. Phase Overcurrent	X	X
50Neg	Neg.-Seq. Overcurrent	X	X
50Gnd	Residual Ground Overcurrent	X	X
50N	Neutral Overcurrent	X	X
50ABC	Per-Phase Overcurrent	X	X
51P	Max. Phase Time Overcurrent	X	X
51Gnd	Residual Ground Time Overcurrent	X	X
51Neg	Neg.-Seq. Time Overcurrent	X	X
51N	Neutral Time Overcurrent	X	X
HBlk	Second-Harmonic Blocking	X	X
27	Undervoltage (Phase-to-Phase)		X
59	Overvoltage (Phase-to-Phase, Residual)		X
60LOP	Loss of Potential		X
32	Directional Power		X
55	Power Factor		X
81	Over- and Underfrequency		X
BF	Breaker Failure	X	X

Table 1.1 SEL-851 Protection Elements (Sheet 2 of 2)

Protection Element		Current Only Model	Current and Voltage Model
79	Reclosing	X	X
AFD	Arc-Flash Detection	X[a]	X[a]

[a] Available as an ordering option.

Monitoring Features

- Event summaries that contain relay ID, date and time, trip cause, and current/voltage magnitudes
- Event reports that include filtered and raw analog data
- Sequential Events Recorder (SER)
- A complete suite of accurate metering functions
- Signal profiling

Communications and Control Features

- USB-C front-panel port
- EIA-232/EIA-485 rear-panel port (RJ45) with IRIG-B time-code input
- Single or dual copper Ethernet rear-panel port
- Built-in web server
- Modbus RTU, Modbus TCP/IP, Simple Network Time Protocol (SNTP), FTP, Telnet, MIRRORED BITS, and optional DNP3 serial or DNP LAN/WAN and IEC 61850 Edition 2
- SEL ASCII, Compressed ASCII, Fast Meter, Fast Operate, Fast SER, and Fast Message protocols
- Programmable Boolean and math operators, logic functions, and analog compare

Models, Options, and Accessories

Models

Complete ordering information is not provided in this instruction manual. See the latest Model Option Table for the SEL-851 at selinc.com on the SEL-851 product page under Documentation > Ordering Information.

SEL-851 Base Unit

- Rack mount
- Built-in HMI
  - Graphical monochrome LCD (4 lines, 21 characters per line)
  - 5 soft keys with text strings on the LCD
  - 10 tricolor target LEDs (8 programmable)
  - 4 control pushbuttons
  - 6 navigation pushbuttons
- Universal power supply (24–250 Vdc/110–240 Vac)
- Four CT (3-phase and neutral) universal 1 A/5 A inputs
- 5 digital outputs (1 Form C, 2 Form A standard, 2 Form A hybrid)
- 4 internally wetted (24 Vdc) digital inputs
- USB-C front-panel port

- Single copper Ethernet rear-panel port
- EIA-232/EIA-485 (RJ45) rear-panel port with IRIG-B time-code input
- Protocols
  - Modbus RTU
  - Telnet
  - FTP
  - HTTP/HTTPS web server
  - SNTP
  - SEL ASCII and Compressed ASCII
  - SEL Fast Meter, Fast Operate, Fast SER, Fast Message
  - Ymodem File Transfer
  - SEL MIRRORED BITS

Options

- Mounting
  - Horizontal mount (with or without a front cover)
  - Horizontal panel mount (with picture frame)
  - Ganged rack mount (left or right)
  - 19-inch horizontal rack mount with adapter plate
- 3-phase ac voltage (300 Vac max.)
- 4 arc-flash detector inputs
- Digital inputs:
  - Wetting voltage: external universal (24–250 Vdc/Vac) or internal (24 Vdc). This selection applies to all digital inputs, 4 base unit inputs and optional 6 additional inputs
  - 6 additional digital inputs (wetting voltage as selected above)
- Communications options (protocol/ports)
  - Dual copper Ethernet rear-panel port
  - IEC 61850 Edition 2
  - DNP3 serial and LAN/WAN
- Conformal coating

Accessories

Contact your Technical Service Center or the SEL factory for additional detail and ordering information for the following accessories:

- SEL-C804 and SEL-C814 multimode fiber-optic arc-flash detection (AFD) sensors and accessories
- SEL-851 configurable labels
- RJ45 cable for rear-panel serial port
- USB-C 10-foot serial cable
- Panel-mount bezel
- Back terminal cover
- Front cover for horizontal rack mount
- Replacement rear connector kit

For all SEL-851 accessories, refer to the SEL-851 Model Option Table at selinc.com on the SEL-851 product page under Documentation > Ordering Information.

Applications

The SEL-851 Feeder Protection Relay has many power system protection, monitoring, and control applications. You can use SELOGIC control equations in all SEL-851 models to provide custom protection and control applications.

Figure 1.1 shows a typical protection application for the SEL-851. You can use the SEL-851 overcurrent, inverse time-overcurrent, breaker failure, reclosing, over- and underfrequency, and voltage-based protection elements to protect the feeder.

Section 2: Installation includes ac and dc connection diagrams for various applications, including arc-flash protection.

Figure 1.1 SEL-851 Feeder Protection Relay Applied Throughout the Power System

Getting Started

Understanding basic relay operation principles and methods will help you use the SEL-851 effectively. This section presents the fundamental knowledge you need to operate the SEL-851, organized by task. These tasks help you become familiar with the relay and include the following:

- *Powering the Relay*
- *Establishing Communication*
- *Checking the Relay Status*
- *Setting the Date and Time*

Perform these tasks to gain a fundamental understanding of relay operation.

Powering the Relay

Power the SEL-851 with a 24–250 Vdc/110–240 Vac power supply.

- ➤ Observe proper polarity, as indicated by the **+/H** (Terminal **B13**) and the **–/N** (Terminal **B14**) on the power connections.
- ➤ Connect the ground lead; see *Ground Terminal Connection on page 2.13*.
- ➤ Once connected to power, the relay does an internal self-check and the **ENABLED** LED illuminates.

Establishing Communication

The SEL-851 has a USB-C front-panel serial communications port. The following steps require PC terminal emulation software and an SEL-C497 Cable (or equivalent) to connect the SEL-851 to the PC. See *Section 7: Communications* for further information on serial communications connections and the necessary cable pinout.

Step 1. Connect the PC and the SEL-851 by using the serial communications cable.

Step 2. Apply power to both the PC and the relay.

Step 3. Start the PC terminal emulation program.

Step 4. Set the PC terminal emulation program to the communications port used.

Step 5. Press the **<Enter>** key on the PC keyboard to check the communications link.

You will see the = prompt at the left side of the computer screen.

If you do not see the = prompt, check the cable connections and confirm that the COMM Port setting in the terminal emulation program is correct.

Step 6. Type **QUIT <Enter>** to view the relay report header.

You will see a computer screen display similar to *Figure 1.2*. If you see jumbled characters, change the terminal emulation type in the PC terminal emulation program.

```
=>>QUIT <Enter>

SEL-851                      Date: 01/14/2021   Time: 12:06:23.259
FEEDER RELAY                 Time Source: External

=
```

Figure 1.2 Response Header

Step 7. Type **ACC <Enter>** and the appropriate password (see *Table 7.32* for factory-default passwords) to go to Access Level 1.

Checking the Relay Status

Use the **STA** serial port command to view the SEL-851 operational status. The analog module and monitored component statuses are listed in the status report depicted in *Figure 1.3*.

```
=>>STA <Enter>

SEL-851                                    Date: 03/25/2020   Time: 15:49:04.317
FEEDER RELAY                               Time Source: Internal


Serial Num = 000000000000101
FID = SEL-851-X028-V2-Z001001-D20210315         CID = 5A17
PART NUM = 085100011110130

SELF TESTS (W=Warn)
  RAM     ROM     CR_RAM  NON_VOL HMI     CLOCK   CLK_BAT AF      PS     ETH
  OK      OK      OK      OK      OK      OK      OK      OK      OK     OK

Analog Module
  FPGA    DAQ
  OK      OK

  Relay Enabled

=>>
```

Figure 1.3 STA Command Response

Table 7.44 provides the definition of each status report designator and *Table 10.7* shows all the self-tests performed by the relay. The beginning of the status report printout (see *Figure 1.3*) contains the relay serial number, firmware identification string (FID), and checksum string (CID). These strings uniquely identify the relay and the version of the operating firmware.

Setting the Date and Time

DAT (Date Command)

Viewing the Date

Type **DAT <Enter>** at the prompt to view the date stored in the SEL-851. If the date stored in the relay is July 29, 2020, and the Time.DateFormat setting is MDY, the relay replies:

```
7/29/2020
```

If the Time.DateFormat setting is YMD, the relay replies:

```
2020/7/29
```

If the Time.DateFormat setting is DMY, the relay replies:

```
29/7/2020
```

Changing the Date

Type **DAT** followed by the correct date at the prompt to change the date stored in the relay. For example, to change the date to May 2, 2020 (Time.DateFormat := MDY), enter the following at the action prompt:

```
DAT 5/2/20
```

You can separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons.

TIM (Time Command)

Viewing the Time

Enter **TIM** at the prompt to view the time stored in the SEL-851. The relay replies with the stored time. For example:

```
13:52:44
```

This time is 1:52 p.m. (and 44 seconds).

Changing the Time

Enter **TIM** followed by the correct time at the action prompt to change the time stored in the relay. For example, to change the time to 6:32 a.m., enter the following at the prompt:

```
TIM 6:32:00
```

You can separate the hours, minutes, and seconds parameters with spaces, commas, slashes, colons, and semicolons.

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

47 CFR 15B, Class A

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

* UL has not yet developed requirements for products intended to detect and mitigate an arc flash; consequently, UL has not evaluated the performance of this feature. While UL is developing these requirements, it will place no restriction on the use of this product for arc-flash detection and mitigation. For test results performed by an independent laboratory and other information on the performance and verification of this feature, please contact SEL customer service.

UL Listed Protective Relays (E212775)

CE Mark in accordance with the requirements of the European Union

RCM Mark in accordance with the requirements of Australia

UKCA Mark in accordance with the requirements of the United Kingdom

General

AC Current Inputs—Phase and Neutral

Rated Range:	1 A/5 A software selectable
Continuous Rating:	20 Arms @ 55°C
1-Second Thermal:	500 Arms
A/D Measurement Limit:	286 A peak (202 Arms symmetrical)
Rated Frequency:	50/60 Hz
Burden (Per Phase):	<0.1 VA @ 5 A

AC Voltage Inputs

Rated Operating Voltage (Ue):	50–250 Vac
Rated Continuous Voltage:	300 Vac
10-Second Thermal:	600 Vac
A/D Measurement Limit:	540 V peak (381 Vrms symmetrical)
Rated Frequency:	50/60 Hz
Input Impedance:	2 MΩ single-ended (phase-to-neutral) 2 MΩ differential (phase-to-phase)
Burden:	<0.1 VA at 120 Vac

Universal Power Supply

Rated Supply Voltage:	24–250 Vdc/110–240 Vac, 50/60 Hz
Absolute Operating Range:	19.2–264 Vac 19.2–275 Vdc
Power Consumption:	<35 VA (ac) <12 W (dc)
Interruptions:	20 ms minimum

Fuse Ratings

Rating:	1.25 A
Maximum Rated Voltage:	600 Vac 250 Vdc
Breaking Capacity:	60 A at 250 Vac
Type:	Time-lag T

Output Contacts

General

The relay supports Form A and Form C outputs

Mechanical Durability:	100,000 no-load operations

Standard

Pickup/Dropout Time:	≤8 ms (coil energization to contact closure)

DC Output Ratings

Form A and Form C

Rated Operational Voltage:	250 Vdc
Rated Voltage Range:	24–250 Vdc
Rated Insulation Voltage:	300 Vdc
Make (Short-Duration Contact Current):	30 Adc (per IEC 60255-27:2013, C37.90-2005, tested for the number of cycles shown) 1000 operations @ 250 Vdc 1000 operations @ 125 Vdc
Continuous Carry:	6 A @ 70°C 5 A @ 85°C
1-Second Thermal:	50 A
Contact Rating Designation:	8 A, 24 Vdc (resistive) 100 k 0.27 A, 250 Vdc
Contact Protection:	385 Vdc, 65 J MOV protection across open contacts

Breaking Capacity (10,000 Operations):

24 V	0.75 A	L/R = 40 ms
48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 20 ms

Cyclic Capacity (2.5 Cycle/Second):

24 V	0.75 A	L/R = 40 ms
48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 20 ms

AC Output Ratings

Contact Rating Designation:	8 A, 250 Vac (resistive) 100 k C150, B300
Utilization Category:	AC-15

AC-15		
Operational Voltage (Ue)	120 Vac	240 Vac
Operational Current (Ie)	3 A	1.5 A
Make Current	30 A	15 A
Break Current	3 A	1.5 A
Electromechanical loads > 72 VA, PF < 0.3, 50–60 Hz		

Voltage Protection Across Open Contacts:	385 Vdc, 65 J

Fast Hybrid (High-Speed, High-Current Interrupting)

DC Output Ratings

Rated Operational Voltage:	250 Vdc
Rated Voltage Range:	19.2–275 Vdc
Rated Insulation Voltage:	300 Vdc

Make (Short-Duration Contact Current):	30 Adc (per IEC 60255-27:2013, C37.90-2005, tested for the number of cycles shown) 1000 operations @ 250 Vdc 1000 operations @ 125 Vdc
Carry:	6 A @ 70°C 4 A @ 85°C
1-Second Thermal:	50 A
Open State Leakage Current:	<500 µA
MOV Protection (Maximum Voltage):	330 Vdc, 145 J MOV
Pickup Time:	≤50 µs, resistive load
Dropout Time:	≤8 ms, resistive load

Breaking Capacity (10,000 Operations)

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

Cyclic Capacity (4 cycles in 1 second followed by 2 minutes idle for thermal dissipation)

48 V	8.0 A	L/R = 40 ms
125 V	8.0 A	L/R = 40 ms
250 V	8.0 A	L/R = 20 ms

AC Output Ratings

See *AC Output Ratings* for standard contacts.

Optoisolated Control Inputs

Externally Wetted (24-250 Vdc/Vac)

Rated Range:	24, 48, 110, 125, 220, and 250 Vdc/Vac, setting selectable
Minimum Current Draw:	1.5 mA
Pickup Time:	2 ms plus ±1 ms (24–250 Vac) 2 ms plus ±1 ms (48–250 Vdc) 4 ms plus ±1 ms (24 Vdc)
Dropout Time:	10 ms plus ±1 ms (24–250 Vac) 2 ms plus ±1 ms (48–250 Vdc) 4 ms plus ±1 ms (24 Vdc)

Nominal Voltage AC/DC	Deassertion Range (±5%)		Assertion Range (±5%)	
	V_{DC} (V)	V_{AC} (V)	V_{DC} (V)	V_{AC} (V)
24 V	0.0–14.4	0.0–10.1	19.2–30.0	16.8–26.4
48 V	0.0–28.8	0.0–20.2	38.4–60.0	33.6–52.6
110 V	0.0–66.0	0.0–46.2	88.0–132.0	77.0–116.2
125 V	0.0–75.0	0.0–52.5	100.0–156.2	87.5–137.5
220 V	0.0–132.0	0.0–92.4	176.0–264.0	154.0–232.3
250 V	0.0–150.0	0.0–105	200.0–300.0	175.0–264.0

Internally Wetted (24 Vdc)

Wetting-Voltage Range:	18–24 Vdc
Guaranteed Pickup Requirements:	<2.50 kΩ
Guaranteed Dropout Requirements:	>4.25 kΩ
Pickup Time:	4 ms plus ±1 ms
Dropout Time:	2 ms plus ±1 ms

Frequency and Rotation

System Frequency:	50, 60 Hz
Phase Rotation:	ABC, ACB
Frequency Tracking:	15.0–70.0 Hz

Time-Code Input

IRIG-B

Format:	Demodulated IRIG-B
On (1) State:	Vih ≥ 2.2 V
Off (0) State:	Vil ≤ 0.8 V
Input Impedance:	2 kΩ

Simple Network Time Protocol (SNTP) Accuracy

Internal Clock:	±5 ms
Unsynchronized Clock Drift Relay Powered:	13 minutes per year, typically
Frequency Tracking:	12.5–72.5 Hz

Communications Ports

Serial EIA-232/EIA-485 Port

Communication Interface:	EIA-232 or EIA-485 software selectable
Connector Type:	RJ45
Data Speed:	EIA-232: 300–115200 bps EIA-485: 300–115200 bps

Communications Protocols

ASCII, Modbus RTU, Modbus TCP, MIRRORED BITS, FTP, TCP/IP, Telnet, SNTP, and HTTP/HTTPS and optional DNP3 serial and LAN/WAN and IEC 61850 Edition 2

Operating Temperature

Rated Range:	–40° to +85°C (–40° to +185°F)
UL Applications:	–20 to 40 (per IEC/EN 61010-1)

Operating Environment

Pollution Degree:	2
Overvoltage Category:	III
Atmospheric Pressure:	80–110 kPa
Relative Humidity:	5%–95%, noncondensing
Insulation Class:	1
Maximum Altitude Without Derating (Consult Factory for Higher-Altitude Derating):	2000 m

Dimensions

260.6 mm (10.26 in) x 88.14 mm (3.47 in) x 137.9 mm (5.43 in)

Weight

1.13 kg (2.5 lb)

Tightening Torque

Relay Mounting Screw Maximum:	2.0 Nm (18 in-lb)
Ganged Unit Fastening Screw Maximum:	1.4 Nm (12 in-lb)

Terminal Connections

Terminal Block

Screw Size:	#6
Ring Terminal Width:	0.310 inch maximum

Terminal Block Tightening Torque

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

Compression Plug Tightening Torque

Minimum:	0.5 Nm (4.4 in-lb)
Maximum:	1.0 Nm (8.8 in-lb)

Compression Plug Mounting Ear Screw Tightening Torque

Minimum:	0.18 Nm (1.6 in-lb)
Maximum:	0.25 Nm (2.2 in-lb)

Note: Crimp ferrule is recommended.

Product Standards

Electromagnetic Compatibility:	IEC 60255-26:2013
Safety Standards:	IEC 60255-27:2013 IEC 61010-1:2010 + AM1:2016 IEC 61010-2-030:2017 IEC 61010-2-201:2017 UL 61010-1, Third Edition UL 61010-2-030, Second Edition UL 61010-2-201, Second Edition UL 1053, Seventh Edition CSA C22.2 No. 61010-1-12 CSA C22.2 No. 61010-2-030:18 CSA C22.2 No. 61010-2-201:18

Type Tests

Environmental Tests

Enclosure Protection:	IEC 60529:2001 IP30 without the relay front-panel cover IP54 with the relay front-panel cover IP1X for the terminals and the relay rear panel
Vibration Resistance:	IEC 60255-21-1:1988
Endurance:	Class 2 (horizontal mount, 19-inch horizontal rack mount with adapter plate, and panel mount) Class 1 (ganged rack mount)
Response:	Class 2
Shock Resistance:	IEC 60255-21-2:1988
Withstand:	Class 1
Response:	Class 2
Bump:	Class 1
Seismic (Quake) Response:	IEC 60255-21-3:1993, Class 2
Cold:	IEC 60068-2-1:2007, –40°C, 16 hours
Damp Heat, Cyclic:	IEC 60068-2-30:2005, 25–55°C, 6 cycles, 95% relative humidity
Dry Heat:	IEC 60068-2-2:2007, 85°C, 16 hours
Damp Heat, Steady State:	IEC 60068-2-78:2001 IEC 60255-27:2013, Section 10.6.1.5 40°C, 93% relative humidity, 10 days
Change of Temperature:	IEC 60068-2-14:2009 IEC 60255-1:2010, Section 6.12.3.5 –40° to +85°C

Dielectric Strength and Impulse Tests

Dielectric (HiPot):	IEC 60255-27:2013 Section 10.6.4.3 Section 10.6.4.4 Section 10.6.4.5 IEEE C37.90-2005 3.6 kVdc on voltage inputs and binary inputs 2.5 kVac on current inputs and output contacts 5.2 kVdc on power supply 1.5 kVdc on the communication ports; Port 2A and Port 2B tested jointly as a group
Impulse:	IEC 60255-27:2013 Section 10.6.4.2 0.5 J, 5.0 kV on power supply, contact I/O, ac current, and ac voltage inputs 0.5 J, 2 kV on serial and Ethernet ports

RFI and Interference Tests

EMC Immunity

Electrostatic Discharge Immunity:	IEC 60255-26:2013 Section 7.2.3 IEC 61000-4-2:2009 Severity Level 4 8 kV contact discharge 15 kV air discharge
Radiated RF Immunity:	IEC 60255-26:2013 Section 7.2.4 IEC 61000-4-3:2008 10 V/m IEEE C37.90.2-2004 35 V/m
Fast Transient, Burst Immunity[a]:	IEC 60255-26:2013 Section 7.2.5 IEC 61000-4-4:2012 4 kV @ 5.0 kHz 2 kV @ 5.0 kHz for comm. ports
Surge Immunity[ab]:	IEC 60255-26:2013 Section 7.2.7 IEC 61000-4-5:2005 2 kV line-to-line 4 kV line-to-earth
Radiated Emissions:	FCC 47 CFR 15.109:2012, Class A IEC 60255-26:2013 Section 7.1, Class A CISPR 11:2009+A1:2010 CISPR 22:2008 ICES-001, Issue 5 Canada ICES-001 (A) / NMB-001 (A)
Conducted Emissions:	FCC 47 CFR 15.107:2012, Class A IEC 60255-26:2013 Section 7.1, Class A CISPR 22:2008 ICES-001, Issue 5 Canada ICES-001 (A) / NMB-001 (A)
Surge Withstand Capability Immunity[a]:	IEC 60255-26:2013 Section 7.2.6 IEC 61000-4-18:2006 2.5 kV common mode 1 kV differential mode 1 kV common mode on comm. ports IEEE C37.90.1-2012 2.5 kV oscillatory 4 kV fast transient
Conducted RF Immunity:	IEC 60255-26:2013 Section 7.2.8 IEC 61000-4-6:2013 10 Vrms
Magnetic Field Immunity:	IEC 61000-4-8:2009 IEC 60255-26:2013, Section 7.2.10 Severity Level 5 1000 A/m for 3 seconds 100 A/m for 1 minute IEC 61000-4-9:2001 IEC 61000-4-10:2001 100 A/m

Power Supply Immunity:	IEC 60255-26:2013 Sections 7.2.11, 7.2.12, and 7.2.13 IEC 61000-4-11:2004 + A1:2001 + A2:2008 IEC 61000-4-17:1999 + A1:2001 + A2:2008 IEC 61000-4-29:2000

Processing Specifications and Oscillography

AC Voltage and Current Inputs:	10 kHz
Frequency Tracking Range:	15–70 Hz
Digital Filtering:	Discrete Fourier Transform after low-pass analog filtering Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental
Protection and Control Processing:	4 ms rate (math variables are processed at a 24 ms rate; for analog quantities, refer to the applicable appendix)
Arc-Flash Processing:	Arc-flash light is sampled at 10 kHz; arc-flash current and light are processed at a 1 ms rate
Contact Inputs and Outputs:	Processed at 1 ms rate

Oscillography

Length:	0.25–2.00 s, 0.01 steps
Sampling Rate:	10 kHz sampling rate for raw (unfiltered) data and 4 ms rate for filtered data
Trigger:	Programmable with Boolean expression
Format:	Files in binary COMTRADE format (ANSI C37.111-2013) for raw and filtered data.
Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy:	±5 ms

Sequential Events Recorder

Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy (Time Source):	±5 ms

Relay Elements

Instantaneous Overcurrent (50P, 50ABC, 50N)

Setting Range:	(0.10–20.00) • NomSec setting
Accuracy (Fundamental):	±3% of setting ±0.01 A
Accuracy (RMS):	±3% of setting ±0.02 A
Maximum Pickup/Dropout Time:	1.25 cycles

Instantaneous Overcurrent (50Gnd, 50Neg)

Setting Range:	(0.10–20.00) • CTP.NomSec setting
Accuracy:	±5% of setting ±0.01 A
Maximum Pickup/Dropout Time:	1.25 cycles

Arc-Flash Instantaneous Overcurrent (AFD.50P/AFD.50N)

Setting Range:	OFF, (0.10–20.00) • NomSec setting
Accuracy:	±5% of setting ±0.01 A
Pickup/Dropout Time:	1 ms/16 ms plus ±1 ms

Arc-Flash Time-Overlight (AFD.Sen01–AFD.Sen04)

Setting Range (Point):	OFF, 3.0%–80.0%
Setting Range (Fiber):	OFF, 0.6%–80.0%
Pickup/Dropout Time:	1 ms/16 ms plus ±1 ms

Inverse-Time Overcurrent (51P, 51N)

Setting Range:	(0.10–4.80) • NomSec setting
Accuracy (Fundamental):	±3% of setting ±0.01 A
Accuracy (RMS):	±3% of setting ±0.02 A
Time Dial	
U.S.:	0.50–15.00, 0.01 steps
IEC:	0.01–1.50, 0.01 steps
Accuracy:	±1.25 cycles, ±4% between 2 and 30 multiples of pickup (within rated range of current)

Inverse-Time Overcurrent (51Gnd, 51Neg)

Setting Range:	(0.10–4.80) • CTP.NomSec setting
Accuracy:	±5% of setting ±0.01 A
Time Dial	
U.S.:	0.50–15.00, 0.01 steps
IEC:	0.01–1.50, 0.01 steps
Accuracy:	±1.25 cycles, ±4% between 2 and 30 multiples of pickup (within rated range of current)

Undervoltage (27PP)

Setting Range:	5.00–300.00 V (with delta inputs) 5.00–520.00 V (with wye inputs)
Accuracy:	±2% (±5% for transient) of setting ±2 V
Maximum Pickup/Dropout Time:	1.25 cycles

Overvoltage (59PP, 59Gnd)

Setting Range:	5.00–300.00 V (59PP elements with delta inputs and 59Gnd elements) 5.00–520.00 V (59PP elements with wye inputs)
Accuracy:	±2% (±5% for transient) of setting ±2 V
Maximum Pickup/Dropout Time:	1.25 cycles

Harmonic Blocking

Pickup Range (% of Fundamental):	5%–100%
Accuracy:	±5% plus ±0.02 A of harmonic current
Time Delay Accuracy:	±0.5% plus ±4 ms

Directional Power (32)

Setting Range:	20.0–200.0 %VA (% of nominal VA)
Accuracy:	±3% of setting ±5 VA
Pickup Types:	+WATTS, –WATTS, +VARS, –VARS
Maximum Pickup/Dropout Time:	3 cycles

Power Factor (55)

Setting Range:	0.05–0.99
Accuracy:	±5% of full scale for current > 0.2 at 120 V
Maximum Pickup/Dropout Time:	3 cycles

Frequency (81)

Setting Range:	15.00–70.00 Hz
Accuracy:	±0.01 Hz
Maximum Pickup/Dropout Time:	3 cycles

Timers

Setting Range:	Various
Accuracy:	±0.5% of setting ±4 ms

Metering Accuracy

Accuracies are specified at 20°C, 50 or 60 Hz nominal frequency, ac currents within 0.1 to 40.0 A, and ac voltages within 50.0–250.0 V unless otherwise specified.

Phase and Neutral Currents:	Magnitude ±1% of reading ±0.01 A; phase ±2°
Average Current:	±1% of reading ±0.01 A
Current Unbalance (%):	±1% of reading of ±0.01 A
IG (Residual Ground Current):	Magnitude ±2% of maximum phase current ±0.01 A
3I2 Negative-Sequence Current:	±2% of maximum phase current ±0.01 A
System Frequency:	±0.01 Hz of reading for frequencies within 15–70 Hz (V1 > 60 V or I1 > 0.8 A
Line-to-Line Voltages:	Magnitude ±1% of reading ±0.1 V, phase ±2°
Three-Phase Average Line-to-Line Voltage:	±2% of reading and ±0.2 V
Line-to-Ground Voltages:	Magnitude ±1% of reading ±0.1 V, phase ±2°
Three-Phase Average Line-to-Ground Voltages:	±2% of reading and ±0.2 V
Voltage Unbalance (%):	±2% of reading and ±0.2 V
3V2 Negative-Sequence Voltage:	Magnitude ±2% of maximum line-to-ground or line-to-line voltage and ±0.2 V

The real, reactive, and apparent power quantities are calculated based on the voltage and current phasors. No additional errors are introduced by this calculation.

Power Factor:	±2% of reading for 0.97 < pf < 1.00

RMS Metering Accuracies

Phase and Neutral (IN) Currents:	±2% of reading ±0.02 A, for current range 0.2 to 15 A (includes signal bandwidth from 1 to 300 Hz)
Voltages:	±2% of reading ±0.1 V (includes signal bandiwdth from 1 to 300 Hz)
Harmonic and THD Metering Range:	0–100%
Accuracy:	5% of full scale

[a] Front-panel serial cable (non-fiber) lengths assumed to be <3 m.
[b] To ensure the correct operation of MIRRORED BITS during surge immunity, Cable SEL-C472N is required.

Section 2

Installation

Overview

The first steps in applying the SEL-851 Feeder Protection Relay are installing and connecting the relay. This section describes common installation features and requirements. To install and connect the relay safely and effectively, you must be familiar with relay configuration features and options. You should carefully plan relay placement, cable connections, and relay communication.

This section contains drawings of typical ac and dc connections to the SEL-851. Use these drawings as a starting point for planning your particular relay application.

Relay Placement

Proper placement of the SEL-851 helps to ensure years of trouble-free feeder protection. Use the following guidelines for proper physical installation of the SEL-851.

Physical Location

The SEL-851 is certified at Installation/Overvoltage Category III and Pollution Degree 2. This allows mounting of the SEL-851 in a sheltered indoor environment that does not exceed the temperature and humidity ratings for the relay.

The SEL-851 is required to be mounted in an indoor or outdoor (extended) locked enclosure that provides a degree of protection to personnel against access to hazardous parts. In either environment, the relay shall be protected from direct sunlight, precipitation, and full wind pressure.

You can place the relay in extreme temperature and humidity locations (see *Operating Temperature* and *Operating Environment on page 1.9*). The SEL-851 rating is 2000 m (6562 ft) above mean sea level. Consult the factory for product derating specifications for higher altitude applications.

Relay Mounting

Horizontal Mount

A single SEL-851 relay when ordered with horizontal mount option comes with the dimension details as shown in *Figure 2.1* and can be installed in the panel. For a horizontal-mount installation, follow these steps:

Step 1. Cut your panel and drill mounting holes according to dimensions in *Figure 2.1*.

Step 2. Insert the relay into the cutout, aligning the holes on the mounting flanges of the relay front-panel with the drilled holes in your panel.

Step 3. Insert the screws to secure the relay to your panel. Ensure that the mounting torque for the screws is not more than 18 in-lb.

Figure 2.2 shows an SEL-851 front panel for the horizontal mount version. The horizontal mount unit can be ordered with an optional front cover as shown in *Figure 2.3*. The front cover protects the relay from dust and water penetration that might interfere with device operation.

Figure 2.1 SEL-851 Horizontal Mount Dimensions, Panel Cutout, and Drill Plan

Figure 2.2 SEL-851 Front-Panel, Horizontal-Mount Version (Mounting Option Digit in MOT = 0)

Figure 2.3 SEL-851 Horizontal Mount With Front Cover (Mounting Option Digit in MOT = 1)

Figure 2.4 SEL-851 Horizontal Mount With Front-Cover Dimensions

Panel Mount

We also offer the SEL-851 in a panel-mount version. Panel-mount relays have sculpted front-panel molding that covers all the installation holes. For a panel-mount installation, follow these steps:

Step 1. Cut your panel and drill mounting holes according to the dimensions in *Figure 2.5*.

Step 2. Insert the relay into the cutout, aligning the four relay mounting studs on the rear of the relay front panel with the drilled holes in your panel.

Step 3. Use nuts to secure the relay to your panel.

Refer to *Figure 2.5* for dimension and cutout details for the panel mount unit. *Figure 2.6* shows an SEL-851 front panel for the panel mount version.

Figure 2.5 SEL-851 Dimensions, Panel Cutout, and Drill Plan

Figure 2.6 SEL-851 Front-Panel, Panel Mount Version (Mounting Option Digit in MOT = 2)

Rack Mount

A single SEL-851 relay is roughly half the size of a standard 19-inch rack (see *Figure 2.7* and *Figure 2.9*). To mount the relay in a standard 19-inch rack, follow the steps included in the horizontal rack mount with adapter plate mounting option.

19-Inch Horizontal Rack Mount With Adapter Plate

Adapt a half rack SEL-851 relay to fill a full rack unit with an included adapter plate (factory-assembled). To mount the relay in a standard 19-inch rack, secure the relay and adapter plate assembly with the four rack screws (two on each side) that you insert from the front of the relays through the holes on the relay mounting flanges. Ensure that the mounting torque for the screws is not more than 18 in-lb.

The adapter plate can also be ordered separately using the 19-inch adapter bracket accessory kit (part number 915900596). Use this kit to install an existing ganged-right rack-mount SEL-851 unit in a standard 19-inch rack. Note that this adapter plate cannot be used to convert an SEL-851 horizontal mount unit to fit in a 19-inch rack.

Refer to *Figure 2.7* and *Figure 2.8* for dimension and assembly details for the rack mount unit with the adapter plate bracket, respectively. *Figure 2.9* shows an SEL-851 rack mount unit with the adapter plate.

Figure 2.7 Relay Dimensions for Mounting an SEL-851 With an Adapter Plate

Figure 2.8 SEL-851 19-Inch Horizontal Rack-Mount Assembly

Figure 2.9 SEL-851 Horizontal Rack Mount With the Adapter Plate (Mounting Option Digit in MOT = 5)

Ganged Rack Mount

You can order a left or right ganged horizontal rack mount. This mounting option allows you to order a ganged left or ganged right relay depending on the selection in the SEL-851 Model Options Table (MOT). This option can be used if you are ordering two SEL-851 relays or you plan to add another SEL-851 relay in the future.

When viewed from the front, the ganged left unit comes with an L-shaped bracket on the right side of the chassis with mounting holes on the left. The ganged right unit comes with an L-shaped bracket on the left side of the chassis with mounting holes on the right.

Figure 2.10 and *Figure 2.11* show the mounting details for ganged units. To assemble the ganged units, align the hole for the top screw on the L-shaped bracket with the ganged left unit and the hole for the bottom screw on the L-shaped bracket with the ganged right unit. Screw in both to complete the assembly as shown in *Figure 2.12*. *Figure 2.13* and *Figure 2.14* show a side view of the ganged (left) and ganged (right) relays with the L-shaped bracket.

Figure 2.10 Relay Dimensions for an SEL-851 Ganged Rack Mount

Figure 2.11 SEL-851 Ganged Rack Mount Assembly Details

Figure 2.12 SEL-851 Ganged Rack Mount

Figure 2.13 SEL-851 Ganged Rack Mount (Left) With L-Shaped Bracket (Mounting Option Digit in MOT = 3)

Figure 2.14 SEL-851 Ganged Rack Mount (Right) With L-Shaped Bracket (Mounting Option Digit in MOT = 4)

Relay Connections

This section provides a guide to complete connections to the relay for various functions.

Figure 2.15 shows the relay features and connections to cover all the ordering options.

* Optional features

Figure 2.15 Relay Features and Connections

Connecting to a PC

The SEL-851 features a plug-and-play USB Type C port on the front panel. Use an SEL-C497 (a 3.0 m [10 foot] USB Type C to Type A cable) to connect this port to a PC.

Terminal Block Connections

The connection terminal blocks are labeled on the relay from A to C. The terminal blocks can be removed by gently prying them with a small, flat screwdriver. After installing them on the relay, it is recommended to tighten the two end screws so that the terminal block is securely fastened to the relay. The torque requirements for the terminal blocks are:

- Compression Plug Tightening Torque
  - Minimum: 0.5 Nm (4.4 in-lb)
  - Maximum: 1.0 Nm (8.8 in-lb)
- Compression Plug Mounting Ear Screw Tightening Torque
  - Minimum: 0.18 Nm (1.6 in-lb)
  - Maximum: 0.25 Nm (2.2 in-lb)

- Ground Terminal Screw Tightening Torque
  - 1 Nm (8.8 in-lb)

All screw/washer styles on SEL relays are recognized by UL for field wiring using terminals or bare wire. However, SEL strongly recommends the use of ring or fork terminals for the following reasons:

- Stray strands and inconsistent wire stripping may compromise hi-pot clearances and give rise to the potential for shorting the adjacent terminals.
- Wire/terminal secureness with ring terminals has been tested at SEL to a 20 lb minimum. Bare wire has not been tested at SEL.

Both the terminal block manufacturer and UL requirements have qualified the standard terminal blocks for use with bare stranded wire; however, SEL's qualification requirements are more stringent as required by the utility and industrial applications of protective relays. The SEL terminal retention and hi-pot test voltage requirements are both twice that required by the UL standard. All SEL qualification testing of terminal blocks and relays is performed with ring or fork terminals.

Wire Sizes and Insulation

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load current. You can use the following table as a guide in selecting wire sizes.

NOTE: Strip the wire insulation to 8.00 mm (0.31 in) before installation.

Connection Type	Wire Size		Insulation Voltage
	Minimum	Maximum	
Grounding (Earthing)	16 AWG (1.30 mm^2)	12 AWG (3.30 mm^2)	300 V min
Current	16 AWG (1.30 mm^2)	12 AWG (3.30 mm^2)	300 V min
Potential (Voltage)	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min
Contact I/O	20 AWG (0.50 mm^2)	14 AWG (2.10 mm^2)	300 V min
Other	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min

The power terminals are isolated from the chassis ground. Use 12 AWG (3.30 mm^2) to 16 AWG (1.30 mm^2) size wire to connect to the power terminals.

Power Supply Connections (Terminal Block B)

Table 2.1 Terminal Block B—Power Supply Connections

Terminal Number	Label	Description
B14	-/N	Negative or neutral terminal
B13	+/H	Positive or hot (line) terminal

The **POWER** terminals on the relay (**B13(+/H)** and **B14(–/N)**) must connect to a 110/240 Vac or 24–250 Vdc power source (see *Universal Power Supply on page 1.8* for complete power input specifications). The **POWER** terminals are isolated from chassis ground. Use 14 AWG (2.1 mm^2) to 16 AWG (1.3 mm^2) size wire to connect to the **POWER** terminals.

Place a suitable external switch or circuit breaker in the power leads for the SEL-851; this device should interrupt both the hot (**+/H**) and neutral (**-/N**) power leads. The maximum current rating for the power disconnect circuit breaker or optional overcurrent device (fuse) should be 20 A. Be sure to place this device within 3.0 m (10.0 ft) of the relay.

Operational power is internally fused by a power supply fuse. Please note that the complete relay is nonserviceable.

Digital Inputs (4) Connections (Terminal Block A)

CAUTION
For internally wetted contact inputs, do not connect external voltages. Because the contact inputs are internally wetted, permanent damage to the relay or external equipment may result from connecting external voltage to a relay contact input.

Table 2.2 Terminal Block A—Base Relay Four (4) Optoisolated Digital Inputs[a]

Terminal Number	Label	Description
A01	IN01	Digital input IN01, drives IN01 element
A02	COM 01, 02	Common for IN01 and IN02
A03	IN02	Digital input IN02, drives IN02 element
A04	IN03	Digital input IN03, drives IN03 element
A05	COM 03, 04	Common for IN03 and IN04
A06	IN04	Digital input IN04, drives IN04 element

[a] All COM terminals are internally connected to each other when there are internally wetted digital inputs only.

Terminal Block A, shown in *Table 2.2*, and Terminal Block C, shown in *Table 2.3*, support either internally or externally wetted contact inputs based on the model option selected. Digital inputs are internally wetted to +24 Vdc, so you only need to connect a dry contact, switch, or jumper to the input. Refer to *Section 4: Protection and Logic Functions* functions for externally wetted input contact settings.

Additional Digital Inputs (6) (Optional) Connections (Terminal Block C)

Table 2.3 Terminal Block C—Optional Six (6) Additional Optoisolated Digital Inputs[a]

Terminal Number	Label	Description
C01	IN05	Digital input IN05, drives IN05 element
C02	COM 05, 06	Common for IN05 and IN06
C03	IN06	Digital input IN06, drives IN06 element
C04	IN07	Digital input IN07, drives IN07 element
C05	COM 07, 08	Common for IN07 and IN08
C06	IN08	Digital input IN08, drives IN08 element
C07	IN09	Digital input IN09, drives IN09 element
C08	COM 09, 10	Common for IN09 and IN10
C09	IN10	Digital input IN10, drives IN10 element

[a] All COM terminals are internally connected to each other where there are internally wetted digital inputs only.

EIA-232/EIA-485 (RJ45) Port Connections

Use Port 1 on the relay rear panel as either an EIA-232 or EIA-485 serial port. Use an SEL-C478A/C478N Cable (with IRIG-B) and an SEL-C662 Cable to connect to the PC. Refer to *Section 7: Communications* for more details on serial communications and available protocols.

Digital Outputs (1 Form C and 4 Form A [2 Hybrid and 2 Standard Contacts]) Connections (Terminal Block B)

Table 2.4 Terminal Block B—Five (5) Digital Outputs (Contact Outputs)

Terminal Number	Label		Description
B01 B02		OUT01	OUT01, driven by the OUT01 SELOGIC control equation Form A output, B01–B02 NO, fast hybrid output
B03 B04		OUT02	OUT02, driven by the OUT02 SELOGIC control equation Form A output, B03–B04 NO, fast hybrid output
B05 B06		OUT03	OUT03, driven by the OUT03 SELOGIC control equation Form A output, B05–B06 NO
B07 B08		OUT04	OUT04, driven by the OUT04 SELOGIC control equation Form A output, B07–B08 NO
B09 B10 B11		OUT05	OUT05, driven by the OUT05 SELOGIC control equation Form C output, B09–B10 NO, B09–B11 NC
B12		N/C	No connection

The SEL-851 comes with one Form C (OUT05) and four Form A output contacts (OUT01, OUT02, OUT03, OUT04). OUT01 and OUT02 are hybrid output contacts, whereas OUT03–OUT05 are standard output contacts. OUT01–OUT05 are rated for a continuous carry current of 6 A at 70 degrees C. OUT01–OUT02 are rated for higher breaking current and faster closing times than OUT03–OUT05. Refer to *Section 1: Introduction and Specifications* for more details. The contact positions indicated in the table above are for the case when the relay is de-energized.

Ground Terminal Connection

You must connect the ground terminal labeled GND on the rear panel to a rack frame or switchgear ground for proper safety and performance. Use 14 AWG (2.1 mm^2) to 18 AWG (0.8 mm^2) wire less than 2 m (6.6 ft) in length for the ground connection.

The relay IN input can be connected to the ground CT, as shown in *Figure 2.26*. Connecting the IN input residually requires you to select a relatively high overcurrent element pickup setting to avoid tripping due to false residual current caused by CT saturation.

The IN connection shown in *Figure 2.26* is preferred and provides for a lower ratio flux-balance CT that avoids saturation and provides greater ground fault sensitivity.

When you use a ground CT, its placement is critical and depends on the type of cable used to connect the load to the source. As *Figure 2.16* shows, using an unshielded cable requires that the CT be placed between the neutral-to-ground connection and the load, with the neutral lead included in the CT window. With a shielded cable, the shield-to-ground connection must pass through the CT window.

Figure 2.16 Ground CT Placement

AC/DC Control Connection Diagrams

This section describes fail-safe versus nonfail-safe tripping, describes voltage connections, and provides the ac and dc wiring diagrams.

Fail-Safe/Nonfail-Safe Tripping

Figure 2.17 shows the output OUT05 relay coil and Form C contact. When the relay coil is de-energized, the contact between B09 and B10 is open while the contact between B09 and B11 is closed.

NOTE: Fast hybrid contacts are designed for fast closing (50 µs) only. Fail-safe mode operating time (time to open the contacts) for fast-hybrid contacts is <8 ms (the same time as for a normal output contact).

Figure 2.17 Output OUT05 Relay Output Contact Configuration

The SEL-851 provides fail-safe and nonfail-safe trip modes (setting selectable) for all output contacts. The following occurs in fail-safe mode:

- The relay coil is energized continuously if the SEL-851 is powered and operational.
- When the SEL-851 generates a trip signal, the relay coil is de-energized.
- The relay coil is also de-energized if the SEL-851 power supply voltage is removed or if the SEL-851 fails (self-test status is FAIL).

Figure 2.18 shows fail-safe and nonfail-safe wiring methods to control breakers.

Figure 2.18 Breaker Trip Coil Connections With OUT_05.FailSafe := Y and OUT_05.FailSafe := N and OUT05 Logic Asserted

High-Speed, High-Current Interrupting DC Tripping Outputs

High-speed outputs are optimized for direct tripping of power circuit breakers. They operate in less than 50 µs, work with dc trip coil circuits, are polarity insensitive and capable of making 30 A, and can interrupt 10 A with an 8 ms dropout time. High-speed outputs are implemented as hybrid circuits, each of which consists of the parallel combination of a high-current, solid-state switch and an electromechanical bypass relay. Avoid using high-speed outputs to drive highly sensitive, high-input-resistance electronic inputs (e.g., <2 mA electronic circuits) unless such inputs are connected in parallel with a low-resistance load (e.g., a breaker trip coil).

Avoid connecting multiple high-speed outputs in parallel when driving highly sensitive electronic inputs. Keep wiring short, and use fiber-based MIRRORED BITS communications to bridge longer distances.

Voltage Connections

With the voltage inputs option, the ac voltages may be wye-wye VT connected or open-delta VT connected. A single-phase VT can also be used. *Figure 2.19* and *Figure 2.20* show the methods of connecting single-phase and three-phase voltages.

Figure 2.19 Single-Phase Voltage Connections

Figure 2.19(a) and (b) show terminal F12 (VN) grounded. You can choose to ground any other terminal (e.g., terminal F09 or F11) instead of F12. In any case, keep the jumper between terminals F10 and F12 when using DELTA VT as shown in Figure 2.19(b).

Figure 2.20 Three-Phase Voltage Connections

Voltage Transformer (VT) Ratios and System Nominal Voltage

The relay setting VTP.Rat is the overall voltage 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 VTs (setting VTP.Conn := WYE, and the relay wired as shown in *Figure 2.20* (*a*)), the correct VTP.Rat setting is 60. For the same 12.5 kV system connected through 12470:115 V VTs in an open-delta configuration (setting VTP.Conn := DELTA, and the relay wired as shown in *Figure 2.20 (b))*, the correct VTP.Rat setting is 108.44.

Single-phase voltage connections follow the same rationale. Refer to *Figure 2.19 (a)* and *Figure 2.19 (b)*. For example, with a single-phase voltage connection to the VA-N terminals (VTP.Conn := WYE and VTP.SingleV := Y) from a 12.5 kV phase-to-phase primary system with a line-neutral connected 7200:120 V VT, the correct VTP.Rat setting is 60. For the same 12.5 kV system connected through 12470:115 V VTs in a line-to-line configuration (VTP.Conn := DELTA and VTP.SingleV := Y) the correct VTP.Rat setting is 108.44.

AC/DC Connections and Applications

Figure 2.21 shows typical phase and neutral current connections for a feeder application. *Figure 2.22* through *Figure 2.26* show ac/dc connection diagrams for various applications. See *Figure 2.19* and *Figure 2.20* for other voltage connections.

The current transformers and the SEL-851 chassis must be grounded in the relay cabinet.

Figure 2.21 Typical Current Connections

Voltages are necessary for voltage elements and metering (e.g., voltage, KW, KVAR). INx indicates user-configurable optional digital inputs.

Channel **IN** provides current I_N for the neutral ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_{Gnd} ($I_{Gnd} = 3I_0 = I_A + I_B + I_C$). But in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_{Gnd}$.

Figure 2.22 SEL-851 Provides Overcurrent Protection and Reclosing for a Distribution Feeder (Includes Fast Bus Trip Scheme) (Delta-Connected PTs and Externally Wetted Digital Inputs)

Voltages are necessary for voltage elements and metering (e.g., voltage, KW, KVAR). INx indicates user-configurable optional digital inputs.

Channel **IN** provides current I_N for the neutral ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_{Gnd} ($I_{Gnd} = 3I_0 = I_A + I_B + I_C$). But in this residual connection example, the neutral ground and residual-ground overcurrent elements operate the same because $I_N = I_{Gnd}$.

Although automatic reclosing is probably not necessary in this example, output contact OUT03 can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.) with desired supervision (e.g., hot bus check).

INx is shown for use with a fast bus trip scheme. The fast bus trip scheme is often referred to as a reverse-interlocking or zone-interlocking scheme.

Figure 2.23 SEL-851 Provides Overcurrent Protection for a Distribution Bus (Includes Fast Bus Trip Scheme) (Wye-Connected PTs and Externally Wetted Digital Inputs)

Voltages are necessary for voltage elements and metering (e.g., voltage, KW, KVAR). INx indicates user-configurable optional digital inputs.

Although automatic reclosing is probably not necessary in this example, output contact OUT03 can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision (e.g., hot bus check).

Figure 2.24 SEL-851 Provides Overcurrent Protection for a Delta-Wye Transformer Bank (Wye-Connected PTs and Externally Wetted Digital Inputs)

Voltages are necessary for voltage elements and metering (e.g., voltage, KW, KVAR). INx indicates user-configurable optional digital inputs.

Although automatic reclosing is probably not necessary in this example, output contact OUT03 can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision (e.g., hot bus check).

Figure 2.25 SEL-851 Provides Overcurrent Protection for a Transformer Bank With a Tertiary Winding (Wye-Connected PTs and Externally Wetted Digital Inputs)

A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

Pass neutral (N) through the core-balance CT only if the neutral is brought out and it is grounded only at the source.

Voltages are necessary for voltage elements and metering (e.g., voltage, KW, KVAR). INx indicates user-configurable optional digital inputs.

Although automatic reclosing is probably not necessary in this example, output contact OUT03 can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision.

Figure 2.26 SEL-851 Provides Overcurrent Protection for an Industrial Distribution Feeder (Core-Balance Current Transformer Connected to Channel IN and Externally Wetted Digital Inputs)

Arc-Flash Protection

System Installation

This section describes an arc-flash system installation, the sensor characteristics, and an arc-flash application. Refer to *Section 4: Protection and Logic Functions* for a description of arc-flash protection and the relay settings. *Section 10: Testing and Troubleshooting* gives a description of the commissioning tests to verify the installation. Also, refer to Application Guide *AG2011-01: Using the SEL-751 and SEL-751A for Arc-Flash Detection*, available on the SEL website, for more details.

Figure 2.27 shows the main arc-flash system current input card with arc-flash sensor terminal block and the fiber-optic-based point-sensor assembly. *Figure 2.27* shows the rear-panel layout for a relay model with the arc-flash inputs.

Figure 2.27 SEL-851 With an Arc-Flash Option and Fiber-Optic Based Point Sensor

Light-Sensor Installation

An arc-flash system installation starts by selecting the best sensor location and the safest path for bringing the sensor fibers back to the relay. The actual sensor location varies depending on the type of switchgear being protected. Although arc-flash light is easily reflected off painted surfaces, make sure to avoid shadows/light obstruction caused by the insulating baffles or moving parts of the breaker truck assembly.

While fiber-optic sensors are inherently nonconductive, they are not intended for direct contact with energized parts, and must be suspended within 25 mm (1 in) of the grounded surface. Make sure to observe the original high-voltage clearance and creepage requirements. Sensors should be permanently affixed through the use of supplied mounting grommets or permanent cable ties. *Figure 2.28* shows an example of a typical black-jacketed fiber installation.

Figure 2.28 Black-Jacketed Fiber Installation Example

Fiber-bending radius must be kept greater than 50 mm (2 in). Care should be exercised when crossing from a moving part (such as control cabinet door) to a stationary switchgear enclosure. Use standard wiring practices with bundled fibers and well-defined strain relief points. Additional attention is necessary to prevent moving parts, such as a breaker truck assembly, from inadvertently damaging the arc-flash sensor fibers. Although easily detected by the sensor diagnostics, such problems can be eliminated through careful installation planning. Once routed, fiber sensors are connected to the SEL-851 as shown in *Figure 2.27*.

Point-Sensor Installation

The point-sensor is optimized for monitoring confined switchgear spaces where the distance between sensors and the potential sources of arc (energized parts) can be kept below 2 m. Such spaces typically include breaker compartments, outgoing and incoming cable compartments, and voltage transformer (VT) compartments. *Figure 2.29* shows a schematic diagram of the point-sensor assembly.

Figure 2.29 Point-Sensor Assembly

There is a standard point sensor or a window point sensor available for the point-sensor assembly.

The standard point sensor is optimized for mounting inside the switchgear compartment. *Figure 2.30* shows the standard point-sensor dimensions.

Figure 2.30 Standard Point-Sensor Dimensions

The sensor is mounted flush on the switchgear cabinet wall, using a standard 1/4-inch hole. Mounting steps are shown in *Figure 2.31*.

1. Mounting Grommet Insertion (1/4" diameter hole)
2. Sensor Insertion (1/4" diameter hole)

Figure 2.31 Standard Point-Sensor Installation

The window point sensor is optimized for mounting outside switchgear, motor control centers, or breaker cabinets to detect an arc flash inside the enclosure. *Figure 2.32* shows the window point-sensor dimensions.

Figure 2.32 Window Point-Sensor Dimensions

The window point sensor requires two holes to be drilled on the enclosure as shown in *Figure 2.33*. The sensor must be mounted from the outside and secured in the correct position to the switchgear by using the self-tapping screws provided.

Figure 2.33 Window Point-Sensor Installation

The point sensor is omnidirectional with a slight loss of sensitivity at the fiber entry point. *Figure 2.34* through *Figure 2.36* show the sensor directivity pattern. The point sensor must be located in clear view of the energized parts, which are most likely to cause an arc-flash event.

Figure 2.34 Point-Sensor Directivity (0–360° Around the Mounting Plane)

Figure 2.35 Point-Sensor Directivity (Front to Back, Above the Mounting Plane)

Figure 2.36 Point-Sensor Directivity (Left to Right, Above the Mounting Plane)

Fiber Sensor Installation

The clear-jacketed fiber sensor is optimized for the monitoring of large distributed resources, such as switchgear system bus enclosures. The clear-jacketed fiber sensor is omnidirectional and can be mounted in close proximity to

the switchgear enclosure walls. *Figure 2.37* shows a schematic diagram of the clear-jacketed fiber sensor. *Figure 2.38* shows a clear-jacketed fiber sensor mounting example photo.

Total loop length = 2 • A + B (allowed range 3 to 70 meters)
Range for A: 1 to 30 meters
Range for B: 1 to 50 meters

Figure 2.37 Clear-Jacketed Fiber Sensor Assembly

Figure 2.38 Clear-Jacketed Fiber Sensor Mounting Example

A clear-jacketed fiber sensor consists of the major components shown in *Figure 2.39*. Two connector options (V-pin and ST) are available to transition from the black-jacketed to the clear-jacketed fiber section, as shown in *Figure 2.40*. The ST connector option is generally superior because of positive locking.

Figure 2.39 Clear-Jacketed Fiber Sensor Components (V-Pin Option)

For correct operation, a clear-jacketed fiber sensor must be located within 2 m of the arcing site, with at least 0.5 m of the fiber sensor exposed to the light. The maximum length of the clear-jacketed fiber sensor is limited to 70 m and includes both clear-jacketed fiber and black-jacketed fiber sections (the black-jacketed section is counted twice because of its dual-fiber construction). Transition between the two sections is accomplished by using a connector splice as shown in *Figure 2.40*.

ST Connection (3/8″ diameter hole)

V-Pin Connection (5/16″ diameter hole)

Figure 2.40 Clear-Jacketed Fiber Sensor Showing Transition From Clear- to Black-Jacketed Fiber Section

The clear-jacketed fiber loop should be returned through the same general area as the forward path, providing dual opportunity to sense the same arc-flash event. This approach ensures that the maximum distance between the relay and the light-producing event remains below 35 m, irrespective of the SEL-851 dual V-pin connector orientation.

Application Example

⚠CAUTION
Before placing the arc-flash protection system in service, first make sure all the sensors are correctly installed, and then execute the **AFD** command to initiate a self-test.

Figure 2.41 shows a typical switchgear application example with one incoming and two radial (outgoing) feeders. All three feeders are protected with an SEL-851 controlling Breakers 1, 2, and 3. Radial feeder Breakers 2 and 3 must be tripped for downstream faults, normally located in the outgoing cable termination compartment. To obtain better coverage, multiple sensors can be installed in the same compartment, as shown in the lower right corner of *Figure 2.41* (Sensors LS1 and LS2).

Bus compartment and the outgoing breaker compartments for Breakers 2 and 3 are protected by the incoming feeder Breaker 1, with Sensors LS1, LS2, and LS3 connected directly to the incoming feeder relay (upper right hand corner of *Figure 2.41*). Sensor LS1 is implemented as a clear-jacketed fiber loop enclosing the entire length of the bus.

When desired, you can use radial feeder relay sensors (such as LS3 connected to the lower right hand relay) to transfer trip the upstream breaker. Logic equations for this function are shown in *Output Logic Programming* in *Section 4: Protection and Logic Functions*.

LS1–LS4 are arc-flash detection inputs, point or clear-jacketed fiber sensors.

Figure 2.41 Switchgear Application Example

Ordering Arc-Flash Fiber Sensors

Arc-flash fiber sensors can be ordered with or without splices. To configure the standard multimode fiber-optic arc-flash detection point and fiber-loop sensor cable assemblies without additional splice connectors, use the C804 Multimode Fiber-Optic Arc-Flash Detection (AFD) Sensors Model Option Table (MOT). For multimode fiber optic arc-flash detection sensors with additional splice connectors, refer to the SEL-C814 Arc-Flash Detection (AFD) Fiber Cables and Accessories MOT. The losses and budget values shown in *Table 2.5* are typical values.

NOTE: Jacketed fiber in a zipcord duplex configuration includes two fiber lengths. Loss calculations must account for the total length of the fiber. This is accounted for in the examples as a "x 2" multiplier.

Table 2.5 Optical Budget Calculations

Link Budget[a]		Loss Data[b]	
Bare-Fiber Sensor	17 dB	ST connector splice	2 dB
Point Sensor	12.25 dB	V-pin connector splice	2 dB
		Bare-fiber	0.175 dB/m
		Jacketed fiber	0.175 dB/m

[a] Link budget is calculated after allowing for the losses of the dual V-pin latch. When using a point sensor it allows for the sensor loss as well.
[b] Link losses are calculated by adding the fiber and the splice connector losses. The link losses should be less than the link budget.

Table 2.6 SEL-C804 and SEL-C814 Arc-Flash Detection Cable Specifications (Sheet 1 of 2)

Specifications	Cable	
	Black Jacket, Zipcord	Clear Jacket, Simplex
Operating Temperature	–40° to +85°C	–55° to +85°C
Core Material	PMMA	PMMA
Cladding Material	Fluorinated Polymer	Fluorinated Polymer

Table 2.6 SEL-C804 and SEL-C814 Arc-Flash Detection Cable Specifications (Sheet 2 of 2)

Specifications	Cable	
	Black Jacket, Zipcord	Clear Jacket, Simplex
Core Diameter	980 µm	980 µm
Cladding Diameter	1000 µm	1000 µm
Jacket Material	PVC	Polyethylene
Outer Cable Diameter	2.2 mm x 4.3 mm (0.087 in x 0.17 in)	2.20 mm (0.087 in)
Weight/Unit Length	11 g/m (0.008 lb/ft)	4 g/m (0.003 lb/ft)
Maximum Cable Pull Tension	140 N (9.6 lb/ft)	70 N (4.8 lb/ft)
Maximum Connector Pull Tension	43.8 N (3.0 lb/ft)	43.8 N (3.0 lb/ft)
Minimum Bend Radius	25 mm (0.98 in)	25 mm (0.98 in)
Attenuation (Loss)	0.175 dB/m	0.175 dB/m

Link Optical Loss Calculation Examples

This example shows a bare-fiber sensor with two V-pin or ST connectors and an **A** dimension of 15 meters and a **B** dimension of 40 meters. Two connectors is the standard configuration, as shown in *Figure 2.42*.

Link Budget	17 dB
– (2 dB x # of connector splices)	–4 dB
– (0.175 dB/m x **A** dimension x 2)	–5.25 dB
– (0.175 dB/m x **B** dimension)	–7 dB
Total Link Losses =	–16.25 dB

Figure 2.42 Bare-Fiber Sensor Assembly With Two Splices

This example shows a point sensor with an **A** dimension of 30 m, as shown in *Figure 2.43*.

Link Budget	12.25 dB
– (0.175 dB/m x **A** dimension x 2)	–10.5 dB
Total Link Losses =	–10.5 dB

Figure 2.43 Point Sensor Assembly

Splice connectors can be added for the arc-flash fiber sensors to meet the shipping needs for large switchgears that require multiple splits for transportation. For multimode fiber-optic arc-flash detection sensors with additional splice connectors, refer to the SEL-C814 Arc-Flash Detection (AFD) Fiber Cables and Accessories MOT.

Ordering Examples Using the SEL-C814 Model Option Table

This example of a bare-fiber sensor with four ST connectors and an **A** dimension of 15 meters, as shown in *Figure 2.44*, shows the part numbers generated using an SEL-C814 MOT and the link optical loss calculations. Two connectors is the standard configuration.

Link Budget	17 dB
– (2 dB x # of connector splices)	–8 dB
– (0.175 dB x **A** dimension x 2)	–5.25 dB
Link Losses = available for **B** meters	3.75 dB
÷ (0.175 dB/m)	21.42 meters
	maximum **B** dimension

Figure 2.44 Bare-Fiber Sensor Assembly With Two Additional ST Splice Connectors

This example of a point sensor with two V-pin connectors, as shown in *Figure 2.45*, shows the part numbers generated using an SEL-C814 MOT and the link optical loss calculations.

Link Budget	12.25 dB
– (2 dB x # of connector splices)	–4 dB
Link Losses = available for **A** meters	8.25 dB
÷ (2 x 0.175 dB/m)	23.6 meters
	maximum **A** dimension

Note: To complete the fiber assembly, you will also need to order two ST connector splice bushings with P/N 915900148.

Figure 2.45 Point Sensor Assembly With Two V-Pin Splice Connectors

Field Serviceability

The SEL-851 firmware can be upgraded in the field; refer to *Appendix B: Firmware Upgrade Instructions*. You may know when a self-test failure has occurred by configuring an output contact to create a diagnostic alarm as explained in *Section 4: Protection and Logic Functions*. By using the metering functions, you may know if the analog front-end (not monitored by relay self-test) is functional.

The SEL-851 does not have any field serviceable parts. Return a faulty or failed unit to the factory for repair or replacement.

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Section 3

PC Interface

Overview

The SEL-851 Feeder Protection Relay is able to communicate with your computer in three different ways. All three methods present the same data (metering, settings, and reports) and provide the same control (trip/close breaker).

NOTE: We have tested the web server for correct operation and formatting with the following browsers: Internet Explorer 20, Edge 90, Firefox 88, and Chrome 89.

There are a wide variety of browsers available. While most browsers have the same functionality, we cannot guarantee the correct operation and formatting for all of them.

- The web server requires a web browser (Microsoft Internet Explorer or Edge, Mozilla Firefox, Google Chrome, etc.) and an Ethernet cable.
- The SEL software solution requires downloading SEL Grid Configurator Software (via Compass) to your computer. Communication to the relay is accomplished through a serial or Ethernet port.
- The ASCII command line requires PC-based terminal emulation software (HyperTerminal, Tera Term, etc.) and a serial or Ethernet cable to connect to the relay (see *Section 7: Communications*).

Web Server

Connection and Login to Web Server

The web server provides a graphical user interface to the relay without loading any software on your PC. The user interface is contained in the relay firmware. To connect to the web server of the SEL-851, the relay and your PC must be connected to the same Ethernet network. The network can be of any size, from a company-wide network to a direct-connect from your PC to the relay. The connection from the relay is through the Ethernet port (Port 2) of the relay. To start communicating with the relay, you must enter a valid IP address (SET P 2 Port_02.IPAddr) and valid default router (SET P 2 Port_02.DfltRout) via the front-panel port (Port F) or the serial port (Port 1) of the relay. Be sure to obtain the IP address and default router from your IT resource to avoid network conflicts with duplicate IP addresses.

The SEL-851 comes pre-loaded with settings that enable you to communicate with the relay over a simple network. The network consists of connecting the SEL-851 (via Port 2) directly to the Ethernet port (via an RJ45 cable) of your computer. This connection requires that the computer not be connected to any other network (see *Figure 3.1*).

Figure 3.1 Direct Connection of SEL-851 to a Computer

The default IP address is 169.254.0.1/16 and the default router is 0.0.0.0. Once the network is configured, as shown in *Figure 3.1*, you can connect to the web server in the relay by entering 169.254.0.1 in the address bar of your web browser (as shown in *Figure 3.2*).

Figure 3.2 Login Page of the Web Server for SEL-851

The Login page of the web server allows you to access either ACC, 2AC, or CAL level. The menu item you select under Access Level determines the access level at which you enter the web server (see *Figure 3.3*). For factory-default passwords, refer to *Table 7.32: Factory-Default Passwords for Access Levels 1, 2, and C*.

Figure 3.3 Selecting Access Level 2 From the Web Server Login

The reports shown in each category on the web server are based on the part number and settings. For example, if the relay does not support arc-flash, the meter light report is not available. The appropriate access level is also required to view or edit data in each category.

Meter

NOTE: All meter reports will automatically update. To disable updates, select the **Disable Page Refresh** button at the bottom of the display window.

The web server offers a convenient method for displaying all the metering reports stored in the relay (Fundamental, RMS, Demand, Energy, Max/Min, Harmonics, Light, Protection Math Variables, and Remote Analogs). Located on the navigation pane, the **Meter** menu contains categories for each of the meter reports. When you select a category from the **Meter** menu, its corresponding meter report is displayed (see *Figure 3.4*).

Figure 3.4 Fundamental Meter Report

Reports

The SEL-851 collects and stores a variety of data and statistics from the power system. These data are stored and reported through a series of reports. Located on the navigation pane, the **Report** menu contains categories for each of the reports stored in the relay (Event Reports, Sequential Events Recorder, and Signal Profile). When you select a category from the **Reports** menu, its corresponding report is displayed.

Event Reports

Event reports stored in the SEL-851 can be exported in COMTRADE format. When the **Event Reports** menu item is selected, the display shows all the event reports presently stored in the relay (see *Figure 3.5*).

Select an event report to export by clicking on the event needed. A pop-up window will enable you to save the corresponding event file.

In addition to retrieving events, the **Event Reports** page allows you to clear all the events stored in the relay or to trigger events. **Clear Event Report History** erases the event from the nonvolatile memory of the relay. **Trigger Event Report** commands the relay to do an event capture of the present voltages and currents seen by the relay (see *Figure 3.5*).

Figure 3.5 Event Report Webpage

Sequential Events Recorder

In addition to **Event Reports**, the SEL-851 collects and stores time-stamped data for assertion and deassertion of Relay Word bits. These data are captured in the Sequential Events Recorder (SER) report and can be exported through the web server.

When you select **Sequential Events Recorder**, all the SER entries presently stored in the relay will display (see *Figure 3.6*). The SER report stored in the SEL-851 can be downloaded or cleared by clicking the appropriate button at the bottom of the webpage.

Figure 3.6 Sequential Events Recorder Report

Signal Profile

The SEL-851 collects and stores time-stamped data of analog quantities. These data are reported in the signal-profile report. When you select the **Signal Profile** menu item, all the signal-profile entries presently stored in the relay display (see *Figure 3.7*). You can download or clear the signal-profile report stored in the SEL-851 using the two buttons at the bottom of the display window.

Figure 3.7 Signal-Profile Webpage

Control

In addition to viewing and downloading data from the SEL-851, you can control output contacts and remote bits from the **Control** webpage. Also, the present target information can be seen on the **Control** webpage. When you select **Control** from the navigation pane, an HMI simulation, as well as access to control of the remote bits and output contacts, is displayed (available at 2AC level only). In addition, you can trip and close the breaker by clicking the corresponding button (TRIP/CLOSE) on the HMI (when in REMOTE mode, see Ctl.RemSta Relay Word bit). Targets can also be cleared by clicking TARGET RESET.

The simulated HMI shown on the **Control** webpage gives real-time updates of the target LEDs (see *Figure 3.8*). The **Control** display window also shows the label of each LED as saved using the TLED_*n*.Label setting (*n* = 01–08) in the HMI settings (see *HMI Settings (SET H Command)*).

Figure 3.8 Control Webpage

To operate the remote bits, click on the remote bit you need and select the operation to perform (see *Figure 3.9*).

Figure 3.9 Confirmation Message for Operating Remote Bits

Communications

The **Communications** menu shows all the communication statistics available through the web server (Ethernet, GOOSE, and MIRRORED BITS). When you select a category, the corresponding statistics report is displayed.

Ethernet

You can view the Ethernet port configuration details, including the MAC address of the relay, by clicking **Communications** > **Ethernet** (see *Figure 3.10*). Click **Clear Ethernet Statistics** to clear packets, bytes, and errors data. Refer to *Section 7: Communications* for additional details on the Ethernet command.

Figure 3.10 Ethernet Statistics

GOOSE

You can view the transmit and receive GOOSE message statistics by clicking **Communications > GOOSE**. This report is displayed only when the IEC 61850 option is enabled. For more information on GOOSE communications, see *Appendix F: IEC 61850 Communications*.

Figure 3.11 GOOSE Statistics

Mirrored Bits

You can view communication statistics for the Mirrored Bits channel by clicking **Communications > Mirrored Bits**. The report is available only when Mirrored Bits communications is enabled on Port 1. Refer to *Appendix G: Mirrored Bits Communications* for more information on Mirrored Bits communications.

Figure 3.12 Mirrored Bits Statistics

Relay Status

Relay Status contains categories for each of the status pages in the web server (Self-Tests, Relay Word Bits, and SELOGIC Protection Counters). When you select a category from the **Relay Status** menu, the corresponding report displays.

Self-Tests

The SEL-851 has continual diagnostics that verify the status of the relay hardware. The results of these diagnostics can be viewed by selecting **Relay Status** > **Self-Tests** from the navigation pane.

When you select **Relay Status** > **Self-Tests**, the status of the relay, including the serial number, part number, and self-tests results, are displayed (see *Figure 3.13*).

Figure 3.13 Self-Tests Webpage

Relay Word Bits

The web server has the capability to display the present state of the Relay Word bits of the relay. Selecting **Relay Word Bits** displays the state of all the Relay Word bits in the relay (see *Figure 3.14*). Note that Relay Word bits shown in yellow are asserted. This webpage is updated automatically. Scroll up or down to view the remaining Relay Word bits not visible on the screen.

Row	Relay Word Bits				
0	EnaLED.Sta	TripLED.Sta	*	*	*
1	TLED_01.Sta	TLED_02.Sta	TLED_03.Sta	TLED_04.Sta	TLED_05.Sta
2	TLED_01.Set	TLED_02.Set	TLED_03.Set	TLED_04.Set	TLED_05.Set
3	50P_01.PU	50P_01.TmOut	50P_01.TorqCtl	50P_02.PU	50P_02.TmOut
4	50P_03.PU	50P_03.TmOut	50P_03.TorqCtl	50P_04.PU	50P_04.TmOut
5	50P_05.PU	50P_05.TmOut	50P_05.TorqCtl	50P_06.PU	50P_06.TmOut
6	50ABC_01.PU_A	50ABC_01.TmOut_A	50ABC_01.PU_B	50ABC_01.TmOut_B	50ABC_01.PU_C
7	50Gnd_01.PU	50Gnd_01.TmOut	50Gnd_01.TorqCtl	50Gnd_02.PU	50Gnd_02.TmOut
8	50Neg_01.PU	50Neg_01.TmOut	50Neg_01.TorqCtl	50Neg_02.PU	50Neg_02.TmOut
9	50N_01.PU	50N_01.TmOut	50N_01.TorqCtl	50N_02.PU	50N_02.TmOut
10	50.TmOut	PkDet.CTSatPU_A	PkDet.CTSatPU_B	PkDet.CTSatPU_C	*
11	51P_01.PU	51P_01.TmOut	51P_01.Rst	51P_01.TorqCtl	51P_02.PU
12	51Gnd_01.PU	51Gnd_01.TmOut	51Gnd_01.Rst	51Gnd_01.TorqCtl	51Gnd_02.PU
13	51Neg_01.PU	51Neg_01.TmOut	51Neg_01.Rst	51Neg_01.TorqCtl	51Neg_02.PU
14	51N_01.PU	51N_01.TmOut	51N_01.Rst	51N_01.TorqCtl	51N_02.PU
15	HBlk.H2_PUA	HBlk.H2_TmOutA	HBlk.H2_PUB	HBlk.H2_TmOutB	HBlk.H2_PUC
16	27PP_01.PU	27PP_01.TmOut	27PP_01.TorqCtl	27PP_02.PU	27PP_02.TmOut
17	59PP_01.PU	59PP_01.TmOut	59PP_01.TorqCtl	59PP_02.PU	59PP_02.TmOut
18	59Gnd_01.PU	59Gnd_01.TmOut	59Gnd_01.TorqCtl	59Gnd_02.PU	59Gnd_02.TmOut
19	81_01.PU	81_01.TmOut	81_01.TorqCtl	81_02.PU	81_02.TmOut

Figure 3.14 Relay Word Bits Webpage

SELOGIC Protection Counters

The SEL-851 has 16 SELOGIC protection counters. The web server has the capability to display the present count of each of the enabled counters. When you select **Relay Status > SELOGIC Protection Counters**, the count of each of the enabled SELOGIC protection counters is displayed (see *Figure 3.15*). Note that a counter is shown on the report only when it is enabled.

Figure 3.15 SELOGIC Protection Counters Webpage

Security

You can import an X.509 certificate via the web server. When Port_02.HTTPS_SrvrEna := Y, HTTPS connections require authentication to confirm that the server with which you are communicating is the correct server. This authentication is done through the use of an X.509 certificate. Refer to *Security (X.509 Certificates)* for additional details.

Figure 3.16 Import X.509 Certificate

Settings

Logging in to the web server with 2AC access allows you to modify relay settings (with ACC access, you can only view settings). When you select **Settings** from the navigation pane, the screen displays all the available settings classes in the SEL-851 (see *Figure 3.17*).

Figure 3.17 Protection Settings Webpage

When you select a class of settings, you can view and set each of the settings in that class (Protection, Logic, Report, HMI, DNP Map *n*, Front Port, Serial Port 1, Ethernet Port 2). *Figure 3.17* shows the Basic Settings category of the Protection class under Settings. Use the right-side scroll bar to reveal additional settings. Each class of settings can be modified on the web server and downloaded to the SEL-851. See *Section 4: Protection and Logic Functions* for descriptions of each of the settings and the class to which they belong.

Once you modify a setting, the changed setting will be shown in italics. After you modify the settings, click **Submit Changes** (located on the bottom of the screen) to download settings to the relay (see *Figure 3.18*).

Figure 3.18 Change Settings Webpage

When you click **Submit Changes**, a prompt appears asking you to verify that you want to save the settings to the relay (see *Figure 3.19*).

Figure 3.19 Save Setting Changes Webpage

System

The System menu contains four categories (File Management, Passwords, Date/Time, and Device Reset). You can import/export settings, upgrade firmware, manage passwords, change the date/time, and initiate a device reset using this menu. Select an appropriate category to perform the required action.

File Management

Export/Import Settings

The web server is a convenient way to both export settings from a relay and import settings to a relay. Each settings class is saved in a separate file. Use **File Management** to export and import settings from the relay.

Select the class of settings you want to export from Settings. You can save these settings as a text file. Then, you can click **Import Settings** to set other relays with the exported file (see *Figure 3.20*).

Figure 3.20 Import Settings, Export Settings, and Upgrade Relay Firmware From the File Management Webpage

Upgrade Firmware

The web server offers a convenient method for upgrading relay firmware. Located on the navigation pane, the **System** menu contains four categories (File Management, Passwords, Date/Time, and Device Reset). File Management allows you to upgrade the relay firmware (see *Figure 3.20*).

When preparing to upgrade relay firmware you must first have the new relay firmware. The firmware is designated with a .zds extension. Use the **Browse** button to select the firmware you want sent to the relay, then click **Upgrade Firmware** to start the upgrade process (see *Figure 3.20*). See *Appendix B: Firmware Upgrade Instructions* for more information.

Change Passwords

The web server offers a convenient method for changing relay passwords. Click **Passwords** to change the relay passwords (see *Figure 3.21*). SEL recommends changing the default passwords immediately upon receiving the relay.

You are able to change the password of any level, including the level into which you are presently logged. For example, to change the 2AC password, you must log in at the 2AC level (see *Connection and Login to Web Server*). To change the password, select the level from the Access Level drop down menu.

Figure 3.21 Change Passwords Webpage

Device Reset

NOTE: In firmware versions R100-V3 and higher, the relay firmware retains the IP address, subnet mask, and default router settings after an **R_S** command is issued.

To restore all relay settings to their default values, select **System** > **Device Reset** (see *Figure 3.22*). This menu item displays the Device Reset webpage. When you click **Reset to Factory Settings and Reboot**, all the relay settings revert to their factory-default values (except the calibration settings).

Figure 3.22 Reset Relay Settings to Default Values Using the Web Server

SEL Grid Configurator Software

SEL Grid Configurator Software is a tool for engineers and technicians to quickly and easily design, deploy, and manage device configurations for power system protection, control, metering, and monitoring. Through use of this software, you can perform the following:

- Configure settings for supported devices.
- Organize and manage device settings.
- Read and send settings for supported devices.
- Read reports from supported devices.

Installation

Overview

To install the software, you must have at least the following.

Table 3.1 Minimum Requirements

Supported Operating Systems:	Microsoft Windows 10 (64-bit) Microsoft Server 2016 (64-bit)
Processor Speed:	1 GHz (64-bit) or faster
RAM:	2 GB
Disk Space:	1 GB available
Printer:	Default printer installed for printer settings
Monitor:	1280 x 800 or higher resolution monitor **Note:** For best viewing of the application windows and text, you may need to enter your Windows operating system settings and adjust the screen resolution settings to make text and other items larger or smaller.
Other Peripherals:	Mouse or other pointing device
Communications:	Serial or Ethernet connections to allow communication with SEL devices
Required Third-Party Software:	Microsoft .NET Framework 4.7.2

Two different installations of Grid Configurator are offered: an Admin Install and a User Install. Both install the same version of the software but support different use cases. SEL recommends using the Admin Install in most cases. *Table 3.2* illustrates the differences and the different use cases for the two installation types.

Table 3.2 Differences Between Admin Install and User Install

Admin Install	User Install
Requires administrative privileges to install on the computer.	Does NOT require administrative privileges to install on the computer.
Accessible by all users on the same computer.	Accessible only to the user that installed the software.
Uses the ACSELERATOR Database, the same database used by ACSELERATOR QuickSet Device Manager, if installed. This provides a means to view and access supported devices from both Grid Configurator and Device Manager.	Uses a separate database from QuickSet Device Manager. The User Install of Grid Configurator cannot connect to an ACSELERATOR Database.

Examples of when to use the User Install:

- A user must install the software but lacks administrative privileges on the computer.
- A user wants to try a new version of Grid Configurator before full deployment.

Installation Instructions

Once you have decided on the best installation, perform the following:

Step 1. Obtain the SEL Grid Configurator installation files from either the website (selinc.com/products/5037) or SEL Compass software.

Step 2. Run the installation file.

Step 3. If you agree to the terms of the license agreement, select **I accept the license agreement**.

Step 4. If you are running the User Install, select **Install** and go to *Step 6*. If you are running the Admin install, select **Next** and continue to *Step 5*.

NOTE: The following option is only available in the Admin Install. Skip *Step 5* if you are running the User Install.

Step 5. Select the desired installation type.

a. Select **Typical** to use all default installation options, and then select **Install** to install the application.

Figure 3.23 Select Typical to Accept All Default Installation Options or Select Custom to View or Modify Them

b. Select **Custom** to choose where to install the application and the ACSELERATOR Database.

c. Select **Next**.

d. Enter the desired folder location or select **Browse** to select a folder and then select **Next**.

Figure 3.24 Select the Install Location for SEL Grid Configurator

e. Enter the desired folder locations for the database binaries and data or select **Browse** to select a folder and then select **Install**.

Figure 3.25 Select the Install Location for the ACSELERATOR Database

Step 6. After the installation process has been completed, select **Next**.

Step 7. Select **Finish** to close the installation wizard.

Figure 3.26 SEL Grid Configuration Installation Completed Successfully

Silent Installation

Grid Configurator supports a command-line interface for silent, automated installations. The following parameters are supported:

- **/Silent**: Requires no end-user interaction and supports automated installs via scripting.
- **/AgreeEULA**: Represents an explicit approval of the License Agreement (EULA) to prevent showing the License Agreement form. This must be included with the /Silent option to perform a silent installation of Grid Configurator.
- **/InstallPath**: Specifies the selected folder location when the default is not desired.
- **/DatabaseBinInstallPath**: Specifies the selected folder location for database binary files.
- **/DatabaseDataInstallPath**: Specifies the selected folder location for database data files.

Examples:

To perform a silent, default installation, execute the following:

```
SEL.Grid.UserInstaller-x.x.x.x.exe /Silent /AgreeEULA
```

To perform a silent installation while specifying the installation paths, execute the following:

```
SEL.Grid.AdminInstaller-x.x.x.x.exe /Silent /AgreeEULA /InstallPath="(Select
   file location)"
/DatabaseBinInstallPath="(Select database binaries location)"
   /DatabaseDataInstallPath=
"(Select Database data location)"
```

Uninstalling Grid Configurator

Grid Configurator supports uninstallation by the following methods:

- Through Windows Apps & features (Admin Install only)
- Through Windows Start Menu via an **Uninstall SEL Grid Configurator** shortcut in the **SEL Applications** folder (User Install only)
- Through SEL Compass
- Silently using the Grid Configurator uninstaller's command-line interface

Grid Configurator Uninstaller

The Grid Configurator uninstaller (uninstall.exe) is located in the Uninstall folder in the Grid Configurator install folder. The following parameters are supported:

- **/Silent**: A silent uninstallation shall be performed.
- **/RemoveDatabaseData**: Database data will be removed as part of uninstallation (User Install only).

Example:

To perform a silent uninstall, execute the following:

```
uninstall.exe /Silent
```

Removing Database Data (User Install Only)

The database data contains device information, settings, and collected device reports. By default, the database data will remain on the machine when uninstalling Grid Configurator. An option to remove the database data is available with the User Uninstall but not the Admin Uninstall. If you intend to reinstall Grid Configurator in the future, it is recommended to not remove this data. To remove the database data, select the box in the User Uninstallation Wizard (see *Figure 3.27*).

Figure 3.27 Option to Remove Database Data on Uninstallation (User Install Only)

In the case of the Admin Uninstall, the ACSELERATOR Database is not automatically removed. The ACSELERATOR Database requires manual removal via Windows Apps & features or SEL Compass.

Grid Configurator Interface

Introduction

The user interface of Grid Configurator is divided into a number of viewable areas that can generally be categorized as follows:

Navigators: One or more navigators can be open and visible in the user interface at any time. These generally sit vertically (top to bottom) in the user interface and contain content in rows. In some cases, the content will be hierarchical and collapsible so you can focus only on what you need. A scroll bar appears if the content still extends beyond the viewable space. When the scroll bar appears, Grid Configurator offers three navigational options:

- Press and drag with your mouse on the scroll bar
- Hover the mouse over the sidebar and use the mouse scroll wheel
- Touch the scroll bar and drag your finger in the direction you want the view to move

IMPORTANT: Opening multiple navigators on a smaller screen can make the workspace too confining. You can collapse or expand any navigator individually.

Workspace: The previously mentioned sections of the user interface enable and support the core of the application, your workspace. The content (or view) in the workspace changes depending on the project type and workflow, but the workspace generally includes editable content and reports. Enter and edit content as necessary. Reports are read-only and provide information about your project. As with navigators, Grid Configurator displays scroll bars if the content extends beyond the viewable space.

Accessing Contextual Information

The menu system in Grid Configurator primarily displays via context menus. Select the ellipsis button, ●●●, to display the context menu for the item with which you are working. Select in the title bar to activate application help.

User Interface Sections

- **System Explorer**: A navigator that includes a hierarchical view of all devices in your system. Open device projects from the System Explorer.
- **Workspace**: The display of any open view or project. Commands and features differ according to the use case for any particular view. The workspace also contains icons for common actions that affect the entire application.

Figure 3.28 Grid Configurator User Interface Overview

Light and Dark Theme

Figure 3.29 Dark Theme

Use the toggle on the top right of the workspace (*Figure 3.29*) to switch between the light and dark themes for the user interface.

Configuration

This section provides the basic process for creating and deploying settings for a new device. More detailed information on each part of the user interface is available in the *SEL Grid Configurator Instruction Manual*. When you create a new device project, the software will prompt you for a part number. If you have none at the present time, start with the default part number; you may change it later.

Step 1. Using a computer on which Windows 10 is installed, open Grid Configurator by selecting the Windows start button (left end of the Taskbar in Windows 10), scroll down and select **SEL Applications**, then select the Grid Configurator icon. Alternatively, you can pin Grid Configurator to the start panel, taskbar, or desktop on your computer.

Step 2. Create a new device by selecting **Add Device** from the context menu at the top of the System Explorer, as *Figure 3.30* illustrates.

Figure 3.30 Add A New Device Project

Step 3. Select the type of device.

Step 4. Fill in a project name, setting version, and part number. Select **OK**. A device project includes all of the information (such as settings, comments, communications parameters, etc.) that Grid Configurator manages for a device, *Figure 3.31* shows how a new device project looks in the System Explorer.

Figure 3.31 New Device in the System Explorer

Step 5. Select **Protection** > **Protection Elements** from the Device Explorer, as illustrated in *Figure 3.32*. Using the controls next to the Available Protection Elements, enable as many protection features as necessary. Click any bubble under Enabled Protection Elements to view or edit corresponding settings.

Figure 3.32 Protection Elements View

Select **Settings Grid** > **Protection** from the Device Explorer, as illustrated in *Figure 3.33*. In the Settings Grid view, settings are organized hierarchically in a tree format. Settings categories have a small triangle to the left. When you click this triangle, the settings category expands to show additional available settings related to the overarching category, as shown in *Figure 3.33*. Click the triangle again to collapse that portion of the tree.

In any device settings view, such as Protection Elements or Settings Grid, an indicator displays next to any setting you have changed. The change indicator persists as long as you have the device project open.

Figure 3.33 Settings Grid View

Some settings are disabled (grayed out) by default. Grid Configurator displays settings as disabled according to your part number selection, enabled protection elements, etc.

Step 6. In the Settings Grid view, expand the tree to see all the settings available in your relay. Select an entry in the tree to view the settings editor for that element. Edit the setting value either by directly editing in the grid or by selecting the ellipsis button in the Value cell if available. *Figure 3.34* shows an example of each editing workflow. For setting 50P_01.PUVal, which requires a numerical entry, you can directly select and edit the necessary value in the Value cell. Setting 50P_01.OpQty requires a value from a list. Select the ellipsis button in the Value cell to open the selection helper, which displays the options available for that setting. Select the value and then select **OK**.

Figure 3.34 Editing Settings and Automatic Validation

If you enter a settings value into a field and that value is invalid or outside the acceptable range, as shown in *Figure 3.34*, Grid Configurator displays an error icon in the Value cell for that setting. A message explaining the error displays if you hover over the Value cell. Correct these errors prior to deploying settings.

Select the alarm icon in the Device Commands menu, as shown in *Figure 3.35*, to see Project Notifications, a report of all settings errors in a device project. Select the notification message to immediately navigate to the invalid setting.

Figure 3.35 Viewing Project Notifications

Step 7. For all remaining settings, navigate the tree or use the search bar to find the necessary settings and alter the appropriate values.

Step 8. Select **Device > Connections**, as shown in *Figure 3.36*. Enter the connection parameters for your device. Grid Configurator can communicate with devices via serial or network connections.

Figure 3.36 Configuring Communications Options

Step 9. Select **Device > Security**, as illustrated in *Figure 3.37*. By default, Grid Configurator has the default passwords for your device type. Enter custom passwords if you use them. Refer to *Section 7: Communications* to learn about the access levels and password options.

Figure 3.37 Configuring Security Options

Step 10. Select **Connect** (located in the top right corner of the workspace). Once the connection is active, you will see a success message and a green dot displays in the device tab and next to the device name in the System Explorer. As long as Grid Configurator has an active connection with the device shown in your workspace, device commands appear similar to *Figure 3.38*.

Figure 3.38 Device Commands Menu for Connected Device

Step 11. Select the **Send** button, as shown in *Figure 3.38*, to deploy settings to the device. Select the blue **Device Operations** icon (located in the top right corner of the workspace), as shown in *Figure 3.39*, to view the progress of the operation.

Figure 3.39 Device Operations Icons and File Status During Settings Deployment

Step 12. From the ellipsis button at the top of the System Explorer, select **Open Send Report**, as shown in *Figure 3.40*, to view a report of all send operations.

Figure 3.40 Opening the Send Report

Step 13. Select **Disconnect** from the Device Commands Menu to terminate the connection to the device.

Terminal Window

Grid Configurator includes an ASCII terminal through which to issue relay commands. Via the commands, you can read metering data, pulse outputs, view device status, etc. Once Grid Configurator is connected to the supported relay, select Terminal in the bar on the bottom of the active device workspace. The Terminal window expands to occupy the bottom portion of the screen, as shown in *Figure 3.41*. Enter a valid command in the "Command to Execute" text area. Refer to *SEL-851 Command Summary* for a list of valid ASCII commands.

Figure 3.41 Terminal Window

Online HMI

The Online HMI allows you to view metering, monitoring, event, and status reports. You can also control remote bits, outputs, and the breaker. Click on the "Online HMI" icon as highlighted to view all the supported reports and functions.

The Meter menu includes the Fundamental, Min/Max, Energy, etc., screens that display the corresponding values. You can also reset metering screens such as energy, demand, and max/min from the Online HMI. *Figure 3.42* shows the Fundamental Metering screen.

Figure 3.42 Fundamental Metering

Click **Monitor > Relay Word Bits** to select the Relay Word bits that you want to monitor. When a Relay Word bit has a value of 1 (Port_02.LinkAAct = 1), the Relay Word bit is asserted. When a Relay Word bit has a value of 0 (Trip_01.Sta = 0), the Relay Word bit is deasserted as shown in *Figure 3.43*.

Figure 3.43 Relay Word Bits

The Reports menu allows you to view and clear SER, events, and signal profile records. From the Control menu, you can pulse remote bits or outputs and also control the breaker. *Figure 3.44* shows the Output Pulsing screen. Select the "Pulse" action to pulse the corresponding output.

Figure 3.44 Output Pulsing

You can view or change date and time settings from the Settings menu. The Device Info menu displays the status of the relay hardware and self-tests.

Reports

Select the Reports icon to view the SOE and event reports. Click **Check for Events** to check for event reports and SOE from the relay as shown in *Figure 3.45*. Click **Collect** to read the corresponding event reports from the relay. Once collected, select the Export button on the right of the event record

to export COMTRADE event files. Each download will include CFG, HDR and DAT files associated with the event. See *Section 9: Analyzing Events* for more information. When you provide a custom file name, only the evzip file name updates. The individual event files within the evzip file retain the original names. Please open the SYNCHROWAVE Event Software and select the saved evzip file you want to view. You can also export the SOE records in CSV format.

Figure 3.45 Reports

Export/Import Settings

Grid Configurator provides a means to export and import individual device projects or entire folders. To share artifacts with another user, use the export and import features. The following sections give a high level overview of the different import and export options supported in Grid Configurator. See the Grid Configurator instruction manual, available at selinc.com, for more information.

Export Settings in .GRX Format

Grid Configurator exports artifacts as file type .grx. As shown in *Figure 3.46*, select the ellipsis button for the device or folder you want to export and select Export. You can export the settings with password protection.

Figure 3.46 Export Settings

Export Settings in CSV Format

You can also export settings in CSV format using the Settings Report option as shown in *Figure 3.47*. You can make changes to the settings and import them as discussed in *Batch Import Settings*.

Figure 3.47 Settings Report

Import Settings in .GRX Format

To import a settings file that was previously exported using Grid Configurator software, select the ellipsis button for the device or folder you want to import and select **Import** from .grx, as shown in *Figure 3.48*.

Figure 3.48 Import From .GRX

Batch Import Settings

You can also batch import settings using Grid Configurator software. In cases where you are calculating settings in a spreadsheet or other software tool, Grid Configurator provides a means to import one or more settings in one step. You must format the settings to be imported into a tabular structure. The setting name and value are mandatory columns. The setting class, description, and range are optional columns.

As an example, *Figure 3.49* shows a table with settings in a spreadsheet. Copy the table.

CTP.Rat	100
CTP.NomSec	1
CTP.Pol	Normal
CTN.Rat	120
CTN.NomSec	1
CTN.Pol	Normal
VTP.Rat	200
VTP.Conn	Wye

Figure 3.49 Settings Table

In the Settings Grid view, select **Import Settings** as shown in *Figure 3.50*. Paste the settings results into the resulting dialog, shown in *Figure 3.51*. Select **Submit**.

Figure 3.50 Import Settings

Figure 3.51 Import Settings CSV

Grid Configurator matches the settings names and values of what you paste, regardless of the sequence of settings. If the paste is successful, you will see a message listing the number of settings successfully written as shown in *Figure 3.52*. The settings grid will automatically be updated with the new values as shown in *Figure 3.53*.

Figure 3.52 Settings Import Successful

Figure 3.53 Updated Settings

Section 4

Protection and Logic Functions

Overview

NOTE: Each SEL-851 is shipped with default factory settings. Calculate the settings for your application to ensure secure and dependable protection. Document and enter the settings (see Section 6: Settings).

This section describes the SEL-851 Feeder Protection Relay settings, including the protection elements and basic functions, control I/O logic, as well as the settings that control the communications ports and front-panel display.

This section includes the following subsections:

Application Data. Lists information that you need to know about the protected equipment before calculating the relay settings. Lists the settings for protection elements included in all models of the SEL-851.

Protection Settings (SET Command).

Basic Settings. Lists the ID settings and the settings that configure the relay inputs to accurately measure and interpret the ac current and voltage input signals.

Nominal Voltage Range Check. Identifies the Sys.VNom range for DELTA and WYE connected VT configurations.

Configuration Settings. Lists the configuration settings for date/time format and settings to block processing of demand/energy metering.

Overcurrent Elements. Lists the settings and describes the logic associated with overcurrent elements.

Time-Overcurrent Elements. Lists the settings and time-overcurrent curves and describes the logic associated with the elements.

Under- and Overvoltage Functions. Lists the settings and logic associated with the under- and overvoltage elements.

Loss-of-Potential (LOP) Protection. Lists the logic and settings associated with the LOP element.

Second-Harmonic Blocking Logic. Lists the settings associated with second-harmonic blocking logic.

Reclose Supervision Logic. Describes the logic that supervises automatic reclosing when an open interval time times out—a final condition check right before the close logic asserts the close output contact.

Reclose Logic. Describes all the reclosing relay settings and logic necessary for automatic reclosing (besides the final close logic and reclose supervision logic described previously).

Power Elements. Lists the settings and describes the logic associated with power elements.

Power Factor Elements. Lists the settings and describes the logic associated with power factor elements.

Frequency Protection. Lists the settings and describes the logic associated with over- and underfrequency elements.

Breaker Failure Settings. Lists the settings and describes the logic for the flexible breaker failure function.

Arc-Flash Protection. Lists the settings for the arc-flash elements including arc-flash overcurrent and time-overlight elements.

Trip/Close Logic. Lists trip and close logic.

Warning List. Describes the text-edit mode actions associated with the Warning.List setting.

Output Contacts. Lists the settings associated with the output contacts.

Input Contacts. Lists the settings and describes the logic associated with the input contacts.

Time and Date Management Settings. Lists settings for time and date management, describes the configuration of the settings, and lists the supported protocols.

Demand Metering. Lists the settings associated with demand metering.

Data Reset. Lists the data reset SELOGIC control equation settings for resetting targets, energy metering, max/min metering, and demand metering.

Alarm Settings. Lists the SELOGIC control equation settings associated with the software and hardware alarms.

IEC 61850 Mode Control. Lists the settings associated with IEC 61850 mode control.

Logic Settings (SET L Command). Lists the settings associated with protection latches, timers, counters, and math variables.

Port Settings (SET P Command). Lists the settings that configure the relay front- and rear-panel communication ports.

HMI Settings (SET H Command). Lists the settings for the front-panel display, pushbuttons, and LED control.

Report Settings (SET R Command). Lists the settings for the SER report, event reports, and signal-profile reports.

DNP Map Settings (SET D Command). Shows the DNP user map register settings.

Modbus Map Settings (SET M Command). Shows the Modbus user map register settings.

When you calculate the protection element settings, proceed through the subsections listed previously. Skip the voltage-based protection and arc-flash detection subsections if they do not apply to your specific relay models or installation.

See *Section 6: Settings* for ways in which the settings for the SEL-851 relay can be viewed and set.

Application Data

It is faster and easier for you to calculate settings for the SEL-851 if you collect the following information before you begin:

- System phase rotation and nominal frequency
- Current transformer primary and secondary ratings and connections
- Voltage transformer ratios and connections, if used
- Highest expected load current
- Expected fault current magnitudes for ground and three-phase faults

Protection Settings (SET Command)

Basic Settings

All models of the SEL-851 have the identifier settings described in *Table 4.1*. The SEL-851 prints the relay and location identifiers at the top of the command responses.

Enter as many as 16 characters, including letters A–Z (not case sensitive), numbers 0–9, periods (.), dashes (-), and spaces. Suggested identifiers include the location or number of the protected feeder.

Table 4.1 Basic Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
RELAY IDENTIFIER	16 characters	Dev.Id := SEL-851
LOCATION IDENTIFIER	16 characters	Dev.Loc := FEEDER 1
COMPANY NAME	5 characters	Dev.CoName := CONAM
NOMINAL FREQUENCY	50, 60 Hz	Sys.FNom := 60
PHASE ROTATION	ABC, ACB	Sys.PhRot := ABC
PHASE CT RATIO	1–6000	CTP.Rat := 1
PHASE CT NOMINAL SECONDARY	1 A or 5 A	CTP.NomSec := 5
PHASE CT POLARITY	NORMAL, REVERSE	CTP.Pol := NORMAL
NEUTRAL CT RATIO	1–6000	CTN.Rat := 1
NEUTRAL CT NOMINAL SECONDARY	1 A or 5 A	CTN.NomSec := 5
NEUTRAL CT POLARITY	NORMAL, REVERSE	CTN.Pol := NORMAL
PHASE VT RATIO	1.00–10000.00	VTP.Rat := 120.00
PHASE VT CONNECTION	DELTA, WYE	VTP.Conn := WYE
NOMINAL LINE-LINE VOLTAGE	0.20–1000.00 kV primary	Sys.VNom := 13.80
PHASE VT SINGLE VOLTAGE INPUT	Y, N	VTP.SingleV := N

Set the Sys.FNom setting equal to your system nominal frequency. The phase rotation setting tells the relay your phase labeling standard. Set Sys.PhRot equal to ABC when B-phase current lags A-phase current by 120 degrees. Set Sys.PhRot equal to ACB when B-phase current leads A-phase current by 120 degrees.

Figure 4.1 Phase Rotation Setting

Use the Dev.CoName setting to include the abbreviated name of your company.

The CT ratio settings configure the relay to accurately scale measured values and report the primary quantities. Calculate the phase and neutral current CT ratios by dividing the primary rating by the secondary rating.

EXAMPLE 4.1 Phase CT Ratio Setting Calculation

Consider an application where the phase CT rating is 100:5 A.
Set CTP.Rat := 100/5 := 20.

Depending on the CT nominal secondary rating, set CTP.NomSec and CTN.NomSec to 1 A or 5 A for phase and neutral CTs, respectively.

To change the polarity of the CT inputs, use the CT polarity setting CTP.Pol and CTN.Pol for phase and neutral CTs, respectively. This ability allows the user to change CT polarity digitally to correct for incorrect wiring to the input on the back of the relay. Practice extreme caution when using this setting. The change of polarity applies directly to the input terminal and is used in phasor calculations and protection logic.

Table 4.1 also shows the basic voltage settings for relay models with optional voltage inputs rated for 300 Vac. These settings configure the voltage inputs to correctly measure and scale the voltage signals. Set the phase VT ratio setting (VTP.Rat) equal to the VT ratio.

Set the nominal line-to-line voltage (Sys.VNom) in primary volts. Note that Sys.VNom is always in line-to-line voltage, irrespective of the DELTA or WYE input configuration. When phase-to-phase potentials are connected to the relay, set VTP.Conn to DELTA. When phase-to-neutral potentials are connected to the relay, set VTP.Conn to WYE.

EXAMPLE 4.2 Phase VT Ratio Setting Calculations

Consider a 13.8 kV feeder application where you use 14400:120 V rated voltage transformers (connected in open delta).

Set VTP.Rat := 14400/120 := 120 and VTP.Conn := DELTA.

In applications where only a single voltage is available, set VTP.SingleV equal to Y. As shown in *Figure 2.19*, the single voltage must be connected to the A-phase input; it can be an A-N or an A-B voltage. Be sure to set VTP.Conn equal to WYE for an A-N input or VTP.Conn equal to DELTA for an A-B input voltage. When you set VTP.SingleV equal to Y, the relay performance changes in the following ways:

- **Power and Voltage Elements**. When you use one voltage, the relay assumes that the system voltages are balanced in both magnitude and phase angle. Power and power factor are calculated assuming balanced voltages.
- **Metering.** When you use one voltage, the relay displays magnitude and phase angle for the measured VT. The relay displays zero for the 3V2 magnitudes and unmeasured voltages. Balanced voltages are assumed for power, power factor, and V1 metering.
- **Event Reports.** When you use one voltage, the unmeasured voltage magnitudes are reported as zero.

Table 4.2 Effect on Protection Settings When VTP.SingleV := Y

Identifier Settings		
Group Setting	**Change**	**Reason**
Overvoltage Elements		
59Gnd.Ena	Forced to OFF and hidden	This function requires zero-sequence voltage.
27PP_*n*.OpQty (*n* = 1, 2)	Forced to Fundamental_Min and hidden	When VTP.SingleV := Y, the operate quantities “Fundamental_Min” and “Fundamental_Max” are identical
59PP_*n*.OpQty (*n* = 1, 2)	Forced to Fundamental_Max and hidden	

Nominal Voltage Range Check

The relay performs a range check for the Sys.VNom setting that depends upon the voltage-input delta or wye configuration. When the setting VTP.Conn is DELTA, then the allowed range of the Sys.VNom is OFF, 20–250 V (l-l sec). When the setting VTP.Conn is WYE, then the allowed range of Sys.VNom is OFF, 20–480 V (l-l sec).

Note that the Sys.VNom setting is always in line-to-line (kV primary), even when set for a wye configuration. Limit the Sys.VNom setting to 250 V (l-l sec) for ungrounded systems and to 480 V (l-l sec) for solidly grounded systems when using WYE-connected VTs. In an ungrounded system, when there is a line-to-ground fault, the terminal voltages can increase by a factor of as much as 1.73.

EXAMPLE 4.3 Sys.VNom Setting Calculation for Standard Voltage Inputs

Consider a 10 kV (phase-to-phase) system with wye-connected VTs rated 7200:120 (VTP.Rat := 60).

The setting for Sys.VNom := 10.00 (kV primary) or 10000/60 := 166.67 (V sec).

Configuration Settings

Table 4.3 shows the configuration settings available in the SEL-851. The Time.DateFormat setting allows you to change the relay date presentation format to the North American standard (month/day/year), the engineering standard (year/month/day), or the European standard (day/month/year).

Set the SELOGIC control equation Meter.Fault to temporarily block maximum and minimum, energy, and demand metering. The Meter.Thres_Min setting determines the behavior of the metering functions when the metered value is lower than a fixed threshold. Refer to *Small Signal Cutoff Metering* for more details.

Table 4.3 Configuration Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
DATE FORMAT	MDY, YMD, DMY	Time.DateFormat := MDY
FAULT CONDITION	SELOGIC	Meter.Fault := 50P_01.PU OR 50Gnd_01.PU OR 51P_01.PU OR 51Gnd_01.PU
METER CUTOFF THRESHOLD	Y, N	Meter.Thres_Min := Y

Overcurrent Elements

Six levels of instantaneous/definite-time elements are available for maximum phase overcurrent, one level is available for per-phase overcurrent, and two levels are available for each of the neutral, residual ground, and negative-sequence overcurrents, as shown in *Table 4.4* through *Table 4.8* and in *Figure 4.2* through *Figure 4.9*.

Each element can be torque controlled through the use of appropriate SELOGIC control equations (e.g., when 50P_01.TorqCtl := IN_01.Sta, the 50P_01 element is operational only if IN_01.Sta is asserted). The 50P, 50ABC, and 50N elements can be set to operate on the fundamental or rms currents using the operate quantity (OpQty) setting. If the operate quantity is set to rms, the measured signal bandwidth extends from 1 to 300 Hz.

When the overcurrent trip delay (50P_01.PUDly–50P_06.PUDly, 50ABC_01.PUDly, 50N_01.PUDly–50N_02.PUDly, 50Gnd_01.PUDly–50Gnd_02.PUDly, and 50Neg_01.PUDly–50Neg_02.PUDly) is set to OFF, the time delayed overcurrent element is disabled and the output Relay Word bits (50P_01.TmOut–50P_06.TmOut, 50ABC_01.TmOut, 50N_01.TmOut–50N_02.TmOut, 50Gnd_01.TmOut–50Gnd_02.TmOut, and 50Neg_01.TmOut–50Neg_02.TmOut) stay deasserted.

NOTE: The Fourier filter provides excellent performance in removing dc offset and harmonics. However, the bipolar peak detector has the best performance in situations of severe CT saturation when the Fourier filter magnitude estimation is significantly degraded. Combining the two methods provides an elegant solution for ensuring dependable short-circuit overcurrent element operation.

NOTE: When using the output of harmonic blocking logic to torque-control 50 elements set with a pickup greater than 8 • CTP.NomSec, the harmonic blocking could nullify the peak detector feature of the corresponding 50 element. Refer to the Second-Harmonic Blocking Logic on page 4.23.

The phase instantaneous overcurrent elements (50P_01 through 50P_06; see *Figure 4.2*) normally operate on one cycle Fourier-filtered phase currents (I*n*,MagSec, where *n* = A, B, C). During severe CT saturation, the filtered phase current magnitude can be substantially reduced because of the high harmonic content and reduced magnitude of the distorted secondary waveform. If the overcurrent element relied only on the output of the Fourier-filtered secondary current, the operation of any high-set instantaneous overcurrent element might be severely delayed and jeopardized. For any phase instantaneous overcurrent element in the SEL-851 that is set greater than eight times the nominal current per the CTP.NomSec setting, the overcurrent element also operates on the output of a bipolar peak detector (I*n*.Pk_MagSec, where *n* = A, B, C) if the current waveform is highly distorted, as is the case with severe CT saturation. This ensures fast operation of the 50P_*n* phase overcurrent elements even with severe CT saturation.

When the harmonic distortion index exceeds the fixed threshold (PkDet.CTSatPU_*k* = 1 where *k* = A, B, or C), which indicates severe CT saturation, the phase overcurrent elements operate on the output of the peak detector. When the harmonic distortion index is below the fixed threshold, the phase overcurrent elements operate on the output of the Fourier filter.

Table 4.4 Maximum Phase Overcurrent Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
MAX. PHASE OC ENABLE	OFF, 1–6	50P.Ena := 1
MAX. PHASE OC *m* OPERATE QUANTITY	Fundamental, RMS	50P_*m*.OpQty := Fundamental
MAX. PHASE OC *m* PICKUP VALUE	0.50–100.00 A[b] 0.10–20.00 A[c]	50P_*m*.PUVal := 15 50P_*m*.PUVal := 3
MAX. PHASE OC *m* TRIP DELAY	OFF, 0.00–240.00 s	50P_*m*.PUDly := 0.00
MAX. PHASE OC *m* TORQUE CONTROL	SELOGIC	50P_*m*.TorqCtl := 1

[a] m = 01–06.
[b] For CTP.NomSec = 5 A.
[c] For CTP.NomSec = 1 A.

S1 Position:
1 if 50P_m.OpQty = RMS
2 if 50P_m.OpQty = Fundamental

S2 Position:
1 if the output of AND1 = 0
2 if the output of AND1 = 1

IP.RMS_Sec = maximum(IA.RMS_Sec, IB.RMS_Sec, IC.RMS_Sec), IP.MagSec = maximum(IA.MagSec, IB.MagSec, IC.MagSec), IP.Pk_MagSec = maximum(IA.Pk_MagSec, IB.Pk_MagSec, IC.Pk_MagSec).

Figure 4.2 Instantaneous Overcurrent Element Logic, Level m

One level for per-phase instantaneous overcurrent is available as shown in *Figure 4.3*. The pickup setting 50ABC_01.PUVal is used for all three per-phase elements. Similar to 50P element, when 50ABC_01.PUVal is set to eight times the nominal current (CTP.NomSec setting) the element also operates on the output of a bipolar peak detector if the current waveform is highly distorted, as is the case with severe CT saturation.

Table 4.5 Per-Phase Overcurrent Elements

Setting Prompt	Setting Range	Setting Name := Factory Default
PER-PHASE OC 01 ENABLE	OFF, 1	50ABC.Ena := OFF
PER-PHASE OC 01 OPERATE QUANTITY	Fundamental, RMS	50ABC_01.OpQty := Fundamental
PER-PHASE OC 01 PICKUP VALUE	0.50–100.00 A[a] 0.10–20.00 A[b]	50ABC_01.PUVal := 15.00 50ABC_01.PUVal := 3.00
PER-PHASE OC 01 TRIP DELAY	OFF, 0.00–240.00 s	50ABC_01.PUDly := 0.50
PER-PHASE OC 01 TORQUE CONTROL	SELOGIC	50ABC_01.TorqCtl := 1

[a] For CTP.NomSec = 5 A.
[b] For CTP.NomSec = 1 A.

Figure 4.3 50ABC Per-Phase Definite-Time Overcurrent Element Logic, Level 01

The relay offers two types of ground fault detection overcurrent elements. The neutral overcurrent elements (50N_01.TmOut and 50N_02.TmOut) operate on current measured by the IN input. The residual ground overcurrent elements (51Gnd_01.TmOut and 51Gnd_02.TmOut) operate on the zero-sequence current derived from the phase currents.

NOTE: When a switch or breaker closes, the three poles may not close at the same time, creating a momentary current unbalance condition. To override this condition use an overcurrent trip delay for 50N, 50Gnd, and 50Neg elements (for example, 50N_n.PUDly := 0.05 s).

When a core-balance CT is connected to the relay IN input, as in *Figure 2.26*, use the neutral overcurrent element to detect the ground faults. Calculate the trip level settings based on the available ground fault current and the core-balance CT ratio.

The relay offers two levels of negative-sequence overcurrent elements to detect phase-to-phase faults, phase reversal, single phasing, and unbalance load.

Table 4.6 Neutral Overcurrent Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
NEUTRAL OC ENABLE	OFF, 1–2	50N.Ena := OFF
NEUTRAL OC *n* OPERATE QUANTITY	Fundamental, RMS	50N_*n*.OpQty := Fundamental
NEUTRAL OC *n* PICKUP VALUE	0.50–100.00 A[b] 0.10–20.00 A[c]	50N_*n*.PUVal := 2.50 50N_*n*.PUVal := 0.50
NEUTRAL OC *n* TRIP DELAY	OFF, 0.00–240.00 s	50N_*n*.PUDly := 0.50
NEUTRAL OC *n* TORQUE CONTROL	SELOGIC	50N_*n*.TorqCtl := 1

[a] n = 01, 02.
[b] For CTP.NomSec = 5 A.
[c] For CTP.NomSec = 1 A.

Table 4.7 Residual Ground Overcurrent Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
GROUND OC ENABLE	OFF, 1–2	50Gnd.Ena := OFF
GROUND OC *n* PICKUP VALUE	0.50–100.00 A[b] 0.10–20.00 A[c]	50Gnd_*n*.PUVal := 2.50 50Gnd_*n*.PUVal := 0.50
GROUND OC *n* TRIP DELAY	OFF, 0.00–240.00 s	50Gnd_*n*.PUDly := 0.50
GROUND OC *n* TORQUE CONTROL	SELOGIC	50Gnd_*n*.TorqCtl := 1

[a] n = 01, 02.
[b] For CTP.NomSec = 5 A.
[c] For CTP.NomSec = 1 A.

Table 4.8 Negative-Sequence Overcurrent Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
NEG. SEQUENCE OC ENABLE	OFF, 1–2	50Neg.Ena := OFF
NEG. SEQUENCE OC *n* PICKUP VALUE	0.50–100.00 A[b] 0.10–20.00 A[c]	50Neg_*n*.PUVal := 2.5[b] 50Neg_*n*.PUVal := 0.5[c]
NEG. SEQUENCE OC *n* TRIP DELAY	OFF. 0.00–240.00 s	50Neg_*n*.PUDly := 0.5
NEG. SEQUENCE OC *n* TORQUE CONTROL	SELOGIC	50Neg_*n*.TorqCtl := 1

[a] n = 01, 02.
[b] For CTP.NomSec = 5 A.
[c] For CTP.NomSec = 1 A.

Figure 4.4 50N Neutral Definite-Time Overcurrent Element Logic, Level n

Figure 4.5 Residual Ground Definite-Time Overcurrent Element Logic, Level n

Figure 4.6 50Neg Negative-Sequence Definite-Time Overcurrent Element Logic, Level n

The 50.TmOut Relay Word bit is the output of the OR combination of all the 50 elements, see *Figure 4.7*.

Figure 4.7 OR Combination of all the 50 Elements

Pickup and Reset Time Curves

NOTE: The pickup time curve in Figure 4.8 is not valid for conditions with a saturated CT, where the resultant current to the relay is nonsinusoidal.

Figure 4.8 and *Figure 4.9* show pickup and reset time curves applicable to all instantaneous overcurrent elements with sinusoidal waveforms applied (60 Hz or 50 Hz relays). These times do not include any programmed pickup delay or output contact operating time and, thus, are accurate for determining element operation time for use in internal SELOGIC control equations.

Figure 4.8 Instantaneous Overcurrent Element Pickup Time Curve

Figure 4.9 Instantaneous Overcurrent Element Reset Time Curve

Time-Overcurrent Elements

Two levels of inverse-time overcurrent elements are available for maximum phase, negative-sequence, residual ground, and neutral overcurrent. See *Table 4.9* through *Table 4.12* for available settings.

You can select from five U.S. and five IEC inverse characteristics. *Table 4.13* and *Table 4.14* show equations for the curves and *Figure 4.14* through *Figure 4.23* show the curves. The reset timing for the element follows the reset mode 51*k*_*n*.RstMod setting (*k* = P, Gnd, Neg, N, *n* = 01–02). If the reset mode is set to Inverse, the relay calculates the reset time based on the 51*k*_*n*.Crv setting and the reset equation in *Table 4.13* and *Table 4.14*. If the reset mode is set to Instantaneous, the reset time is 1 cycle.

Each element can be torque controlled through use of appropriate SELOGIC control equations (e.g., when 51P_01.TorqCtl := IN_01.Sta the 51P_01 element is operational only if IN_01.Sta is asserted).

Table 4.9 Maximum Phase Time-Overcurrent[a] (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
MAX. PHASE TOC ENABLE	OFF, 1–2	51P.Ena := OFF
MAX. PHASE TOC *n* OPERATE QUANTITY	Fundamental, RMS	51P_*n*.OpQty := Fundamental
MAX. PHASE TOC *n* PICKUP VALUE	0.50–24.00 A[b] 0.10–4.80 A[c]	51P_*n*.PUVal := 6 51P_*n*.PUVal := 1.2
MAX. PHASE TOC *n* CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51P_*n*.Crv := U3
MAX. PHASE TOC *n* TIME DIAL	0.50–15.00 for U1–U5, 0.01–1.50 for C1–C5	51P_*n*.TmDial := 3.00

Table 4.9 Maximum Phase Time-Overcurrent[a] (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
MAX. PHASE TOC *n* RESET MODE	Instantaneous, Inverse	51P_*n*.RstMod := Instantaneous
MAX. PHASE TOC *n* TORQUE CONTROL	SELOGIC	51P_*n*.TorqCtl := 1

[a] n = 01, 02.
[b] For CTP.NomSec = 5 A.
[c] For CTP.NomSec = 1 A.

The maximum phase time-overcurrent elements, 51P_01.TmOut and 51P_02.TmOut, respond to the highest of A-, B-, and C-phase currents as shown in *Figure 4.10*.

Figure 4.10 Maximum Phase Time-Overcurrent Elements

NOTE: When a switch or breaker closes, the three poles may not close at the same time. This creates a momentary current unbalance condition. To avoid tripping for this transient condition, do not use a time-dial setting that results in curve times slower than three cycles for 51Neg, 51Gnd, and 51N elements.

The negative-sequence time-overcurrent element 51Neg_*n*.TmOut responds to the negative-sequence current as shown *Figure 4.11*.

The neutral time-overcurrent elements, 51N_01.TmOut and 51N_02.TmOut, respond to neutral channel current IN as shown *Figure 4.12*.

The residual ground time-overcurrent elements, 51Gnd_01.TmOut and 51Gnd_02.TmOut, respond to residual current IGnd as shown in *Figure 4.13*.

Table 4.10 Negative-Sequence Time-Overcurrent Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
NEG. SEQUENCE TOC ENABLE	OFF, 1–2	51Neg.Ena := OFF
NEG. SEQUENCE TOC *n* PICKUP VALUE	0.50–24.00[b] 0.10–4.80[c]	51Neg_*n*.PUVal := 6 51Neg_*n*.PUVal := 1.2
NEG. SEQUENCE TOC *n* CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51Neg_*n*.Crv := U3
NEG. SEQUENCE TOC *n* TIME DIAL	0.50–15.00 for U1–U5 0.01–1.50 for C1–C5	51Neg_*n*.TmDial := 3.00
NEG. SEQUENCE TOC *n* RESET MODE	Instantaneous, Inverse	51Neg_*n*.RstMod := Instantaneous
NEG. SEQUENCE TOC *n* TORQUE CONTROL	SELOGIC	51Neg_*n*.TorqCtl := 1

[a] n = 01, 02.
[b] For CTP.NomSec = 5 A.
[c] For CTP.NomSec = 1 A.

Figure 4.11 Negative-Sequence Time-Overcurrent Element

Table 4.11 Neutral Time-Overcurrent Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
NEUTRAL TOC ENABLE	OFF, 1–2	51N.Ena := OFF
NEUTRAL TOC *n* OPERATE QUANTITY	Fundamental, RMS	51N_*n*.OpQty := Fundamental
NEUTRAL TOC *n* PICKUP VALUE	0.50–24.00 A[b] 0.10–4.80 A[c]	51N_*n*.PUVal := .5.00 51N_*n*.PUVal := 0.50
NEUTRAL TOC *n* CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51N_*n*.Crv := U3
NEUTRAL TOC *n* TIME DIAL	0.50–15.00 for U1–U5, 0.01–1.50 for C1–C5	51N_*n*.TmDial := 3.00
NEUTRAL TOC *n* RESET MODE	Instantaneous, Inverse	51N_*n*.RstMod := Instantaneous
NEUTRAL TOC *n* TORQUE CONTROL	SELOGIC	51N_*n*.TorqCtl := 1

[a] n = 01, 02.
[b] For CTP. NomSec = 5 A.
[c] For CTP.NomSec = 1 A.

Figure 4.12 Neutral Time-Overcurrent Elements

Table 4.12 Residual Ground Time-Overcurrent Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
GROUND TOC ENABLE	OFF, 1–2	51Gnd.Ena := OFF
GROUND TOC *n* PICKUP VALUE	0.50–24.00 A[b] 0.10–4.80 A[c]	51Gnd_*n*.PUVal := 2.5 51Gnd_*n*.PUVal := 0.5
GROUND TOC *n* CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51Gnd_*n*.Crv := U3
GROUND TOC *n* TIME DIAL	0.50–15.00 for U1–U5, 0.01–1.50 for C1–C5	51Gnd_*n*.TmDial := 1.50
GROUND TOC *n* RESET MODE	Instantaneous, Inverse	51Gnd_*n*.RstMod := Instantaneous
GROUND TOC *n* TORQUE CONTROL	SELOGIC	51Gnd_*n*.TorqCtl := 1

[a] n = 01, 02.
[b] For CTP.NomSec = 5 A.
[c] For CTP.NomSec = 1 A.

Figure 4.13 Residual Ground Time-Overcurrent Elements

Time-Overcurrent Curves

NOTE: The time-overcurrent curves in Figure 4.14 through Figure 4.23 show operating times flattening at M = 30 (30 multiples of pickup). This is true for the overcurrent pickup set equal to the CT nominal rating (CTP.NomSec) and no significant dc offset. The flattening may start at different points depending on the actual pickup setting, e.g., if pickup is 4.8 • CTP.NomSec, the curve starts flattening at M = 30/4.8 = 6.25.

The following information describes the curve timing for the curve and time dial settings made for the time-overcurrent elements (see *Figure 4.10* through *Figure 4.13*). The U.S. and IEC time-overcurrent relay curves are shown in *Figure 4.14* through *Figure 4.23*. Curves U1, U2, and U3 (*Figure 4.14* through *Figure 4.16*) conform to IEEE C37.112-1996 IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays.

Table 4.13 Equations Associated With U.S. Curves

Curve Type	Operating Time	Reset Time	Figure
U1 (Moderately Inverse)	$t_p = TmDial \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$t_r = TmDial \bullet \left(\frac{1.08}{1 - M^2}\right)$	*Figure 4.14*
U2 (Inverse)	$t_p = TmDial \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$t_r = TmDial \bullet \left(\frac{5.95}{1 - M^2}\right)$	*Figure 4.15*
U3 (Very Inverse)	$t_p = TmDial \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$t_r = TmDial \bullet \left(\frac{3.88}{1 - M^2}\right)$	*Figure 4.16*
U4 (Extremely Inverse)	$t_p = TmDial \bullet \left(0.0352 + \frac{5.67}{M^2 - 1}\right)$	$t_r = TmDial \bullet \left(\frac{5.67}{1 - M^2}\right)$	*Figure 4.17*
U5 (Short-Time Inverse)	$t_p = TmDial \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$t_r = TmDial \bullet \left(\frac{0.323}{1 - M^2}\right)$	*Figure 4.18*

where:
t_p = operating time in seconds (see *Note on page 4.15*)
t_r = electromechanical induction—disk emulation reset time in seconds (if you select electromechanical reset setting)
TmDial = time-dial setting
M = applied current in multiples of pickup current [for operating time (t_p), M>1; for reset time (t_r), M≤1]

Table 4.14 Equations Associated With IEC Curves

Curve Type	Operating Time	Reset Time	Figure
C1 (Standard Inverse)	$t_p = TmDial \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$t_r = TmDial \bullet \left(\frac{13.5}{1 - M^2}\right)$	*Figure 4.19*
C2 (Very Inverse)	$t_p = TmDial \bullet \left(\frac{13.5}{M - 1}\right)$	$t_r = TmDial \bullet \left(\frac{47.3}{1 - M^2}\right)$	*Figure 4.20*
C3 (Extremely Inverse)	$t_p = TmDial \bullet \left(\frac{80}{M^2 - 1}\right)$	$t_r = TmDial \bullet \left(\frac{80}{1 - M^2}\right)$	*Figure 4.21*
C4 (Long-Time Inverse)	$t_p = TmDial \bullet \left(\frac{120}{M - 1}\right)$	$t_r = TmDial \bullet \left(\frac{120}{1 - M}\right)$	*Figure 4.22*
C5 (Short-Time Inverse)	$t_p = TmDial \bullet \left(\frac{0.05}{M^{0.04} - 1}\right)$	$t_r = TmDial \bullet \left(\frac{4.85}{1 - M^2}\right)$	*Figure 4.23*

where:
t_p = operating time in seconds (see *Note on page 4.15*)
t_r = electromechanical induction—disk emulation reset time in seconds (if you select electromechanical reset setting)
TmDial = time-dial setting
M = applied current in multiples of pickup current [for operating time (t_p), M>1; for reset time (t_r), M≤1]

Figure 4.14 U.S. Moderately Inverse Curve: U1

Figure 4.15 U.S. Inverse Curve: U2

Figure 4.16 U.S. Very Inverse Curve: U3

Figure 4.17 U.S. Extremely Inverse Curve: U4

Figure 4.18 U.S. Short-Time Inverse Curve: U5

Figure 4.19 IEC Class A Curve (Standard Inverse): C1

Figure 4.20 IEC Class B Curve (Very Inverse): C2

Figure 4.21 IEC Class C Curve (Extremely Inverse): C3

Figure 4.22 IEC Long-Time Inverse Curve: C4

Figure 4.23 IEC Short-Time Inverse Curve: C5

Under- and Overvoltage Functions

The SEL-851 provides two levels of phase-to-phase overvoltage and undervoltage elements regardless of the phase voltage input connections. Two levels of residual ground overvoltage elements are available when the voltage inputs are connected in wye configuration (VTP.Conn := WYE and VTP.SingleV := N) as shown in *Figure 2.20*.

Each of the elements has an associated pick up value, trip delay, and torque control setting. You can select Fundamental_Min or Fundamental_Max as the operating quantity for the undervoltage and overvoltage functions. When only a single voltage input is available, 27PP_*n*.OpQty and 59PP_*n*.OpQty are forced to Fundamental_Min and Fundamental_Max, respectively, and the settings are hidden because the operating quantities are identical. You can use these elements as you choose for tripping and warning. *Figure 4.24* and *Figure 4.25* show the logic diagrams for the undervoltage and overvoltage elements, respectively. To disable any of these elements, set the corresponding enable settings equal to OFF.

Table 4.15 Phase-to-Phase Undervoltage Function[a] (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PH-PH UNDERVOLTAGE ENABLE	OFF, 1–2	27PP.Ena := OFF
PH-PH UNDERVOLTAGE *n* OPERATE QUANTITY	Fundamental_Min, Fundamental_Max	27PP_*n*.OpQty := Fundamental_Min
PH-PH UNDERVOLTAGE *n* PICKUP VALUE	5.00–300.00 V sec[b] 5.00–520.00 V sec[c]	27PP_*n*.PUVal := 50.00

Table 4.15 Phase-to-Phase Undervoltage Function[a] (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PH-PH UNDERVOLTAGE *n* TRIP DELAY	OFF, 0.00–240.00 s	27PP_*n*.PUDly := 0.00
PH-PH UNDERVOLTAGE *n* TORQUE CONTROL	SELOGIC	27PP_*n*.TorqCtl := 1

[a] n = 01, 02.
[b] When VTP.Conn := DELTA.
[c] When VTP.Conn := WYE.

Table 4.16 Phase-to-Phase Overvoltage Function[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
PH-PH OVERVOLTAGE ENABLE	OFF, 1–2	59PP.Ena := OFF
PH-PH OVERVOLTAGE *n* OPERATE QUANTITY	Fundamental_Min, Fundamental_Max	59PP_*n*.OpQty := Fundamental_Max
PH-PH OVERVOLTAGE *n* PICKUP VALUE	5.00–300.00 V sec[b] 5.00–520.00 V sec[c]	59PP_*n*.PUVal := 80.00
PH-PH OVERVOLTAGE *n* TRIP DELAY	OFF, 0.00–240.00 s	59PP_*n*.PUDly := 0.00
PH-PH OVERVOLTAGE *n* TORQUE CONTROL	SELOGIC	59PP_*n*.TorqCtl := 1

[a] n = 01, 02.
[b] When VTP.Conn := DELTA.
[c] When VTP.Conn := WYE.

Table 4.17 Residual Ground Overvoltage Function[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
GROUND OVERVOLTAGE ENABLE	OFF, 1–2	59Gnd.Ena := OFF
GROUND OVERVOLTAGE *n* PICKUP VALUE	5.0–300.0 V sec	59Gnd_*n*.PUVal := 6.0
GROUND OVERVOLTAGE *n* TRIP DELAY	OFF, 0.00–240.00 s	59Gnd_*n*.PUDly := 0.50
GROUND OVERVOLTAGE *n* TORQUE CONTROL	SELOGIC	59Gnd_*n*.TorqCtl := 1

[a] n = 01, 02.

S1 Position:
1 if 27PP_n.OpQty = Fundamental_Min
2 if 27PP_n.OpQty = Fundamental_Max

VPP.MinMagSec = Minimum(VAB.MagSec, VBC.MagSec, VCA.MagSec)
VPP.MaxMagSec = Maximum(VAB.MagSec, VBC.MagSec, VCA.MagSec)

Figure 4.24 Phase-to-Phase Definite-Time Undervoltage Element Logic

Figure 4.25 Phase-to-Phase Definite-Time Overvoltage Element Logic

Figure 4.26 Residual Ground Definite-Time Overvoltage Logic

Loss-of-Potential (LOP) Protection

The loss-of-potential logic is used to detect the loss of relay ac voltage input caused by blown potential fuses or by the operation of molded-case circuit breakers. This element is available in models with the voltage option. Because accurate relaying potentials are necessary for certain protection elements (undervoltage 27 elements, for example), you can use the LOP function to supervise these protection elements. Refer to *Figure 4.27* through *Figure 4.30* for the LOP logic. The relay uses two methods to detect an LOP condition—incremental loss-of-potential logic and negative-sequence loss-of-potential logic.

Incremental Loss-of-Potential Logic

The relay latches 60LOP.IncPU when there is more than a 10 percent drop in the measured positive-sequence voltage (VPos.MagSec) with no corresponding magnitude or angle change (greater than a pre-determined threshold) in positive-sequence (IPos.MagSec), negative-sequence (INeg.MagSec), or zero-sequence currents (IGnd.MagSec). The detector for change in zero-sequence (IGnd.DeltaPU) current is shown in *Figure 4.27*. Similar logic applies to the positive-sequence (IPos.DeltaPU; uses threshold of 0.1 • CTP.NomSec) and negative-sequence (INeg.DeltaPU) current detectors. The relay resets the 60LOP.InPU Relay Word bit when the conditions of the RESET input of the latch are met, as shown in *Figure 4.28*.

Figure 4.27 Detector for Change in Zero-Sequence Current

Figure 4.28 Incremental Loss-of-Potential (LOP) Logic

Negative-Sequence Loss-of-Potential Logic

The negative-sequence logic, shown in *Figure 4.29*, checks for a significant negative-sequence voltage, i.e., greater than 15 percent of VPos.NegSec, without a coincident negative-sequence current. This logic can be used to detect slow-blow fuses where the negative-sequence voltage drops significantly without a matching change in currents.

Figure 4.29 Negative-Sequence Loss-of-Potential Logic

Loss-of-Potential Latch Logic

Assertion of 60LOP.InPU or 60LOP.NegPU for more than 0.3 seconds latches the output 60LOP.PU. This output can be used for alarm or trip conditions. The output deasserts immediately after an LOP reset condition when 60LOP.Rst is asserted.

Figure 4.30 Loss-of-Potential Latch Logic

Settings

For models with the voltage option, the LOP function is always active unless blocked by the corresponding SELOGIC control equation, 60LOP.Blk (see *Table 4.18* for the setting and *Figure 4.27* through *Figure 4.30* for the LOP logic). The default value is 60LOP.Blk := 0. Certain switching operations can result in LOP assertion when the drop in V1 is greater than 10 percent with no or very little change in sequence currents. Consider using 60LOP.Blk to avoid assertion of LOP under such conditions. You must incorporate the LOP function in a SELOGIC control equation to supervise relay protection elements (see *Example 4.4*).

Table 4.18 Loss-of-Potential (LOP) Setting

Setting Prompt	Setting Range	Setting Name := Factory Default
LOSS OF POTENTIAL BLOCK	SELOGIC	60LOP.Blk := 0

LOP Impact on Other Protection Elements

Undervoltage, power, and power factor elements require accurate relaying potentials for correct operation. It is critical that the relay detects an LOP condition and prevents operation of these elements. For example, when dropping a wrench on the phase-voltage input fuse holders, the relay LOP logic accurately determines that this loss of input voltages is an LOP condition and does not trip if the 60LOP.PU Relay Word bit supervises selected tripping elements (see *Example 4.4*). If you are using voltage-determined relay elements for tripping decisions, then blocking these elements is crucial when the voltage component is no longer valid.

EXAMPLE 4.4 Supervising Voltage-Element Tripping With LOP

If you want the voltage-affected elements (e.g., 27, 55) to act only when there are correct relaying potentials, supervise the corresponding element via its SELOGIC torque-control setting:

27PP_01.TorqCtl = NOT 60LOP.PU

LOP Monitoring and Alarms

You should take steps to immediately correct an LOP problem so that normal protection is rapidly re-established. Include the 60LOP.PU Relay Word bit in an output contact alarm to notify operation personnel of a fuse loss condition and any abnormal voltage input conditions and failures that can be detrimental to the protection system performance if not quickly corrected.

Second-Harmonic Blocking Logic

When a distribution feeder supplies many transformers, magnetizing inrush currents may cause sensitive overcurrent elements to operate when the line is energized. The second-harmonic blocking logic can prevent this by blocking such elements until inrush currents have subsided. As shown in *Figure 4.31*, this logic uses the ratio of the second-harmonic content of each phase to the fundamental current of the same phase to calculate the percent harmonic content.

When the SELOGIC torque-control equation HBlk.H2_TorqCtl evaluates to logical 1, and if the second-harmonic content of a particular phase (e.g., IA.H2_MagSec for A-phase in *Figure 4.31*) exceeds the adjustable pickup threshold HBlk.H2_PUVal for the pickup time delay HBlk.H2_PUDly, the blocking Relay Word bit for that phase asserts. Once the output is asserted, if the second-harmonic content falls below the threshold for the dropout time delay HBlk.H2_DODly, the output deasserts. If any of the phase outputs asserts, Relay Word bit HBlk.H2_TmOut also asserts.

Figure 4.31 A-Phase Second-Harmonic Blocking

Figure 4.32 Three-Phase Second-Harmonic Blocking Logic

Table 4.19 Harmonic Blocking Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
2ND HARMONIC BLOCK ENABLE	Y, N	HBlk.H2_Ena := N
2ND HARMONIC BLOCK PICKUP VALUE	5–100%	HBlk.H2_PUVal := 10
2ND HARMONIC BLOCK PICKUP DELAY	0.00–320.00 s	HBlk.H2_PUDly := 0.00
2ND HARMONIC BLOCK DROPOUT DELAY	0.00–320.00 s	HBlk.H2_DODly := 0.00
2ND HARMONIC BLOCK TORQUE CONTROL	SELOGIC	HBlk.H2_TorqCtl := 1

Second-harmonic blocking elements are typically used to supervise sensitive overcurrent elements. CT saturation during faults can cause the relay to measure harmonic currents. The harmonic blocking elements may also assert briefly when the fundamental current changes. Either condition might delay the supervised element. Set an unsupervised element above the expected inrush current to provide fast protection during large faults. Set the harmonic blocking timer pickup for more than one cycle in applications that cannot tolerate the element operating because of current changes.

EXAMPLE 4.5 Instantaneous Overcurrent Element Blocking

In this example, including second-harmonic blocking element HBlk.H2_TmOut in the torque-control equation for Level 1 phase overcurrent element 50P_01 prevents operation during transformer inrush.

50P_01.PUVal := **10.00 A**
50P_02.PUVal := **20.00 A**
50P_01.PUDly := **0.03 sec**
50P_01.TorqCtl := **NOT HBlk.H2_TmOut**
50P_02.TorqCtl := **1**
Trip_01.Init := **...OR 50P_01.TmOut OR 50P_02.TmOut OR...**

The Level 1 time delay 50P_01.PUDly allows time for the blocking element to assert. Level 2 phase overcurrent element setting 50P_02.PUVal is high enough that the element does not operate when the line is energized but low enough to operate for high current faults while current transformer saturation or fundamental frequency current change might briefly block the Level 1 element.

EXAMPLE 4.6 Time-Overcurrent Element Blocking

For time-overcurrent elements, it may be desirable for the element to continue timing when transformer inrush is detected, yet trip the breaker if the time-overcurrent element remains asserted after the inrush conditions have subsided.

51P_01.PUVal := **6.00 A**
51P_02.PUVal := **10.00 A**
HBlk.H2_DODly := **0.03 sec**
51P_01.TorqCtl := **1**

51P_02.TorqCtl := **1**

Trip_01.Init := **...OR 51P_01.TmOut * NOT HBlk.H2_TmOut OR 51P_02.TmOut OR...**

Event.Trg := **...OR R_TRIG 51P_01.PUVal OR R_TRIG 51P_01.TmOut OR...**

In this example, 51P_01.TmOut is allowed to assert regardless of the state of the second-harmonic blocking element. However, 51P_01.TmOut cannot cause a trip if HBlk.H2_TmOut is asserted. Dropout timer HBlk.H2_DODly ensures that the blocking condition is maintained until 51P_01.TmOut deasserts. If the reset mode is set to instantaneous (51P_n.RstMod =Instantaneous), 51P_01.TmOut remains asserted for 1 cycle after the phase current falls below pickup setting 51P_01.PUVal. HBlk.H2_DODly may be increased to provide additional security should the second-harmonic current fall below the pickup threshold before the fundamental current falls below the overcurrent element pickup. Because the relay may not trip when 51P_01.TmOut asserts, the Event.Trg Event Report Trigger SELOGIC control equation is modified to trigger an event report. This event report can be used to evaluate the effectiveness of the harmonic blocking and determine if setting adjustments are necessary.

EXAMPLE 4.7 Changing the Pickup of a Time-Overcurrent Element

Use the second-harmonic blocking elements to increase the pickup current of a time-overcurrent element during inrush conditions without changing the time delay characteristics. For example,

51P_01.PUVal := **6.00 A**

51P_02.PUVal := **15.00 A**

50P_03.PUVal := **12.00 A**

51P_01.TorqCtl := **NOT HBlk.H2_TmOut OR 50P_03.PUVal**

51P_02.TorqCtl := **1**

Trip_01.Init := **...OR 51P_01.TmOut OR 51P_02.TmOut OR...**

In this example, the maximum-phase time-overcurrent element operates if the harmonic blocking element is deasserted or the phase current exceeds the Level 3 phase instantaneous overcurrent setting. If harmonic blocking is asserted and the phase current is below the Level 3 phase instantaneous overcurrent setting, the time-overcurrent element 51P_01.PUVal does not operate. Thus the pickup of the maximum-phase time-overcurrent element 51P_01 is increased from 6 amperes secondary to 12 amperes secondary during inrush. Once the maximum phase current exceeds 50P_03.PUVal, the timing of the 51P_01 element does not change, so coordination is maintained for large faults.

As shown in Figure 4.10, if the torque control equation 51P_01.TorqCtl deasserts, the Level 1 phase time-overcurrent element may fully or partially reset. When second-harmonic blocking elements are included in torque control equations for time-overcurrent elements, the element will need to time from reset after the blocking element deasserts. Consider this when evaluating time-overcurrent coordination and when reviewing event reports in which harmonic blocking has operated.

Power Elements

You can enable as many as two independent three-phase power elements in the SEL-851. Each enabled element can be set to detect real power or reactive power. When voltage inputs to the relay are from delta-connected VTs or when you use a single voltage input, the relay cannot account for unbalance in the voltages in calculating the power. When you use one voltage (only the VA or VAB) and set VTP.SingleV := Y, the relay assumes that the system voltages are balanced in both magnitude and phase angle. Power and power factor are calculated assuming balanced voltages. Take this into consideration in applying the power elements.

Table 4.20 Voltages When Setting VTP.SingleV := Y

VTP.Conn Setting	Sys.PhRot Setting	Voltages
WYE	ABC	VA = |Va| ∠ϕ° VB = |Va| ∠ϕ–120° VC = |Va| ∠ϕ+120°
WYE	ACB	VA = |Va| ∠ϕ° VB = |Va| ∠ϕ+120° VC = |Va| ∠ϕ–120°
DELTA	ABC	VAB = |Vab| ∠ϕ° VBC = |Vab| ∠ϕ–120° VCA = |Vab| ∠ϕ+120°
DELTA	ACB	VAB = |Vab| ∠ϕ° VBC = |Vab| ∠ϕ+120° VCA = |Vab| ∠ϕ–120°

With SELOGIC control equations, the power elements provide a wide variety of protection and control applications. Typical applications are:

- Overpower protection/control
- Forward/reverse power protection/control
- VAR control for capacitor banks

Table 4.21 Power Element Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
POWER ELEMENTS ENABLE	OFF, 1–2	32.Ena := OFF
POWER ELEMENT *n* PICKUP VALUE	20.0–200.0% VA	32_*n*.PUVal := 50
POWER ELEMENT *n* OPERATE QUANTITY	+WATTS, –WATTS, +VARS, –VARS	32_*n*.OpQty := –WATTS
POWER ELEMENT *n* PICKUP DELAY	OFF, 0.00–240.00 s	32_*n*.PUDly := 10
POWER ELEMENT *n* TORQUE CONTROL	SELOGIC	32_*n*.TorqCtl := 1

[a] n = 01, 02.

Set the element pickup settings, 32_*n*.PUVal (where *n* = 01, 02), to the values you want in percent of nominal VA. For example:

$$\text{Nominal VA} = 1.732 \bullet \text{Sys.VNom} \bullet \text{CTP.NomSec} \bullet \text{CTP.Rat kVA primary}$$

Figure 4.33 shows the power element logic diagram, and *Figure 4.34* shows the operation in the real/reactive power plane.

Notes:
A. S1 Position: 1 if 32_n.OpQty = ±WATTS
2 if 32_n.OpQty = ±VARS

B. S2 Position: 1 if 32_n.OpQty = +WATTS or +VARS
2 if 32_n.OpQty = –WATTS or –VARS

C. 32_[n] Pickup = (32_n.PUVal / 100) • 1.732 • (Sys.VNom • 1000 / VTP.Rat) • CTP.NomSec
= (17.32 • 32_n.PUVal •Sys.VNom •CTP.NomSec) / VTP.Rat VA, sec

Figure 4.33 Three-Phase Power Elements Logic

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
- –VARS: negative or reverse reactive power

The two power element time delay settings, 32_01.PUDly and 32_02.PUDly, 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 0.1 second 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.

The power elements are not supervised by any relay elements other than the minimum voltage check shown in *Figure 4.33*. Additional supervision can be provided via the torque control (TorqCtl) setting.

Figure 4.34 Power Elements Operation in the Real/Reactive Power Plane

Power Factor Elements

Table 4.22 Power Factor Element Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
POWER FACTOR ELEMENT ENABLE	OFF, 1–2	55.Ena := OFF
POWER FACTOR ELEMENT *n* PICKUP VALUE	0.05–0.99	55_*n*.PUVal := 0.80
POWER FACTOR ELEMENT *n* TYPE	LEAD, LAG	55_*n*.Type := LAG
POWER FACTOR ELEMENT *n* PICKUP DELAY	OFF, 0.00–240.00 s	55_*n*.PUDly := 1.00
POWER FACTOR ELEMENT *n* TORQUE CONTROL	SELOGIC	55_*n*.TorqCtl := 1

[a] n = 01, 02.

If the measured power factor falls below the leading or lagging pick up value for longer than the time-delay setting, the relay can issue a warning or trip signal. Each element can be torque controlled through the use of appropriate SELOGIC control equations (e.g., when 55_*n*.TorqCtl := Bkr_01.52A_Sta, the

55 element is operational only if Bkr_01.52A_Sta is asserted). *Figure 4.35* shows the logic diagram for the power factor elements. Refer to *Figure 5.1* for the relay power measurement convention.

Figure 4.35 Power Factor Elements Logic

Frequency Protection

NOTE: The frequency measurement gives priority to the voltage inputs when available. If there is 10 V of positive-sequence voltage (V1), then the frequency algorithm tracks on V1; otherwise, it uses the zero-crossing of Valpha, where Valpha = (2 • Va–Vb–Vc)/3. If there is 0.1 A of positive-sequence current (I1), then the frequency algorithm tracks on I1; otherwise, it uses the zero-crossings of Ialpha, where Ialpha = (2 • Ia–Ib–Ic)/3. The relay needs Valpha >5 V or Ialpha >0.1 A to measure frequency. Otherwise, the measured frequency is set to the nominal frequency setting (Sys.FNom).

The SEL-851 with the voltage option provides two over- or underfrequency elements with independent pick up time-delay and torque control settings. *Table 4.23* lists the ranges and settings. When an element pick up value is less than the nominal frequency setting, the element operates as an underfrequency element. When the level setting is greater than or equal to the nominal frequency setting, the element operates as an overfrequency element. *Figure 4.36* shows the logic diagram for the frequency elements.

Table 4.23 Frequency Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
FREQUENCY ELEMENT ENABLE	OFF, 1–2	81.Ena := OFF
FREQUENCY ELEMENT *n* PICKUP VALUE	15.00–70.00 Hz	81_*n*.PUVal := 60.00
FREQUENCY ELEMENT *n* TRIP DELAY	OFF, 0.04–240.00 s	81_*n*.PUDly := 1.00
FREQUENCY ELEMENT *n* TORQUE CONTROL	SELOGIC	81_*n*.TorqCtl := 1

[a] n = 01, 02.

Figure 4.36 Over- and Underfrequency Element Logic

Breaker Failure Settings

The SEL-851 provides flexible breaker failure logic (see *Figure 4.37*). The breaker failure initiate SELOGIC control equation, BF_01.Init, is set to Trip_01.Sta by default. Assertion of Relay Word bit Trip_01.Sta starts the BF_01.PUDly timer if any of the phase currents remain greater than the BF_01.50P_PUVal setting or the breaker failure supervision SELOGIC control equation, BF_01.Supv, is asserted. Program BF_01.Supv to additional supervising conditions applicable to your application.

For added security against inadvertent breaker failure initiations (e.g. wiring or testing errors), program the breaker failure retrip delay setting, BF_01.RetripDly, to a value other than OFF. BF_01.RetripDly begins timing when BF_01.Init and one of the supervisory elements asserts. Coordinate BF_01.PUDly setting for any added BF_01.RetripDly delay. Program BF_01.Retrip_TmOut in the Trip_01.Init SELOGIC control equation to issue a retrip to the breaker.

Table 4.24 Breaker Failure Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
BREAKER FAIL 01 ENABLE	Y, N	BF_01.Ena := Y
BREAKER FAIL 01 CURRENT DETECTOR PICKUP	0.02–10.00 A	BF_01.50P_PUVal := 0.50
BREAKER FAIL 01 PICKUP DELAY	0.00–2.00 s	BF_01.PUDly := 0.50
BREAKER FAIL 01 SUPERVISION	SELOGIC	BF_01.Supv := 0
BREAKER FAIL 01 INITIATE	SELOGIC	BF_01.Init := Trip_01.Sta
BREAKER FAIL 01 SEAL-IN DELAY	OFF, 0.00–2.00 s	BF_01.SealinDly := OFF
BREAKER FAIL 01 RETRIP DELAY	OFF, 0.00–2.00 s	BF_01.RetripDly := 0.05
BREAKER FAIL 01 TRIP EQUATION	SELOGIC	BF_01.Trip_Init := BF_01.TmOut
BREAKER FAIL 01 UNLATCH TRIP	SELOGIC	BF_01.UnltTrip := 0

IP.MagSec is the maximum of the fundamental phase current (In.MagSec), where n = A, B, or C.

Figure 4.37 Breaker Failure Logic

Changing the BF_01.Init, BF_01.50P_PUVal, BF_01.SealinDly, or BF_01.RetripDly settings will modify the default breaker failure logic.

➤ To maintain a seal-in of the breaker failure initiate, set BF_01.SealinDly to a value other than OFF. To bias your application towards security set BF_01.SealinDly to a finite delay or OFF.

- If breaker failure initiation is not desired on manual trip, set BF_01.Init to the protective element Relay Word bits used in the Trip_01.Init SELOGIC equation (e.g., BF_01.Init := 50P_01.TmOut OR 51P_01.TmOut OR...).
- BF_01.RetripDly may be set to provide a security time delay for a retrip attempt of the breaker.

Figure 4.38 Breaker Failure Trip Logic

Include Relay Word bit BF_01.TmOut in the SELOGIC control equation BF_01.Trip_Init (breaker failure trip equation), if you want to use the breaker failure trip logic shown in *Figure 4.38*. When BF_01.Trip_Init evaluates to logical 1, Relay Word bit BF_01.Trip asserts and seals in. Include BF_01.Trip in a contact output equation to trip backup breakers via an auxiliary tripping relay, or use multiple contact outputs to direct trip adjacent breakers to clear the zone. For example,

OUT_04.Sta = BF_01.Trip

Relay Word bit Trip.TrgtRstSta and SELOGIC control equation BF_01.UnltTrip reset BF_01.Trip. The minimum trip duration of BF_01.Trip is controlled by protection setting Trip_01.MinDur. See *Trip/Close Logic on page 4.36* for a description of minimum trip duration timers, trip unlatch conditions, and operation of Relay Word bit Trip.TrgtRstSta.

The breaker failure logic does not automatically trigger an event report. Modify the SELOGIC event report trigger equation Event.Trg to trigger an event when a breaker failure trip occurs. For example:

Event.Trg = R_TRIG 51P_01.PU OR R_TRIG 51Gnd_01.PU OR R_TRIG BF_01.Trip OR…

Arc-Flash Protection

The SEL-851 offers advanced arc-flash protection capability aimed at minimizing the hazards associated with high energy arc (faults) in metal-enclosed and metal-clad switchgear. The system supports as many as four fiber-optic light sensors capable of detecting the high energy arc-flash events and tripping the breaker within milliseconds of the fault. Light sensors are supervised with an instantaneous overcurrent element offering enhanced security against false trips. Each of the four sensors can be routed to multiple tripping outputs by using SELOGIC control equations, offering ultimate flexibility in creating multiple protection zones (breaker truck cabinet, bus, VT cubicle, etc.).

SEL-851 arc-flash protection is exceptionally fast. Typical relay operating times are in the order of 1–2 ms with the default configuration using the fast hybrid (high-speed) output contact. With standard, electromechanical outputs, tripping time increases to 6–10 ms. Fault clearing time is typically longer, determined by the breaker operating time, which often adds three to five cycles.

This system supports two distinct types of fiber-optic light sensors. The first type is the omni-directional ***point sensor*** optimized for installation in individual switchgear compartments. The second sensor is the ***clear-jacketed fiber*** loop sensor optimized for protection of long, distributed resources, such as the switchgear bus compartment. Supervision of both types of sensors comes from use of a loopback-based attenuation measurement method, and you can use both sensors interchangeably on each of the four light inputs. Refer to *Application Guide AG2011-01: Using the SEL-751 and SEL-751A for Arc-Flash Detection* for more details.

Arc-Flash Overcurrent Elements (AFD.50P_PUVal, AFD.50N_PUVal)

Table 4.25 shows the settings for the arc-flash instantaneous overcurrent elements. Two elements are provided; the three-phase overcurrent element AFD.50P_PU and the neutral overcurrent element AFD.50N_PU.

Table 4.25 Arc-Flash Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ARC FLASH DETECTION ENABLE	Y, N	AFD.Ena := N
ARC FLASH PHASE OC PICKUP VALUE	OFF, (0.10–20.00) • CTP.NomSec	AFD.50P_PUVal := OFF
ARC FLASH NEUTRAL OC PICKUP VALUE	OFF, (0.10–20.00) • CTN.NomSec	AFD.50N_PUVal := OFF

The arc-flash overcurrent elements use raw A/D converter samples and the elements are processed every 1 ms. Individual samples are compared with the setting threshold as shown in *Figure 4.39*, followed by a security counter requiring that four samples in a row be greater than the setting threshold. Although both elements operate on instantaneous current values, additional scaling is applied to present settings in the user-friendly "rms" format.

Fast overcurrent detectors do not reject harmonics and therefore may "overreach" under high harmonic load conditions. To avoid unintended element pickup, Arc-flash trip level AFD.50P_PUVal should be set at least 2 times the expected maximum load. Temporary activation of the arc-flash overcurrent element during inrush/load pickup conditions is expected and is normally taken into account by the arc-flash "light based" supervision.

Figure 4.39 Arc-Flash Instantaneous Overcurrent Element Logic

Arc-Flash Time-Overlight Elements (AFD.Sen01 through AFD.Sen04)

The SEL-851 offers as many as four fiber-optic light sensor inputs. Each input is associated with one inverse time-overlight element offering enhanced security coupled with exceptionally fast operation. Shape of the inverse-time characteristic is fixed offering robust rejection of unrelated light events without adding unnecessary settings. *Table 4.26* shows the arc-flash time-overlight element settings.

Each sensor channel has a user selectable sensor type (NONE, POINT, or FIBER) representing the type of sensor installed. Keyword POINT represents a point sensor, while the keyword FIBER represents a clear-jacketed fiber loop sensor.

The AFD.Sen*n*_PUVal (where *n* = 01–04) pickup parameter makes it possible to set the individual light threshold levels for each of the four sensors. The pickup level is expressed in the percent of full scale, which is directly related to the light intensity level measured by the sensor.

When necessary, channel sensitivity can be compared to a light intensity level expressed in lux as shown in *Table 4.27*. However, because light sensitivity is associated with fiber length (which is installation dependent), AFD.Sen*n* element settings are expressed as a percentage of the available A/D converter range.

Table 4.26 Arc-Flash Time-Overlight Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ARC FLASH INPUT SENSOR 1 TYPE	NONE, POINT, FIBER	AFD.Sen01_Typ := NONE
ARC FLASH INPUT SENSOR 1 PICKUP VALUE	3.0–80.0 % [a] 0.6–80.0 % [b]	AFD.Sen01_PUVal := 3.0
ARC FLASH INPUT SENSOR 2 TYPE	NONE, POINT, FIBER	AFD.Sen02_Typ := NONE
ARC FLASH INPUT SENSOR 2 PICKUP VALUE	3.0–80.0 % [a] 0.6–80.0 % [b]	AFD.Sen02_PUVal := 3.0
ARC FLASH INPUT SENSOR 3 TYPE	NONE, POINT, FIBER	AFD.Sen03_Typ := NONE
ARC FLASH INPUT SENSOR 3 PICKUP VALUE	3.0–80.0 % [a] 0.6–80.0 % [b]	AFD.Sen03_PUVal := 3.0
ARC FLASH INPUT SENSOR 4TYPE	NONE, POINT, FIBER	AFD.Sen04_Typ := NONE
ARC FLASH INPUT SENSOR 4 PICKUP VALUE	3.0–80.0 % [a] 0.6–80.0 % [b]	AFD.Sen04_PUVal := 3.0

[a] Setting range with point sensor.
[b] Setting range with fiber sensor.

Figure 4.40 Inverse Time-Overlight Element Logic

Figure 4.41 shows the inverse time-overlight element curve shape. The element uses 10 kHz data that is processed every 1 ms. It ensures that for low light levels, element operation cannot be delayed for more than 4 ms.

Figure 4.41 TOL Element Inverse Curve Characteristic

Setting the Arc-Flash Time-Overlight Element

Given the critical nature of the arc-flash protection function it is recommended that the element be set based on the ambient light level. This approach guarantees maximum sensitivity coupled with the fastest tripping time.

Typical ambient light levels are shown in *Table 4.27*. It is easy to see, that the arc-flash event significantly exceeds virtually all illumination levels normally found in a substation environment. The only exception is exposure to direct sunlight, which can easily reach or exceed arc-flash AFD.Sen*n* element setting thresholds.

The AFD.Sen*n*_PUVal pickup is typically set based on the ambient light level. Ambient light is continuously measured and can be easily displayed by using the **MET L** command. Set the AFD.Sen*n*_PUVal pickup to the lowest possible light intensity level but greater than the highest-expected ambient light intensity level at each light-sensor installation.

Table 4.27 Typical Ambient Illumination Light Levels

Light Level	Example
50 lux	Living room
80 lux	Brightly lit room
500 lux	Brightly lit office
1,000 lux	TV studio
> 20,000 lux	Direct sunlight
20,000 to >1,000,000 lux	Arc-flash event[a]

[a] A. D. Stokes, D. K. Sweeting, "Electric Arc Burn Hazards", IEEE Transactions on industry applications, Vol. 42, No. 1. January/February 2006.

Arc-flash protection, in general, requires both the measuring of an overcurrent (AFD.50P and/or AFD.50N pickup) and the detection of light (AFD.Sen*n* pickup). The AND combination of the above two conditions should be used to trip in most cases for secure operation (see Trip_01.Init in *Table 4.28* for default configuration). In applications where intermittent loss of load can be tolerated (noncritical loads), it may be desirable to operate without overcurrent element supervision, relying only on the light detection element instead of having the overcurrent element supervise the light element. This approach offers the fastest tripping times, but is less secure. Refer to *Example 4.8* and *Example 4.9* for additional output logic programming.

Output Logic Programming

As stated earlier, arc-flash protection involves detecting an overcurrent as well as light (arc). Location of the light sensors and source(s) of the arc energy must also be considered in developing the trip output logic. If the relay detects both signals simultaneously, it is desirable to trip the "source breaker(s)."

NOTE: Fast hybrid contacts are designed for fast closing (50 µs) only. Fail-safe mode operating time (time to open the contacts) for fast-hybrid contacts is <8 ms (the same time as for a normal output contact).

The Relay Word bits for arc-flash protection (see *Figure 4.39* and *Figure 4.40*) are: AFD.50P_PU, AFD.50N_PU, AFD.Sen01_PU, AFD.Sen02_PU, AFD.Sen03_PU, and AFD.Sen04_PU.

You should use the high-speed contact, OUT_01.Sta or OUT_02.Sta for arc-flash tripping. Also to ensure all the advantages of the trip logic (trip seal-in, event report trigger, etc.) the arc-flash trip should be included in the trip equation Trip_01.Init (see *Table 4.28* and *Figure 4.42* for detail).

EXAMPLE 4.8 Output Logic Programming Example 1:

SEL-851 applied at the source breaker.

Assume light sensors 1, 2, and 3 are located downstream of the source breaker and output contact OUT_01.Sta is selected.

Set:

OUT_01.FailSafe := **N**

OUT_01.Sta := **(AFD.50P_PUVal OR AFD.50N_PUVal) AND (AFD.Sen01_PU OR AFD.Sen02_PU OR AFD.Sen03_PU) OR Trip_01.Sta**

Trip_01.Init := **50.TmOut OR 51P_01.TmOut OR … OR (AFD.50P_PU OR AFD.50N_PU) AND (AFD.Sen01_PU OR AFD.Sen02_PU OR AFD.Sen03_PU**)

EXAMPLE 4.9 Output Logic Programming Example 2:

SEL-851 applied at the radial feeder breaker.

Assume light sensors 1 and 2 are located downstream, light sensor 3 is located upstream of the feeder breaker, and output contacts OUT_01.Sta and OUT_02.Sta are selected.

Set:

OUT_01.FailSafe := **N,** OUT_02.FailSafe := **N**

OUT_01.Sta := **(AFD.50P_PU OR AFD.50N_PU) AND (AFD.Sen01_PU OR AFD.Sen02_PU) OR Trip_01.Sta**

OUT_02.Sta := **AFD.Sen03_PU**

Trip_01.Init := **50.TmOut OR 51P_01.TmOut OR … OR (AFD.50P_PU OR AFD.50N_PU) AND (AFD.Sen01_PU OR AFD.Sen02_PU)**

Use the OUT_02.Sta contact to trip upstream breaker. Note that OUT_02.Sta does not include overcurrent element supervision. When desired, this supervision should be added by upstream relay(s). For instance, you can do the following:

- Connect OUT_02.Sta of feeder breaker 2 relay to drive IN_01.Sta of the source breaker 1 relay.
- Add IN_04.Sta to the OR string of TOLn in both OUT_01.Sta and Trip_01.Init equations of source breaker 1 relay. You can use MIRRORED BITS instead of IN_04.Sta for faster operation if desired.

Trip/Close Logic

NOTE: The factory-default assignment of Relay Word bit Trip_01.Sta is output OUT01. See Table 4.34 for the output contacts settings.

The SEL-851 tripping logic is designed to trip the circuit breakers. The relay logic lets you define the conditions that cause a trip, the conditions that unlatch the trip, and the performance of the relay output contact. *Figure 4.42* illustrates the tripping logic.

Table 4.28 Trip/Close Logic Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
MINIMUM TRIP DURATION	0.0–400.00 s	Trip_01.MinDur := 0.5
PROTECTION TRIP EQUATION[a]	SELOGIC	Trip_01.Init := 50TmOut OR 51P_01.TmOut OR 51Gnd_01.TmOut OR 51Neg_01.TmOut OR Trip_01.InitX
EXTENDED PROTECTION TRIP EQUATION	SELOGIC	Trip_01.InitX := 0
LOCAL TRIP EQUATION	SELOGIC	Trip_01.LocInit := IN_03.Sta
REMOTE TRIP EQUATION	SELOGIC	Trip_01.RemInit := 0
UNLATCH TRIP EQUATION	SELOGIC	Trip_01.Unlt := NOT Bkr_01.52A_Sta
BREAKER STATUS	SELOGIC	Bkr_01.52A_Sta := IN_01.Sta
REMOTE CONTROL EQUATION	SELOGIC	Ctl.RemSel := 0
LOCAL CLOSE EQUATION	SELOGIC	Close_01.LocInit := IN_04.Sta
REMOTE CLOSE EQUATION	SELOGIC	Close_01.RemInit := 0
CLOSE FAILURE DELAY	OFF, 0.0–400.0 s	Close_01.FailDly := 1.0
UNLATCH CLOSE EQUATION	SELOGIC	Close_01.Unlt := 0

[a] This default is for models without the arc-flash detection option. When the arc-flash detection option is supported, default setting is Trip_01.Init := 50.TmOut OR 51P_01.TmOut OR 51Gnd_01.TmOut OR 51Neg_01.TmOut OR (AFD.50P_PU OR AFD.50N_PU) AND (AFD.Sen01_PU OR AFD.Sen02_PU OR AFD.Sen03_PU OR AFD.Sen04_PU) OR Trip_01.InitX.

Note: Switch S1 is normally in position 2, except when control from the HMI is blocked by setting HMI.CtlBlk = BlkCtl. See Figure 4.43 for the close logic.

Figure 4.42 Trip Logic

The trip logic settings, including the SELOGIC control equations, are described in the following text.

Minimum Trip Duration Time

This timer establishes the minimum time duration for which the Trip_01.Sta Relay Word bit asserts. This is a rising-edge initiated timer.

Trips initiated by the Trip_01.Init, Trip_01.LocSta, and Trip_01.RemSta Relay Word bits are maintained for at least the duration of the minimum trip duration time (Trip_01.MinDur) setting.

Relay Word bit Trip_01.LocSta includes trips initiated via the front-panel TRIP pushbutton or HMI. Relay Word bit Trip_01.RemSta includes trips initiated via communication protocols.

Trip Conditions SELOGIC Control Equation

NOTE: Avoid using the rising-edge trigger (R_TRIG) of Relay Word bit in the Trip_01.Init equation. It will cause a 4 ms delay in tripping and may report an incorrect trip type in the event report and on the HMI.

The SEL-851 Trip_01.Init SELOGIC control equation initiates the breaker trip. Make sure Trip_01.Init includes an OR combination of all the Relay Word bits required for the application. The factory-default setting already includes all commonly necessary Relay Word bits as shown in *Table 4.28*. The trip conditions trigger an event report.

The outputs in the SEL-851 are not designed to interrupt the trip coil current. An auxiliary contact with adequate current interrupting capacity must clear the trip coil current before the output of the SEL-851 opens. Failure to observe this safeguard could result in damage to the SEL-851 output contacts. Avoid programming Relay Word bit Trip_01.Init in the output equation to directly trip the breaker. Instead, use Relay Word bit Trip_01.Sta (output of trip logic), which stays asserted for at least the duration of the Trip_01.MinDur setting or

until Trip_01.Sta is unlatched, whichever is longer. Default relay settings have output OUT_01.Sta set to Trip_01.Sta and fail-safe setting OUT_01.FailSafe at N (see *Fail-Safe/Nonfail-Safe Tripping on page 2.14*).

Local Trip Conditions SELOGIC Control Equation

The Trip_01.LocInit SELOGIC control equation is intended to define a local trip condition. For example, the following settings trip the breaker via a local switch that is hardwired to relay Input IN03.

Trip_01.LocInit := IN_03.Sta

Trip_01.Init := ... OR Trip_01.LocInit

The HMI displays `Local Trip` to indicate the trip by Local trip logic.

You can map any Relay Word bit or SELOGIC control equation to Trip_01.LocInit to trip the breaker.

Remote Trip Conditions SELOGIC Control Equation

The Trip_01.RemInit SELOGIC control equation is intended to define a remote trip condition. For example, the following settings trip the breaker via a control room switch that is hardwired to relay Input IN04.

Trip_01.RemInit := IN_04.Sta

Trip_01.Init := ... OR Trip_01.RemInit

The HMI displays `Remote Trip` to indicate the trip by Remote trip logic.

You can map any Relay Word bit or SELOGIC control equation to the Trip_01.RemInit to trip the breaker.

Unlatch Trip Logic

Following a fault, the trip signal is maintained until all of the following conditions are true:

NOTE: The factory-default setting Trip_01.Unlt provides an automatic reset of the trip when the breaker opens.

- Minimum trip duration time (Trip_01.MinDur) passes.
- The Trip_01.Init SELOGIC control equation result deasserts to logical 0.
- One of the following occurs:
  - Unlatch Trip SELOGIC control equation setting Trip_01.Unlt asserts to logical 1.
  - Target Reset SELOGIC control equation setting Trip.TrgtRst asserts to logical 1.
  - Target Reset Relay Word Trip.TrgtRstSta asserts. Trip.TrgtRstSta is asserted when the front-panel **TARGET RESET** pushbutton is pressed or a target reset serial port command is executed (ASCII or Modbus).

52A Breaker Status SELOGIC Control Equation

You can connect an auxiliary contact of the breaker to the relay. SELOGIC control equation 52A allows you to configure the relay for either the 52b or 52a contact input (or other contact that indicates a closed breaker). The factory-default setting assumes the auxiliary contact is connected to IN01 (Bkr_01.52A_Sta := IN_01.Sta).

Close Logic

The SEL-851 Close Logic offers three ways to close the circuit breaker:

- Conditions mapped to Close_01.LocInit (Local mode) or Close_01.RemInit (Remote mode)
- Front-panel or serial port (including Modbus) **CLOSE** command
- Automatic reclosing when open interval times out (qualified by SELOGIC control equation setting 79.ClsSupv—see *Figure 4.44*).

The relay controls the closing output contact(s) when the Relay Word bit Close_01.Sta appears in an output contact SELOGIC control equation. Default relay settings have output OUT_03.Sta set to Close_01.Sta. See *Figure 2.23* for typical close circuit connection.

Set the Close_01.LocInit or Close_01.RemInit SELOGIC control equation to include an OR-combination of all Relay Word bits that you want to cause the relay to close breaker.

Unlatch Close Logic

Once the Close_01.Sta bit is asserted it is sealed-in until any of the following conditions are true:

- Unlatch Close SELOGIC control equation setting Close_01.Unlt asserts to logical 1.
- Relay Word Bkr_01.52A_Sta asserts to logical 1.
- Close failure Close_01.Fail Relay Word bit asserts to logical 1.

Close Failure Logic

Set the close failure delay (setting Close_01.FailDly) equal to highest breaker close time plus a safety margin. If the breaker fails to close, the Relay Word Close_01.Fail asserts for 4 ms. Use the Close_01.Fail bit as desired.

Local/Remote Control

At any one time, the SEL-851 can either be in Local or Remote mode for manual close and trip controls. The control mode can be selected using one of the following:

- Local/Remote pushbutton on the HMI
- Contact input (via SELOGIC setting Ctl.RemSel)

Per the logic shown in *Figure 4.42* and *Figure 4.43*, if the HMI.CtlBlk is not set to BLK_CTRL, then the relay forces Switch S1 to position 2. When Switch S1 is in position 2, the relay makes use of the LOCAL/REMOTE pushbutton on the HMI for control mode selection. When Switch S1 is in position 1, the relay makes use of the SELOGIC control equation Ctl.RemSel for control mode selection. Assign a contact input to the Ctl.RemSel setting for Local/Remote mode control when HMI.CtlBlk is set to BLK_CTRL. See *Section 8: HMI* for a description of the HMI. In any case, the relay must be in Local control mode for manual operation (e.g., trip or close via the HMI pushbuttons) and in Remote mode (Relay Word bit Ctl.RemSta := 1) for remote control operation (e.g., serial/Ethernet, etc.). Use the Local control mode for personnel safety (e.g., during equipment maintenance operations).

Reclose Supervision Logic

Note that one of the inputs into the close logic in *Figure 4.43* is reclosing relay open interval time-out (qualified by 79.ClsSupv), which is routed from the output of *Figure 4.44*. This input into the close logic in *Figure 4.43* is the indication that a reclosing relay open interval has timed out (see *Figure 4.45*), a qualifying condition (SELOGIC control equation setting 79.ClsSupv) has been met, and thus automatic reclosing of the circuit breaker should proceed by asserting the Close_01.Sta Relay Word bit to logical 1.

Note: Switch S1 is normally in position 2, except when control from the HMI is blocked by setting HMI.CtlBlk = BlkCtl.

① To Figure 4.44

Figure 4.43 Close Logic

① To Figure 4.43

Figure 4.44 Reclose Supervision Logic (Following Open Interval Time-Out)

Figure 4.45 Reclose Supervision Limit Timer Operation

Settings and General Operation

Figure 4.44 contains the following SELOGIC control equation setting:

> 79.ClsSupv (reclose supervision conditions—checked after reclosing relay open interval time-out)

and setting:

> 79.ClsSupvTm (Reclose Supervision Limit Time)

See *Table 4.30* for Recloser Control settings.

For Most Applications

Refer to the top of *Figure 4.44*. For most applications, the Reclose Supervision Limit Time setting should be set to zero seconds:

> 79.ClsSupvTm := **0.00**

With this setting, the logic in the top of *Figure 4.44* is operative. When an open interval times out, the SELOGIC control equation reclose supervision setting 79.ClsSupv is *checked just once*.

If 79.ClsSupv is *asserted* to logical 1 at the instant of an open interval time-out, then the now-qualified open interval time-out propagates onto the final close logic in *Figure 4.44* to automatically reclose the circuit breaker.

If 79.ClsSupv is *deasserted* to logical 0 at the instant of an open interval time-out, the following occurs:

- No automatic reclosing takes place.
- Relay Word bit 79.ClsSupvFail (reclose supervision failure indication) asserts to logical 1 for one processing interval.
- If setting 79.Ena := 1, 2, 3, or 4, the reclosing relay is driven to the lockout state.
- If setting 79.Ena := C1, C2, C3, or C4, the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay—going on to the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not satisfied. If the reclosing relay increments to the last shot value (no more open intervals left; see *Figure 4.48* and *Table 4.31*), the reclosing relay is then driven to the lockout state.

See *Example 4.10*.

For a Few, Unique Applications

Refer to the bottom of *Figure 4.44* and *Figure 4.45*.

For a few unique applications, the Reclose Supervision Limit Time setting is *not* set equal to zero seconds, e.g.,

79.ClsSupvTm := **1.00 second**

With this setting, the logic in the bottom of *Figure 4.44* is operative. When an open interval times out, the SELOGIC control equation reclose supervision setting 79.ClsSupv is then *checked for a time window* equal to setting 79.ClsSupvTm.

If 79.ClsSupv *asserts* to logical 1 at any time during this 79.ClsSupvTm time window, then the now-qualified open interval time-out propagates onto the final close logic in *Figure 4.43* to automatically reclose the circuit breaker.

If 79.ClsSupv remains *deasserted* to logical 0 during this entire 79.ClsSupvTm time window, when the time window times out, the following occurs:

- No automatic reclosing takes place.
- Relay Word bit 79.ClsSupvFail (reclose supervision failure indication) asserts to logical 1 for one processing interval.
- If setting 79.Ena := 1, 2, 3, or 4, the reclosing relay is driven to lockout state.

The logic in the bottom of *Figure 4.44* is explained in more detail in the following text.

Set Reclose Supervision Logic.

Refer to the bottom of *Figure 4.44*. If *all* the following are true:

- The close logic output Close_01.Sta (also see *Figure 4.43*) is *not* asserted (Relay Word bit Close_01.Sta = logical 0).
- The reclosing relay is *not* in the lockout state (Relay Word bit 79.LO = logical 0).
- The circuit breaker is open (Bkr_01.52A_Sta = logical 0).
- The reclose initiation condition (79.Init) is *not* making a rising edge (logical 0 to logical 1) transition.
- The Reclose Supervision Limit Timer is *not* timed out (Relay Word bit 79.ClsSupvFail = logical 0).

then a reclosing relay open interval time-out seals as shown in *Figure 4.44*. Then, when 79.ClsSupv asserts to logical 1, the sealed-in reclosing relay open interval time-out condition propagates through *Figure 4.44* and on to the close logic in *Figure 4.43*.

Unlatch Reclose Supervision Logic.

Refer to the bottom of *Figure 4.44*. If the reclosing relay open interval time-out condition is sealed-in, it stays sealed-in until *one* of the following occurs:

- The close logic output Close_01.Sta (also see *Figure 4.44*) asserts (Relay Word bit Close_01.Sta = logical 1).
- The reclosing relay goes to the lockout state (Relay Word bit 79.LO = logical 1).
- The circuit breaker closes (Bkr_01.52A_Sta = logical 1).
- The reclose initiation condition (79.Init) makes a rising-edge (logical 0 to logical 1) transition.
- SELOGIC control equation setting 79.ClsSupv asserts (79.ClsSupv = logical 1).
- The Reclose Supervision Limit Timer times out (Relay Word bit 79.ClsSupvFail = logical 1 for one processing interval).

The Reclose Supervision Limit Timer is inoperative if setting 79.ClsSupvTm := OFF. With 79.ClsSupvTm := OFF, reclose supervision condition 79.ClsSupv is not time limited. When an open interval times out, reclose supervision condition 79.ClsSupv is checked indefinitely until one of the other unlatch conditions listed previously comes true.

The unlatching of the sealed-in reclosing relay open interval time-out condition by the assertion of SELOGIC control equation setting 79.ClsSupv indicates successful propagation of a reclosing relay open interval time-out condition on to the close logic in *Figure 4.43*. See *Example 4.10*.

EXAMPLE 4.10 Settings Example 1

Refer to the top of Figure 4.44 and Figure 4.46.

Supervise SEL-851 reclose with Bus 1 hot condition.

Figure 4.46 SEL-851 Reclose Supervision Under Hot Bus Condition

SEL-851 Relay

Before allowing circuit breaker 52/1 to be reclosed after an open interval time-out, the SEL-851 checks that Bus 1 voltage is hot. This requires reclose supervision settings:

79.ClsSupvTm := **0.00 seconds** (only one check)

79.ClsSupv := **59PP_01.TmOut**

where:

59PP_01.TmOut = Bus 1 is hot

Other Setting Considerations for SEL-851 Relay

Refer to *Skip Shot (79.Skip) and Stall Open Interval Timing (79.Stall) Settings on page 4.55*.

SELOGIC control equation setting 79.Stall stalls open interval timing if it asserts to logical 1. If setting 79.Stall is deasserted to logical 0, open interval timing can continue. In *Figure 4.46*, say the SEL-851 has to see Bus 1 hot, for open interval timing to begin. SEL-851 open interval timing can be stalled while Bus 1 voltage is not hot:

79.Stall := **NOT 59PP_01.TmOut**

Set 59PP_01.PUDly to desired value to ensure a sustained Bus 1 hot condition. Once Bus 1 becomes hot, 79.Stall deasserts, allowing open interval timing to be processed.

Reclose Logic

Note that input:

Reclosing Relay Open Interval Time-Out

in *Figure 4.44* is the logic input that is qualified by SELOGIC control equation setting 79.ClsSupv, and then propagated on to the close logic in *Figure 4.43* to automatically reclose a circuit breaker. The explanation that follows in this reclosing relay subsection describes all the reclosing relay settings and logic that eventually result in this open interval time-out logic input into *Figure 4.44*. Other aspects of the reclosing relay are also explained. As many as four (4) automatic reclosures (shots) are available.

The reclose enable setting, 79.Ena, has setting choices N, 1, 2, 3, 4, C1, C2, C3, and C4. Setting 79.Ena := N defeats the reclosing relay. Setting choices 1–4 and C1–C4 are the number of automatic reclosures (see *Open Interval*

Timers on page 4.49) you want. With setting choices 1–4, the reclosing relay goes to the lockout state on reclose supervision failure (refer to *Reclose Supervision Logic on page 4.40*).

With setting choices C1–C4, however, the reclosing relay does not go to the lockout state on reclose supervision failure. Instead, the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay—going on to the next open interval time and reclose opportunity when supervising conditions for the present reclose opportunity are not true.

Reclosing Relay States and General Operation

Figure 4.47 explains in general the different states of the reclosing relay and its operation.

Figure 4.47 Reclosing Relay States and General Operation

Table 4.29 Relay Word Bit and Front-Panel Correspondence to Reclosing Relay States

Reclosing Relay State	Corresponding Relay Word Bit
Reset	79.Rst
Reclose Cycle	79.Cyc
Lockout	79.LO

The reclosing relay is in one (and only one) of these states (listed in *Table 4.29*) at any time. When in a given state, the corresponding Relay Word bit asserts to logical 1. Automatic reclosing only takes place when the relay is in the reclose cycle state.

Lockout State

The reclosing relay goes to the lockout state if any *one* of the following occurs:

- The shot counter is equal to or greater than the last shot at time of reclose initiation (e.g., all automatic reclosing attempts are unsuccessful—see *Figure 4.45*).
- Reclose initiation is unsuccessful because of SELOGIC control equation setting 79.InitSupv (see *Reclose Initiate and Reclose Initiate Supervision Settings (79.Init and 79.InitSupv, Respectively) on page 4.52*).
- The circuit breaker opens without reclose initiation (e.g., an external trip).
- The shot counter is equal to or greater than last shot, and the circuit breaker is open [e.g., the shot counter is driven to last shot with SELOGIC control equation setting 79.DrvToLast while open interval timing is in progress. See *Drive-to-Lockout and Drive-to-Last Shot Settings (79.DrvToLO and 79.DrvToLast, Respectively) on page 4.54*].
- The close failure timer (setting Close_01.FailDly) times out (see *Figure 4.43*).
- SELOGIC control equation setting 79.DrvToLO = logical 1 (see *Drive-to-Lockout and Drive-to-Last Shot Settings (79.DrvToLO and 79.DrvToLast, Respectively)*).
- The Reclose Supervision Limit Timer (setting 79.ClsSupvTm) times out (see *Figure 4.44* and top of *Figure 4.45*) and the reclose enable setting, 79.Ena, has setting choices N, 1, 2, 3, 4, C1, C2, C3, and C4.
- A new reclose initiation occurs while the reclosing relay is timing on an open interval (e.g., flashover in the tank while breaker is open).

The **OPEN** command is included in the reclosing relay logic via the factory SELOGIC control equation settings:

79.DrvToLO := **Comm.TripCmd OR ...** (drive-to-lockout)

Relay Word bit Comm.TripCmd asserts for execution of the **OPEN** command. See *OPEN Command (Open Breaker) on page 7.35* for more information on the **OPEN** command. Also, see *Drive-to-Lockout and Drive-to-Last Shot Settings (79.DrvToLO and 79.DrvToLast, Respectively) on page 4.54*.

Reclosing Relay States and Settings Changes

If individual settings are changed, *all* of the following occur:

- The reclosing relay remains in the state it was in before the settings change.
- The shot counter is driven to last shot (last shot corresponding to the new settings; see discussion on last shot that follows).
- The reset timer is loaded with reset time setting 79.RstTmLO (see discussion on reset timing later in this section).

If the relay happened to be in the Reclose Cycle State and was timing on an open interval before the settings change, the relay would be in the Reclose Cycle State after the settings change, but the relay would immediately go to the lockout state. This is because the breaker is open, and the relay is at last shot after the settings change, and thus no more automatic reclosures are available.

If the circuit breaker remains closed through the settings change, the reset timer times out on reset time setting 79.RstTmLO after the settings change and goes to the Reset State (if it is not already in the Reset State), and the shot counter returns to shot = 0. If the relay happens to trip during this reset timing, the relay immediately goes to the lockout state, because shot = last shot.

Defeat the Reclosing Relay

If *any one* of the following reclosing relay settings are made then the reclosing relay is defeated, and no automatic reclosing can occur.

- Reclose enable setting 79.Ena := N.
- Open Interval 1 time setting 79.OpnTm1 := 0.00.

If the reclosing relay is defeated, the following also occur:

- All three reclosing relay state Relay Word bits (79.Rst, 79.Cyc, and 79.LO) are forced to logical 0 (see *Table 4.29*).
- All shot counter Relay Word bits (79.Shot0, 79.Shot1, 79.Shot2, 79.Shot3, and 79.Shot4) are forced to logical 0 (the shot counter is explained later in this section).
- The front-panel LEDs **RECL RESET** and **RECL LOCKOUT** are both extinguished.

Close Logic Can Still Operate When the Reclosing Relay Is Defeated

If the reclosing relay is defeated, the close logic (see *Figure 4.43*) can still operate if SELOGIC control equation circuit breaker status setting Bkr_01.52A_Sta is set to something other than numeral 0 or NA. Making the setting Bkr_01.52A_Sta := 0 or NA defeats the close logic *and* also defeats the reclosing relay.

For example, if Bkr_01.52A_Sta := IN_01.Sta, a 52A circuit breaker auxiliary contact is connected to input **IN_01**. If the reclosing relay does not exist, the close logic still operates, allowing closing to take place via SELOGIC control equation setting Close_01.RemInit (close conditions, other than automatic reclosing). See *Trip/Close Logic* for more discussion on SELOGIC control equation settings Bkr_01.52A_Sta and Close_01.RemInit.

Reclosing Control Settings

The reclosing control settings are shown in *Table 4.30*.

Table 4.30 Reclosing Control Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE RECLOSER	N, 1–4, C1–C4, Shots	79.Ena := N
OPEN INTERVAL TIME 1	0.00–3000.00 s	79.OpnTm1 := 0.00
OPEN INTERVAL TIME 2	0.00–3000.00 s	79.OpnTm2 := 0.00
OPEN INTERVAL TIME 3	0.00–3000.00 s	79.OpnTm3 := 0.00
OPEN INTERVAL TIME 4	0.00–3000.00 s	79.OpnTm4 := 0.00

Table 4.30 Reclosing Control Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
STALL OPEN INTERVAL TIMING	SELOGIC	79.Stall := Trip_01.Sta
RESET TIME FROM RECLOSE CYCLE	0.00–3000.00 s	79.RstTmRec := 15.00
RESET TIME FROM LOCKOUT	0.00–3000.00 s	79.RstTmLO := 5.00
BLOCK RESET TIMING	SELOGIC	79.BlkRst := Trip_01.Sta
RECLOSE INITIATE	SELOGIC	79.Init := Trip_01.Sta
RECLOSE INITIATE SUPERVISION	SELOGIC	79.InitSupv := Bkr_01.52A_Sta OR 79.Cyc
RECLOSE SUPERVISION	SELOGIC	79.ClsSupv := 1
RECLOSE SUPERVISION TIME LIMIT	OFF, 0.00–3000.00 s	79.ClsSupvTm := OFF
DRIVE-TO-LOCKOUT	SELOGIC	79.DrvToLO := Trip_01. LocSta OR Trip_01.RemSta
DRIVE-TO-LAST SHOT	SELOGIC	79.DrvToLast := 79.LO
SKIP SHOT	SELOGIC	79.Skip := 0
SEQUENCE COORDINATION	SELOGIC	79.Seq := 0

The operation of open interval timers is affected by SELOGIC control equation settings discussed later in this section.

Open Interval Timers

The reclose enable setting, 79.Ena, determines the number of open interval time settings that can be set. For example, if setting 79.Ena := 3, the first three open interval time settings in *Table 4.30* are made available for setting.

If an open interval time is set to zero, then that open interval time is not operable, *and* neither are the open interval times that follow it.

In the factory settings in *Table 4.30*, the open interval 2 time setting 79.OpnTm2 is the first open interval time setting set equal to zero:

79.OpnTm2 := **0.00 seconds**

Thus, open interval times 79OpnTm2, 79.OpnTm3, and 79.OpnTm4 are not operable. In the factory settings, both open interval times 79.OpnTm3 and 79.OpnTm4 are set to zero. But if the settings were:

79.OpnTm2 := **0.00 seconds**

79.OpnTm3 := **15.00 seconds** (set to some value other than zero)

open interval time 79.OpnTm3 would still be inoperative, because a preceding open interval time is set to zero (i.e., 79.OpnTm2 := 0.00).

If open interval 1 time setting, 79.OpnTm1, is set to zero (79.OpnTm1 := 0.00 seconds), no open interval timing takes place, and the reclosing relay is defeated.

The open interval timers time consecutively; they do not have the same beginning time reference point. For example, with settings 79.OpnTm1 := 0.50, and 79.OpnTm2 := 10.00, open interval 1 time setting, 79.OpnTm1, times first. If subsequent first reclosure is not successful, then open interval 2

time setting, 79.OpnTm2, starts timing. If the subsequent second reclosure is not successful, the relay goes to the lockout state. See the example time line in *Figure 4.48*.

Figure 4.48 Reclosing Sequence From Reset to Lockout With Example Settings

SELOGIC control equation setting 79.Stall (stall open interval timing) can be set to control open interval timing (see *Skip Shot (79.Skip) and Stall Open Interval Timing (79.Stall) Settings on page 4.55*).

Determination of Number of Reclosures (Last Shot)

The number of reclosures is equal to the number of open interval time settings that precede the first open interval time setting set equal to zero. The "last shot" value is also equal to the number of reclosures.

In the previous example settings, two set open interval times precede open interval 3 time, which is set to zero (79.OpnTm3 := 0.00):

79.OpnTm1 := **0.50**
79.OpnTm2 := **10.00**
79.OpnTm3 := **0.00**

For this example:

Number of reclosures (last shot) = 2 = the number of set open interval times that precede the first open interval set to zero.

Observe Shot Counter Operation

Observe the reclosing relay shot counter operation, especially during testing, using ASCII command **TARGET** (e.g., *TARGET Command (Display Relay Word Bit Status) on page 7.45* for detail).

Reset Timer

The reset timer qualifies circuit breaker closure before taking the relay to the reset state from the reclose cycle state or the lockout state. Circuit breaker status is determined by the SELOGIC control equation setting Bkr_01.52A_Sta. (See *Trip/Close Logic on page 4.36* for more discussion on SELOGIC control equation setting Bkr_01.52A_Sta.)

Setting 79.RstTmOut. Qualifies closures when the relay is in the reclose cycle state. These closures are usually automatic reclosures resulting from open interval time-out.

It is also the reset time that the sequence coordination schemes (see *Sequence Coordination Setting (79.Seq) on page 4.57*) use.

Setting 79.RstTmLO. Qualifies closures when the relay is in the lockout state. These closures are usually manual closures. These manual closures can originate external to the relay, via the **CLOSE** command, or via the SELOGIC control equation setting Close_01.RemInit (see *Figure 4.43*).

Setting 79.RstTmLO is also the reset timer the relay uses when it powers up or has individual settings changed (see *Reclosing Relay States and Settings Changes on page 4.47*).

Typically, setting 79.RstTmLO is set less than setting 79.RstTmOut. Setting 79.RstTmLO emulates reclosing relays with motor-driven timers that have a relatively short reset time from the lockout position to the reset position.

The 79.RstTmOut and 79.RstTmLO settings are set independently (setting 79.RstTmLO can even be set greater than setting 79.RstTmOut, if desired). SELOGIC control equation setting 79.BlkRst (block reset timing) can be set to control reset timing (see *Block Reset Timing Setting (79.BlkRst) on page 4.56*).

Monitoring Open Interval and Reset Timing

Open interval and reset timing can be monitored with the following Relay Word bits:

Relay Word Bits	Definition
79.OpnTmSta	Indicates that the open interval timer is *actively* timing
79.RstTmSta	Indicates that the reset timer is *actively* timing

If the open interval timer is actively timing, 79.OpnTmSta asserts to logical 1. When the relay is not timing on an open interval (e.g., it is in the reset state or in the lockout state), 79.OpnTmSta deasserts to logical 0. The relay can only time on an open interval when it is in the reclose cycle state, but just because the relay is in the reclose cycle state does not necessarily mean the relay is timing on an open interval. The relay only times on an open interval after successful reclose initiation and no stall conditions are present (see *Skip Shot (79.Skip) and Stall Open Interval Timing (79.Stall) Settings on page 4.55*).

If the reset timer is actively timing, 79.RstTmSta asserts to logical 1. If the reset timer is not timing, 79.RstTmSta deasserts to logical 0. See *Block Reset Timing Setting (79.BlkRst) on page 4.56*.

Reclosing Relay Shot Counter

Refer to *Figure 4.48*. The shot counter increments for each reclose operation. For example, when the relay is timing on open interval 1, 79.OpnTm1, it is at shot = 0. When the open interval times out, the shot counter increments to shot = 1 and so forth for the set open intervals that follow. The shot counter cannot increment beyond the last shot for automatic reclosing (see *Determination of Number of Reclosures (Last Shot) on page 4.50*). The shot counter resets back to shot = 0 when the reclosing relay returns to the Reset State.

Table 4.31 Shot Counter Correspondence to Relay Word Bits and Open Interval Times (Sheet 1 of 2)

Shot	Corresponding Relay Word Bit	Corresponding Open Interval
0	79.Shot0	79.OpnTm1
1	79.Shot1	79.OpnTm2
2	79.Shot2	79.OpnTm3

Table 4.31 Shot Counter Correspondence to Relay Word Bits and Open Interval Times (Sheet 2 of 2)

Shot	Corresponding Relay Word Bit	Corresponding Open Interval
3	79.Shot3	79.OpnTm4
4	79.Shot4	

When the shot counter is at a particular shot value (e.g., shot = 2), the corresponding Relay Word bit asserts to logical 1 (e.g., 79.Shot2 = logical 1).

The shot counter also increments for sequence coordination operation. The shot counter can increment beyond the last shot for sequence coordination (see *Sequence Coordination Setting (79.Seq) on page 4.57*).

Reclose Initiate and Reclose Initiate Supervision Settings (79.Init and 79.InitSupv, Respectively)

The reclose initiate setting 79.Init is a rising-edge detect setting. The reclose initiate supervision setting 79.InitSupv supervises setting 79.Init. When setting 79.Init senses a rising edge (logical 0 to logical 1 transition), setting 79.InitSupv has to be at logical 1 (79.InitSupv := logical 1) for open interval timing to be initiated.

If 79.InitSupv := logical 0 when setting 79.Init senses a rising edge (logical 0 to logical 1 transition), the relay goes to the lockout state.

EXAMPLE 4.11 Factory Settings Example

With factory settings:

79.Init := **Trip_01.Sta**

79.InitSupv := **Bkr_01.52A_Sta OR 79.Cyc**

the transition of the Trip_01.Sta Relay Word bit from logical 0 to logical 1 initiates open interval timing only if the Bkr_01.52A_Sta or 79.Cyc Relay Word bit is at logical 1 (Bkr_01.52A_Sta = logical 1, or 79.Cyc = logical 1). You must assign an input as the breaker status input (e.g., Bkr_01.52A_Sta := IN_01.Sta).

The circuit breaker has to be closed (circuit breaker status Bkr_01.52A_Sta = logical 1) at the instant of the first trip of the auto-reclose cycle for the SEL-851 to successfully initiate reclosing and start timing on the first open interval. The SEL-851 is not yet in the reclose cycle state (79.Cyc = logical 0) at the instant of the first trip.

Then for any subsequent trip operations in the auto-reclose cycle, the SEL-851 is in the reclose cycle state (79.Cyc = logical 1) and the SEL-851 successfully initiates reclosing for each trip. Because of factory setting 79.InitSupv := Bkr_01.52A_Sta OR 79.Cyc, successful reclose initiation in the reclose cycle state (79.Cyc = logical 1) is not dependent on the circuit breaker status (Bkr_01.52A_Sta). This allows successful reclose initiation for the case of an instantaneous trip, but the circuit breaker status indication is slow—the instantaneous trip (reclose initiation) occurs before the SEL-851 sees the circuit breaker close.

If a flashover occurs in a circuit breaker tank during an open interval (circuit breaker open and the SEL-851 calls for a trip), the SEL-851 goes immediately to lockout.

EXAMPLE 4.12 Additional Settings Example

The preceding settings example initiates open interval timing on rising edge of the Trip_01.Sta Relay Word bit. The following is an example of reclose initiation on the opening of the circuit breaker.

Presume input **IN_01** is connected to a 52a circuit breaker auxiliary contact (Bkr_01.52A_Sta := IN_01.Sta).

With setting:

79.Init := **NOT Bkr_01.52A_Sta**

the transition of the Bkr_01.52A_Sta Relay Word bit from logical 1 to logical 0 (breaker opening) initiates open interval timing. Setting 79.Init looks for a logical 0 to logical 1 transition, thus Relay Word bit Bkr_01.52A_Sta is inverted in the 79.Init setting.

The reclose initiate supervision setting 79.InitSupv supervises setting 79.Init. With settings:

79.Init := **NOT Bkr_01.52A_Sta**

79.InitSupv := **TRIP_01.Sta**

the transition of the Bkr_01.52A_Sta Relay Word bit from logical 1 to logical 0 initiates open interval timing only if the Trip_01.Sta Relay Word bit is at logical 1 (Trip_01.Sta = logical 1). Thus, the Trip_01.Sta Relay Word bit has to be asserted when the circuit breaker opens to initiate open interval timing. With a long enough setting of the Minimum Trip Duration Timer (Trip_01.MinDur), the Trip_01.Sta Relay Word bit still asserts to logical 1 when the circuit breaker opens (see Figure 4.42).

If the Trip_01.Sta Relay Word bit is at logical 0 (Trip_01.Sta = logical 0) when the circuit breaker opens (logical 1 to logical 0 transition), the relay goes to the lockout state. This helps prevent reclose initiation for circuit breaker openings caused by trips external to the relay.

If circuit breaker status indication (Bkr_01.52A_Sta) is slow, additional setting change Close_01.Unlt := 0 (unlatch close; refer to Figure 4.43 and accompanying explanation) may need to be made when 79.Init := NOT Bkr_01.52A_Sta. Close_01.Unlt := 0 avoids going to lockout prematurely for an instantaneous trip after an auto-reclose by not turning Close_01.Sta off until the circuit breaker status indication tells the relay that the breaker is closed. The circuit breaker anti-pump circuitry should take care of the Trip_01.Sta and Close_01.Sta being on together for a short period of time.

Other Settings Considerations

In *Example 4.12*, the preceding additional setting example, the reclose initiate setting (79.Init) includes input **IN_01**, which is connected to a 52a breaker auxiliary contact (Bkr_01.52A_Sta := IN_01.Sta).

79.Init := **NOT Bkr_01.52A_Sta**

If a 52b breaker auxiliary contact is connected to input **IN_01** (Bkr_01.52A_Sta := NOT IN_01.Sta), the reclose initiate setting (79.Init) remains the same.

If no reclose initiate supervision is desired, make the following setting:

79.InitSupv := **1** (numeral 1)

Setting 79.InitSupv := logical 1 at all times. Any time setting 79.Init detects a logical 0 to logical 1 transition, the relay initiates open interval timing (unless prevented by other means).

If the following setting is made:

79.Init := **0** (numeral 0)

reclosing never takes place (reclosing is never initiated). The reclosing relay is effectively inoperative.

If the following setting is made:

79.InitSupv := **0** (numeral 0)

reclosing never takes place (the reclosing relay goes directly to the lockout state any time reclosing is initiated). The reclosing relay is effectively inoperative.

Drive-to-Lockout and Drive-to-Last Shot Settings (79.DrvToLO and 79.DrvToLast, Respectively)

When 79.DrvToLO := logical 1, the reclosing relay goes to the lockout state (Relay Word bit 79.LO = logical 1), and the front-panel **LO** (Lockout) LED illuminates.

79.DrvToLO has a 1 second dropout time. This keeps the drive-to-lockout condition up 1 second after 79.DrvToLO has reverted back to 79DrvToLO := logical 0. This is useful for situations where both of the following conditions are true:

- Any of the trip and drive-to-lockout conditions are "pulsed" conditions (e.g., the **OPEN** command Relay Word bit, Comm.TripCmd, asserts for only 1/4 cycle—refer to *Factory Settings Example on page 4.54*).
- Reclose initiation is by the breaker contact opening (e.g., 79.Init := NOT Bkr_01.52A_Sta—refer to *Additional Settings Example on page 4.52*).

Then the drive-to-lockout condition overlaps reclose initiation and the SEL-851 stays in lockout after the breaker trips open.

When 79.DrvToLast := logical 1, the reclosing relay goes to the last shot, if the shot counter is not at a shot value greater than or equal to the calculated last shot (see *Reclosing Relay Shot Counter on page 4.51*).

EXAMPLE 4.13 Factory Settings Example

The drive-to-lockout factory setting is:

79.DrvToLO := **Comm.TripCmd OR PCT_004.Sta**

Relay Word bit Comm.TripCmd asserts for execution of the **OPEN** command. See the Note in the lockout state discussion, following Table 4.29.

Relay Word bit PCT_004.Sta asserts for execution of the **OPEN** command from the front-panel pushbutton (see CLOSE, TRIP, and LOCAL/REMOTE Pushbuttons on page 8.11 for more detail).

The drive-to-last shot factory setting is:

79.DrvToLast := **79.LO**

One open interval is also set in the factory settings, resulting in last shot = 1. Any time the relay is in the lockout state (Relay Word bit 79.LO = logical 1), the relay is driven to last shot (if the shot counter is not already at a shot value greater than or equal to shot = 1):

79DrvToLast := **79.LO** = logical 1

Thus, the relay is driven to the lockout state (by setting 79.DrvToLO) and, subsequently, last shot (by setting 79.DrvToLast).

EXAMPLE 4.14 Additional Settings Example

To drive the relay to the lockout state for fault current greater than a certain level when tripping (e.g., level of phase instantaneous overcurrent element 50P_03.PU), make settings similar to the following:

79.DrvToLO := **Trip_01.Sta AND 50P_03.PU OR ...**

Additionally, if the reclosing relay should go to the lockout state for an underfrequency trip, make settings similar to the following:

79.DrvToLO := **TRIP_01.Sta AND 81_01.TmOut OR ...**

Other Settings Considerations

If no special drive-to-lockout or drive-to-last shot conditions are desired, make the following settings:

79.DrvToLO := **0** (numeral 0)
79.DrvToLast := **0** (numeral 0)

With settings 79.DrvToLO and 79.DrvToLast inoperative, the relay still goes to the lockout state (and to last shot) if an entire automatic reclose sequence is unsuccessful.

Overall, settings 79.DrvToLO or 79.DrvToLast are necessary to take the relay to the lockout state (or to last shot) for immediate circumstances.

Skip Shot (79.Skip) and Stall Open Interval Timing (79.Stall) Settings

The skip shot setting 79.Skip causes the relay to skip a reclose shot. Thus, the relay skips an open interval time and uses the next open interval time instead.

If 79.Skip = logical 1 at the instant of successful reclose initiation (see preceding discussion on settings 79.Init and 79.InitSupv), the relay increments the shot counter to the next shot and then loads the open interval time corresponding to the new shot (see *Table 4.31*). If the new shot is the "last shot," no open interval timing takes place, and the relay goes to the lockout state if the circuit breaker is open (see *Lockout State on page 4.47*).

After successful reclose initiation, open interval timing does not start until allowed by the stall open interval timing setting 79.Stall. If 79.Stall = logical 1, open interval timing is stalled. If 79.Stall = logical 0, open interval timing can proceed.

If an open interval time has not yet started timing (79.Stall = logical 1 still), the 79.Skip setting is still processed. In such conditions (open interval timing has not yet started timing), if 79.Skip = logical 1, the relay increments the shot counter to the next shot and then loads the open interval time corresponding to the new shot (see *Table 4.31*). If the new shot turns out to be the "last shot," no open interval timing takes place, and the relay goes to the lockout state if the circuit breaker is open (see *Lockout State on page 4.47*).

If the relay is in the middle of timing on an open interval and 79.Stall changes state to 79.Stall = logical 1, open interval timing stops where it is. If 79.Stall changes state back to 79.Stall = logical 0, open interval timing resumes where it left off. Use the 79.OpnTmSta Relay Word bit to monitor open interval timing (see *Monitoring Open Interval and Reset Timing on page 4.51*).

EXAMPLE 4.15 Factory Settings Example

The skip shot function is not enabled in the factory settings:

79.Skip := **0** (numeral 0)

The stall open interval timing factory setting is:

79.Stall := **Trip_01.Sta**

After successful reclose initiation, open interval timing does not start as long as the trip condition is present (Relay Word bit Trip_01.Sta = logical 1). As discussed previously, if an open interval time has not yet started timing (79.Stall = logical 1 still), the 79.Skip setting is still processed. Once the trip condition goes away (Relay Word bit Trip_01.Sta = logical 0), open interval timing can proceed.

EXAMPLE 4.16 Additional Settings Example 1

With skip shot setting:

79.Skip := **50P_02.PU AND 79.Shot0**

if shot = 0 (Relay Word bit 79.Shot0 = logical 1) and phase current is greater than the phase instantaneous overcurrent element 50P_02.PU threshold (Relay Word bit 50P_02.PU = logical 1), at the instant of successful reclose initiation, the shot counter is

incremented from shot = 0 to shot = 1. Then, open interval 1 time (setting 79.OpnTm1) is skipped, and the relay times on the open interval 2 time (setting 79.OpnTm2) instead.

Table 4.32 Open Interval Time Example Settings

Shot	Corresponding Relay Word Bit	Corresponding Open Interval	Open Interval Time Example Setting (seconds)
0	79.Shot0	79.OpnTm1	0.50
1	79.Shot1	79.OpnTm2	10.00

In Table 4.32, note that the open interval 1 time (setting 79.OpnTm1) is a short time, while the following open interval 2 time (setting 79.OpnTm2) is significantly longer. For a high magnitude fault (greater than the phase instantaneous overcurrent element 50P_02.PU threshold), open interval 1 time is skipped, and open interval timing proceeds on the following open interval 2 time.

Once the shot is incremented to shot = 1, Relay Word bit 79.Shot0 = logical 0 and then setting 79.Skip = logical 0, regardless of Relay Word bit 50P_02.PU.

EXAMPLE 4.17 Additional Settings Example 2

Refer to Figure 4.46 and accompanying setting example, showing an application for setting 79.Stall.

Other Settings Considerations

If no special skip shot or stall open interval timing conditions are desired, make the following settings:

79.Skip := **0** (numeral 0)

79.Stall := **0** (numeral 0)

Block Reset Timing Setting (79.BlkRst)

The block reset timing setting 79.BlkRst keeps the reset timer from timing. Depending on the reclosing relay state, the reset timer can be loaded with either reset time:

79.RstTmOut (Reset Time from Reclose Cycle)

or

79.RstTmLO (Reset Time from Lockout)

Depending on how setting 79.BlkRst is set, none, one, or both of these reset times can be controlled. If the reset timer is timing and then 79.BlkRst asserts to:

79.BlkRst = logical 1

reset timing is stopped and does not begin timing again until 79.BlkRst deasserts to:

79.BlkRst = logical 0

When reset timing starts again, the reset timer is fully loaded. Thus, successful reset timing has to be continuous. Use the 79.RstTmSta Relay Word bit to monitor reset timing (see *Monitoring Open Interval and Reset Timing on page 4.51*).

EXAMPLE 4.18 Factory Settings Example

The reset timing is blocked if Relay Word bit Trip_01.Sta is asserted, regardless of the reclosing relay state:

79.BlkRst := **Trip_01.Sta**

EXAMPLE 4.19 Additional Settings Example 1

The block reset timing setting is:

79.BlkRst := **(51P_01.PUVal OR 51Gnd_01.PUVal) AND 79.Cyc**

Relay Word bit 79.Cyc corresponds to the reclose cycle state. The reclosing relay is in one of the three reclosing relay states at any one time (see Figure 4.47 and Table 4.29).

When the relay is in the reset or lockout states, Relay Word bit 79.Cyc is deasserted to logical 0. Thus, the 79.BlkRst setting has no effect when the relay is in the reset or lockout states. When a circuit breaker is closed from lockout, there could be cold load inrush current that momentarily picks up a time-overcurrent element [e.g., phase time-overcurrent element 51P_01 pickup (51P_01.PU) asserts momentarily]. But, this assertion has no effect on reset timing because the relay is in the lockout state (79.Cyc = logical 0). The relay times immediately on reset time 79.RstTmLO and takes the relay from the lockout state to the reset state with no additional delay because 79.BlkRst is deasserted to logical 0.

When the relay is in the reclose cycle state, Relay Word bit 79.Cyc is asserted to logical 1. Thus, the example 79.BlkRst setting can function to block reset timing if time-overcurrent pickup 51P_01.PU or 51G_01.PU is picked up while the relay is in the reclose cycle state. This helps prevent repetitive "trip-reclose" cycling.

EXAMPLE 4.20 Additional Settings Example 2

If the block reset timing setting is:

79.BlkRst := **51P_01.PU OR 51G_01.PU**

then reset timing is blocked if time-overcurrent pickup 51P_01.PU or 51G_01.PU is picked up, regardless of the reclosing relay state.

Sequence Coordination Setting (79.Seq)

The sequence coordination setting 79.Seq keeps the relay in step with a downstream line recloser in a sequence coordination scheme, which prevents overreaching SEL-851 overcurrent elements from tripping for faults beyond the line recloser. This is accomplished by incrementing the shot counter and supervising overcurrent elements with resultant shot counter elements.

For the sequence coordination setting 79.Seq to increment the shot counter, *both* the following conditions must be true:

- No trip present (Relay Word bit Trip_01.Sta = logical 0)
- Circuit breaker closed (SELOGIC control equation setting Bkr_01.52A_Sta = logical 1, effectively)

The sequence coordination setting 79.Seq is usually set with some overcurrent element pickups. If the previous two conditions are both true, and a set overcurrent element pickup asserts for at least 1.25 cycles and then deasserts, the shot counter increments by one count. This assertion/deassertion indicates that a downstream device (e.g., line recloser—see *Figure 4.49*) has operated to clear a fault. Incrementing the shot counter keeps the SEL-851 "in step" with the downstream device, as is shown in *Additional Settings Example 1 on page 4.58* and *Additional Settings Example 2 on page 4.60*.

Every time a sequence coordination operation occurs, the shot counter is incremented, and the reset timer is loaded up with reset time 79.RstTmOut. Sequence coordination can increment the shot counter beyond last shot, but no further than shot = 4. The shot counter returns to shot = 0 after the reset timer times out. Reset timing is subject to SELOGIC control equation setting 79.BlkRst (see *Block Reset Timing Setting (79.BlkRst) on page 4.56*).

Sequence coordination operation does not change the reclosing relay state. For example, if the relay is in the Reset State and there is a sequence coordination operation, it remains in the Reset State.

EXAMPLE 4.21 Factory Settings Example

Sequence coordination is not enabled in the factory settings:

79.Seq := **0**

EXAMPLE 4.22 Additional Settings Example 1

With sequence coordination setting:

79.Seq := **79.Rst AND 51P_01.PU**

sequence coordination is operable only when the relay is in the Reset State (79.Rst = logical 1). Refer to Figure 4.49 and Figure 4.50.

Figure 4.49 Sequence Coordination Between the SEL-851 and a Line Recloser

Assume that the line recloser is set to operate twice on the fast curve and then twice on the slow curve. The slow curve is allowed to operate after two fast curve operations because the fast curves are then inoperative for tripping. The SEL-851 phase time-overcurrent element 51P_01.TmOut is coordinated with the line recloser fast curve. The SEL-851 phase time-overcurrent element 51P_02.TmOut are coordinated with the line recloser slow curve.

① Fault occurs beyond line recloser; ② fault cleared by line recloser fast curve; ③ line recloser recloses into fault; ④ fault cleared by line recloser slow curve.

Figure 4.50 Operation of SEL-851 Shot Counter for Sequence Coordination With Line Recloser (Additional Settings Example 1)

If the SEL-851 is in the Reset State (79.Rst = logical 1) and then a permanent fault beyond the line recloser occurs (fault current I_F in Figure 4.49), the line recloser fast curve operates to clear the fault. The SEL-851 also sees the fault. The phase time-overcurrent pickup 51P_01.PU asserts and then deasserts without tripping, incrementing the relay shot counter from:

shot = 0 to shot = 1

When the line recloser recloses its circuit breaker, the line recloser fast curve operates again to clear the fault. The SEL-851 also sees the fault again. The phase time-overcurrent pickup 51P_01.PU asserts and then deasserts without tripping, incrementing the relay shot counter from:

shot = 1 to shot = 2

The line recloser fast curve is now disabled after operating twice. When the line recloser recloses its circuit breaker, the line recloser slow curve operates to clear the fault. The relay does not operate on its faster-set phase time-overcurrent element 51P_01 (51P_01.TmOut is "below" the line recloser slow curve) because the shot counter is now at shot = 2. For this sequence coordination scheme, the SELOGIC control equation trip equation is:

Trip_01.Init := **51P_01.TmOut AND (79.Shot0 OR 79.Shot1)**

With the shot counter at shot = 2, Relay Word bits 79.Shot0 (shot = 0) and 79.Shot1 (shot = 1) are both deasserted to logical 0. This keeps the 51P_01.TmOut phase time-overcurrent element from tripping. The 51P_01.TmOut phase time-overcurrent element is still operative, and its pickup (51P_01.PU) can still assert and then deassert, thus continuing the sequencing of the shot counter to shot = 3, etc. The 51P_01.TmOut phase time-overcurrent element cannot cause a trip because shot ≥ 2, and 79.Shot0 and 79.Shot1 both are deasserted to logical 0.

The shot counter returns to shot = 0 after the reset timer (loaded with reset time 79.RstTmOut) times out.

NOTE: Sequence coordination can increment the shot counter beyond last shot in this example (last shot = 2 in this factory setting example) but no further than shot = 4.

The following Example 2 limits sequence coordination shot counter incrementing.

EXAMPLE 4.23 Additional Settings Example 2

Review preceding Example 1.

Assume that the line recloser in Figure 4.49 is set to operate twice on the fast curve and then twice on the slow curve for faults beyond the line recloser.

Assume that the SEL-851 is set to operate once on 51P_01.TmOut and then twice on 51P_02.TmOut for faults between the SEL-851 and the line recloser. This results in the following trip setting:

Trip_01.Init := **51P_01.TmOut AND 79.Shot0**

This requires that two open interval settings be made (see Table 4.30 and Figure 4.48). This corresponds to the last shot being:

last shot = 2

If the sequence coordination setting is:

79.Seq := **79.Rst AND 51P_01.PU**

and there is a permanent fault beyond the line recloser, the shot counter of the SEL-851 increments all the way to shot = 4 (see Figure 4.50). If there is a coincident fault *between* the SEL-851 and the line recloser, the SEL-851 trips and goes to the lockout state. Any time the shot counter is at a value equal to or greater than last shot and the relay trips, it goes to the lockout state.

To avoid this problem, make the following sequence coordination setting:

79.Seq := **79.Rst AND 51P_01.PU AND 79.Shot0**

Refer to Figure 4.51.

If the SEL-851 is in the reset state (79.Rst = logical 0) with the shot counter reset (shot = 0; 79.Shot0 = logical 1) and then a permanent fault beyond the line recloser occurs (fault current I_F in Figure 4.49), the line recloser fast curve operates to clear the fault. The SEL-851 also sees the fault. The phase time-overcurrent pickup 51P_01.PU asserts and then deasserts without tripping, incrementing the relay shot counter from:

shot = 0 to shot = 1

Now the SEL-851 cannot operate on its faster-set phase time-overcurrent element 51P_01.TmOut because the shot counter is at shot = 1 (79.Shot0 = logical 0):

Trip_01.Init := **51P_01.TmOut AND 79.Shot0**

① Fault occurs beyond line recloser; ② fault cleared by line recloser fast curve; ③ line recloser recloses into fault; ④ fault cleared by line recloser slow curve.

Figure 4.51 Operation of SEL-851 Shot Counter for Sequence Coordination With Line Recloser (Additional Settings Example 2)

The line recloser continues to operate for the permanent fault beyond it, but the SEL-851 shot counter does not continue to increment.

Sequence coordination setting 79.Seq is effectively disabled by the shot counter incrementing from shot = 0 to shot = 1.

79.Seq := **79.Rst AND 51P_01.PU AND (logical 0) = logical 0**

The shot counter stays at shot = 1.

Thus, if there is a coincident fault between the SEL-851 and the line recloser, the SEL-851 operates on 51P_02.TmOut and then recloses once, instead of going straight to the lockout state (shot = 1 < last shot = 2).

As stated earlier, the reset time setting 79.RstTmOut takes the shot counter back to shot = 0 after a sequence coordination operation increments the shot counter. Make sure that reset time setting 79.RstTmOut is set long enough to maintain the shot counter at shot = 1 as shown in Figure 4.51.

Reclose Supervision Setting (79.ClsSupv)

See *Reclose Supervision Logic on page 4.40*.

Warning List

Enter as many as 24 Relay Word bits. The Warning List entries (**SET WARN** command) are Text-Edit mode settings with line number prompts. The available Text-Edit Mode actions are shown in the following table.

Table 4.33 Text-Edit Mode Actions

Action	Control Response
<Enter>	Accept the setting and move to the next line; if at the last line or at a blank line, exit settings.
>*n* <Enter>	Move to line *n*. If this is beyond the end of the list, move to a blank line following the last line.
^ <Enter>	Move to the previous line; if at the first line, stay at the present line.
< <Enter>	Move to the first line.
> <Enter>	Move to a blank line following the last line.
LIST <Enter>	List all settings and return to the present action prompt.
DELETE *n* <Enter>	Delete the present line and subsequent lines for a total of *n* lines; *n* = 1 if not provided. Lines after deletion shift upward by the number of lines deleted.
INSERT <Enter>	Insert a blank line at the present location; the present line and subsequent lines shift downward.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the `Save settings (Y,N)?` prompt.
<Ctrl+X>	Abort editing session without saving changes.

The factory-default value for the Warning.List setting consists of Diag.Hw_Alm Relay Word bit in line number 1. The setting only allows one element per line and does not permit repeat occurrences.

The relay HMI uses the Relay Word bit alias to display the warning message when the Relay Word bits in the Warning List settings have a corresponding Alias setting under the Report settings.

For example, if SER.Alias01 := Diag.Hw_Alm,“Hardware_Alarm”, “Asserted”,“Deasserted,” then the relay HMI displays Hardware_Alarm = Asserted when Diag.Hw_Alm asserts.

Output Contacts

NOTE: When an output contact is not used for a specific function you must set the associated SELOGIC control equation to either 0 or 1.

NOTE: Fast hybrid contacts are designed for fast closing (50 µs) only. Fail-safe mode operating time (time to open the contacts) for fast hybrid contacts is <8 ms (same time as for a normal output contact).

Table 4.34 Output Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
OUTPUT 01 FAIL-SAFE	Y, N	OUT_01.FailSafe := N
OUT_01.Sta	SELOGIC	OUT_01.Sta := Trip_01.Sta
OUTPUT 02 FAIL-SAFE	Y, N	OUT_02.FailSafe := N
OUT_02.Sta	SELOGIC	OUT_02.Sta := 0
OUTPUT 03 FAIL-SAFE	Y, N	OUT_03.FailSafe := N
OUT_03.Sta	SELOGIC	OUT_03.Sta := Close_01.Sta
OUTPUT 04 FAIL-SAFE	Y, N	OUT_04.FailSafe := N
OUT_04.Sta	SELOGIC	OUT_04.Sta := 0
OUTPUT 05 FAIL-SAFE	Y, N	OUT_05.FailSafe := Y
OUT_05.Sta	SELOGIC	OUT_05.Sta := Diag.Hw_Alm OR Diag.Secu_Alm

The SEL-851 provides the ability to use SELOGIC control equations to map protection (trip and warning) and general-purpose control elements to the outputs. In addition, you can enable fail-safe output contact operation for relay contacts on an individual basis.

If the contact fail-safe is enabled, the relay output is held in its energized position when relay control power is applied. The output falls to its de-energized position when control power is removed. Contact positions with de-energized output relays are indicated on the relay chassis and in *Figure 2.23*.

When TRIP output fail-safe is enabled and the **TRIP** contact is appropriately connected, the breaker is automatically tripped when relay control power fails.

Input Contacts

Contact inputs can be either internally wetted or externally wetted based on the MOT option selected. The SEL-851 includes separate debounce modes for internally wetted or externally wetted inputs. In general, debounce refers to a qualifying time delay before processing the change of state of a digital input. Normally, this delay applies to both the processing of the debounced input when you use it in device logic and the time stamping in the SER. Following is a description for both types of inputs.

Internally Wetted Inputs

Digital inputs are internally wetted to +24 Vdc, so you only need to connect a dry contact, switch, or jumper to the input. *Figure 4.52* shows the contact input logic for internally wetted inputs.

Figure 4.52 Contact Input Logic, Internally Wetted INn

Externally Wetted Inputs

Table 4.35 shows the settings available for externally wetted input contacts. Select the input wetting voltage as per the IN.VNom setting and voltage type as per the IN.VTyp setting.

Table 4.35 Contact Input Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
INPUT WETTING VOLTAGE VALUE	24, 48, 110, 125, 220, 250 V	IN.VNom := 125
INPUT WETTING VOLTAGE TYPE	DC, AC	IN.VTyp := DC

Based on the above setting selection, the relay uses the logic shown in *Figure 4.53* for the externally wetted contact inputs.

	24-250 Vac	48-250 Vdc	24 Vdc
PU	2 ms	2 ms	4 ms
DO	10 ms	2 ms	4 ms

Figure 4.53 Contact Input Logic, Externally Wetted INn

Time and Date Management Settings

The SEL-851 supports several methods of updating the relay time and date. For SNTP applications, refer to *Simple Network Time Protocol (SNTP) on page 7.14*. For time update from a DNP Master, see *Time Synchronization on page D.10*.

Table 4.36 shows the time and date management settings that are available in the Protection settings.

Table 4.36 Time and Date Management Settings

Setting Description	Setting Range	Setting Name := Factory Default
IRIG-B CONTROL BITS DEFINITION	NONE, C37.118	Time.IRIG_CtlBits := NONE
OFFSET FROM UTC	–24.00 to 24.00 hours, rounds up to nearest 0.25 hour	Time.UTC_Ofs := 0.00
MONTH TO BEGIN DST	NA, 1–12	Time.DST_StrMo := NA
WEEK OF THE MONTH TO BEGIN DST	1–3, L	Time.DST_StrWk := 2
DAY OF THE WEEK TO BEGIN DST	SUN, MON, TUE, WED, THU, FRI, SAT, SUN	Time.DST_StrDay := SUN
LOCAL HOUR TO BEGIN DST	0–23	Time.DST_StrHr := 2
MONTH TO END DST	1–12	Time.DST_EndMo := 11
WEEK OF THE MONTH TO END DST	1–3, L	Time.DST_EndWk := 1
DAY OF THE WEEK TO END DST	SUN, MON, TUE, WED, THU, FRI, SAT, SUN	Time.DST_EndDay := SUN
LOCAL HOUR TO END DST	0–23	Time.DST_EndHr := 2

IRIG-B Control Bits

Time.IRIG_CtlBits defines whether IEEE C37.118 control bit extensions are in use. Control bit extensions contain information such as leap second, UTC, daylight-saving time (DST), and time quality. When your satellite-synchronized clock provides these extensions, your relay adjusts the synchrophasor time-stamp accordingly.

- Time.IRIG_CtlBits := NONE ignores bit extensions
- Time.IRIG_CtlBits := C37.118 extracts bit extensions and corrects the time accordingly

Coordinated Universal Time (UTC) Offset Setting

The SEL-851 setting Time.UTC_Ofs is settable from –24.00 to 24.00 hours in 0.25 hour increments. The relay also uses the Time.UTC_Ofs setting to calculate local (relay) time from the UTC source when configured for Simple Network Time Protocol (SNTP) updating via Ethernet. When a time source other than SNTP is updating the relay time, the Time.UTC_Ofs setting is not considered because the other time sources are defined as local time.

Automatic Daylight-Saving Time Settings

The SEL-851 can automatically switch to and from daylight-saving time, as specified by the eight settings Time.DST_StrMo through Time.DST_EndHr. The first four settings control the month, week, day, and time that daylight-saving time shall commence, while the last four settings control the month, week, day, and time that daylight-saving time shall cease.

Once configured, the SEL-851 changes to and from daylight-saving time every year at the specified time. Device Word bit Time.DST asserts when daylight-saving time is active.

The SEL-851 interprets the week number settings Time.DST_StrWk and Time.DST_EndWk (1–3, L = Last) as follows:

- The first seven days of the month are considered to be in week 1.
- The second seven days of the month are considered to be in week 2.
- The third seven days of the month are considered to be in week 3.
- The last seven days of the month are considered to be in week “L”.

This method of counting of the weeks allows easy programming of statements like “the first Sunday”, “the second Saturday”, or “the last Tuesday” of a month.

As an example, consider the following settings:

```
Time.DST_StrMo := 3
Time.DST_StrWk := L
Time.DST_StrDay := SUN
Time.DST_StrHr := 2
Time.DST_EndMo := 10
Time.DST_EndWk := 3
Time.DST_EndDay := WED
Time.DST_EndHr := 3
```

With these example settings, the relay enters daylight-saving time on the last Sunday in March at 0200 h, and leave daylight-saving time on the third Wednesday in October at 0300 h. The relay asserts Relay Word bit Time.DST when DST is active.

When you use an IRIG-B time source, the relay time follows the IRIG-B time, including daylight-saving time start and end, as commanded by the time source. If there is a discrepancy between the daylight-saving time settings and the received IRIG-B signal, the relay follows the IRIG-B signal.

When using IEEE C37.118 compliant IRIG-B signals (e.g., setting Time.IRIG_CtlBits := C37.118), the relay automatically populates the Time.DST Relay Word bit, regardless of the daylight-saving time settings.

When using regular IRIG-B signals (e.g., setting Time.IRIG_CtlBits := NONE), the relay only populates the Time.DST Relay Word bit of the daylight-saving time settings are properly configured.

Simple Network Time Protocol (SNTP)

The SEL-851 Port 2 (Ethernet port) supports the SNTP Client protocol. See *Section 7: Communications*, *Simple Network Time Protocol (SNTP) on page 7.14* for a description and *Table 7.7* for the settings.

Demand Metering

The SEL-851 provides demand and peak demand metering, selectable between thermal and rolling demand types, for the following values:

- IA, IB, IC, phase currents (A primary)
- IG residual ground current (A primary; IG = 3I0 = IA + IB + IC)
- 3I2 negative-sequence current (A primary)

Table 4.37 shows the demand metering settings. Also refer to *Section 5: Metering and Monitoring* and *Section 7: Communications* for other related information for the demand meter.

Table 4.37 Demand Meter Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
DEMAND METER ENABLE	THM, ROL	Meter.Dmd_Ena := THM
DEMAND METER TIME CONSTANT	5, 10, 15, 30, 60 min	Meter.Dmd_TmConst := 5
DEMAND METER PHASE CURRENT PICKUP	OFF, 0.1–16.0 A sec	Meter.Dmd_IP_PUVal := OFF
DEMAND METER GROUND CURRENT PICKUP	OFF, 0.1–16.0 A sec	Meter.Dmd_IGnd_PUVal := OFF
DEMAND METER NEG. SEQUENCE CURRENT PICKUP	OFF, 0.1–16.0 A sec	Meter.Dmd_INeg_PUVal := OFF

The demand current level settings are applied to demand current meter outputs as shown in *Figure 4.54*.

Figure 4.54 Demand Current Logic Outputs

For example, when residual ground demand current IGnd_DmdSec exceeds corresponding demand pickup Meter.Dmd_IGnd_PUVal, Relay Word bit Meter.Dmd_IGnd_PU asserts to logical 1. Use these demand current logic outputs (Meter.Dmd_IP_PU, Meter.Dmd_IGnd_PU, Meter.Dmd_INeg_PU, Meter.Dmd_PU) to alarm for high loading or unbalance conditions.

The demand values are updated approximately once a second. The relay stores peak demand values to nonvolatile storage every six hours (it overwrites the previous stored value if it is exceeded). Should the relay lose control power, it restores the peak demand values saved by the relay.

Demand metering peak recording is momentarily suspended when SELOGIC control equation setting Meter.Fault is asserted (= logical 1). 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 4.55* 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 4.55 Response of Thermal and Rolling Demand Meters to a Step Input (Setting Meter.Dmd_TmConst = 15 minutes)

Thermal Demand Meter Response

The response of the thermal demand meter in *Figure 4.55* (middle) to the step current input (top) is analogous to the series RC circuit in *Figure 4.56*.

Figure 4.56 Voltage VS Applied to Series RC Circuit

In the analogy:

Voltage VS in *Figure 4.56* corresponds to the step current input in *Figure 4.55* (top).

Voltage VC across the capacitor in *Figure 4.56* corresponds to the response of the thermal demand meter in *Figure 4.55* (middle).

If voltage VS in *Figure 4.56* has been at zero (VS = 0.0 per unit) for some time, voltage VC across the capacitor in *Figure 4.56* is also at zero (VC = 0.0 per unit). If voltage VS is suddenly stepped up to some constant value (VS = 1.0 per unit), voltage VC 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 4.54* (middle) to the step current input (top).

In general, as voltage VC across the capacitor in *Figure 4.56* cannot change instantaneously, the thermal demand meter response is not immediate either for the increasing or decreasing applied instantaneous current. The thermal demand meter response time is based on the demand meter time constant setting Meter.Dmd_TmConst (see *Table 4.37*). Note that in *Figure 4.55*, 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 Meter.Dmd_TmConst = 15 minutes, referenced to when you first apply the step current input.

The SEL-851 updates thermal demand values approximately every second.

Rolling Demand Meter Response

The response of the rolling demand meter in *Figure 4.55* (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 Meter.Dmd_TmConst (see *Table 4.37*). Note in *Figure 4.55*, 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 Meter.Dmd_TmConst = 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 second. 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 4.55* example, the rolling demand meter

averages the three latest five-minute totals because setting Meter.Dmd_TmConst = 15 (15/5 = 3). The rolling demand meter response is updated every five minutes, after a new five-minute total is calculated.

The following is a step-by-step calculation of the rolling demand response example in *Figure 4.55* (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 three 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 three 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 three 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 three five-minute intervals in the sliding time-window at "Time = 15 minutes" each integrate into the following 5-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.

Data Reset

The Trip.TrgtRst setting resets the trip output and front-panel TRIP LED, provided there is no trip condition present. See *Figure 4.42* for more details. The Meter.En_Rst and Meter.MaxMin_Rst settings reset the Energy and Max/Min Metering values respectively. You should assign a contact input (e.g., Trip.TrgtRst := IN_01.Sta) to each of these settings if you want remote reset. The Meter.Dmd_Rst setting reset demand. See *Figure 4.54* for the demand current logic diagram.

Table 4.38 Data Reset Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
RESET TARGETS	SELOGIC	Trip.TrgtRst := 0
RESET ENERGY	SELOGIC	Meter.En_Rst := 0
RESET MAX/MIN	SELOGIC	Meter.MaxMin_Rst := 0
RESET DEMAND	SELOGIC	Meter.Dmd_Rst := 0

Alarm Settings

Table 4.39 shows the alarm settings. Program software alarm conditions into the Diag.Secu_Alm SELOGIC setting. Refer to *Table 4.39* for the factory-default Diag.Secu_Alm setting. Program a reset hardware alarm condition into the Diag.Hw_Rst SELOGIC setting.

Table 4.39 Alarm Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
SOFTWARE ALARM CONDITIONS[a]	SELOGIC	Diag.Secu_Alm := Diag.Secu_PassLO OR Diag.Secu_PassChg OR Diag.Secu_SetChg OR Diag.Secu_AccLev2 OR Diag.Secu_PassBad
RESET HARDWARE ALARM	SELOGIC	Diag.Hw_Rst := 0

[a] The Diag.Secu_Alm bit pulses for 1 second when the relay enters Access Level 2. The Diag.Secu_Alm bit also pulses when the relay powers up.

IEC 61850 Mode Control

You can control IEC 61850 Mode/Behavior using SELOGIC control equations 61850.Mod_Blk and 61850.Mod_Test. These variables are the SELOGIC control for the Blocked and Test modes, respectively. Refer to *Appendix F: IEC 61850 Communications* for details.

Table 4.40 IEC 61850 Mode Control Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
IEC 61850 BLOCKED MODE CONTROL EQUATION	SELOGIC	61850.Mod_Blk := 0
IEC 61850 TEST MODE CONTROL EQUATION	SELOGIC	61850.Mod_Test := 0

Logic Settings (SET L Command)

The following discussion lists the settings associated with latches, timers, counters, math variables, and output contacts.

SELOGIC Enables

NOTE: Upon relay initial turn on, Port 1 setting changes, or Logic setting changes, you may have to wait as long as two minutes before an additional setting change can occur. Note that the relay is functional with protection enabled as soon as the **ENABLED** LED comes on (approximately 5–10 seconds from turn on).

Table 4.41 shows the enable settings for latch bits (PLT.Ena), SELOGIC control equations (including timers) (PCT.Ena), Counters (PCN.Ena), and math variable equations (PMV.Ena). This helps limit the number of settings that you need to make. For example, if you need six timers, only enable six timers.

Table 4.41 Enable Settings

Setting Prompt	Setting Range	Default Setting
Enable Protection Latches	N, 1–16	PLT.Ena := N
Enable Protection Conditioning Timers	N, 1–16	PCT.Ena := N
Enable Protection Counters	N, 1–16	PCN.Ena := N
Enable Protection Math Variables[a]	N, 1–16	PMV.Ena := N

[a] If a protection math variable is set equal to NA (e.g., PMV_001.Val := NA), it is treated as 0.

SELOGIC Protection Latches

Latch control switches (latch bits are the outputs of these switches) replace traditional latching devices. Traditional latching devices maintain output contact state. The SEL-851 latch control switch also retains state even when power to the device is lost. If the latch control switch is set to a programmable output contact and power to the device is lost, the state of the latch control switch is stored in nonvolatile memory, but the device de-energizes the output contact. When power to the device is restored, the programmable output contact returns to the state of the latch control switch after device initialization. Traditional latching device output contact states are changed by pulsing the latching device inputs (see *Figure 4.57*). Pulse the set input to close (set) the latching device output contact. Pulse the reset input to open (reset) the latching device output contact. The external contacts wired to the latching device inputs are often from remote control equipment (e.g., SCADA, RTU).

Figure 4.57 Schematic Diagram of a Traditional Latching Device

Sixteen latch control switches in the SEL-851 provide latching device functionality. *Figure 4.58* shows the logic diagram of a latch switch. The output of the latch control switch is a Relay Word bit PLT_*n*.Sta (*n* = 001–016), called a latch bit.

Figure 4.58 Logic Diagram of a Latch Switch

If setting PLT_*n*.Set asserts to logical 1, latch bit PLT_*n*.Sta asserts to logical 1. If setting PLT_*n*.Rst asserts to logical 1, latch bit PLT_*n*.Sta deasserts to logical 0. If both settings PLT_*n*.Set and PLT_*n*.Rst assert to logical 1, setting PLT_*n*.Rst has priority and latch bit PLT_*n*.Sta deasserts to logical 0. You can use these latch bits in SELOGIC control equations to create custom logic for your application.

The SEL-851 includes 16 latches. *Table 4.42* shows the **SET** and **RESET** default settings for the SELOGIC protection latches. All latches are set to NA.

Table 4.42 SELOGIC Protection Logic Settings

Settings Prompt	Setting Range	Setting Name := Factory Default
PLT_001.Set	SELOGIC	PLT_001.Set := NA
PLT_001.Rst	SELOGIC	PLT_001.Rst := NA
⋮	⋮	⋮
PLT_016.Set	SELOGIC	PLT_016.Set := NA
PLT_016.Rst	SELOGIC	PLT_016.Rst := NA

Latch Bits: Nonvolatile State

Power Loss

The states of the latch bits (PLT_001.Sta–PLT_016.Sta) are retained if power to the device is lost and then restored. If a latch bit is asserted (e.g., PLT_002.Sta := logical 1) when power is lost, it is asserted (PLT_002.Sta := logical 1) when power is restored. If a latch bit is deasserted (e.g., PLT_003.Sta := logical 0) when power is lost, it is deasserted (PLT_003.Sta := logical 0) when power is restored.

Settings Change

If individual settings are changed, the states of the latch bits (Relay Word bits PLT_001.Sta through PLT_016.Sta) are retained, as in the preceding *Power Loss on page 4.72* explanation. If the individual settings change causes a change in SELOGIC control equation settings PLT_*n*.Set or PLT_*n*.Rst (*n* = 001 through 016), the retained states of the latch bits can be changed, subject to the newly enabled settings PLT_*n*.Set or PLT_*n*.Rst.

Make Latch Control Switch Settings With Care

The latch bit states are stored in nonvolatile memory so they can be retained during power loss or settings 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 device service life.*

Settings PLT_*n*.Set and PLT_*n*.Rst cannot result in continuous cyclical operation of latch bit PLT_*n*.Sta. Use timers to qualify conditions set in settings PLT_*n*.Set and PLT_*n*.Rst. If you use any optoisolated inputs in settings PLT_*n*.Set and PLT_*n*.Rst, the inputs each have a separate debounce timer that can help in providing the necessary time qualification.

SELOGIC Control Equation Protection Conditioning Timers

Enable the number of SELOGIC control equation protection conditioning timers necessary for your application. Only the enabled SELOGIC control equation protection conditioning timers appear for settings. Each SELOGIC control equation has a SELOGIC control equation setting input and variable/timer outputs as shown in *Figure 4.59*. Timers PCT_001.Sta through PCT_016.Sta in *Figure 4.59* have a setting range of 0.00–3000.00 seconds. This timer setting range applies to both pickup and dropout times (PCT_*n*.PU and PCT_*n*.DO, *n* = 001 through 016).

NOTE: Any SELOGIC control equation that contains a Relay Word bit/analog quantity that gets hidden because of a setting change or a configuration change will show up as a `BAD SELOGIC EQUATION`.

Figure 4.59 SELOGIC Control Equation Protection Conditioning Timers PCT_001.Sta–PCT_016.Sta

You can enter as many as 15 elements per SELOGIC control equation, including a total of 14 elements in parentheses (see *Table 4.44* for more information).

SELOGIC Control Equation Operators

Use the 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. SELOGIC control equations are either Boolean type or math type. Because you have already used the equals sign (=) as an equality comparison, both Boolean type and math type of SELOGIC control equation settings begin with an “assignment” operator (:=) instead of with an equals sign.

Boolean SELOGIC control equation settings use logic similar to Boolean algebra logic, combining Relay Word bits together with one or more of the Boolean operators listed in *Table 4.44*. Math SELOGIC control equation settings operate on numerical values, using one or more of the Mathematical operators listed in *Table 4.44*. These numerical values can be mathematical variables or actual real numbers.

The relay converts variables from decimal to integer before performing math operations, i.e., scales it by multiplying by 128 followed by rounding. After the math operations, the relay converts the result back from integer to decimal by scaling the value down by 128 before reporting the results. This effectively means that math calculations are rounded. See *Example 4.24* for an explanation on improving the accuracy of the math operations by managing the processing order.

EXAMPLE 4.24 Improving the Accuracy of Math Operations

If PMV_001.Val : = (60/4160) • 100,000, the relay performs the 60/4160 calculation and scales it by 128, then rounds this up to a 2. The relay then multiplies it by 100,000 and stores it as 200,000. When the number is reported it divides out the scale factor (128) and reports 1562.5.

Alternately, If PMV_001.Val := (60 • 100,000) / 4160, the relay multiplies (60 • 100,000) and then scales by 128 and then divides by 4160. This result is then rounded and stored as 184,615. The relay then divides 184,615 by 128 and reports 1442.3.

Example 4.24 illustrates how important it is to avoid calculations where a small number is divided by a large number followed by multiplication. It will amplify the error significantly.

The executed result of a math SELOGIC control equation is stored in a math variable. The storage format of the math variable is a 32-bit fixed point signed integer; 24 bits represent the integer portion, 7 bits represent the fractional portion, and one bit represents the sign. The smallest and largest values a math variable can represent are –16777215.99 and +16777215.99, respectively. If the executed result exceeds these limits, it will be clipped at the limit value. For example, when the PMV_001.Val := executed result is –16777219.00, PMV_001.Val will be –16777215.99. Similarly, when the PMV_002.Val := executed result is +16777238.00, PMV_002.Val will be +16777215.99. Because there are only 7 bits available for the fractional portion, the result of multiplication and division with decimals will have lower accuracy than one would expect with a floating point processor. As illustrated by the results in *Table 4.43*, the results vary from 20 percent at the smallest end of the fractional values to 0.2 percent at the largest. Using scaling factors where possible is recommended to avoid the error introduced by the fixed point processor when multiplying and dividing fractional numbers.

Table 4.43 Math Variable Fractional Multiplication Results

PMV_001.Val := 0.01 • 10	Result = 0.08	Error = 20%
PMV_001.Val := 0.05 • 10	Result = 0.47	Error = 6.0%
PMV_001.Val := 0.10 • 10	Result = 1.02	Error = 2.0%
PMV_001.Val := 0.50 • 10	Result = 5.00	Error = 0.0%
PMV_001.Val := 0.99 • 10	Result = 9.92	Error = 0.2%

Comments can be added to both Boolean and math SELOGIC control equations by inserting a # symbol. Everything following the # symbol in a SELOGIC control equation is treated as a comment. See *Table 4.45* for this and other Boolean and math operators and values.

Operator Precedence

When you combine several operators and operands within a single expression, the SEL-851 evaluates the operators from left to right, starting with the highest precedence operators and working down to the lowest precedence. This means that if you write an equation with three AND operators, for

example PCT_001.In AND PCT_002.In AND PCT_003.In, each AND is evaluated from the left to the right. If you substitute NOT PCT_004.In for PCT_003.In to make PCT_001.In AND PCT_002.In AND NOT PCT_004.In, the device will evaluate the NOT operation of PCT_004.In first and uses the result in subsequent evaluation of the expression.

Table 4.44 SELOGIC Control Equation Operators (Listed in Operator Precedence)

Operator	Function	Function Type (Boolean and/ or Mathematical)
( )	parentheses	Boolean and Mathematical (highest precedence)
–	negation	Mathematical
NOT	NOT	Boolean
R_TRIG	rising-edge trigger/detect	Boolean
F_TRIG	falling-edge trigger/detect	Boolean
* /	multiply divide	Mathematical
+ -	add subtract	Mathematical
<, >, <=, >=	comparison	Boolean
= <>	equality inequality	Boolean
AND	AND	Boolean
OR	OR	Boolean (lowest precedence)

Parentheses Operator ( )

You can use more than one set of parentheses in a SELOGIC control equation setting. For example, the following Boolean SELOGIC control equation setting has two sets of parentheses:

PCT_004.In := **(PCT_004.In OR IN_02.Sta) AND (TLED_01.Sta OR RB_001.Sta)**

In the previous example, the logic within the parentheses is processed first and then the two parentheses resultants are ANDed together. Use as many as 14 sets of parentheses in a single SELOGIC control equation setting. The parentheses can be “nested” (parentheses within parentheses).

Math Negation Operator (–)

The negation operator – changes the sign of a numerical value. For example:

PMV_001.Val := **RB_001.Sta**

When Remote bit RB_001.Sta asserts, Math variable PMV_001.Val has a value of 1, i.e., PMV_001.Val = 1. We can change the sign on PMV_001.Val with the following expression:

PMV_001.Val := **–1 * RB_001.Sta**

Now, when Remote bit RB_001.Sta asserts, Math variable PMV_001.Val has a value of –1, i.e., PMV_001.Val = –1.

Boolean NOT Operator (NOT)

Apply the NOT operator to a single Relay Word bit and to multiple elements (within parentheses).

An example of a single Relay Word bit is as follows:

PCT_001.In := **NOT RB_001.Sta**

When Remote bit RB_001.Sta asserts from logical 0 to logical 1, the Boolean NOT operator, in turn, changes the logical 1 to a logical 0. In this example, PCT_001.In deasserts when RB_001.Sta asserts.

Following is an example of the NOT operator applied to multiple elements within parentheses.

The Boolean SELOGIC control equation OUT_01.Sta setting could be set as follows:

OUT_01.Sta := **NOT(RB_001.Sta OR PCT_002.In)**

If both RB_001.Sta and PCT_002.In are deasserted (= logical 0), output contact OUT_01.Sta asserts, i.e., OUT_01.Sta := NOT (logical 0 OR logical 0) = NOT (logical 0) = logical 1.

In a Math SELOGIC control equation, use the NOT operator with any Relay Word bits. This allows a simple if/else type equation, as shown in the following example.

PMV_001.Val := **12 * IN_01.Sta + (PMV_001.Val + 1) * NOT IN_01.Sta**

The previous equation sets PMV_001.Val to 12 whenever IN_01.Sta asserts, otherwise it increments PMV_001.Val by 1 each time the equation is executed.

Boolean Rising-Edge Operator (R_TRIG)

Apply the rising-edge operator, R_TRIG, to individual Relay Word bits only; you cannot apply R_TRIG to groups of elements within parentheses. When any Relay Word bit asserts (going from logical 0 to logical 1), R_TRIG interprets this logical 0 to logical 1 transition as a “rising edge” and asserts to logical 1 for one processing interval.

For example, the Boolean SELOGIC control equation event report generation setting uses rising-edge operators:

Event.Trg := **R_TRIG IN_01.Sta OR R_TRIG IN_02.Sta**

The rising-edge operators detect a logical 0 to logical 1 transition each time one of IN_01.Sta or IN_02.Sta asserts. Using these settings, the device triggers a new event report each time IN_01.Sta or IN_02.Sta asserts anew, if the device is not already recording an event report. You can use the rising-edge operator with the NOT operator as long as the NOT operator precedes the R_TRIG operator. The NOT R_TRIG combination produces a logical 0 for one processing interval when it detects a rising edge on the specified element.

Boolean Falling-Edge Operator (F_TRIG)

Apply the falling-edge operator, F_TRIG, to individual Relay Word bits only; you cannot apply F_TRIG to groups of elements within parentheses. The falling-edge operator, F_TRIG, operates similarly to the rising-edge operator, but operates on Relay Word bit deassertion (elements going from logical 1 to logical 0) instead of Relay Word bit assertion. When the Relay Word bit deasserts, F_TRIG interprets this logical 1 to logical 0 transition as a “falling edge” and asserts to logical 1 for one processing interval, as shown in *Figure 4.60*.

Figure 4.60 Result of Falling-Edge Operator on a Deasserting Input

You can use the falling-edge operator with the NOT operator as long as the NOT operator precedes the F_TRIG operator. The NOT F_TRIG combination produces a logical 0 for one processing interval when it detects a falling edge on the specified element.

Math Arithmetic Operators (*, /, +, and –)

If you use Relay Word bits (which are effectively Boolean resultants, equal to logical 1 or logical 0) in mathematical operations, the relay treats these as numerical values 0 and 1, depending on whether the Relay Word bit is equal to logical 0 or logical 1, respectively.

Boolean Comparison Operators (<, >, <=, and >=)

Comparisons are mathematical operations that compare two numerical values, with the result being a logical 0 (if the comparison is not true) or logical 1 (if the comparison is true). Thus, what starts out as a mathematical comparison ends up as a Boolean resultant. For example, if the output of a math variable is greater than a certain value, an output contact is asserted:

OUT_03.Sta := **PMV_001.Val > 8**

If the math variable (PMV_001.Val) is greater than 8 in value, output contact OUT_03.Sta asserts (OUT_03.Sta = logical 1). If the math variable (PMV_001.Val) is less than or equal to 8 in value, output contact OUT_03.Sta deasserts (OUT_03.Sta = logical 0).

Boolean Equality (=) and Inequality (<>) Operators

Equality and inequality operators operate similar to the comparison operators. These are mathematical operations that compare two numerical values, with the result being a logical 0 (if the comparison is not true), or logical 1 (if the comparison is true). Thus, what starts out as a mathematical comparison, ends up as a Boolean resultant. For example, if the output of a math variable is not equal to a certain value, an output contact is asserted:

OUT_02.Sta := **PMV_001.Val <> 45**

If the math variable (PMV_001.Val) is not equal to 45 in value, output contact OUT_02.Sta asserts (effectively OUT_02.Sta := logical 1). If the math variable (PMV_001.Val) is equal to 45 in value, output contact OUT_02.Sta deasserts (effectively OUT_02.Sta := logical 0). *Table 4.45* shows other operators and values that you can use in writing SELOGIC control equations.

Table 4.45 Other SELOGIC Control Equation Operators/Values

Operator/ Value	Function	Function Type (Boolean and/or Mathematical)
0	Set SELOGIC control equation directly to logical 0 (XXX := 0)	Boolean
1	Set SELOGIC control equation directly to logical 1 (XXX := 1)	Boolean
#	Characters entered after the # operator are not processed and deemed as comments	Boolean and Mathematical
\	Indicates that the preceding logic should be continued on the next line ("\" is entered only at the end of a line)	Boolean and Mathematical

Timers Reset When Power Lost or Settings Changed

If the device loses power or settings change, the SELOGIC control equation variables/timers reset. Relay Word bits PCT_*n*.In and PCT_*n*.In (*n* = 001–016) reset to logical 0 after power restoration or a settings change.

SELOGIC Control Equation Protection Conditioning Timer Settings

The SEL-851 includes 16 SELOGIC control equation protection conditioning timers. *Table 4.46* shows the pickup, dropout, and equation settings for SELOGIC control equation protection conditioning timers.

Table 4.46 SELOGIC Control Equation Protection Conditioning Timer Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
TIMER INPUT	SELOGIC	PCT_001.In := NA
TIMER PICKUP	0.00–3000.00 s	PCT_001.PU := 0.00
TIMER DROPOUT	0.00–3000.00 s	PCT_001.DO := 0.00
• • •	• • •	• • •
TIMER INPUT	SELOGIC	PCT_016.In := NA
TIMER PICKUP	0.00–3000.00 s	PCT_016.PU := 0.00
TIMER DROPOUT	0.00–3000.00 s	PCT_016.DO := 0.00

Counter Variables

NOTE: These counter elements conform to the standard counter function block #3 in IEC 1131-3 First Edition 1993-03 International Standard for Programmable controllers—Part 3: Programming languages.

NOTE: If setting PCN_n.CD is set to NA, the entire counter n is disabled.

NOTE: If setting PCN_n.CU is set to NA, the counter counts downwards only.

NOTE: SELOGIC counters are reset to zero if the relay loses power because the counters are stored in volatile memory.

SELOGIC control equation protection counters are up- or down-counting elements, updated every processing interval.

Each counter element consists of one count setting, four control inputs, two digital outputs, and one analog output. *Figure 4.61* shows Counter 1, the first of 16 counters available in the device.

Figure 4.61 Counter 01

Digital output PCN_001.QD asserts when the counter is at position zero, and digital output PCN_001.QU asserts when the counter reaches the programmable count value. Use the reset input (PCN_001.Rst) to force the count to zero, and the analog output (PCN_*n*.CV) with analog comparison operators. *Table 4.47* describes the counter inputs and outputs, and *Table 4.48* shows the order of precedence of the control inputs.

Table 4.47 Counter Input/Output Description

Name	Type	Description
PCN_*n*.LD	Active High Input	Load counter with the preset value to assert the output (PCN_*n*.LD) (follows SELOGIC setting).
PCN_*n*.PV	Input Value	This Preset Value is loaded when PCN_001.LD pulsed. This Preset Value is the number of counts before the output (PCN_001.QU) asserts (follows SELOGIC setting).
PCN_*n*.CU	Rising-Edge Input	Count Up increments the counter (follows SELOGIC setting).
PCN_*n*.CD	Rising-Edge Input	Count Down decrements the counter (follows SELOGIC setting).
PCN_*n*.Rst	Active High Input	Reset counter to zero (follows SELOGIC setting)
PCN_*n*.QU	Active High Output	This Q Up output asserts when the Preset Value (maximum count) is reached (PCN_*n*.CV = PCN_*n*.PV, *n* = 001 to 016).
PCN_*n*.QD	Active High Output	This Q Down output asserts when the counter is equal to zero (PCN_*n*.CV = 0, *n* = 001 to 016).
PCN_*n*.CV	Output Value	This counter output is an analog value that you can use with analog comparison operators in a SELOGIC control equation and view using the **PCN** command.

Table 4.48 Order of Precedence of the Control Inputs

Order	Input
1	PCN_*n*.Rst
2	PCN_*n*.LD
3	PCN_*n*.CU
4	PCN_*n*.CD

Figure 4.62 shows an example of the effects of the input precedence, with PCN_001.PV set to 7. The vertical dashed line indicates the relationship between PCN_001.CU first being seen as a rising edge and the resultant outputs. This indicates that there is no intentional lag between the control input asserting and the count value changing. Most of the pulses in the diagram are on every second processing interval. The “one processing interval” valley is an example where the CD and CU pulses are only separated by one processing interval.

Figure 4.62 Example of the Effects of the Input Precedence

The shaded areas illustrate the precedence of the inputs:

- When PCN_001.Rst is asserted, the PCN_001.LD input is ignored.
- When PCN_001.Rst or PCN_001.LD is asserted, rising edges on the PCN_001.CU or PCN_001.CD inputs are ignored.
- When input PCM_001.CU has a rising edge, a rising edge on PCN_001.CD is ignored (unless PCN_001.CV is already at the maximum value PCN_001.PV (= 7), in which case PCN_001.CU is ignored, and the PCN_001.CD is processed). An example of this exception appears in the previous diagram, just before the "one processing interval" notation.

A maintained logical 1 state on the PCN_001.CU or PCN_001.CD inputs is ignored (after the rising edge is processed). A rising edge received on the PCN_001.CU or PCN_001.CD inputs is ignored when the PCN_001.Rst or PCN_001.LD inputs are asserted.

A maintained logical 1 on the PCN_001.CU or PCN_001.CD inputs does not get treated as a rising edge when the PCN_001.Rst or PCN_001.LD input deasserts. The same operating principles apply for all of the counters: PCN_001.CV–PCN_*m*.CV, where *m* = the number of enabled counters.

Mirrored Bits Transmit SELogic Control Equations

See *Appendix G: Mirrored Bits Communications* for details.

Port Settings (SET P Command)

The SEL-851 provides settings that allow you to configure the parameters for the communications ports. See *Section 2: Installation* for a detailed description of port connections. On the base unit: **Port F** (front panel) is a USB-C port; **Port 1** is a standard EIA-232 or EIA-485 port; **Port 2A** is a standard Ethernet port; and **Port 2B** is an optional Ethernet port. See *Table 4.49* through *Table 4.52* for the port settings. For detailed information on

communications protocols, refer to *Appendix C: SEL Communications Processors*, *Appendix D: DNP3 Communications*, *Appendix E: Modbus Communications*, *Appendix F: IEC 61850 Communications*, *Appendix G: MIRRORED BITS Communications*.

The Port_*n*.Ena and Port_*n*.AccLev settings provide you with access controls for the corresponding port. Setting Port_*n*.Ena to N disables the port and hides the remaining port settings. The Port_*n*.AccLev setting selects the highest access level for the port.

PORT F

Table 4.49 Front-Panel USB Port Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	Port_F.Ena := Y
MINUTES TO PORT TIME-OUT	0–30 min	Port_F.TmOut := 15
MAXIMUM ACCESS LEVEL	1, 2, C	Port_F.AccLev := 2

PORT 1

Table 4.50 Serial Port Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
PROTOCOL SELECTION	SEL, MOD, DNP, MBA, MB8A	Port_01.Proto := SEL
COMMUNICATIONS INTERFACE	232, 485	Port_01.CommIntfTyp := 232
BAUD RATE	300, 1200, 2400, 4800, 9600, 19200, 38400, 115200	Port_01.Spd := 115200
DATA BITS	7, 8	Port_01.DataBits := 8
PARITY	O, E, N	Port_01.Prty := N
STOP BITS	1, 2	Port_01.StopBits := 1
ENABLE HARDWARE HANDSHAKING	Y, N	Port_01.HndShk := N
MINUTES TO PORT TIME-OUT	0–30 min	Port_01.TmOut := 15
SEND AUTO MESSAGES TO PORT	Y, N	Port_01.AutoMsg_Ena := N
FAST OPERATE ENABLE	Y, N	Port_01.FastOp_Ena := N
MODBUS SLAVE ID	1–247	Port_01.Modbus_SlaveId := 1

Set the speed, data bits, parity, and stop bits settings to match the serial port configuration of the equipment that is communicating with the serial port.

After Port Timeout minutes of inactivity on a serial port at Access Level 2, the port automatically returns to Access Level 0. This security feature helps prevent unauthorized access to the relay settings if the relay is accidentally left in Access Level 2. If you do not want the port to time out, set Port Timeout equal to 0 minutes.

The relay EIA-232 serial ports support software (XON/XOFF) flow control. If you want to enable support for hardware (RTS/CTS) flow control, set the Port_01.HndShk setting equal to Y.

Set the Port_01.AutoMsg_Ena := Y to allow automatic messages at a serial port.

Set Port_01.FastOp_Ena := Y to enable binary Fast Operate messages at the serial port. Set Port_01.FastOp_Ena := N to block binary Fast Operate messages. Refer to *Appendix C: SEL Communications Processors* for the description of the SEL-851 Fast Operate commands.

PORT 2

IMPORTANT: Upon relay initial turn on, Port 1 setting changes, or Logic setting changes, you may have to wait as long as two minutes before an additional setting change can occur. Note that the relay is functional with protection enabled, as soon as the **ENABLED** LED comes on (about 2 seconds from turn on).

NOTE: The FAST OP MESSAGES setting only functions when using SEL Fast Operate protocol to operate/set/pulse breaker bits and remote bits. This setting has no effect on the other protocols.

NOTE: The Telnet LANG setting also applies to the web server interface.

Table 4.51 Ethernet Port Settings (Sheet 1 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	Port_02.Ena := N
ENABLE ETHERNET FIRMWARE UPGRADE	Y, N	Port_02.FwUpgrd_Ena := N
DEVICE IP ADDRESS/ CIDR PREFIX	zzz.yyy.xxx.www/tt zzz:1–126, 128–223 yyy: 0–255 xxx: 0–255 www: 0–255 tt: 1–31	Port_02.IPAddr := 169.254.0.1/16
DEFAULT ROUTER	zzz.yyy.xxx.www zzz:1–126, 128–223 yyy: 0–255 xxx: 0–255 www: 0–255	Port_02.DfltRout := 0.0.0.0
ENABLE TCP KEEP-ALIVE	Y, N	Port_02.TCP_KpAlvEna := N
TCP KEEP-ALIVE IDLE RANGE	1–20 s	Port_02.TCP_KpAlvIdleTm := 10
TCP KEEP-ALIVE INTERVAL RANGE	1–20 s	Port_02.TCP_KpAlvIntvTm := 1
TCP KEEP-ALIVE COUNT RANGE	1–20	Port_02.TCP_KpAlvCnt := 6
OPERATING MODE	FIXED, FAILOVER, SWITCHED	Port_02.OpMod := FAILOVER
FAILOVER TIME-OUT	OFF, 0.10–65.00 s	Port_02.FailoverTm := 1.00
FORCE NETWORK LINK	SELOGIC	Port_02.LinkForcOv := 0
PRIMARY NETWORK PORT	A, B	Port_02.PriNetPort := A
PORT A SPEED	AUTO, 10, 100 Mbps	Port_02.PortASpd := AUTO
PORT B SPEED	AUTO, 10, 100 Mbps	Port_02.PortBSpd := AUTO
ENABLE TELNET	Y, N	Port_02.Telnet_Ena := N
MAXIMUM ACCESS LEVEL	1, 2, C	Port_02.Telnet_AccLev := 2
TELNET PORT	23, 1025–65534	Port_02.Telnet_Port := 23
TELNET CONNECT BANNER	254 ASCII printable characters	Port_02.Telnet_Banr := Terminal Server
TELNET PORT TIME-OUT	1–30 min	Port_02.Telnet_TmOut := 15

Table 4.51 Ethernet Port Settings (Sheet 2 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
SEND AUTO MESSAGES TO PORT	Y, N	Port_02.AutoMsg_Ena := N
FAST OPERATE ENABLE	Y, N	Port_02.FastOp_Ena := N
ENABLE FTP	Y, N	Port_02.FTP_Ena := N
FTP MAXIMUM ACCESS LEVEL	1, 2, C	Port_02.FTP_AccLev := 2
FTP USER NAME	20 ASCII printable characters	Port_02.FTP_Username := FTPUSER
FTP CONNECT BANNER	254 ASCII printable characters	Port_02.FTP_Banr := FTP Server
FTP IDLE TIMEOUT	5–255 min	Port_02.FTP_TmOut := 5
ENABLE IEC 61850 PROTOCOL	Y, N	Port_02.61850_Ena := N
ENABLE IEC 61850 GSE	Y, N	Port_02.Goose_Ena := N
ENABLE MMS FILE SERVICES	Y, N	Port_02.MMS_FileSvcEna := N
ENABLE 61850 MODE/ BEHAVIOR CONTROL	Y, N	Port_02.61850_ModCtrlEna := N
ENABLE GOOSE TX IN OFF MODE	Y, N	Port_02.GOOSE_TxOffModEna := N
ENABLE FIXED GOOSE PUBLICATIONS	0–1	Port_02.FG_TxEna := 0
ENABLE MODBUS	0–2	Port_02.Modbus_Ena := 0
IP ADDRESS[a]	zzz.yyy.xxx.www zzz: 0–126, 128–223 yyy: 0–255 xxx: 0–255 www: 0–255	Port_02.Modbus_MastIP1 := 192.168.1.101
IP ADDRESS[a]	zzz.yyy.xxx.www zzz: 0–126, 128–223 yyy: 0–255 xxx: 0–255 www: 0–255	Port_02.Modbus_MastIP2 := 192.168.1.102
MODBUS TCP/IP PORT 1	1–65534	Port_02.Modbus_TCPPort1 := 502
MODBUS TCP/IP PORT 2	1–65534	Port_02.Modbus_TCPPort2 := 502
MODBUS SESSION TIME-OUT 1	15–900 s	Port_02.Modbus_TmOut1 := 15
MODBUS SESSION TIME-OUT 2	15–900 s	Port_02.Modbus_TmOut2 := 15
ENABLE HTTP SERVER	Y, N	Port_02.HTTP_SrvrEna := N
ENABLE HTTPS SERVER	Y, N	Port_02.HTTPS_SrvrEna := N
HTTP MAXIMUM ACCESS LEVEL	1, 2, C	Port_02.HTTP_AccLev := 2
HTTP SERVER TCP/IP PORT NUMBER	1–65534	Port_02.HTTP_TCPPort := 80

Table 4.51 Ethernet Port Settings (Sheet 3 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
HTTPS SERVER TCP/IP PORT NUMBER	1–65534	Port_02.HTTPS_TCPPort := 443
HTTP CONNECT BANNER	254 ASCII printable characters	Port_02.HTTP_Banr := This system is for the use of authorized personnel only
HTTP WEB SERVER TIMEOUT	1–60 min	Port_02.HTTP_TmOut := 10
ENABLE DNP SESSIONS[b]	0–3	Port_02.DNP_Ena := 0
ENABLE SNTP CLIENT[c]	OFF, UNICAST, MANYCAST, BROADCAST	Port_02.SNTP_Ena := OFF

[a] Port_02.Modbus_MastIP1 and Port_02.Modbus_MastIP2 cannot share an address and must be unique (except when 0.0.0.0, which effectively disables security and allows any master to communicate).
[b] See Table D.7 for a complete list of the DNP3 session settings.
[c] See Table 7.7 for a complete list of SNTP settings and their descriptions.

Port Number Settings Must Be Unique

When making the SEL-851 Port 2 settings, port number settings cannot be used for more than one protocol. The relay checks all of the settings shown in *Table 4.52* before saving changes. If a port number is used more than once, or if it matches any of the fixed port numbers (20, 21, 23, 102, 502), the relay displays an error message and returns to the first setting that is in error or contains a duplicate value.

Table 4.52 Port Number Settings That Must Be Unique

Setting	Name	Setting Required When
Port_02.Telnet_Port	Telnet Port	Always
Port_02.Modbus_TCPPort1[a]	Modbus TCP/IP Port 1	Port_02.Modbus_Ena > 0
Port_02.Modbus_TCPPort2[a]	Modbus TCP/IP Port 2	Port_02.Modbus_Ena > 1
Port_02.DNP_PortNum	DNPTCP and UDP Port	Port_02.DNP_Ena > 0
Port_02.SNTP_PortNum	SNTPIP (Local) Port Number	Port_02.SNTP_Ena ≠ OFF

[a] Port_02.Modbus_TCPPort1 and Port_02.Modbus_TCPPort2 can have the same port number. The relay displays an error message if this number matches with the port numbers of other protocols.

HMI Settings (SET H Command)

The SEL-851 relay has a built-in HMI interface, making system monitoring, data collection, and control quick and efficient. This section covers all of the HMI related settings. Refer to *Section 8: HMI* for more information.

General Settings

Display points display selected information on the LCD. However, you need to first enable the appropriate number of display points necessary for your application. When your SEL-851 arrives, two display points are already enabled. If more display points are necessary for your application, use the DP.Ena setting to enable as many as eight display points. Factory-default HMI general settings are shown in *Table 4.53*.

Table 4.53 HMI General Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE DISPLAY POINTS	N, 1–8	DP.Ena := 2
HMI CONTROL MODE	ACK_EN, ACK_DIS, BLK_CTRL	HMI_CtlBlk := ACK_DIS
HMI DISPLAY TIMEOUT	OFF, 1–30 min	HMI_TmOut := 15
HMI AUTOMESSAGES	OVERRIDE, ROTATING	HMI.AutoMsg := OVERRIDE
HMI CLOSE DELAY	0–30 s	HMI.ClsDly := 0
HMI TRIP DELAY	0–30 s	HMI.TripDly := 0
RESET TRIP-LATCHED LEDS ON CLOSE	Y, N	TLED.RstCls := Y

NOTE: If HMI.CtlBlk := ACK_DIS, you can trip or close the breaker with a single press of the **TRIP** or **CLOSE** pushbutton.

NOTE: If you make a change to the HMI_CtlBlk setting, the HMI will restart upon saving the settings.

NOTE: To adjust the backlight of the HMI, simultaneously press the right and left navigation keys (< >) for 5 seconds. This will display the backlight adjust control.

NOTE: To adjust the contrast on the HMI, simultaneously press the **ESC** and **ENT** keys for 5 seconds. This will display the contrast adjust control.

Use the HMI control mode setting, HMI.CtlBlk, to either enable (ACK_EN) or disable (ACK_DIS) the acknowledgment of a control action performed via the HMI. It can also be set to block (BLK_CTRL) some of the control actions via the HMI. The HMI.CtlBlk setting affects TRIP, CLOSE, and LOCAL/REMOTE control from the HMI.

Use the HMI LCD time-out setting (HMI_TmOut) to set the LCD time-out. The LCD will go into the rotating display mode with the backlight dimmed if the LCD is in one of the menus not already in the rotating display mode. Disable the LCD time-out by setting HMI.TmOut := OFF.

Use the HMI automessage setting HMI.AutoMsg to define displaying of the trip or warning message. Set HMI.AutoMsg either to OVERRIDE or ROTATING to add to the rotating display when the relay triggers a trip or warning message. Refer to *Section 8: HMI* for more information on automessages.

You can delay a breaker close or trip long enough to walk away to a safe distance after initiating a **CLOSE** or **TRIP** from the HMI by setting the HMI close and trip delay settings (HMI.ClsDly/HMI.TripDly). Pressing the HMI **CLOSE** or **TRIP** pushbutton at any time during the delay cancels the close or trip operation.

Set TLED.RstCls := Y to reset the latched LEDs automatically when the breaker closes.

Display Points

Use display points to view either the state of internal relay elements (Boolean information) or analog information on the LCD. The HMI allocates two rows to display each of the programmed display points, binary or analog quantity. A maximum of 21 characters can be displayed in each row.

If the resulting length of the display point to be displayed is within 21 characters, then the HMI displays it on the 1st row and leaves the 2nd row empty. If the resulting length of the display point to be displayed is greater than 21 characters but less than or equal to 42 characters, then the HMI displays it on both the rows. If the resulting length of the display point to be displayed is greater than 42 characters, then the HMI displays part or all of the Alias or user text if it fits. The HMI does not show the value associated with the Name if the resulting length is greater than 42 characters (see below for more information on the terms Name, Alias, and user text).

NOTE: Display points are updated every 5 seconds.

Although the LCD screen displays a maximum of 21 characters per row and a total of 42 characters in two rows for each display point, you can program as many as 60 valid characters in each of the display point setting. Valid characters are 0–9, A–Z, -, /, ", {, }, space. For text exceeding 21 characters, the LCD shows the first 21 characters, then scrolls through the remaining text not initially displayed on the screen.

Boolean Display Point Entry Composition

Boolean information is the status of Relay Word bits (see *Appendix H: Relay Word Bits*). In general, the legal syntax for Boolean display points consists of the following four fields or strings, separated by commas:

Relay Word Bit Name, “Alias”, “Set String”, “Clear String”.

where:

Name is the Relay Word bit name (IN_01.Sta, for example). If only the Name is provided as part of the setting without the Alias string, then the HMI will add “=” at the end of Name when it is displayed on the LCD.

“Alias” is a more descriptive name for the Relay Word bit (such as BREAKER), or the analog quantity (such as TEMPERATURE). If an Alias string is provided in the setting, then the HMI will add “ = ” at the end of Alias string when it is displayed on the LCD.

“Set String” is the state that should be displayed on the LCD when the Relay Word bit is asserted (CLOSED, for example).

“Clear String” is the state that should be displayed on the LCD when the Relay Word bit is deasserted (OPEN, for example).

Any or all of Alias, Set String, or Clear String can be empty. Although the relay accepts an empty setting Name as valid, a display point with an empty Name setting is always hidden (see below). Commas are significant in identifying and separating the four strings. Use quotation marks only if the text you enter for Alias, Set String, or Clear String contains commas or spaces. For example, DP_*nn*.Set = Name,Text is valid, but Name, Alias 3 is not valid (contains a space). Correct the Alias name by using the quotation marks: Name, “Text 3”. You can customize the data display format by entering data in selected strings only. *Table 4.54* shows the various display appearances resulting from entering data in selected strings.

Hidden (No Display)

A display point is hidden when settings are entered (DP_01.Set = XX, where *n* = 01–08 and XX = any valid setting), but nothing shows on the HMI display. *Table 4.54* shows examples of settings that always, never, or conditionally hide a display point.

Table 4.54 Settings That Always, Never, or Conditionally Hide a Display Point

Programmable Automation Controller Setting	Name	Alias	Set String	Clear String	Comment
DP_01.Set := IN_01.Sta,BREAKER,CLOSED,OPEN	IN_01.Sta	BREAKER	CLOSED	OPEN	Never hidden
DP_01.Set := IN_01.Sta,BREAKER	IN_01.Sta	BREAKER	—	—	Never hidden
DP_01.Set :=	—	—	—	—	Always hidden
DP_01.Set := IN_01.Sta,,,	IN_01.Sta	—	—	—	Always hidden
DP_01.Set := IN_01.Sta,BREAKER	IN_01.Sta	BREAKER	—	—	Always hidden
DP_01.Set := IN_01.Sta,BREAKER,CLOSED,	IN_01.Sta	BREAKER	CLOSED	—	Hidden when IN_01.Sta is deasserted
DP_01.Set := IN_01.Sta“BREAKER”,, OPEN	IN_01.Sta	BREAKER	—	OPEN	Hidden when IN_01.Sta is asserted

Following are examples of selected display point settings, showing the resulting HMI displays. For example, at a certain station we want to display the status of both HV and LV circuit breakers of Transformer 1. When the HV circuit breaker is open, we want the LCD to show: `XFR1 HV BKR = OPEN`, and when the HV circuit breaker is closed, we want the display to show: `XFR1 HV BKR = CLOSED`. We also want similar displays for the LV breaker.

After connecting a form a (normally open) auxiliary contact from the HV circuit breaker to Input **IN01** and a similar contact from the LV circuit breaker to Input **IN02** of the SEL-851, we are ready to program the display points, using the following information for the HV breaker (LV breaker similar):

- Relay Word bit—IN_01.Sta
- Alias—TRFR 1 HV BRKR
- Set String—CLOSED (the Form A [normally open] contact asserts or sets Relay Word bit IN_01.Sta when the circuit breaker is closed)
- Clear String—OPEN (the Form A [normally open] contact deasserts or clears Relay Word bit IN_01.Sta when the circuit breaker is open)

Name, Alias, Set String, and Clear String

When all four strings have entries, the relay reports all states.

Table 4.55 Entries for the Four Strings

Name	Alias	Set String	Clear String
IN_01.Sta	XFR1 HV BKR	CLOSED	OPEN

Figure 4.63 displays the settings for the example when you click **Settings** > **HMI** on the navigation panel of the webpage.

Figure 4.63 Display Point Settings, Viewed Using Web Browser

Figure 4.64 shows the display when both HV and LV breakers are open (both IN01 and IN02 deasserted). *Figure 4.65* shows the display when the HV breaker is closed, and the LV breaker is open (IN01 asserted, but IN02 still deasserted).

Figure 4.64 HMI Display—Both HV and LV Breakers Open

Figure 4.65 HMI Display—HV Breaker Closed, LV Breaker Open

Name String, Alias String, and Either Set String or Clear String Only

The following discusses omission of the Clear String; omission of the Set String gives similar results. Omitting the Clear String causes the relay to only show display points in the set state, using the **SET H** command as follows:

```
DP_01.Set := IAvg.120ms_MagPri,“Ave Curr {6} A”
 ? IN_01.Sta,"XFR1 HV BKR","CLOSED" <Enter>
```

When the Relay Word bit IN_01.Sta deasserts, the relay removes the complete line with the omitted Clear String (XFR1 HV BKR). When both breakers are closed, the relay has the set state information for both HV and LV breakers, and the relay displays the information as shown in *Figure 4.66*. When the HV breaker opens (LV breaker is still closed), the relay removes the line containing the HV

breaker information because the Clear String information was omitted. Because the line containing the HV breaker information is removed, the relay now displays the LV breaker information on the top line, as shown in *Figure 4.67*.

Figure 4.66 HMI Display—Both HV and LV Breakers Closed

Figure 4.67 HMI Display—HV Breaker Open, LV Breaker Closed

If you want the relay to display a blank state when IN_01.Sta deasserts, instead of removing the line altogether, use the curly brackets { } for the Clear String, as follows:

```
DP_01.Set := IAvg.120ms_MagPri,“Ave Curr {6} A”
 ? IN_01.Sta,"XFR1 HV BKR","CLOSED",{} <Enter>
```

When Input IN_01.Sta now deasserts, the relay still displays the line with the HV breaker information, but the state is left blank, as shown in *Figure 4.68*.

Figure 4.68 HMI Display—HV Breaker Open With Blank State, LV Breaker Closed

Name Only

Table 4.56 shows an entry in the Name String only (leaving the Alias string, Set String, and Clear String void), using the **SET H** command as follows:

```
DP_01.Set := IAvg.120ms_MagPri,“Ave Curr {6} A”
 ? IN_01.Sta <Enter>
```

Table 4.56 Binary Entry in the Name String Only

Name	Alias	Set String	Clear String
IN_01.Sta	—	—	—

Figure 4.69 shows the HMI display for the entry in *Table 4.56*. Input IN01 is deasserted in this display (`IN_01.Sta = 0`), but changes to `IN_01.Sta = 1` when Input IN01 asserts.

Figure 4.69 HMI Display for a Binary Entry in the Name String Only

Analog Display Point Entry Composition

In general, the legal syntax for analog display points consists of the following two fields or strings:

Name, “User Text and Formatting.”

where:

Name is the analog quantity name (IAvg.120ms_MagPri for example). If only the Name is provided as part of the setting without User text and numerical formatting, then the HMI will add “ = ” at the end of Name when it is displayed on the LCD.

“User Text and Numerical Formatting” displays the user text followed by the value associated with Name in the set numerical format {width.dec,scale}. The value associated with Name is scaled by “scale”, formatted with total width “width” and “dec” decimal places.

If only the user text is specified without any numerical formatting ({width.dec,scale}), then the HMI will add “ = ” at the end of Name when it is displayed on the LCD.

The width value includes the decimal point and sign character, if applicable. The “scale” value is optional; if omitted, the scale factor is 1. If the numeric value is smaller than the string size requested, the string is padded with spaces to the left of the number. If the numeric value does not fit within the string width given, the string grows (to the left of the decimal point) to accommodate the number.

The maximum value that can be displayed is 10^{21}. If the resulting value after taking the product of the value associated with Name and the “scale” is greater than 10^{21} then the LCD shows it as $$$$$$$$$$.

Table 4.57 shows an entry in the Name string only (leaving the User Text and Formatting string void) with the following syntax:

Table 4.57 Analog Entry in the Name String Only

Name	Alias	Set String	Clear String
IAvg.120ms_MagPri	—	—	—

Consider that the analog quantity, IAvg.120ms_MagPri, contains a value of 100.51 A. *Figure 4.70* shows the HMI display for the entry in *Table 4.57*, using the **SET H** command as follows:

```
DP_01.Set := IAvg.120ms_MagPri,”Ave Curr {6} A”
? IAvg.120ms_MagPri <Enter>
```

Figure 4.70 HMI Display for an Analog Entry in the Name String Only

Name and Alias

For a more descriptive name of the Relay Word bit, enter the Relay Word bit in the Name String, and an alias name in User Text and Formatting String. *Table 4.58* shows a Boolean entry in the Name and Alias Strings (DP_01.Set) and an entry in the Name and User Text and Formatting Strings (DP_02.Set), using the **SET H** command as follows:

```
DP_01.Set := IAvg.120ms_MagPri, “Ave Curr {6} A”
 ? IN_01.Sta,"INPUT IN01" <Enter>
DP_02.Set := IGnd.120ms_MagPri, “Gnd Curr {6} A”
 ? MWh.Rec,“REAL ENERGY RECEIVED” <Enter>
```

Table 4.58 Entry in the Name String and the Alias Strings

Name	Alias	Set String	Clear String
IN_01.Sta	INPUT IN01	—	—
MWh.Rec	REAL ENERGY RECEIVED	—	—

Figure 4.71 shows the HMI display for the entry in *Table 4.58*. Input IN_01.Sta is deasserted in this display (0), and the display changes to `INPUT IN01 = 1` when Input IN_01.Sta asserts. REAL ENERGY RECEIVED is 112.40 MWh in this display.

Figure 4.71 HMI Display for an Entry in (a) Boolean Name and Alias Strings and (b) Analog Name and User Text and Formatting Strings

For fixed text, enter a 1 in the Name String, then enter the fixed text as the alias text. For example, to display the word DEFAULT and SETTINGS on two different lines, use a display point for each word, i.e., DP_01.Set = 1, “DEFAULT” and DP_02.Set = 1,“SETTINGS”. *Table 4.59* shows other options and HMI displays for the User Text and Formatting settings. PMV_001.Val with a value of 1234.00 stored in the variable is used as an example in the table.

Table 4.59 Example Settings and Displays

Example Display Point Setting Value	Example Display
PMV_001.Val.“PMV01 = {4}%”	PMV01 = 1234%
PMV_001.Val,“PMV01 = {4.1}”	PMV01 = 1234.0
PMV_001.Val,“PMV01 = {5}”	PMV01 = 1234
PMV_001.Val,“PMV01 = {4.2,0.001}%”	PMV01 = 1.23%
PMV_001.Val,“PMV01 ANALOG = {4,1000}”	PMV01 ANALOG = 1234000
1,{}	Empty line

Rotating Display

With more than two display points enabled, the relay scrolls through all enabled display points, thereby forming a rotating display, as shown in *Figure 4.72*.

Figure 4.72 Rotating Display

Target LED Settings

The SEL-851 offers two fixed and eight programmable target LEDs on the HMI. See *Figure 8.1* for the programmable LED locations.

Target LEDs

NOTE: If the LED latch setting (TLED_n.Latch) is set to Y, and Trip_01.Sta asserts, the LED latches to the state at Trip_01.Sta assertion. The latched LED targets can be reset using **TARGET RESET** if the target conditions are absent.

Settings TLED_*n*.Latch and TLED_*n*.Set (*n* = 01–08) control the eight HMI LEDs. With TLED_*n*.Latch set to Y, the LEDs latch the LED state at Trip_01.Sta assertion. The latched LEDs can be reset by one of the following approaches:

- Pressing **TARGET RESET** on the front panel.
- Issuing the serial port command **TAR R**.
- The assertion of the SELOGIC control equation Trip.TrgtRst.

With TLED_*n*.Latch settings set to N, the LEDs do not latch and directly follow the state of the associated SELOGIC control equation setting. Enter any of the Relay Word bits (or combinations of Relay Word bits) as conditions in the TLED_*n*.Set SELOGIC control equation settings. When these Relay Word bits assert, the corresponding LED also asserts. Default target LED settings are shown in *Table 4.60*.

Table 4.60 Target LED Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
TRIP LATCH TARGET LED 01	Y, N	TLED_01.Latch := N
TARGET LED 01 ASSERTED COLOR	R, G, A	TLED_01.Color := A
TARGET LED 01 EQUATION	SELOGIC	TLED_01.Set := Warning.Sta
TARGET LED 01 LABEL	12 characters	TLED_01.Label := WARNING

Table 4.60 Target LED Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
TRIP LATCH TARGET LED 02	Y, N	TLED_02.Latch := N
TARGET LED 02 ASSERTED COLOR	R, G, A	TLED_02.Color := A
TARGET LED 02 EQUATION	SELOGIC	TLED_02.Set := Ctl.LocSta
TARGET LED 02 LABEL	12 characters	TLED_02.Label := LOCAL
TRIP LATCH TARGET LED 03	Y, N	TLED_03.Latch := Y
TARGET LED 03 ASSERTED COLOR	R, G, A	TLED_03.Color := R
TARGET LED 03 EQUATION	SELOGIC	TLED_03.Set := 50.TmOut
TARGET LED 03 LABEL	12 characters	TLED_03.Label := INST OC
TRIP LATCH TARGET LED 04	Y, N	TLED_04.Latch := Y
TARGET LED 04 ASSERTED COLOR	R, G, A	TLED_04.Color := R
TARGET LED 04 EQUATION	SELOGIC	TLED_04.Set := 51P_01.TmOut OR 51P_02.TmOut
TARGET LED 04 LABEL	12 characters	TLED_04.Label := PHASE OC
TRIP LATCH TARGET LED 05	Y, N	TLED_05.Latch := Y
TARGET LED 05 ASSERTED COLOR	R, G, A	TLED_05.Color := R
TARGET LED 05 EQUATION	SELOGIC	TLED_05.Set := 51Gnd_01.TmOut OR 51Gnd_02.TmOut OR 51N_01.TmOut OR 51N_02.TmOut
TARGET LED 05 LABEL	12 characters	TLED_05.Label := GND/NEU OC
TRIP LATCH TARGET LED 06	Y, N	TLED_06.Latch := N
TARGET LED 06 ASSERTED COLOR	R, G, A	TLED_06.Color := R
TARGET LED 06 EQUATION	SELOGIC	TLED_06.Set := (BF_01.TmOut OR TLED_06.Set) AND (NOT Trip.TrgtRstSta) OR BF_01.Trip)
TARGET LED 06 LABEL	12 characters	TLED_06.Label := BREAKER FAIL
TRIP LATCH TARGET LED 07	Y, N	TLED_07.Latch := N
TARGET LED 07 ASSERTED COLOR	R, G, A	TLED_07.Color := G
TARGET LED 07 EQUATION	SELOGIC	TLED_07.Set := 79.Rst
TARGET LED 07 LABEL	12 characters	TLED_07.Label := REC RESET
TRIP LATCH TARGET LED 08	Y, N	TLED_08.Latch := N
TARGET LED 08 ASSERTED COLOR	R, G, A	TLED_08.Color := R
TARGET LED 08 EQUATION	SELOGIC	TLED_08.Set := 79.LO
TARGET LED 08 LABEL	12 characters	TLED_08.Label := RECL LOCKOUT

Report Settings (SET R Command)

The report settings use Relay Word bits for the SER and event report trigger as shown in *Table 4.61*. See *Appendix H: Relay Word Bits* for details. Refer to *Section 9: Analyzing Events* for additional information about SER and event reports.

SER Trigger Lists

Enter as many as 96 Relay Word bits. The SER List entries (**SET R SER** command) are text-edit mode settings with line number prompts.
See *Table 4.33* for the text-edit mode actions.

Table 4.61 SER List Factory-Default Values

Line Number	Factory-Default Setting	Line Number	Factory-Default Setting	Line Number	Factory-Default Setting
1:	IN_01.Sta	17:	Comm.ClsCmd	33:	Diag.Hw_Alm
2:	IN_02.Sta	18:	HMI.CtlBlkSta	34:	Warning.Sta
3:	IN_03.Sta	19:	Trip_01.LocSta	With Voltage Option	
4:	IN_04.Sta	20:	Trip_01.RemSta	35:	27PP_01.TmOut
5:	OUT_01.Sta	21:	Comm.TripCmd	36:	27PP_02.TmOut
6:	OUT_02.Sta	22:	Trip_01.Sta	37:	59PP_01.TmOut
7:	OUT_03.Sta	23:	Trip_01.Init	38:	59PP_02.TmOut
8:	OUT_04.Sta	24:	Trip_01.Unlt	39:	50Gnd_01.TmOut
9:	Bkr_01.52A_Sta	25:	Trip_01.InitX	40:	50Gnd_02.TmOut
10:	Ctl.RemSta	26:	50P_01.TmOut	With Arc Flash	
11:	Close_01.LocSta	27:	51P_01.TmOut	41:	AFD.50P_PU
12:	Close_01.RemSta	28:	50Gnd_01.TmOut	42:	AFD.50N_PU
13:	Close_01.Sta	29:	50Gnd_01.TmOut	43:	AFD.Sen01_PU
14:	Ctl.RemSel	30:	50N_01.TmOut	44:	AFD.Sen02_PU
15:	HMI.RemSel	31:	51N_01.TmOut	45:	AFD.Sen03_PU
16:	Close_01.RemInit	32:	Diag.Secu_Alm	46:	AFD.Sen04_PU

Relay Word Bit Aliases

Table 4.62 Enable Alias Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE ALIAS SETTINGS	N, 1–10	SER.AliasEna := 2

To simplify your review of the information displayed in the SER record, the relay provides the Alias setting function. Using the Alias settings, you can change the way relay elements listed in the previous SER settings are displayed in the SER report. In addition, the Alias settings allow you to change the text displayed when a particular element is asserted and deasserted. The relay permits as many as 10 unique aliases, as defined by the Enable Alias Settings (SER.AliasEna) setting. Factory default alias settings are shown in *Table 4.63*.

Define the enabled alias settings by entering the Relay Word bit name, a space, the alias you want, a space, the text to display when the condition asserts, a space, and the text to display when the condition deasserts.

```
SER.Alias01 = Bkr_01.52A_Sta BREAKER CLOSED OPEN
```

See *Table H.1* for the complete list of Relay Word bits. Use as many as 15 characters to define the alias, asserted text, and deasserted text strings. You can use capital letters (A–Z), numbers (0–9), and the underscore character (_) within each string. Do not attempt to use a space within a string because the relay interprets a space as the break between two strings. If you want to clear a string, simply type **NA**.

Table 4.63 SET R SER Alias Settings

Setting Name	Relay Word Bit	Alias	Asserted Text	Deasserted Text
SER.Alias01 :=	Bkr_01.52A_Sta	BREAKER	CLOSED	OPEN
SER.Alias02 :=	Ctl.RemSta	CONTROL	REMOTE	LOCAL
SER.Alias03–SER.Alias10	NA			

Event Report Settings

Table 4.64 Event Report Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
EVENT TRIGGER	SELOGIC	Event.Trg := R_TRIG 51P_01.PU OR R_TRIG 51Gnd_01.PU OR R_TRIG 51N_01.PU OR R_TRIG 50P_01.PU OR R_TRIG 50Gnd_01.PU OR R_TRIG 50N_01.PU
SAMPLE RATE OF EVENT REPORT	2, 5, or 10 kHz	Event.SampRate := 2
LENGTH OF EVENT REPORT	0.25 to 2.00 s	Event.Len := 0.50
LENGTH OF PRE-FAULT	0.10–EventLen s	Event.PreFlt := 0.10

Data are acquired and stored at a rate of 10 kHz. The events can be retrieved at a rate of 2 kHz, 5 kHz, or 10 kHz as specified by the sample rate setting (Event.SampRate). Event reports can be between 0.25 seconds and 2.00 seconds in length as determined by the Event.Len setting. The prefault length is determined by the Event.PreFlt setting. The relay can hold as many as two 2.0-second reports, six 1.0-second reports, or twenty seven 0.25-second reports.

Signal-Profiling Settings

Set the Profile.SampRate to the desired acquisition rate for the report. Use the Profile.List setting to declare the analog quantities you want included in the signal-profile report. Enter as many as 16 analog quantities, separated by spaces or commas, into Profile.List setting. See *Appendix I: Analog Quantities* for a list of the available analog quantities.

IMPORTANT: All stored signal data are lost when changing the Profile.List.

Table 4.65 Signal-Profiling Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
PROFILING ACQ. RATE	5, 10, 15, 30, 60 min	Profile.SampRate := 15
PROFILE LIST	Enter as many as 16 analog quantities, one per line	Profile.List := IA.120ms_MagPri IB.120ms_MagPri IC.120ms_MagPri

DNP Map Settings (SET D Command)

Table 4.66 shows the available settings. See *Appendix D: DNP3 Communications* for additional details.

Table 4.66 DNP Map Settings[a] (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
DNP BINARY INPUT LABEL NAME	30 characters	BI_00 := EnaLED.Sta
DNP BINARY INPUT LABEL NAME	30 characters	BI_01 := TripLED.Sta
DNP BINARY INPUT LABEL NAME	30 characters	BI_02 := TLED_01.Sta
DNP BINARY INPUT LABEL NAME	30 characters	BI_03 := TLED_02.Sta
.		
.		
.		
DNP BINARY INPUT LABEL NAME	30 characters	BI_99 := NA
DNP BINARY OUTPUT LABEL NAME	30 characters	BO_00 := RB_001.Sta
.		
.		
.		
DNP BINARY OUTPUT LABEL NAME	30 characters	BO_31 := NA
DNP ANALOG INPUT LABEL NAME	30 characters	AI_00 := IA.120ms_MagPri
DNP ANALOG INPUT LABEL NAME	30 characters	AI_01 := IB.120ms_MagPri
.		
.		
.		
DNP ANALOG INPUT LABEL NAME	30 characters	AI_99 := NA
DNP ANALOG OUTPUT LABEL NAME	30 characters	AO_00 := RA_001.Val
.		
.		
.		
DNP ANALOG OUTPUT LABEL NAME	30 characters	AO_31 := NA

Table 4.66 DNP Map Settings[a] (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
DNP COUNTER LABEL NAME	30 characters	CO_00 := NA
•		
•		
•		
DNP COUNTER LABEL NAME	30 characters	CO_31 := NA

[a] See Appendix D: DNP3 Communications for complete list of the DNP Map labels and factory-default settings.

Modbus Map Settings (SET M Command)

Modbus User Map

Table 4.67 shows the available settings. See *Appendix E: Modbus Communications* for additional details.

Table 4.67 User Map Register Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
USER REG#1	NA, 1 Modbus Register Label	MOD_001 :=
•	•	•
•	•	•
•	•	•
USER REG#250	NA, 1 Modbus Register Label	MOD_250 :=

[a] See Appendix E: Modbus Communications for a complete list of the Modbus Register Labels and factory-default settings.

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Section 5

Metering and Monitoring

Overview

The SEL-851 Feeder Protection Relay includes metering functions to display the present values of current, voltage, and analog inputs. The relay provides the following methods to read the present meter values:

- Front-panel rotating display
- Front-panel menu
- Web server via Ethernet port
- USB-C serial port (by using SEL ASCII text commands or SEL Grid Configurator Software)
- Telnet via Ethernet port
- Modbus via EIA-232 port or EIA-485 port
- Modbus TCP via Ethernet port
- DNP3 serial via EIA-232 or EIA-485 port
- DNP3 LAN/WAN via Ethernet port
- IEC 61850 Edition 2 via Ethernet port

Feeder monitoring and trending are possible by using the signal-profile function. The relay automatically configures itself to save as many as 16 quantities (selected from the analog quantities) every 5, 10, 15, 30, or 60 minutes. The data are stored in nonvolatile memory. As many as 6500 time samples can be stored in the relay.

Power Measurement Conventions

The SEL-851 uses the IEEE convention for power measurement. The implications of this convention are depicted in *Figure 5.1*.

Figure 5.1 Complex Power Measurement Conventions

Metering

The SEL-851 meter data fall into the following categories:

- Fundamental metering
- Energy metering
- Maximum and minimum metering
- Math variable metering
- RMS metering
- Demand and peak demand metering
- Light metering for arc-flash detection (AFD)
- Remote analog metering
- Harmonic metering

Small Signal Cutoff Metering

With the factory default of Meter.Thres_Min := Y (see *Table 4.3*), the SEL-851 applies a threshold to the fundamental and rms current and voltage magnitude metering quantities to force the reading of zero when the measurement is near zero. The threshold for the current is 0.05 • CTP.INom A secondary and 1.0 V secondary for voltage. Set Meter.Thres_Min := N if the small signal cutoff metering is not desired in a specific application.

Fundamental Metering

Table 5.1 details each of the fundamental meter data types in the SEL-851. *Section 7: Communications* and *Section 8: HMI* describe the communications ports and how to access the various types of meter data by using the relay front panel.

Table 5.1 Measured Fundamental Meter Values

Relay Option	Meter Values
All Models	Line Currents IA, IB, IC, and IN (Core-Balance Ground Fault Current) magnitudes (A primary) and phase angles (deg) IG (Residual Ground Fault Current) magnitude (A primary) and phase angle (deg) IAVG (Average Current Magnitude A primary) Positive-Sequence Current (I1 A primary) Negative-Sequence Current (3I2 A primary) System Frequency (Hz) (FREQ)
With AC Voltage Inputs	VAB, VBC, VCA or VAN, VBN, VCN, 3V0 magnitudes (V primary) and phase angles (deg) VAVG, Average Voltage Magnitude (L-L V primary) Positive-Sequence Voltage (V1 V primary) Negative-Sequence Voltage (3V2 V primary) Real Power (kW) Reactive Power (kVAR) Apparent Power (kVA) Power Factor

NOTE: Calculated phase-to-phase voltages for wye-connected VTs are available in the analog quantities and can be selected as display points. See Appendix I: Analog Quantities.

All angles are displayed between –180 and +180 degrees. The angles are referenced to VAB or VAN (for delta- or wye-connected VT, respectively) or IA. The angles are referenced to IA current if the secondary voltage VAB <5 V rms (for delta-connected PT) or the secondary voltage VAN <5 V rms (for wye-connected PT). *Figure 5.2* shows an example of the **METER** command report.

```
=>>MET <Enter>

SEL-851                                  Date: 02/04/2021   Time: 09:22:34.420
FEEDER RELAY                             Time Source: Internal

                                     IA        IB        IC      IG       IN
Current Magnitude (A pri.)     2001.38   1999.70   2008.17    9.34   120.31
Current Angle (deg)                0.1    -120.0     120.1   125.6      0.1

Ave Curr Mag (A pri.)          2003.08
Pos-Seq Curr I1 (A pri.)       2003.07
Neg-Seq Curr 3I2 (A pri.)         9.16

                                     VAB          VBC         VCA        VAVG
Voltage Magnitude (V pri.)     20754.72     20751.03    20772.64    20759.46
Voltage Angle (deg)                30.0        -90.0       150.0

                                      VA           VB          VC         3V0
Voltage Magnitude (V pri.)     11991.00     11971.36    11994.10       21.54
Voltage Angle (deg)                 0.0       -120.0       120.0        84.8


Pos-Seq Volt V1 (V pri.)       11985.47
Neg-Seq Volt 3V2 (V pri.)         48.96

Real Power (kW)                72023.547
Reactive Power (kVAR)           -131.181
Apparent Power (kVA)           72023.664
Power Factor (LEAD)             0.99

Frequency (Hz)                 59.99

=>>
```

Figure 5.2 METER Command Report With Voltage/Arc-Flash Detection

Energy Metering

The SEL-851 includes energy metering in models with AC voltage inputs. Use this form of metering to quantify real, reactive, and apparent energy supplied to the feeder load. Following are the energy meter values.

- MWh3P-Received—Real three-phase energy (from feeder into bus)
- MWh3P-Delivered—Real three-phase energy (out of bus, into feeder)
- MVARh3P-Received—Reactive three-phase energy (from feeder, into bus)
- MVARh3P-Delivered—Reactive three-phase energy (out of bus, into feeder)
- MVAh3P—Apparent three-phase energy
- Last date and time of energy meter quantities were reset

NOTE: Energy values rollover after 99999.999 MVAh and reset to 0.

Figure 5.3 shows the device response to the **METER E** command.

```
=>MET E <Enter>

SEL-851                                    Date: 02/04/2021   Time: 09:26:27.933
FEEDER RELAY                               Time Source: Internal


Energy
MWh3P-Received (MWh)            0.000
MWh3P-Delivered (MWh)       31064.896
MVARh3P-Received (MVARh)       32.487
MVARh3P-Delivered (MVARh)       0.000
MVAh3P(MVAh)                31064.924

LAST RESET = 01/30/2021  03:07:36.003

=>
```

Figure 5.3 METER E Command Response

To reset the energy meter values, issue the **METER E R** command (shown in *Figure 5.4*) or the **METER E C** command.

```
=>>MET E R <Enter>
Reset Metering Quantities (Y,N)? Y <Enter>
Reset Complete
=>>
```

Figure 5.4 METER E R Command Response

Energy metering values are stored to nonvolatile memory four times per day and within one minute of the energy metering values being reset.

Maximum and Minimum Metering

Maximum and minimum metering allows you to determine maximum and minimum operating quantities such as currents, voltages, power, and frequency. *Table 5.2* lists the max/min metering quantities.

Table 5.2 Maximum/Minimum Meter Values (Sheet 1 of 2)

Relay Option	Max/Min Meter Values
All Models	Maximum and minimum line currents I_A, I_B, I_C, and I_N (core-balance ground fault current) magnitudes (A primary) Maximum and minimum I_G (residual ground fault current) magnitude (A primary)

Table 5.2 Maximum/Minimum Meter Values (Sheet 2 of 2)

Relay Option	Max/Min Meter Values
With AC Phase Voltage Inputs	Maximum and minimum V_{AB}, V_{BC}, V_{CA} or V_{AN}, V_{BN}, V_{CN} magnitudes (V primary) Maximum and minimum real, reactive, and apparent three-phase power (kW, kVAR, kVA) Maximum and minimum system frequency (Hz)

All maximum and minimum metering values have the date and time that they occurred. The analog quantities from *Table 5.2* are checked approximately every 0.5 seconds and, if a new maximum or minimum value occurs, this value is saved along with the date and time that the maximum or minimum value occurred. Maximum and minimum values are only checked if Relay Word bit Meter.Fault is deasserted (no fault condition exists) for at least one second.

Additionally, the following minimum thresholds must also be met:

- Current values I_A, I_B, I_C, and I_N: 3 percent of the nominal CT rating.
- Current value I_G: I_A, I_B, and I_C must all be greater than their thresholds.
- Voltage (secondary) values (phase and phase-to-phase): 7.5 V and 13 V, respectively.
- Power values (real, reactive, and apparent): All three currents (I_A, I_B, I_C) and all three voltages (V_A, V_B, V_C or V_{AB}, V_{BC}, V_{CA}) must be greater than their thresholds.

Figure 5.5 shows an example relay response to the **METER MM** command.

```
=>>MET MM <Enter>

SEL-851                                   Date: 02/04/2021 Time: 15:46:02
FEEDER RELAY                              Time Source: External

                   MAX        DATE       TIME       MIN        DATE      TIME
IA (A)            1005.8  02/03/2021  15:41:43       19.8  02/03/2021 03:55:41
IB (A)            1097.1  02/03/2021  15:41:26      197.3  02/03/2021 11:41:10
IC (A)             972.7  02/03/2021  15:45:11      206.0  02/03/2021 11:40:47
IN (A)               0.5  02/03/2021  18:20:00        0.4  02/03/2021 11:39:43
IG (A)             155.9  02/03/2021  15:42:32        0.4  02/03/2021 00:31:39
VAB (V)           6650.4  02/03/2021  15:45:45     6647.4  02/03/2021 15:41:14
VBC (V)           6671.9  02/03/2021  15:42:56     6666.8  02/03/2021 15:39:54
VCA (V)           7505.1  02/03/2021  15:41:05     7502.9  02/03/2021 15:45:42
KW3P (kW)         7797.2  02/03/2021  13:45:15   -11108    02/03/2021 15:41:42
KVAR3P (kVAR)     5031.8  02/03/2021  15:42:49    -1396.3  02/03/2021 15:45:24
KVA3P (kVA)      12187    02/03/2021  15:41:42      608.1  02/03/2021 11:42:27
FREQ (Hz)           60.1  02/03/2021  11:36:54       60.0  02/03/2021 15:45:23

LAST RESET = 01/30/2021 03:54:34

=>>
```

Figure 5.5 METER MM Command Response

To reset maximum/minimum meter values, issue the **METER MM R** command (shown in *Figure 5.6*) or the **METER MM C** command. The max/min meter values can be reset from the serial port, Modbus, the front panel, or assertion of the Meter.MaxMin_Rst Relay Word bit. The date and time of the reset are preserved and shown in the max/min meter report.

```
=>>MET MM R <Enter>

Reset Metering Quantities (Y,N)? Y <Enter>
Reset Complete

=>>
```

Figure 5.6 METER MM R Command Response

All maximum and minimum metering values are stored to nonvolatile memory four times per day and within one minute of the maximum and minimum metering values being reset.

Math Variable Metering

The SEL-851 includes 16 math variables. When you receive your SEL-851, no math variables are enabled. To use math variables, enable the number of math variables (between 1 and 16) you require, using the PMV.Ena setting in the logic setting category. *Figure 5.7* shows the relay response to the **METER PMV** command with 8 of the 16 math variables enabled.

```
=>>MET PMV <Enter>

SEL-851                                    Date: 02/04/2021   Time: 01:40:30.437
FEEDER RELAY                               Time Source: Internal

PMV_001                 2002.34
PMV_002                 1998.88
PMV_003                 2007.09
PMV_004                    0.00
PMV_005                 1000.00
PMV_006                    0.98
PMV_007                 2000.54
PMV_008                    0.00

=>>
```

Figure 5.7 METER PMV Command Response

RMS Metering

The SEL-851 includes root-mean-square (rms) metering. Use rms metering to measure the entire signal (including harmonics). You can measure the rms quantities shown in *Table 5.3*.

Table 5.3 RMS Meter Values

Relay Option	RMS Meter Values
All Models	RMS current IA, IB, IC, and IN magnitudes (A primary)
With AC Phase Voltage Inputs	VAB, VBC, VCA or VAN, VBN, VCN magnitudes (V primary)

RMS quantities contain the total signal content, including harmonics. This differs from the fundamental meter (**METER** command) in that the fundamental meter quantities only contain the fundamental frequency (60 Hz for a 60-Hz system).

Figure 5.8 shows the **METER RMS** command.

```
=>>MET RMS <Enter>

SEL-851                                    Date: 02/04/2021   Time: 01:33:14.828
FEEDER RELAY                               Time Source: Internal

                IA        IB        IC        IN
RMS (A pri.)    2005.52   2003.11   2008.93   120.50

                VA        VB        VC
RMS (V pri.)    11992.49  11971.53  11996.15

=>>
```

Figure 5.8 METER RMS Command Response

Arc-Flash Light Intensity Metering

When the SEL-851 is ordered with the arc-flash detection (AFD) option and the element is enabled, the relay provides light metering data with the METER LIGHT (**METER L** command) report. The light inputs LS1–LS4 are given in percent of full scale.

Figure 5.9 provides an example of the **METER L** (Light) command report.

```
=>>MET L <Enter>

SEL-851                                    Date: 02/04/2021   Time: 15:45:14
FEEDER RELAY                               Time Source: External

Light Intensity
LS1 (%)    2.4
LS2 (%)    1.9
LS3 (%)    0.7
LS4 (%)    2.3

=>>
```

Figure 5.9 METER L Command Response

Demand Metering

The SEL-851 offers the choice between two types of demand metering, settable with the enable setting:

Meter.Dmd_Ena = THM (Thermal Demand Metering)

or

Meter.Dmd_Ena = ROL (Rolling Demand Metering)

The relay provides demand and peak demand (**METER D** command) metering. *Table 5.4* shows the values reported. *Figure 5.10* provides an example of the **METER D** (demand) command report. Refer to *Demand Metering on page 4.65* for detailed descriptions and settings selection.

Table 5.4 Demand Values

Relay Option	Demand/Peak Demand Values
All Models	Demand/peak demand values of line currents IA, IB, and IC magnitudes (A primary) Demand/peak demand value of IG (residual ground current) magnitude (A primary) Demand/peak demand value of negative-sequence current (3I2) magnitude (A primary)

```
=>>MET D <Enter>

SEL-851                                    Date: 02/04/2021   Time: 02:26:10.528
FEEDER RELAY                               Time Source: Internal


                         IA         IB        IC       IGnd       INeg
DEMAND (A pri.)          0.0        0.0       0.0      0.0        0.0

PEAK DEMAND (A pri.)     0.0        0.0       0.0      0.0        0.0


LAST DEMAND RESET = 01/30/2021  01:57:25.070
```

Figure 5.10 MET D Command Response

Remote Analog Metering

Use remote analog metering to verify the values received from an external device. The SEL-851 includes 32 remote analog variables. *Figure 5.11* shows the relay response to the **METER RA** command.

```
=>>MET RA <Enter>

SEL-851                                    Date: 02/01/2021   Time: 13:42:23
FEEDER RELAY                               Time Source: External

RA_001      1.00
RA_002 -32767.00
RA_003     -1.00
RA_004      0.00
RA_005   1000.59
RA_006  -1000.61
RA_007   2411.01
RA_008   2410.99
RA_009  98303.00
RA_010 -98303.00
RA_011 -38400.00
RA_012 -65536.00
RA_013      0.00
RA_014      0.00
RA_015      0.00
 .           .
 .           .
 .           .
RA_030     0.00
RA_031     0.00
RA_032     0.00

=>>
```

Figure 5.11 MET RA Command Response

Harmonic Metering

The harmonic metering function in the SEL-851 reports the current and voltage harmonics through the fifth harmonic and the total harmonic distortion percentage (THD %). *Table 5.5* shows the harmonic values reported. *Figure 5.12* provides an example of the **METER H** (harmonic) command report.

Table 5.5 Measured Harmonic Meter Values

Relay Option	RMS Meter Values
All Models	Fundamental, 2nd-, 3rd-, 4th-, and 5th-harmonic values, magnitude (A primary), and THD % of line currents IA, IB, and IC
With AC Phase Voltage Inputs	Includes the harmonic meter values shown for all models and fundamental magnitude (V primary), 2nd-, 3rd-, 4th-, and 5th-harmonic % values, THD % of voltages VA, VB, VC or VAB, VBC, VCA

```
=>>MET H <Enter>

SEL-851                                    Date: 02/04/2021   Time: 02:15:09.455
FEEDER RELAY                               Time Source: Internal

                IA      IB         IC       VA         VB        VC
Fund (Pri)  2001.82  2001.33  2005.31   11990.55  11973.04  11995.24
2nd  (%)      0.40     0.40     0.39      0.39      0.40      0.39
3rd  (%)      0.53     0.58     0.53      0.54      0.57      0.53
4th  (%)      0.44     0.86     0.81      0.44      0.86      0.81
5th  (%)      0.53     1.06     1.03      0.52      1.06      1.00
THD  (%)      5.68     5.57     5.60      1.74      0.00      0.00

=>>
```

Figure 5.12 MET H Command Response

Signal Profiling

The SEL-851 includes a signal-profiling function. The relay automatically records selected quantities into nonvolatile memory every 5, 10, 15, 30, or 60 minutes, depending on the Profile.SampRate signal-profile report setting (see *Signal-Profiling Settings on page 4.95*). Choose which analog quantities you want to monitor from the analog quantities listed in *Appendix I: Analog Quantities*. Set these quantities into the Profile.List signal-profile list report setting.

The relay memory can store 6500 time-stamped entries. For example, if you choose to monitor 10 values at an acquisition rate of every 15 minutes, you can store 66 days worth of data.

Use the serial port **PRO** command described in *PRO Command (Signal-Profile Report)* to download the signal rate profile data. See *Figure 5.13* for an example of a **PRO** serial port command response.

```
=>PRO <Enter>

SEL-851                                 Date: 02/04/2021   Time: 03:02:01.522
FEEDER RELAY                            Time Source: Internal

   #        DATE         TIME          IAvg.120ms_MagPri   VAvg.120ms_MagPri   P.120ms_Mag   PF.120ms_Mag
   8    02/04/2021  02:25:36.088                2003.078           20759.961     72025.094          0.984
   7    02/04/2021  02:30:17.896                2002.813           20759.953     72015.633          0.984
   6    02/04/2021  02:35:18.721                2002.852           20760.734     72019.859          0.984
   5    02/04/2021  02:40:18.541                2003.055           20759.359     72022.359          0.984
   4    02/04/2021  02:45:18.363                2002.609           20760.773     72011.156          0.984
   3    02/04/2021  02:50:18.187                2002.672           20760.859     72013.859          0.984
   2    02/04/2021  02:55:18.005                2003.000           20759.867     72022.102          0.984
   1    02/04/2021  03:00:18.835                2002.797           20760.687     72017.687          0.984

=>
```

Figure 5.13 PRO Command Response

PRO data are also available as a read-only file that can be retrieved using Ethernet FTP or MMS. MMS is only available in models that support IEC 61850 and only when IEC 61850 and MMS file transfer are enabled (Port_02.61850_Ena := Y, Port_02.MMS_FileSvcEna := Y). See *File Transfer Protocol (FTP) and MMS File Transfer on page 7.12*, *Virtual File Interface on page 7.49*, and *MMS on page F.5* for additional information.

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Section 6

Settings

Overview

This section is an overview of the ways in which the settings for the SEL-851 Feeder Protection Relay can be viewed and set. Setting entry error messages, together with corrective actions, are also covered in this section to assist you with settings entry. Settings, which are stored in nonvolatile memory, are divided into the following setting classes:

- Protection
- Logic
- Report
- HMI
- Port *p* (where *p* = 1 [EIA-232/EIA-485 serial port], 2 [Ethernet port], or F [USB-C port])
- Modbus
- DNP3

Some setting classes have multiple instances, e.g., there are three port setting instances, one for each port. Settings may be viewed or set in several ways, as shown in *Table 6.1*.

Table 6.1 Methods of Accessing Settings

	Web Server[a]	Serial Port Commands[b]	SEL Grid Configurator Software[a]
Display Settings	All settings	All settings (**SHO** command)	All settings
Change Settings	All settings	All settings (**SET** command)	All settings

[a] Refer to Section 3: PC Interface for detailed information.
[b] Refer to Section 7: Communications for detailed information on set up and use of the serial communications port and Ethernet port.

Refer to *Section 4: Protection and Logic Functions* for detailed information on setting definitions and ranges. You can download the settings sheets by selecting **Settings Grid** in SEL Grid Configurator Software and clicking on **Reports** (top right). You can download the settings sheets in CSV, JSON, or HTML format. Delete the settings under the Settings column for a blank settings sheet.

View or Change Settings Using the Web Server

Refer to *Section 3: PC Interface* for information on how to set up communication and how to access the relay on an Ethernet port with a personal computer.

View Settings

Once communication with the relay is established through the web server and you are logged in, the home page screen appears in your browser window. Click on **Settings** from the navigation pane to view all the available setting classes, as shown in *Figure 6.1*. Access Level 1 is view only. At this level, settings are dimmed and you cannot modify them. Click on a setting class to view its settings.

Figure 6.1 Web Server Settings Screen

Enter Settings

To set or modify the relay settings, log in to the relay at Access Level 2. On the navigation pane, click **Settings** to access the settings you want to edit. If an edited setting is out of range or invalid, the following message appears: **The settings colored red are in error. Changes cannot be submitted until the errors are corrected.** As shown in *Figure 6.2*, the green **Submit Changes** button is also unavailable.

Figure 6.2 Web Server Submit Changes Button is Disabled When Entered Settings are Incorrect

If the settings are edited without any errors, the **Submit Changes** button is enabled. Click on the button to submit the changes. As shown in *Figure 6.3*, the following message appears: **Are you sure you want to save your changes?**

Figure 6.3 Web Server Confirmation to Submit Setting Changes to the Relay

Click **Yes** to save the edited settings to the relay; otherwise, click **No**. When **Yes** is selected, the web server saves the settings to the relay, refreshes the webpage, and acknowledges with the message, **Changes Saved**, as shown in *Figure 6.4*.

Figure 6.4 Web Server Acknowledges Submitted Settings Were Saved to Relay

View or Change Settings Using SEL Grid Configurator

Refer to *Section 3: PC Interface* for detailed information on how to set up communication and how to access the relay on an Ethernet or serial port with a personal computer.

View/Edit Settings

With SEL Grid Configurator, you can edit relay settings online or offline. Once the settings database has been created and communication to the relay has been established at Access Level 1, select **Read** from the Device Commands menu to read the current settings in the relay. The software may take a few minutes to read all the relay settings. Once read, all the settings are populated for viewing or editing, as shown in *Figure 6.5*. From the navigation pane, select the **Settings** class for the settings you want to view or edit. If the edited settings are out-of-range or invalid, then a message appears in the Errors window, as shown in *Figure 6.5*.

Figure 6.5 SEL Grid Configurator Settings Editor—Displays Error if Invalid Settings Entered

You do not have to be at Access Level 2 to edit the settings; however, you must be at Access Level 2 to send the edited settings to the relay. Select **Send** in the Device Commands menu to initiate a connection to your device. The settings have to be free of errors before you can send them to the relay. One of the many advantages of SEL Grid Configurator is its ability to save settings on your computer for record keeping, offline access, or anytime viewing or editing.

View or Change Settings Using the Communications Port

Refer to *Section 7: Communications* for information on how to set up and access the relay serial or Ethernet port with a personal computer and how to use ASCII commands to communicate with the relay.

View Settings

Use the **SHOW** command to view relay settings. The **SHOW** command is available from Access Level 1. *Table 6.2* lists the **SHOW** command options.

Table 6.2 SHOW Command Options

Command	Description
SHOW	Show relay protection settings.
SHOW L	Show logic settings.
SHOW HMI	Show HMI settings.
SHOW P *n*	Show port settings for Port *n* (*n* = 1, 2, or F).
SHOW R	Show Sequential Events Recorder (SER) and event report settings.
SHOW D	Show DNP3 settings.
SHOW M	Show Modbus settings.

You may append a setting name to each of the commands to specify the first setting to display (e.g., **SHOW 50P_01.PUVal** displays the relay settings starting with setting 50P_01.PUVal). The default is the first setting. The **SHOW** command displays only the enabled settings.

Enter Settings

The **SET** command (available from Access Level 2) allows you to view or change settings. *Table 6.3* lists the **SET** command options.

NOTE: The **SET** command is not available for as long as 90 seconds after the relay is powered up and for as long as 40 seconds after a setting change. If you issue a **SET** command during this period, the relay responds with the following message:

```
Command Unavailable;
Relay Configuration in
Progress. Try Again.
```

Table 6.3 SET Command Options

Command	Description
SET	Protection elements, timers, etc., settings
SET L	SELOGIC control equations for settings protection
SET HMI	HMI display settings
SET P *n*	Serial port settings for serial Port *n* (*n* = 1, 2, or F)
SET R	SER and event report settings
SET D	DNP3 map settings
SET M	Modbus user map

You may append a setting name to each of the commands to specify the first setting to display (e.g., **SET 50P_01.PUVal** displays the relay settings starting with setting 50P_01.PUVal). The default is the first setting.

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 listed in *Table 6.4*.

Table 6.4 SET Command Editing Keystrokes

Press Key(s)	Results
<Enter>	Retains the setting and moves to the next setting.
^ <Enter>	Returns to the previous setting.
< <Enter>	Returns to the previous setting category.
> <Enter>	Moves to the next setting category.
END <Enter>	Exits the editing session, then prompts you to save the settings.
<Ctrl+X>	Aborts the editing session without saving changes.

The relay checks each entry to ensure that the entry is within the setting range. If it is not in range, an `Out of Range` message is generated, and the relay prompts you for the setting again.

When all the settings are entered, the relay displays the new settings and prompts you for approval to enable them. Press **Y <Enter>** to enable the new settings. The relay is disabled for as long as five seconds while it saves the new settings. The Diag.Secu_Alm Relay Word bit is set momentarily, and the **ENABLED** LED extinguishes while the relay is disabled.

To change a specific setting, enter the command shown in *Table 6.5*.

Table 6.5 SET Command Format

SET n m s TERSE	
where:	
n	is left blank or is L, HMI, R, M, or P to identify the class of settings.
m	is left blank or is 1, 2, or F when *n* = P.
s	is 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 (e.g., enter **50P_01.PUVal** to start at phase overcurrent trip level setting).
TERSE	instructs the relay to skip the settings 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.

Setting Entry Error Messages

As you enter relay settings, the relay checks the setting entered against the range for the setting. If any setting entered falls outside the corresponding range for that setting, the relay immediately responds `Out of Range` and prompts you to reenter the setting.

In addition to the immediate range check, several of the settings have interdependency checks with other settings. The relay checks setting interdependencies after you answer **Y** to the `Saves Settings?` prompt, but before the settings are stored. If any of these checks fail, the relay issues an error message and returns you to the settings list for a correction.

Section 7

Communications

Overview

A communications interface and protocol are necessary for communicating with the SEL-851 Feeder Protection Relay. A communications interface is the physical connection on a device. Once you have established a physical connection, you must use a communications protocol to interact with the relay.

The first part of this section describes communications interfaces and protocols available with the relay, including communications interface connections. The remainder of the section describes the ASCII commands you can use to communicate with the relay to obtain information, reports, data, or perform control functions.

Communications Interfaces

The SEL-851 physical interfaces are shown in *Table 7.1*. The SEL-851 provides for a variety of physical interfaces, including USB-C, EIA-232/EIA-485, and copper Ethernet (single- or dual-redundant).

Table 7.1 SEL-851 Communications Port Interfaces

Port	Communications Port Interfaces	Location	Feature
PORT F	USB-C	Front	Standard
PORT 1	Setting-selectable EIA-232/EIA-485 (RJ45 connector) with IRIG-B time code input	Rear	Standard
PORT 2A	10/100 BASE-T Ethernet (RJ45 connector)	Rear	Standard
PORT 2B	Dual-redundant 10/100 BASE-T Ethernet (Port 2A, Port 2B)	Rear	Ordering Option

Be sure to evaluate the installation and communications necessary to integrate with existing devices before ordering your SEL-851. Following is general information on possible applications of the different interfaces.

USB-C Front-Panel Port

The SEL-851 features a plug-and-play USB Type C port on the front panel. This port functions as a high-speed serial port that supports SEL ASCII protocol. The port does not require speed configuration. You can use an SEL-C497 (10-foot USB Type C to Type A cable) to connect this port to a PC. A variety of computer terminal emulation programs can communicate with the relay. For the best display, use VT-100 terminal emulation software or the closest available variation.

Serial (EIA-232/ EIA-485) Port

Figure 7.1 shows the rear-panel EIA-232/EIA-485 serial port (PORT 1) RJ45 connector pinout for the SEL-851.

Figure 7.1 Connector Pin Numbers

Table 7.2 shows the pin functions for EIA-232 and EIA-485 serial port configuration.

NOTE: Although the SEL-851 does not have a +5 Vdc output, it is compatible with certain transceivers that can be parasitically powered from the RS-232 RTS line held at +5 Vdc. Refer to the SEL-5801 Cable Selector Software for all transceivers compatible with the SEL-851.

Table 7.2 EIA-232/EIA-485 Serial Port Pin Functions

Pin	EIA-232 Mode Default Pinouts	EIA-485 Mode Default Pinouts
1	–IRIG-B input	–IRIG-B input
2	Not connected	Not connected
3	+IRIG-B input	+IRIG-B input
4	Signal ground (GND)	Signal ground (GND)
5	Receive data (RxD in)	+Receive data (+RxD in)
6	Transmit data (TxD out)	+Transmit data (+TxD out)
7	Clear to send (CTS in)	–Receive data (–RxD in)
8	Request to send (RTS out)	–Transmit data (–TxD out)

Use the EIA-232/EIA-485 port for communications distances as far as 30 m (100 ft) in low noise environments. Use the SEL-3530 Real-Time Automation Controller (RTAC) for integration or communications system robustness. Use the SEL-2505 with an EIA-232 (DB-9) serial port to connect to EIA-232 Port 1 on the relay.

To connect a PC serial port to the relay rear-panel serial port and enter relay commands, you need the following:

- A personal computer
- A communications cable to connect the computer to the relay serial port
- Terminal emulation software to control the computer serial port
- An SEL-851 relay

A variety of terminal emulation programs on personal computers can communicate with the relay. For the best display, use VT-100 terminal emulation or the closest variation.

The default settings for the EIA-232/EIA-485 serial port are as follows:

Port_01.CommIntfTyp = 232
Port_01.Spd = 115200
Port_01.DataBits = 8
Port_01.Prty = N
Port_01.StopBits = 1

To change the port settings, use the **SET P** command (see *Section 6: Settings*), the web server, or SEL Grid Configurator. *Section 8: HMI* provides details on making settings.

Hardware Flow Control

The EIA-232/EIA-485 port supports RTS/CTS hardware handshaking (hardware flow control). To enable hardware handshaking, use the **SET P 1** command to set Port_01.HndShk := Y. Disable hardware handshaking by setting Port_01.HndShk := N.

- If Port_01.HndShk := N, the relay permanently asserts the RTS line.
- If Port_01.HndShk := Y, the relay deasserts RTS when it is unable to receive characters.
- If Port_01.HndShk := Y, the relay does not send characters until the CTS input is asserted.

IRIG-B

The SEL-851 can receive a single IRIG-B input via serial Port 1. Use a cable that can receive an IRIG-B signal. Refer to the cable diagrams for commonly used configurations with an IRIG-B input (see *Figure 7.2* through *Figure 7.4*).

The relay automatically switches to the IRIG-B time source when present. If you want to connect to a device that produces an IRIG-B signal output, such as an RTAC, but you do not want the relay to use this as the time source, use a serial cable that does not send the IRIG-B signal to the relay.

The following cable diagrams show several types of EIA-232 serial communications cables that connect the SEL-851 to other devices. Refer to the SEL-5801 Cable Selector for additional cables that are compatible with the SEL-851. These cables are available from SEL. Contact the factory for more information.

Figure 7.2 SEL-C605A Serial Cable—SEL-851 to DTE Device (With IRIG-B Input)

Figure 7.3 SEL-C629A Serial Cable—SEL-851 to DTE Device With RJ45 Serial Connector (With IRIG-B Input)

NOTE: An SEL-C662 or equivalent cable and an SEL-C478N cable are required to connect to a standard PC interface.

Figure 7.4 SEL-C478N Serial Cable—SEL-851 to DCE Transceiver Device (With IRIG-B Input)

Figure 7.5 SEL-C472N Serial Cable—SEL-851 to DTE Device (With IRIG-B Input)

Ethernet Port

Use the Ethernet port for interfacing with an Ethernet network environment. To enable the Ethernet port, set Port_02.Ena := Y.

Ethernet Network Operation Settings

Several settings control how the SEL-851 with the Ethernet port operates on an Ethernet network. These settings include IP addressing information, network port failover options, and network speed.

Network Configuration

Use the network configuration settings shown in *Table 7.3* to configure the SEL-851 for operation on an IP network and to set other parameters affecting the physical Ethernet network interface operation.

Table 7.3 Ethernet Port Configuration Settings (Sheet 1 of 2)

Setting Prompt	Range	Setting Name := Factory Default	Description
ENABLE PORT	Y, N	Port_02.Ena := Y	Enable Ethernet port communication
ENABLE ETHERNET FIRMWARE UPGRADE	Y, N	Port_02.FwUpgrd_Ena := N	Enable firmware upgrade via Ethernet port
DEVICE IP ADDRESS/CIDR PREFIX (zzz.yyy.xxx.www/tt)	z = 0–126, 128–223 y = 0–255 x= 0–255 w = 0–255 t = 1–31	Port_02.IPAddr := 169.254.0.1/16	IP network address/CIDR network prefix

Table 7.3 Ethernet Port Configuration Settings (Sheet 2 of 2)

Setting Prompt	Range	Setting Name := Factory Default	Description
DEFAULTROUTER (zzz.yyy.xxx.www)	z = 0–126, 128–223 y = 0–255 x = 0–255 w = 0–255	Port_02.DfltRout := 0.0.0.0	Default router
ENABLE TCP KEEP-ALIVE	Y, N	Port_02.TCP_KpAlvEna := N	TCP keep-alive functionality enable
TCP KEEP-ALIVE IDLE RANGE	1–20 s (must be greater than or equal to Port_02.TCP_ KpAlvIntvTm)	Port_02.TCP_KpAlvIdleTm := 10	Length of time to wait with no detected activity before sending a keep-alive packet
TCP KEEP-ALIVE INTERVAL RANGE	1–20 s (must be less than or equal to Port_02.TCP_ KpAlvIdleTm)	Port_02.TCP_KpAlvIntvTm := 1	Length of time to wait between sending keep-alive packets after receiving no response for the prior keep-alive packet
TCP KEEP-ALIVE COUNT RANGE	1–20	Port_02.TCP_KpAlvCnt := 6	Maximum number of keep-alive packets to send
OPERATING MODE	FIXED, FAILOVER, SWITCHED	Port_02.OpMod := FAILOVER	Network operating mode
FAILOVER TIME-OUT	OFF, 0.10–65.00 s	Port_02.FailoverTm := 1.00	Failover time-out
FORCE NETWORK LINK	SELOGIC	Port_02.LinkForcOv := 0	Force network link switchover
PRIMARY NETWORK PORT	A, B	Port_02.PriNetPort := A	Primary network port
PORT A SPEED	AUTO, 10 Mbps, 100 Mbps	Port_02.PortASpd := AUTO	Network speed or autodetect on Port A
PORT B SPEED	AUTO, 10 Mbps, 100 Mbps	Port_02.PortBSpd := AUTO	Network speed or autodetect on Port B

The SEL-851 Port_02.IPAddr setting uses classless inter-domain routing (CIDR) notation and a variable-length subnet mask (VLSM) to define its local network and host address.

An IP address consists of two parts: a prefix that identifies the network followed by a host address within that network. Early network devices used a subnet mask to define the network prefix of an associated host address. Within the mask, subnet boundaries were defined by the 8-bit segments of the 32-bit IP address. These boundaries constrained network prefixes to 8, 16, or 24 bits, defining Class A, B, and C networks, respectively.

This classful networking often created subnetworks that were not sized efficiently for actual requirements. CIDR allows more effective usage of a given range of IP addresses. In CIDR notation, you enter the Port_02.IPAddr setting in the form z.y.x.w/t, where *zzz.yyy.xxx.www/tt* is the host address in standard dotted decimal form and *tt* is the network prefix expressed as the number of "1" bits in the mask. For example, if Port_02.IPAddr := 192.168.1.2/24, the host address is 192.168.1.2 and the network prefix is the first 24 bits of the address, or 192.168.1. The network address is derived by applying the network prefix to Port_02.IPAddr and filling the remaining bits with zeros (in our example, it is 192.168.1.0). The broadcast address is derived similarly, but the remaining bits are filled with ones (192.168.1.255 for the example above). Neither the network (base) address nor the broadcast address can be used for any host or router addresses on the network.

The SEL-851 uses the Port_02.DfltRout address setting to determine how to communicate with nodes on other local networks. The SEL-851 communicates with the default router to send data to nodes on other local networks. The default router must be on the same local network as the SEL-851 or the SEL-851 will reject the Port_02.DfltRout setting. You must also coordinate the default router with your general network implementation and administration plan. See *Table 7.4* for examples of how Port_02.IPAddr defines the network and node and how it affects the Port_02.DfltRout setting.

Table 7.4 Port_02.DfltRout Address Setting Examples

Port_02.IPAddr (CIDR)	Subnet Mask (Non-CIDR)	Network Address	Broadcast Address	Port_02.DfltRout Range[a]
192.168.1.2/28	255.255.255.240	192.168.1.0	192.168.1.15	192.168.1.0–192.168.1.15
192.168.1.2/24	255.255.255.0	192.168.1.0	192.168.1.255	192.168.1.z^b
192.168.1.2/20	255.255.240.0	192.168.0.0	192.168.15.255	192.168.0.z^b–192.168.15.z^b
192.168.1.2/16	255.255.0.0	192.168.0.0	192.168.255.255	192.168.y^b.z^b
192.168.1.2/12	255.240.0.0	192.160.0.0	192.175.255.255	192.160.y^b.z^b–192.175.y^b.z^b
192.168.1.2/8	255.0.0.0	192.0.0.0	192.255.255.255	192.x^b.y^b.z^b
192.168.1.2/4	240.0.0.0	192.0.0.0	207.255.255.255	192.x^b.y^b.z^b–207.x^b.y^b.z^b

[a] Port_02.DfltRout cannot be the same as Port_02.IPAddr, network address, or broadcast address.
[b] Value in the range 0–255.

The Port_02.TCP_KpAlvEna setting, along with the Port_02.TCP_KpAlvIdleTm, Port_02.TCP_KpAlvIntvTm, and Port_02.TCP_KpAlvCnt settings, can be used to verify that the computer at the remote end of a TCP connection is still available. If Port_02.TCP_KpAlvEna is enabled and the SEL-851 does not transmit any TCP data within the interval specified by the Port_02.TCP_KpAlvIdleTm setting, the SEL-851 sends a keep-alive packet to the remote computer. If the SEL-851 does not receive a response from the remote computer within the time specified by Port_02.TCP_KpAlvIntvTm, the keep-alive packet is retransmitted as many as Port_02.TCP_KpAlvCnt times. After this count is reached, the SEL-851 considers the remote device no longer available and terminates the connection without waiting for the idle timer (Port_02.Telnet_TmOut or Port_02.FTP_TmOut) to expire.

The SEL-851 Ethernet port operates over twisted-pair media. For twisted-pair connections, the Ethernet port can autodetect the network speed or you can set a fixed speed (10 or 100 Mbps).

SEL-851 Ethernet port choices include single or dual copper configurations. With dual Ethernet ports, the relay includes an unmanaged Ethernet switch. Redundant configurations support automatic failover switching from the primary to a standby network if a failure in the primary network is detected. In addition to failover mode, the unit can operate in a “fixed connection” (to netport) mode or in a “switched mode” (as an unmanaged switch).

Figure 7.6 shows an example of a simple Ethernet network configuration, *Figure 7.7* shows an example of an Ethernet network configuration with dual redundant connections, and *Figure 7.8* shows an example of an Ethernet network configuration with ring structure. *Figure 7.9* shows an example using the force network link setting (Port_02.LinkForcOv SELOGIC equation) to force switchover in a dual Ethernet configuration with Port_02.OpMod := FAILOVER.

Figure 7.6 Simple Ethernet Network Configuration

Figure 7.7 Ethernet Network Configuration With Dual Redundant Connections (Failover Mode)

Figure 7.8 Ethernet Network Configuration With Ring Structure (Switched Mode)

Figure 7.9 Dual Ethernet Configuration With Port_02.OpMod := FAILOVER and Using Force Network Link (SELOGIC Equation) Setting to Force Switchover

Dual Network Port Operation

The SEL-851 dual Ethernet port option has two network ports. Network port failover mode enables the dual Ethernet port to operate as a single network adapter with a primary and standby physical interface. You can connect the two network ports to the same network or to different networks depending on your specific Ethernet network architecture.

Failover Mode

In failover mode, the relay determines the active port. To use failover mode, proceed with the following steps.

Step 1. Set Port_02.OpMod to FAILOVER.

Step 2. Set the Port_02.LinkForcOv SELOGIC equation to cover link failures that are not detectable by the relay to initiate failover switching.

Step 3. Set Port_02.FailoverTm to the desired network port failover time (OFF, 0.01–65.00 seconds).

Step 4. Set Port_02.PriNetPort to the preferred network interface.

NOTE: If you change settings for the host port in the relay and the standby network port is active, the relay resets and returns to operation on the primary port.

On startup, the relay communicates via the Port_02.PriNetPort (primary port) selected. If the SEL-851 detects a link failure on the primary port, it activates the standby port after the failover time, Port_02.FailoverTm, elapses. If the link returns to normal before the failover time expires, the failover timer resets and uninterrupted operation continues on the primary network port.

Setting Port_02.FailoverTm = OFF allows for fast port switching (with no intentional delay). Fast port switching can occur within one processing interval (typically 4 to 5 ms) and can help with IEC 61850 GOOSE performance. The relay processes the rising edge of the Port_02.LinkForcOv SELOGIC control equation to initiate the switchover. The switchover time depends on the Port_02.FailoverTm setting. The next rising edge of Port_02.LinkForcOv after the switchover causes the relay to switchback to the primary network.

After failover, while communicating via the standby port, the SEL-851 checks the primary link periodically and continues checking until it detects a normal link status. The relay continues to communicate via the standby port even after the primary port returns to normal. The relay reevaluates the port of choice for

communication upon a change of settings, at failure of the standby port, or upon reboot. The relay returns to operation on the primary link under those conditions if it detects a normal link status. When the active and standby links both fail, the relay alternates checking for the link status of the primary and standby ports.

Unmanaged Switch Mode

If you have a network configuration where you want to use the relay as an unmanaged switch, set Port_02.OpMod to SWITCHED. In this mode, both links are enabled. The relay will respond to the messages received on either port. All the messages received on one network port that are not addressed to the relay will be transmitted out of the other port without any modifications. In this mode, the relay ignores the Port_02.PriNetPort setting.

Fixed Connection Mode

If you have a single network and want to use only one network port, or if you have both ports connected but want to force usage of only one port for various reasons, set Port_02.OpMod to FIXED and set Port_02.PriNetPort to the port you want to use. Only the selected network port operates and the other port is disabled.

Autonegotiation, Speed, and Duplex Mode

Single or dual copper Ethernet ports are capable of autonegotiating to determine the link speed and duplex mode. This is accomplished by setting the Port_02.PortASpd and Port_02.PortBSpd (network speed) to AUTO. Single or dual copper ports can also be set to a specific speed to be able to apply them in networks with older switch devices.

Network Port Selection

The Port_02.PriNetPort setting gives you the option to select the primary port of communication in failover or fixed communication modes. Setting Port_02.Ena to N disables both the ports thereby providing you with the security of turning off the ports even if the ports are physically connected to the network.

Telnet or Web Server

NOTE: Telnet and the web server work with other Port_02.OpMod settings also, but Port_02.OpMod = SWITCHED is easiest to begin communication. The relay hides setting Port_02.OpMod when equipped with a single Ethernet port.

Factory-default settings for the Ethernet ports disable all Ethernet protocols except Telnet, FTP, HTTP, and PING. Command **SET P 2** accesses settings for both Ethernet ports on the SEL-851: Port 2A and Port 2B. See Ethernet port settings in *Table 4.51 on page 4.82* for a sample of the **SET P 2** command with factory-default settings. Use the **SET P 2** command to make the following settings:

- Port_02.IPAddr := IP address assigned by network administrator
- Port_02.DfltRout := Default router IP address assigned by network administrator
- Port_02.OpMod := SWITCHED (available with dual Ethernet ports)
- Port_02.Telnet_Ena := Y
- Port_02.HTTP_SrvrEna := Y

Leave all other settings at their default values.

Connect an Ethernet cable between your PC or a network switch and any Ethernet port on the relay. Verify that the amber link LED illuminates on the connected relay port. Many computers and most Ethernet switches support autocrossover, so nearly any Cat 5 Ethernet cable with RJ45 connectors, such as an SEL-C627 cable, will work. When the computer does not support autocrossover, use a crossover cable, such as an SEL-C628 cable. If your relay is equipped with dual Ethernet ports, connect to either port. Use a Telnet application or SEL Grid Configurator Software on the host PC to communicate with the relay. To terminate a Telnet session, use the **EXIT** command from any access level.

In addition, you can communicate with the relay through your web browser. Launch a web browser and enter address http://IPAddress for unsecure HTTP communication, where IPAddress is the Port_02.IPAddress setting. To terminate the session, close the web browser (see *Section 3: PC Interface* for more details).

Communications Protocols

Protocols

Although the SEL-851 supports a wide range of protocols, not all protocols are available on all ports. *Table 7.5* shows the ports and the protocols available on each port.

Table 7.5 Protocols Supported on the Various Ports

PORT	Supported Protocol
PORT F	SEL ASCII and Compressed ASCII Protocols, SEL Settings File Transfer
PORT 1	SEL ASCII and Compressed ASCII Protocols, SELBOOT, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, SEL Fast Message, MIRRORED BITS, DNP3, and Modbus RTU Slave
PORT 2	Modbus TCP/IP, FTP, IEC 61850, DNP3 LAN/WAN, SNTP, Telnet (SEL ASCII, Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, SEL Fast Message), and web server (HTTP/HTTPS)

Session Limits

The SEL-851 supports multiple simultaneous sessions of many of the protocols listed in *Table 7.6*. The number of allowed protocol sessions depends on what other protocols are enabled, as shown in *Table 7.6*.

Table 7.6 Protocol Session Limits (Sheet 1 of 2)

Protocol	Sessions Supported[a]
IEC 61850	The relay supports six simultaneous sessions of IEC 61850.
DNP3	The relay supports four total DNP3 sessions (combined serial and Ethernet).
Modbus	The relay supports three total Modbus sessions (combined serial and Ethernet).
FTP	The relay supports one session of File Transfer Protocol on Port 2.

Table 7.6 Protocol Session Limits (Sheet 2 of 2)

Protocol	Sessions Supported[a]
Telnet	The number of available simultaneous Telnet sessions depends on Port 2 relay settings Port_02.61850_Ena, Port_02.HTTP_SrvrEna/Port_02.HTTPS_SrvrEna (web server), and Port_02.Modbus_Ena (Modbus TCP) as follows: When Port 2 setting Port_02.61850_Ena = N[b], the relay supports three simultaneous Telnet sessions. When Port 2 settings Port_02.61850_Ena = Y, Port_02.HTTP_SrvrEna = N, Port_02.HTTPS_SrvrEna = N, and Port_02.Modbus_Ena = 0, the relay supports three simultaneous Telnet sessions. When Port 2 settings Port_02.61850_Ena = Y, Port_02.HTTP_SrvrEna = Y, or Port_02.HTTPS_SrvrEna = Y, and Port_02.Modbus_Ena = 0, the relay supports two simultaneous Telnet sessions. When Port 2 settings Port_02.61850_Ena = Y, Port_02.HTTP_SrvrEna = N, Port_02.HTTPS_SrvrEna = N, and Port_02.Modbus_Ena > 0, the relay supports two simultaneous Telnet sessions. When Port 2 settings Port_02.61850_Ena = Y, Port_02.HTTP_SrvrEna = Y, or Port_02.HTTPS_SrvrEna = Y, and Port_02.Modbus_Ena > 0, the relay supports one Telnet session.
Web Server (HTTP/HTTPS)	The relay always supports three simultaneous web server sessions.
SNTP	The relay supports one session of SNTP on Port 2. Some operation modes of SNTP allow the relay to synchronize to one of multiple NTP servers.

[a] When properly configured (enable settings, IP addresses, etc.).
[b] Relays ordered without IEC 61850 are treated as if Port_02.61850_Ena = N.

SEL Communications Protocols

SEL ASCII

This protocol is described in *SEL ASCII Protocol and Commands on page 7.17*.

SEL Compressed ASCII

This protocol provides compressed versions of some of the ASCII commands. The compressed commands are described in *SEL ASCII Protocol and Commands*, and the protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Meter

This protocol supports binary messages to transfer metering and digital element messages. Compressed ASCII commands that support Fast Meter are described in *SEL ASCII Protocol and Commands*, and the protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Operate

This protocol supports binary messages to transfer operation messages. The protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Message

This protocol uses binary messages to receive/transmit data from/to an SEL communications processor. The protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast SER

This protocol is used to receive binary Sequential Events Record unsolicited responses. The protocol is described in *Appendix C: SEL Communications Processors*.

Other Supported Protocols

MIRRORED BITS Protocol

The SEL-851 supports a single MIRRORED BITS communications channel, designated Channel A. Within each MIRRORED BITS communications message there are eight logical data channels (1–8). The MIRRORED BITS protocol is described in *Appendix G: MIRRORED BITS Communications*.

Modbus RTU Protocol

The SEL-851 provides Modbus RTU support. This protocol is described in *Appendix E: Modbus Communications*.

Distributed Network Protocol (DNP3)

The SEL-851 provides DNP3 protocol support if the option is selected. The DNP3 protocol is described in *Appendix D: DNP3 Communications*.

Ethernet Protocols

As with other communications interfaces, you must choose a data exchange protocol that operates over the Ethernet network link to exchange data. The relay supports FTP, Telnet, Ping, Modbus/TCP, HTTP/HTTPS, DNP3 LAN/WAN, and IEC 61850 protocols.

You should carefully design your Ethernet network to maximize reliability, minimize system administration effort, and provide adequate security. Work with a networking professional to design your substation Ethernet network.

File Transfer Protocol (FTP) and MMS File Transfer

FTP is a standard protocol for exchanging files between computers over a TCP/IP network. The SEL-851 operates as an FTP server, presenting files to FTP clients. To create an FTP session, you need the FTP username and password. The default username and password are FTPUSER and TAIL, respectively. The SEL-851 supports one FTP session. Requests to establish additional FTP sessions are denied.

Manufacturing Message Specification (MMS) is used in IEC 61850 applications and provides services for the transfer of real-time data, including files, within a substation LAN.

File Structure

The file structure is organized as a directory and subdirectory tree similar to that used by Windows and other common operating systems. See *Virtual File Interface on page 7.49* for information on available files.

File dates within the last 12 months are displayed with month, day, hour, and minutes. Dates older than twelve months have the year, month, and day. The times are in UTC.

Access Control

To log in to the FTP server, enter the value of the Port 2 setting Port_02.FTP_Username as the user name in your FTP application. Enter the Port 2 setting Port_02.FTP_AccLev level password as the password in your FTP application. Note that FTP does not encrypt passwords before sending them to the server.

MMS is enabled when the Port 2 setting Port_02.61850_Ena is set to Y. No authentication is required. MMS File Transfer is enabled when setting Port_02.MMS_FileSvcEna is equal to Y. If MMS authentication is enabled via the CID file, then an authenticated connection must be established via MMS for MMS file transfer to take place.

Using FTP and MMS

A free FTP application is included with most web browser software and PC operating systems. You can also obtain free or inexpensive FTP applications from the Internet. Once you have retrieved the necessary files, be sure to close the FTP connection using the disconnect function of your FTP application or completely closing the application. Failure to do so can cause the FTP connection to remain open, which blocks subsequent connection attempts until Port_02.FTP_TmOut time expires. See *Appendix F: IEC 61850 Communications* for information about using MMS.

Telnet Server

Use the Telnet session (Port_02.Telnet_Port default setting is Port 23) to connect to the relay to use the protocols, which are described in more detail below:

- SEL ASCII
- Compressed ASCII
- Fast Meter
- Fast Operate
- Fast SER

NOTE: Use the **QUIT** command prior to closing the Telnet-to-Host session to set the relay to Access Level 0. Otherwise, the relay remains at an elevated access level until Port_02.Telnet_TmOut expires.

Telnet is a terminal connection across a TCP/IP network that operates in a manner very similar to a direct serial port connection to one of the relay ports. As with FTP, Telnet is a part of TCP/IP. A free Telnet application is included with most computer operating systems, or you can obtain low-cost or free Telnet applications on the Internet.

Ping Server

Ping is an application based on Internet Control Message Protocol (ICMP) over an IP network. A free Ping application is included with most computer operating systems. Use a Ping client with the relay Ping server to verify that your network configuration is correct.

IEC 61850

Use as many as six sessions of MMS over a TCP network to exchange data with the relay. Use GOOSE to do real-time data exchange with as many as 16 incoming messages and 8 outgoing messages. For more details on the IEC 61850 protocol, see *Appendix F: IEC 61850 Communications*.

Simple Network Time Protocol (SNTP)

When Port 2 (Ethernet port) setting Port_02.SNTP_Ena is not OFF, the internal clock of the relay conditionally synchronizes to the time of day served by a Network Time Protocol (NTP) server. The relay uses a simplified version of NTP called the Simple Network Time Protocol (SNTP). SNTP is not as accurate as IRIG-B. The relay can use SNTP as a less accurate primary time source, or as a backup to the higher accuracy IRIG-B time source.

SNTP as Primary or Backup Time Source

If an IRIG-B time source is connected and either Relay Word bit Time.SyncOk or Relay Word bit Time.IRIG_Ok asserts, then the relay synchronizes the internal time-of-day clock to the incoming IRIG-B time code signal, even if SNTP is configured in the relay and an NTP server is available. If the IRIG-B source is disconnected (if both Time.SyncOk and Time.IRIG_Ok deassert) then the relay synchronizes the internal time-of-day clock to the NTP server, if available. In this way, an NTP server acts either as the primary time source or as a backup time source to the more accurate IRIG-B time source.

Creating an NTP Server

Three SEL application notes, available from the SEL website, describe how to create an NTP server.

- *AN2009-10: Using an SEL-2401, SEL-2404, or SEL-2407® to Serve NTP Via the SEL-3530 RTAC*
- *AN2009-38: Using SEL Satellite-Synchronized Clocks With the SEL-3332 or SEL-3354 to Output NTP*
- *AN2010-03: Using an SEL-2401, SEL-2404, or SEL-2407® to Create a Stratum 1 Linux® NTP Server*

Configuring SNTP Client in the Relay

To enable SNTP in the relay, make Port 2 setting Port_02.SNTP_Ena = UNICAST, MANYCAST, or BROADCAST. *Table 7.7* shows each setting associated with SNTP.

Table 7.7 Settings Associated With SNTP (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default	Description
ENABLE SNTP CLIENT	OFF, UNICAST, MANYCAST, BROADCAST	Port_02.SNTP_Ena := OFF	Selects the mode of operation of SNTP. See descriptions in *SNTP Operation Modes on page 7.15*.
SNTP PRIMARY SERVER IP ADDRESS	Valid IP Address	Port_02.SNTP_SrvrIPAddr1 := 192.168.1.1	Selects the primary NTP server when Port_02.SNTP_Ena = UNICAST or the broadcast address when Port_02.SNTP_Ena = MANYCAST or BROADCAST.
SNTP BACKUP SERVER IP ADDRESS	Valid IP Address	Port_02.SNTP_SrvrIPAddr2 := 192.168.1.1	Selects the backup NTP server when Port_02.SNTP_Ena = UNICAST.
SNTP IP (LOCAL) PORT NUMBER	1–65534	Port_02.SNTP_PortNum := 123	Ethernet port used by SNTP. Leave at default value unless otherwise necessary.

Table 7.7 Settings Associated With SNTP (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default	Description
SNTP UPDATE RATE	15–3600 s	Port_02.SNTP_UpdtRate := 60	Determines the rate at which the relay asks for updated time from the NTP server when Port_02.SNTP_Ena = UNICAST or MANYCAST. Determines the time the relay waits for an NTP broadcast when Port_02.SNTP_Ena = BROADCAST.
SNTP TIMEOUT	5–20 s	Port_02.SNTP_TmOut := 5	Determines the time the relay waits for the NTP master to respond when Port_02.SNTP_Ena = UNICAST or MANYCAST.

SNTP Operation Modes

The following sections explain the setting associated with each SNTP operation mode (UNICAST, MANYCAST, and BROADCAST).

Port_02.SNTP_Ena = UNICAST. In UNICAST mode of operation, the SNTP client in the relay requests time updates from the primary (IP address setting Port_02.SNTP_SrvrIPAddr1) or backup (IP address setting Port_02.SNTP_SrvrIPAddr2) NTP server at a rate defined by setting Port_02.SNTP_UpdtRate. If the NTP server does not respond with the period defined by setting Port_02.SNTP_TmOut, then the relay tries the other SNTP server. When the relay successfully synchronizes to the primary NTP time server, Relay Word bit Time.SNTP_PriSrvr asserts. When the relay successfully synchronizes to the backup NTP time server, Relay Word bit Time.SNTP_BackupSrvr asserts.

Port_02.SNTP_Ena = MANYCAST. In the MANYCAST mode of operation, the relay initially sends an NTP request to the broadcast address contained in setting Port_02.SNTP_SrvrIPAddr1. The relay continues to broadcast requests at a rate defined by setting Port_02.SNTP_UpdtRate. When a server replies, the relay considers that server to be the primary NTP server, and switches to UNICAST mode, asserts Relay Word bit Time.SNTP_PriSrvr, and thereafter requests updates from the primary server. If the NTP server stops responding for time Port_02.SNTP_TmOut, the relay deasserts Time.SNTP_PriSrvr and begins to broadcast requests again until the original or another server responds.

Port_02.SNTP_Ena = BROADCAST. If setting Port_02.SNTP_SrvrIPAddr1 = 0.0.0.0 while setting Port_02.SNTP_Ena = BROADCAST, the relay listens for and synchronizes to any broadcasting NTP server. If setting Port_02.SNTP_SrvrIPAddr1 is set to a specific IP address while setting Port_02.SNTP_Ena = BROADCAST, then the relay listens for and synchronizes to only NTP server broadcasts from that address. When synchronized, the relay asserts Relay Word bit Time.SNTP_PriSrvr. Relay Word bit Time.SNTP_PriSrvr deasserts if the relay does not receive a valid broadcast within five seconds after the period defined by setting Port_02.SNTP_UpdtRate.

SNTP Accuracy Considerations

The accuracy of the SNTP server and the networking environment limit SNTP time synchronization accuracy. You can achieve the highest degree of SNTP time synchronization by minimizing the number of switches and routers between the SNTP server and the SEL-851. You can also use network monitoring software to ensure that average and worst-case network bandwidth use is moderate.

When installed on a network configured with one Ethernet switch between the SEL-851 and the SNTP server, and when using Port_02.SNTP_Ena = UNICAST or MANYCAST, the relay time synchronization error with the SNTP server is typically less than ±1 millisecond.

Embedded Web Server (HTTP/HTTPS)

When Port 2 setting Port_02.HTTP_SrvrEna := Y, the relay serves webpages displaying settings, metering, status reports, event files, etc. The relay embedded web server has been optimized and tested to work with the most popular web browsers, but it should also work with any standard web browser. As many as three users can access the embedded web server simultaneously. To begin using the embedded read-only web server, launch your web browser, and browse to http://Port_02.IPAddr, where Port_02.IPAddr is the Port 2 setting Port_02.IPAddr.

Log in using your username and password to view or export various reports, view settings, monitor communications or relay status, or upgrade firmware (Access Level 2 only).

To log out of the web server, either close the web browser window or click **Logout** in the banner bar near the top of the webpage. For more information on the web server, see *Section 3: PC Interface*.

Table 7.8 lists the HTTP/HTTPS settings that are available for configuring the web server.

Table 7.8 HTTP/HTTPS Server Configuration

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE HTTP SERVER	Y, N	Port_02.HTTP_SrvrEna := Y
ENABLE HTTPS SERVER	Y, N	Port_02.HTTPS_SrvrEna := N
HTTP MAXIMUM ACCESS LEVEL [a]	1, 2	Port_02.HTTP_AccLev := 2
HTTP SERVER TCP/IP PORT NUMBER	1–65534	Port_02.HTTP_TCPPort := 80
HTTPS SERVER TCP/IP PORT NUMBER	1–65534	Port_02.HTTPS_TCPPort := 443
HTTP CONNECT BANNER [a]	254 ASCII printable characters	Port_02.HTTP_Banr := This system is for the use of authorized personnel only.
HTTP WEB SERVER TIMEOUT [a]	1–60 min	Port_02.HTTP_TmOut := 10

[a] These settings are applicable to both HTTP and HTTPS connections.

Security (X.509 Certificates)

When Port 2 setting Port_02.HTTPS_SrvrEna := Y, HTTPS connections require authentication to confirm that the server with which you are communicating is the correct server. This authentication is through X.509 certificates. By default, the device has a self-signed X.509 certificate that can cause your web browser to issue a security alert. This security alert requires a security exception for authentication to continue.

To prevent this security alert from appearing, install a CA-signed X.509 certificate on the device. If your web browser has been configured to trust the CA issuing and signing the certificate, the X.509 certificate will be trusted and the

security alert will no longer appear. The device supports one X.509 certificate that is used for HTTPS communications between the client web browser and the web server running on the device. The certificate must have an RSA signature using SHA-256 and be imported as a PEM file with a private key. The private key must be an RSA key no longer than 4096 bits.

Note that a device reset, either done via the web server or terminal or by holding the **TARGET RESET** pushbutton on the relay for 10 seconds or longer during power up, will delete the installed X.509 certificate and the relay will revert back to its default certificate.

SEL ASCII Protocol and Commands

Message Format

SEL ASCII protocol is designed for manual and automatic communication. All commands the relay receives must be of the following form:

```
<command><CR>  or  <command><CRLF>
```

NOTE: The **<Enter>** key on most keyboards is configured to send the ASCII character 13 (**<Ctrl+M>**) for a carriage return. This manual instructs you to press the **<Enter>** key after commands to send the proper ASCII code to the SEL-851.

A command transmitted to the relay consists of the command followed by either a CR (carriage return) or a CRLF (carriage return and line feed). You can truncate commands to the first three characters. For example, **CLOSE <Enter>** becomes **CLO <Enter>**. Use upper- and lowercase characters without distinction, except in passwords.

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.

Software Flow Control

The relay implements XON/XOFF flow control. 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 XON. If there is no message in progress when the relay receives XOFF, it blocks transmission of any message presented to the relay input buffer. Messages are accepted after the relay receives XON.

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 capacity.

The relay transmits XOFF (ASCII hex 13) when the buffer is at or above 75 percent capacity. If hardware handshaking is enabled, the relay deasserts the RTS output when the buffer is at approximately 95 percent capacity. Automatic transmission sources should monitor for the XOFF character to avoid overwriting the buffer. Transmission should terminate at the end of the message in progress when the relay receives XOFF. It can resume when the relay sends XON.

The CAN character (ASCII hex 18) aborts a pending transmission. This is useful for terminating an unwanted transmission. You can send control characters from most keyboards with the following keystrokes:

- XOFF**: <Ctrl+S>** (hold down the **<Ctrl>** key and press **S**)
- XON: **<Ctrl+Q>** (hold down the **<Ctrl>** key and press **Q**)
- CAN: **<Ctrl+X>** (hold down the **<Ctrl>** key and press **X**)

Automatic Messages

When the serial port Port_01.AutoMsg_Ena setting is Y, the relay sends automatic messages to indicate specific conditions. *Table 7.9* lists these messages.

Table 7.9 Serial Port Automatic Messages

Condition	Description
Power Up	The relay sends a message containing the present date and time, relay and location 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 9: Analyzing Events*.
Self-Test Warning or Failure	The SEL-851 sends a status report each time it detects a self-test warning or failure condition. See *STATUS Command (Relay Self-Test Status) on page 7.43*.

Access Levels

You can issue commands to the SEL-851 via the serial port or Telnet session to view metering values, change relay settings, etc. The available serial port commands are listed in the *SEL-851 Command Summary* at the end of this manual. You can access these commands only from the corresponding access level, as shown in the *SEL-851 Command Summary*. The access levels are:

- Access Level 0 (the lowest access level)
- Access Level 1
- Access Level 2 (the highest access level)
- Access Level C (restricted access level, should be used under direction of SEL only)

The Port_F.Ena/Port_02.Ena and Port_F.AccLev/Port_02.AccLev settings provide you with access control for the corresponding port. Setting Port_F.Ena/Port_02.Ena to N disables the port and hides the remaining port settings. The Port_F.AccLev/Port_02.AccLev setting selects the highest access level for the port. Port 1 does not have a corresponding enable and access level setting.

Access Level 0

Once serial port communication is established with the SEL-851, the relay sends the following prompt:

```
=
```

This is referred to as Access Level 0. Only a few commands are available at Access Level 0. One is the **ACC** command. See the *SEL-851 Command Summary* at the end of this manual. Enter the **ACC** command at the Access Level 0 prompt:

```
=ACC <Enter>
```

The **ACC** command takes the SEL-851 to Access Level 1. See *Access Commands (ACCESS, 2ACCESS, and CAL) on page 7.21* for more detail.

Access Level 1

When the SEL-851 is in Access Level 1, the relay sends the following prompt:

```
=>
```

See the *SEL-851 Command Summary* at the end of this manual for the commands available from Access Level 1. The relay can go to Access Level 2 from this level.

The **2AC** command places the relay in Access Level 2. See *Access Commands (ACCESS, 2ACCESS, and CAL)* for more detail. Enter the **2AC** command at the Access Level 1 prompt:

```
=>2AC <Enter>
```

Access Level 2

When the relay is in Access Level 2, the SEL-851 sends the prompt:

```
=>>
```

See the *SEL-851 Command Summary* at the end of this manual for the commands available from Access Level 2.

Any of the Access Level 1 commands are also available in Access Level 2.

Access Level C

Access Level C is for use exclusively by the SEL factory and SEL field service personnel to diagnose troublesome installations. A list of commands available at Access Level C is available from SEL upon request. Do not enter Access Level C except as directed by SEL.

The **CAL** command allows the relay to go to Access Level C (see *SEL-851 Command Summary*). Enter the **CAL** command at the Access Level 2 prompt:

```
=>>CAL <Enter>
```

Command Summary

The *SEL-851 Command Summary* at the end of this manual lists the serial port commands alphabetically. Much of the information available from the serial port commands is also available via the front-panel pushbuttons.

Access Level Functions

The serial port commands at the different access levels offer varying levels of control:

- The Access Level 0 commands provide the first layer of security. In addition, Access Level 0 supports several commands that SEL communications processors require.
- The Access Level 1 commands are primarily for reviewing information only (settings, metering, etc.), not changing it.
- The Access Level 2 commands are primarily for changing relay settings.
- Access Level C (restricted access level, should be used under direction of SEL only).

The SEL-851 responds with `Invalid Access Level` when a command is entered from an access level lower than the specified access level for the command. The relay responds with `Invalid Command` to commands that are not available or are entered incorrectly.

Header

Many of the command responses display the following header at the beginning:

```
[Dev.Id Setting]                          Date: mm/dd/yyyy  Time: hh:mm:ss.sss
[Dev.Loc Setting]                         Time Source: External
```

Table 7.10 lists the header items and their definitions.

Table 7.10 Command Response Header Definitions

Item	Definition
`[Dev.Id Setting]`:	This is the relay identifier setting. The relay ships with the default setting `Dev.Id = 851`.
`[Dev.Loc Setting]`:	This is the location identifier setting. The relay ships with the default setting `Dev.Loc = FEEDER RELAY`.
`Date`:	This is the date when the command response was given. You can modify the date display format (Month/Day/Year, Year/Month/Day, or Day/Month/Year) by changing the Time.DateFormat relay setting.
`Time`:	This is the time when the command response was given.
`Time Source`:	This is internal if no time-code input is attached and external if an input is attached.

Command Explanations

This section lists ASCII commands alphabetically. Commands, command options, and command variables to enter are shown in bold. Lowercase italic letters and words in a command represent command variables that are determined based on the application. For example, time ***t*** = 1 to 30 seconds, remote bit number ***n*** = 001 to 016, and ***level***.

Command options appear with brief explanations about the command function. Refer to the references listed with the commands for more information on the control function corresponding to the command or examples of the control response to the command.

You can simplify the task of entering commands by shortening any ASCII command to the first three characters; for example, **ACCESS** becomes **ACC**. Always send a carriage return **<CR>** character or a carriage return character followed by a line feed character **<CR><LF>** to command the control to process the ASCII command. Usually, most terminals and terminal programs interpret the Enter key as a **<CR>**. For example, to send the **ACCESS** command, type **ACC <Enter>**.

Tables in this section show the access level(s) where the command or command option is active. Access levels in this device are Access Level 0, Access Level 1, and Access Level 2.

Access Commands (ACCESS, 2ACCESS, and CAL)

The **ACC**, **2AC**, and **CAL** commands (see *Table 7.11*) provide entry to the multiple access levels. Different commands are available at the different access levels, as shown in the *SEL-851 Command Summary* at the end of this manual. Commands **ACC** and **2AC** are explained together because they operate similarly. See *Access Levels on page 7.18* for a discussion of placing the relay in an access level.

Table 7.11 Access Commands

Command	Description	Access Level
ACC	Moves from Access Level 0 to Access Level 1.	0
2AC	Moves from Access Level 1 to Access Level 2.	1
CAL	Moves from Access Level 2 to Access Level CAL.	2

Password Requirements

You must enter passwords unless they are disabled. See *PASSWORD Command (Change Passwords)* for the list of default passwords and for more information on changing and disabling passwords.

Access Level Attempt (Password Required). Assume the following conditions:

- Access Level 1 password is not disabled.
- Access Level is 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the password is not disabled, the relay prompts you for the Access Level 1 password:

```
Password: ? <Enter>
```

The relay is shipped with the default Access Level 1 password shown in *PASSWORD Command (Change Passwords) on page 7.36*. At the prompt, enter the default password and press the **<Enter>** key. The relay responds with the following:

```
[Dev.Id Setting]                          Date: mm/dd/yyyy  Time: hh:mm:ss
[Dev.Loc Setting]                         Time Source: external

Level 1
=>
```

The => prompt indicates that the relay is now in Access Level 1.

If the entered password is incorrect, the relay prompts you for the password again (`Password: ?`). The relay prompts for the password as many as three times. If the requested password is incorrectly entered three times, the relay pulses the Diag.Secu_Alm Relay Word bit for one second and remains at Access Level 0 (= prompt).

Access Level Attempt (Password Not Required). Assume the following conditions:

- Access Level 1 password is disabled.
- Access Level is 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the password is disabled, the relay does not prompt you for a password and goes directly to Access Level 1. The relay responds with the following:

```
[Dev.Id Setting]                          Date: mm/dd/yyyy  Time: hh:mm:ss.sss
[Dev.Loc Setting]                         Time Source: external

Level 1
=>
```

The => prompt indicates that the relay is now in Access Level 1.

The two previous examples demonstrate going from Access Level 0 to Access Level 1. The procedure to go from Access Level 1 to Access Level 2 with the **2AC** command entered at the access level screen prompt is similar. You can get to Access Level C from Access Level 2 with the **CAL** command. The relay pulses the Diag.Secu_Alm Relay Word bit for one second after a successful Level 2 or Level C access, or if access is denied.

AFD Command (Arc-Flash Detection Channels Self-Test)

Use the **AFD** command (Access Level 2) to initiate a self-test of the arc-flash detection Channels 1 to 4. This test requires that the relay has the arc-flash input option and that the external fiber-optic connections are complete. The test checks the integrity of the arc-flash detection system. *Figure 7.10* shows an example of the **AFD** command response. Refer to *Section 10: Testing and Troubleshooting* for details on the arc-flash self-tests.

```
=>>AFD <Enter>

Arc Flash Diagnostic in progress . . . . . .

SEL-851                                  Date: 04/09/2021   Time: 09:20:13
FEEDER RELAY                             Time Source: Internal

Channel #   Sensor  Test Light Limits  Measured      Sensor      Excess Ambient
            Type     Min(%)   Max(%)   Test Light(%) Diagnostic  Light

AF Input 1  Fiber    10.00    100.00   31.94         Pass        OK
AF Input 2  Fiber    10.00    100.00   27.08         Pass        OK
AF Input 3  None     ---.--   ---.--   ---.--        ---         ---
AF Input 4  Point    0.10     79.00    2.27          Pass        OK

=>>
```

Figure 7.10 AFD Command Response

The relay asserts the AFD.Alm Relay Word bit when the sensor diagnostics fail or the relay detects excessive ambient light. Sensor diagnostics failure is indicated by the assertion of the AFD.Sen*n*_DiagFail (*n* = 01 to 04) Relay Word bits and excessive ambient light is indicated by the assertion of the AFD.Sen*n*_AmbLight (*n* = 01 to 04) Relay Word bits. The relay asserts the AFD.Sen*n*_AmbLight Relay Word bits when the corresponding AFD.Sen*n*_PU (*n* = 01 to 04) Relay Word bits stay asserted continuously for 10 seconds.

CLOSE Command (Close Breaker)

The **CLO** command (see *Table 7.12*) uses internal relay logic to initiate a breaker close. For the **CLO** command to work, the relay must be in remote mode. For further details, refer to *Figure 4.43* and *Local/Remote Control*.

Table 7.12 CLOSE Command

Command	Description	Access Level
CLO	Initiates user-operation of breaker close when in remote mode.	2

COMMUNICATIONS Command

The **COM** command (see *Table 7.13*) displays communications statistics for the MIRRORED BITS communications channel. For more information on MIRRORED BITS communications, see *Appendix G: MIRRORED BITS Communications*. The summary report includes information on the status of Relay Word bit MB_A.RxOk that indicates if the received data are valid. The `Last error` field displays the reason for the most recent channel error, even if the channel was already failed. We define failure reasons as one of the following error types:

- Device disabled
- Framing error
- Parity error
- Overrun
- Resynchronization
- Data error
- Loopback
- Underrun

Table 7.13 COM Command

Command	Description	Access Level
COM S A	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1
COM A	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1
COM L A	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1
COM C A	Clears all communications records for Channel A.	1

CONTROL Command

Use the **CON** command (see *Table 7.14*) to control remote bits (Relay Word bits RB_001.Sta–RB_016.Sta). You can use the **CON** command to pulse the outputs. Remote bits are device variables that you set via serial port communication. You can select the control operation from three states: set, clear, or pulse, as described in *Table 7.15*.

Table 7.14 CONTROL Command

Command	Description	Access Level
CON O OUT_*a*.STA *b*	Pulses an output.	2
CON RB_*c*.STA *d*	Sets a remote bit to set, clear, or pulse.	2
Parameters		
a	A number from 01 to 05, representing OUT_01.Sta through OUT_05.Sta	
b	The pulse duration from 1–30 seconds	
c	A number from 001 to 016, representing RB_001.Sta through RB_016.Sta	
d	S, C, or P	

Table 7.15 Three Remote Bit States

Subcommand	Description	Access Level
S	Set remote bit (ON position)	2
C	Clear remote bit (OFF position)	2
P	Pulse remote bit for 1/4 cycle (MOMENTARY position)	

For example, use the following command to set Remote Bit RB_005.Sta:

```
=>>CON RB_005.Sta S <Enter>
```

DATE Command (View/Change Date)

Use the **DATE** command (see *Table 7.16*) to view and set the relay date. The relay can overwrite the date you enter by using other time sources such as IRIG. Enter the **DATE** command with a date to set the internal clock date.

Table 7.16 DATE Command

Command	Description	Access Level
DATE	Displays the internal clock date.	1
DATE*mm/dd/yyyy, yyyy/mm/dd,* or ***dd/mm/yyyy***	Sets the internal clock date (Time.DateFormat set to MDY, YMD, or DMY).	1

Separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons. Set the year in 4-digit form (for dates 2000–2099). Setting Time.DateFormat sets the date format.

ETHERNET Command

The **ETH** command (Access Level 1) may be used to display the Ethernet port (Port 2) status for the redundant Ethernet PORT 2A and PORT 2B configuration, as shown in *Figure 7.11*. The nonredundant port response is similar.

```
=>>ETH <Enter>

SEL-851                                    Date: 04/09/2021   Time: 10:30:51.614
FEEDER RELAY                               Time Source: Internal

MAC: 00-30-A7-78-12-23
IP ADDRESS: 169.254.0.1/16
DEFAULT GATEWAY: 0.0.0.0

NETMODE: FAILOVER
PRIMARY PORT:  2A
ACTIVE PORT:   2A

             LINK   SPEED  DUPLEX
PORT 2A      Up     100M   Full
PORT 2B      Down   --     --

      PACKETS          BYTES          ERRORS
    SENT  RCVD      SENT    RCVD    SENT  RCVD
       2     0       128       0       0     0

=>>
```

Figure 7.11 Ethernet Port (PORT 2) Status Report

The nonredundant port response is as shown in *Figure 7.12*.

```
=>>ETH <Enter>

SEL-851                                    Date: 04/09/2021   Time: 10:29:56.846
FEEDER RELAY                               Time Source: Internal

MAC: 00-30-A7-78-12-23
IP ADDRESS: 169.254.0.1/16
DEFAULT GATEWAY: 0.0.0.0

             LINK   SPEED  DUPLEX
PORT 2       Up     100M   Full

      PACKETS          BYTES          ERRORS
    SENT  RCVD      SENT    RCVD    SENT  RCVD
       2  3378       128  258848       0     0

=>>
```

Figure 7.12 Nonredundant Port Response

FILE Command

The **FIL** command (see *Table 7.17*) is intended to be a safe and efficient means of transferring files between IEDs and external support software (ESS). The **FIL** command ignores the hide rules and transfers visible as well as hidden settings, except the settings hidden by a part number. The **FIL** command is supported if you connect over serial or Ethernet ports.

Table 7.17 FILE Command

Command	Description	Access Level
FIL DIR	Returns a list of files.	1
FIL READ *filename*	Transfers settings file *filename* from the relay to the PC.	1
FIL WRITE *filename*	Transfers settings file *filename* from the PC to the relay.	2
FIL SHOW *filename*	Displays contents of the file *filename*.	1

FGS (Fixed GOOSE) Command

Use the **FGS** command to display transmit and receive Fixed GOOSE messaging and statistics information, which you can use for troubleshooting. The **FGS** command variants and options are shown in *Table 7.18*.

Table 7.18 FGS Command Varients

Command Variant	Description	Access Level
FGS	Displays Fixed GOOSE information.	1
FGS *k*	Displays Fixed GOOSE information *k* times.	1
FGS S	Displays a list of Fixed GOOSE subscriptions with their ID.	1
FGS S *n*	Displays a list of Fixed GOOSE statistics for subscription ID *n*.	1
FGS S ALL	Displays Fixed GOOSE statistics for all subscriptions.	1
FGS S *n* **L**	Displays Fixed GOOSE statistics for subscription ID *n* including error history.	1
FGS S ALL L	Displays Fixed GOOSE statistics for all subscriptions including error history.	1
FGS S *n* **C**	Clears Fixed GOOSE statistics for subscription ID *n*.	1
FGS S ALL C	Clears Fixed GOOSE statistics for all subscriptions.	1

The information displayed for Fixed GOOSE is described in *Table 7.19*.

Table 7.19 Fixed GOOSE Description

Information Field	Description
`MultiCastAddr` (Multicast Address)	This hexadecimal field represents the GOOSE multicast address.
`StNum` (State Number)	This hexadecimal field represents the state number that increments with each state change.

Table 7.19 Fixed GOOSE Description

Information Field	Description
SqNum (Sequence Number)	This hexadecimal field represents the sequence number that increments with each retransmitted GOOSE message sent.
TTL (Time to Live)	This field contains the time (in ms) before the next message is expected.
Code	When appropriate, this text field contains warning or error condition text that is abbreviated as follows: **Code Abbreviation** — **Explanation** OUT OF SEQUENC — Out of sequence error CONF REV MISMA — Configuration revision mismatch MSG CORRUPTED — Message corrupted TTL EXPIRED — Time to live expired HOST DISABLED — Optional code for when the host is disabled or becomes unresponsive after the **FGS** command has been issued
SubsID	This is the identifier for the subscription.
From	This is the date and time the current statistics collection started.
To	This is the date and time the GOOSE statistics command was executed.
Accumulated downtime duration	This represents the total amount of time a subscription was in an error state. The duration is displayed in the format: *hhhh*:*mm*:*ss*.*zzz*.
Maximum downtime duration	This represents the maximum amount of time a subscription was continuously in error state. The duration is displayed in the format: *hhhh*:*mm*:*ss*.*zzz*.
Date & time maximum downtime began	This is the date and time the recorded maximum downtime started.
Number of messages received out-of-sequence (OOS)	This represents the total number of messages received with either the state number and/or sequence number out-of-sequence. This includes cases where more than one instance of a message is received within a single relay processing interval. In this case, the most recent message is processed and the others are discarded.
Number of time-to-live (TTL) violations detected	This represents the total number of times a message was not received within the expected period/interval.
Number of messages incorrectly encoded or corrupted	This represents the total number of messages that were identified with this subscription but were either incorrectly encoded or encoded with a wrong dataset.
Number of messages lost due to receive overflow	This represents the total number of messages that were not processed because memory resources were exhausted. This includes cases where more than one instance of a message is received within a single relay processing interval. In this case, the most recent message is processed and the others are discarded.
Calculated max. sequential messages lost due to OOS	This represents the maximum estimated number of messages that were missed after receiving a message with a higher state or sequence number than expected.
Calculated number of messages lost due to OOS	This represents the total of all estimated number of messages lost due to state or sequence number skip in received messages.

Figure 7.13 shows an example response to the **FGS** command.

```
=>FGS <Enter>
Fixed GOOSE Transmit Status
 MultiCastAddr   StNum      SqNum      TTL    Code
-------------------------------------------------------------------------------
 01-0C-CD-FF-00-01 2          55         957


Fixed GOOSE Receive Status
 MultiCastAddr   StNum      SqNum      TTL    Code
-------------------------------------------------------------------------------
 01-0C-CD-FF-00-02  2          9          2000
 01-0C-CD-FF-00-03  0          0          0
 01-0C-CD-FF-00-04  0          0          0
 01-0C-CD-FF-00-05  0          0          0

=>FGS S 1 L <Enter>
 SubsID 001   01-0C-CD-FF-00-02
-------------------------------------------------------------------------------
From: 11/28/2023 11:10:19.623
To: 11/28/2023 11:14:21.130
 Accumulated downtime duration                      : 0000:00:00.000
 Maximum downtime duration                          : 0000:00:00.000
 Date & time maximum downtime began                 :
 Number of messages received out-of-sequence(OOS)   : 0
 Number of time-to-live(TTL) violations detected    : 0
 Number of messages incorrectly encoded or corrupted: 0
 Number of messages lost due to receive overflow    : 0
 Calculated max. sequential messages lost due to OOS: 0
 Calculated number of messages lost due to OOS      : 0
 #    Date        Time          Duration        Failure
```

Figure 7.13 FGS Command Response

GOOSE Command

Use the **GOOSE** command to display transmit and receive GOOSE messaging and statistics information, which you can use for troubleshooting. The **GOOSE** command variants and options are shown in *Table 7.20*.

Table 7.20 GOOSE Command Variants

Command Variant	Description	Access Level
GOOSE	Displays GOOSE information.	1
GOOSE *k*	Displays GOOSE information *k* times.	1
GOOSE S	Displays a list of GOOSE subscriptions with their ID.	1
GOOSE S *n*	Displays GOOSE statistics for subscription ID *n*.	1
GOOSE S ALL	Displays GOOSE statistics for all subscriptions.	1
GOOSE S *n* L	Displays GOOSE statistics for subscription ID *n* including error history.	1
GOOSE S ALL L	Displays GOOSE statistics for all subscriptions including error history.	1
GOOSE S *n* C	Clears GOOSE statistics for subscription ID *n*.	1
GOOSE S ALL C	Clears GOOSE statistics for all subscriptions.	1

The information displayed for each GOOSE IED is described in the following table.

Table 7.21 GOOSE IED Description (Sheet 1 of 2)

Information Field	Description
Transmit GOOSE Control Reference	This field represents the GOOSE control reference information that includes the IED name, ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and GSEControl name (GSE Control Block Name) (e.g., SEL_351S_1CFG/LLN0GOGooseDSet13).
Receive GOOSE Control Reference	This field represents the goCbRef (GOOSE Control Block Reference) information that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and cbName (GSE Control Block Name) (e.g., SEL_351S_1CFG/LLN0GOGooseDSet13).
MultiCastAddr (Multicast Address)	This hexadecimal field represents the GOOSE multicast address.
Ptag	This three-bit decimal field represents the priority tag value, where spaces are used if the priority tag is unknown.
Vlan	This 12-bit decimal field represents the virtual LAN (Local Area Network) value, where spaces are used if the virtual LAN is unknown.
StNum (State Number)	This hexadecimal field represents the state number that increments with each state change.
SqNum (Sequence Number)	This hexadecimal field represents the sequence number that increments with each retransmitted GOOSE message sent.
TTL (Time to Live)	This field contains the time (in ms) before the next message is expected.
Code	When appropriate, this text field contains warning or error condition text that is abbreviated as follows: **Code Abbreviation** — **Explanation** OUT OF SEQUENC — Out of sequence error CONF REV MISMA — Configuration revision mismatch NEED COMMISSIO — Needs commissioning TEST MODE — Test mode MSG CORRUPTED — Message corrupted TTL EXPIRED — Time to live expired
Transmit Data Set Reference	This field represents the DataSetReference (Data Set Reference) that includes the IED name, LN0 lnClass (Logical Node Class), and GSEControl datSet (Data Set Name) (e.g., SEL_351S_1CFG/LLN0$DSet13).
Receive Data Set Reference	This field represents the datSetRef (Data Set Reference) that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and datSet (Data Set Name) (e.g., SEL_351S_1CFG/LLN0$DSet13).
Ctrl Ref/ ControlBlockReference	This is the GOOSE control block reference. It is a concatenation of the logical device name, LLN0 (logical node containing the control block), GO (functional constraint), and the GSEControl name. (e.g. SEL_351S_1CFG/LLN0GOGooseDSet13)
AppID	This is the application identifier as a decimal number.
From	This is the date and time the current statistics collection started.
To	This is the date and time the GOOSE statistics command was executed.
Accumulated downtime duration	This represents the total amount of time a subscription was in an error state. The duration is displayed in the format: *hhhh*:*mm*:*ss*.*zzz*.
Maximum downtime duration	This represents the maximum amount of time a subscription was continuously in error state. The duration is displayed in the format: *hhhh*:*mm*:*ss*.*zzz*.
Date & time maximum downtime began	This is the date and time the recorded maximum downtime started.
Number of messages received out-of-sequence (OOS)	This represents the total number of messages received with either the state number and/or sequence number out-of-sequence. This includes cases where more than one instance of a message is received within a single relay processing interval. In this case, the most recent message is processed and the others are discarded.

Table 7.21 GOOSE IED Description (Sheet 2 of 2)

Information Field	Description
Number of time-to-live (TTL) violations detected	This represents the total number of times a message was not received within the expected period/interval.
Number of messages incorrectly encoded or corrupted	This represents the total number of messages that were identified with this subscription but were either incorrectly encoded or encoded with a wrong dataset.
Number of messages lost due to receive overflow	This represents the total number of messages that were not processed because memory resources were exhausted. This includes cases where more than one instance of a message is received within a single relay processing interval. In this case, the most recent message is processed and the others are discarded.
Calculated max. sequential messages lost due to OOS	This represents the maximum estimated number of messages that were missed after receiving a message with a higher state or sequence number than expected.
Calculated number of messages lost due to OOS	This represents the total of all estimated number of messages lost due to state or sequence number skip in received messages.

Table 7.22 Warning and Error Codes for GOOSE Subscriptions

Code	Enumeration[a]	Definition	Error/Warning
—	0	No errors present.	—
HOST DISABLED	1	Optional code for when the subscribing device is disabled or becomes unresponsive after the **GOOSE** command has been issued.	Error
CONF REV MISMA	2	Configuration revision mismatch. Displayed when the value of the configuration revision number in the received GOOSE message does not match with the value of the configuration revision number present in the CID file.	Error
NEED COMMISSIO	3	Needs commissioning. Displayed when the received GOOSE message has NdsCom = true.	Error
MSG CORRUPTED	4	Message corrupted. Displayed when a received GOOSE message does not meet the proper format or is corrupted.	Error
TTL EXPIRED	5	Time-to-live expired.	Error
OUT OF SEQUENC	6	Out-of-sequence (OOS) error. This error is present when the StNum or SqNum value between received GOOSE message is not sequential.	Warning
INVALID QUAL	7	Invalid data quality received.	Warning

[a] Enumerations are used to communicate GOOSE error codes in the LGOS logical node.

An example response to the **GOOSE** command is shown in *Figure 7.14*.

```
=>GOOSE <Enter>

GOOSE Transmit Status

 MultiCastAddr   Ptag:Vlan AppID  StNum      SqNum      TTL    Code
-------------------------------------------------------------------------------
A0851_006_ICD_1CFG/LLN0$GO$NewGOOSEMessage1
 01-0C-CD-01-00-04 4:3     4      1          74         196
 Data Set: A0851_006_ICD_1CFG/LLN0$GPDSet01

A0851_006_ICD_1CFG/LLN0$GO$NewGOOSEMessage2
 01-0C-CD-01-00-04 4:3     4      1          74         182
 Data Set: A0851_006_ICD_1CFG/LLN0$GPDSet01

A0851_006_ICD_1CFG/LLN0$GO$NewGOOSEMessage3
 01-0C-CD-01-00-04 4:3     4      1          74         168
 Data Set: A0851_006_ICD_1CFG/LLN0$GPDSet01
```

Figure 7.14 GOOSE Command Response

```
A0851_006_ICD_1CFG/LLN0$GO$NewGOOSEMessage4
 01-0C-CD-01-00-04 4:3     4      1          74         154
 Data Set: A0851_006_ICD_1CFG/LLN0$GPDSet01

A0851_006_ICD_1CFG/LLN0$GO$NewGOOSEMessage5
 01-0C-CD-01-00-04 4:3     4      1          74         141
 Data Set: A0851_006_ICD_1CFG/LLN0$GPDSet01

A0851_006_ICD_1CFG/LLN0$GO$NewGOOSEMessage6
 01-0C-CD-01-00-04 4:3     4      1          74         127
 Data Set: A0851_006_ICD_1CFG/LLN0$GPDSet01

A0851_006_ICD_1CFG/LLN0$GO$NewGOOSEMessage7
 01-0C-CD-01-00-04 4:3     4      1          74         113
 Data Set: A0851_006_ICD_1CFG/LLN0$GPDSet01

A0851_006_ICD_1CFG/LLN0$GO$NewGOOSEMessage8
 01-0C-CD-01-00-04 4:3     4      1          74         99
 Data Set: A0851_006_ICD_1CFG/LLN0$GPDSet01

GOOSE Receive Status

 MultiCastAddr   Ptag:Vlan AppID  StNum      SqNum      TTL    Code
-------------------------------------------------------------------------------
GOOSE_SIM_CFG/LLN0$GO$GooseDSet01
 01-0C-CD-01-00-01 4:1     4113   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet01

GOOSE_SIM_CFG/LLN0$GO$GooseDSet02
 01-0C-CD-01-00-02 4:1     4114   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet02

GOOSE_SIM_CFG/LLN0$GO$GooseDSet03
 01-0C-CD-01-00-03 4:1     4115   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet03

GOOSE_SIM_CFG/LLN0$GO$GooseDSet04
 01-0C-CD-01-00-04 4:1     4116   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet04

GOOSE_SIM_CFG/LLN0$GO$GooseDSet05
 01-0C-CD-01-00-05 4:1     4117   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet05

GOOSE_SIM_CFG/LLN0$GO$GooseDSet06
 01-0C-CD-01-00-06 4:1     4118   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet06

GOOSE_SIM_CFG/LLN0$GO$GooseDSet07
 01-0C-CD-01-00-07 4:1     4119   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet07

GOOSE_SIM_CFG/LLN0$GO$GooseDSet08
 01-0C-CD-01-00-08 4:1     4120   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet08

GOOSE_SIM_CFG/LLN0$GO$GooseDSet09
 01-0C-CD-01-00-09 4:1     4121   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet09

GOOSE_SIM_CFG/LLN0$GO$GooseDSet10
 01-0C-CD-01-00-0A 4:1     4122   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet10

GOOSE_SIM_CFG/LLN0$GO$GooseDSet11
 01-0C-CD-01-00-0B 4:1     4123   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet11

GOOSE_SIM_CFG/LLN0$GO$GooseDSet12
 01-0C-CD-01-00-0C 4:1     4124   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet12

GOOSE_SIM_CFG/LLN0$GO$GooseDSet13
 01-0C-CD-01-00-0D 4:1     4125   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet13

GOOSE_SIM_CFG/LLN0$GO$GooseDSet14
 01-0C-CD-01-00-0E 4:1     4126   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet14

GOOSE_SIM_CFG/LLN0$GO$GooseDSet15
 01-0C-CD-01-00-0F 4:1     4127   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet15

GOOSE_SIM_CFG/LLN0$GO$GooseDSet16
 01-0C-CD-01-00-10 4:1     4128   1          5402       2000
 Data Set: GOOSE_SIM_CFG/LLN0$DSet16
```

Figure 7.14 GOOSE Command Response (Continued)

```
=>>GOO S 1 L

SubsID 1
-----------------------------------------------------------------------------
 Ctrl Ref: GOOSE_SIM_CFG/LLN0$GO$GooseDSet01
 AppID   : 4113
 From    : 04/07/2021 23:52:47.657  To: 04/08/2021 00:02:52.390

 Accumulated downtime duration                      : 0000:10:04.732
 Maximum downtime duration                          : 0000:10:04.732
 Date & time maximum downtime began                 : 04/07/2021 23:52:47.657
 Number of messages received out-of-sequence(OOS)   : 0
 Number of time-to-live(TTL) violations detected    : 1
 Number of messages incorrectly encoded or corrupted: 0
 Number of messages lost due to receive overflow    : 0
 Calculated max. sequential messages lost due to OOS: 0
 Calculated number of messages lost due to OOS      : 0

 #    Date        Time          Duration        Failure
 1    04/07/2021  23:52:47.657  0000:10:04.732  TTL EXPIRED

=>>
```

Figure 7.14 GOOSE Command Response (Continued)

HELP Command

The **HELP** command (see *Table 7.23*) gives a list of commands available at the present access level. You can also get a description of any particular command; type **HELP** followed by the name of the command for information on each command.

Table 7.23 HELP Command

Command	Description	Access Level
HELP	Displays a list of each command available at the present access level with a one-line description.	1
HELP *command*	Displays information on the command *command*.	1

HISTORY Command

Use the **HIS** command (see *Table 7.24*) to view a list of one-line descriptions of relay events or to clear the list (and corresponding event reports) from nonvolatile memory. For more information on event reports, see *Section 9: Analyzing Events*.

Table 7.24 HISTORY Command (Sheet 1 of 2)

Command	Description	Access Level
HIS	Returns event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1
HIS *n* **HIS *row1 row2*** **HIS *date1 date2***	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list, beginning at event *n*.	1

Table 7.24 HISTORY Command (Sheet 2 of 2)

Command	Description	Access Level
HIS C or **R**	Clears/resets the event history and all corresponding event reports from nonvolatile memory.	1
HIS CA or **RA**	Clears/resets the event history and all corresponding event reports from nonvolatile memory and resets the unique reference number to 10000.	1
Parameters		
row1 row2	Append *row1* to return a chronological progression of the first *row1* rows. Append *row1* and *row2* to return all rows between *row1* and *row2*, beginning with *row1* and ending with *row2*. Enter the smaller number first to display a numeric progression of rows through the report. Enter the larger number first to display a reverse numeric progression of rows.	
date1 date2	Append *date1* to return all rows with this date. Append *date1* and *date2* to return all rows between *date1* and *date2* beginning with *date1* and ending with *date2*. Enter the oldest date first to display a chronological progression through the report. Enter the newest date first to display a reverse chronological progression. Date entries are dependent on the date format setting Time.DateFormat.	

ID Command

Use the **ID** command (see *Table 7.25*) to extract device identification codes.

Table 7.25 ID Command

Command	Description	Access Level
ID	Returns a list of device identification codes.	0

L_D Command (Load Firmware)

Use the **L_D** command (see *Table 7.26*) to load firmware. See *Appendix A: Firmware, ICD, and Manual Versions* for information on changes to the firmware and instruction manual. See *Appendix B: Firmware Upgrade Instructions* for further details on downloading firmware.

Table 7.26 L_D Command (Load Firmware)

Command	Description	Access Level
L_D	Loads new firmware.	2

LOOPBACK Command

Use the **LOO** command (see *Table 7.27*) for testing the MIRRORED BITS communications channel for proper communication. For more information on MIRRORED BITS, see *Appendix G: MIRRORED BITS Communications*.

Table 7.27 LOO Command (Sheet 1 of 2)

Command	Description	Access Level
LOO	Enables loopback mode on the MIRRORED BITS channel.	2
LOO A	Enables loopback mode on MIRRORED BITS Channel A for the next 5 minutes.	2

Table 7.27 LOO Command (Sheet 2 of 2)

Command	Description	Access Level
LOO *x* DATA	Enables loopback mode on MIRRORED BITS Channel A for *x* minutes.	2
LOO R	Disables loopback mode.	2

With the transmitter of the communications channel physically looped back to the receiver, the MIRRORED BITS addressing is wrong and MB_A.RxOk is 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, MB_A.LoopOk asserts if error-free data are received. The **LOO** command, with just the channel specifier, enables loopback mode on that channel for five minutes, and 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)?
=>>
```

To enable loopback mode for other than the 5-minute default, enter the number of minutes (1–5000) you want as a command parameter. To allow the loopback 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 loopback mode before the selected number of minutes, re-issue the **LOO** command with the R parameter. The R parameter returns the device to normal operation.

```
=>>LOO R <Enter>
Mirrored Bits Loopback Disabled.
=>>
```

MAC Command

Use the **MAC** command to display the MAC addresses of **PORT 2**, as shown in the following.

```
=>>MAC <Enter>

Port 2 (IP) MAC Address:      00-30-A7-67-32-10

=>>
```

METER Command (Metering Data)

The **MET** command (see *Table 7.28* and *Table 7.29*) provides access to the relay metering data.

Table 7.28 MET Command

Command	Description	Access Level
MET *c n*	Displays metering data.	1
MET *c* R	Resets metering data.	1
Parameters		
c	Identifies the meter class.	
n	Specified the number of times (1–32767) to repeat the meter response.	

Table 7.29 Meter Class

c	Meter Class
F (or **MET**)	Fundamental Metering
E[a]	Energy Metering
M[a]	Maximum/Minimum Metering
RMS	RMS Metering
DE[a]	Demand and Peak Demand Metering
L	Light Metering for Arc-Flash Detection (AFD)
PMV	SELOGIC Protection Math Variable Metering
RA	Remote Analog Metering

[a] Reset command available.

For more information on metering and example responses for each meter class, see *Section 5: Metering and Monitoring*.

On issuing the **MET *c* R** command for resetting metering quantities in class *c*, the relay responds: `Reset Metering Quantities (Y,N)?` Upon confirming (entering **Y**), the metering quantities are reset and the relay responds with `Reset Complete`.

OPEN Command (Open Breaker)

The **OPEN** command (see *Table 7.30*) uses internal relay logic to initiate a breaker trip. For the **OPEN** command to work, the relay must be in remote mode. For further details, refer to *Figure 4.42* and *Local/Remote Control*.

Table 7.30 OPEN Command (Open Breaker)

Command	Description	Access Level
OPEN	Initiates a breaker open operation when in remote mode.	2

PASSWORD Command (Change Passwords)

Use the **PAS** command (see *Table 7.31*) to change existing passwords.

Table 7.31 PASSWORD Command

Command	Description	Access Level
PAS *level*	Changes password for Access Level *level*.	2, C
Parameter		
level	Represents relay Access Level 1, 2, or C.	

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.

The factory-default passwords are as shown in *Table 7.32*.

Table 7.32 Factory-Default Passwords for Access Levels 1, 2, and C

Access Level	Factory-Default Password
1	OTTER
2	TAIL
C	CLARKE

To change the password for Access Level 1 to #Ot3579!ijd7, enter the following command sequence:

```
=>>PAS 1 <Enter>
New PW: ? *********** <Enter>
Confirm PW: ? *********** <Enter>
Password Changed
=>>
```

Similarly, use **PAS 2** to change the Access Level 2 password and **PAS C** to change the Access Level C password.

Passwords can contain as many as 12 characters. Upper- and lowercase letters are treated as different characters. Strong passwords consist of 12 characters, with at least one special character or digit and mixed-case sensitivity, but do not form a name, date, acronym, or word. Passwords formed in this manner are less susceptible to password guessing and automated attacks.

Table 7.33 Valid Password Characters

Alpha	A B C D E F G H I J K L M N O P Q R S T U V W X Y Z a b c d e f g h i j k l m n o p q r s t u v w x y z
Numeric	0 1 2 3 4 5 6 7 8 9
Special	! " # $ % & ' ( ) * + , - . / : ; < = > ? @ [\ ] ^ _ ` { | } ~

Examples of valid, distinct, and strong passwords are as follows:

- #0t3579!ijd7
- (Ih2dcs)36dn
- $A24.68&,mvj
- *4u-Iwg+?lf-

PCN Command (Counter Values)

The relay displays the values of the enabled counters in response to the **PCN** command (see *Table 7.34*).

Table 7.34 PCN Command

Command	Description	Access Level
PCN *n*	Displays the current state of the device counters *n* times, with a 1/2-second delay between each display.	1

PING Command

When you are setting up or testing substation networks, it is helpful to determine if the network is connected properly and if the other devices are powered up and configured properly. The **PING** command (Access Level 1) allows a user of the relay to determine if a host is reachable across an IP network and/or if the Ethernet port (Port 2) is functioning and configured correctly. A typical **PING** command response is shown in *Figure 7.15*.

The command structure is:

PING *x.x.x.x t*

where:

x.x.x.x is the host IP address and

t is the ping interval in seconds, with a 2 to 255 second range.

The default ping interval is one second when *t* is not specified. The relay sends ping messages to the remote node until you stop the ping test by pressing the **Q** key.

```
=>PING 10.201.7.52 <Enter>

Press the Q key to end the ping test.

Pinging 10.201.7.52 every 1 second(s):

Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Ping test stopped.

Ping Statistics for 10.201.7.52
   Packets: Sent = 7, Received = 6, Lost = 1
   Duplicated = 0

=>
```

Figure 7.15 PING Command Response

PRO Command (Signal-Profile Report)

Use the **PRO** commands (see *Table 7.35*) to view and manage the signal-profile report (see *Figure 5.13*). If there is no stored data and a **PRO** command is issued, the relay responds with `No data available`.

Table 7.35 PRO Commands

Command	Description	Access Level
PRO	Displays a numeric progression of all the signal-profile report rows.	1
PRO *row1 row2* **PRO *date1 date2***	Displays a numeric or reverse numeric subset of the signal-profile rows within the defined parameters.	1
PRO C	Clears the signal-profile report from nonvolatile memory.	1
Parameters		
row1 row2	Append *row1* to return a chronological progression of the first *row1* rows. Append *row1* and *row2* to return all rows between *row1* and *row2*, beginning with *row1* and ending with *row2*. Enter the smaller number first to display a numeric progression of rows through the report. Enter the larger number first to display a reverse numeric progression of rows.	
date1 date2	Append *date1* to return all rows with this date. Append *date1* and *date2* to return all rows between *date1* and date beginning with *date1* and ending with *date2*. Enter the oldest date first to display a chronological progression through the report. Enter the newest date first to display a reverse chronological progression. Date entries are dependent on the date format setting Time.DateFormat.	

PULSE Command

Use the **PULSE** command (see *Table 7.36*) to pulse any of the relay control outputs for a specified time. This function aids you in relay testing and commissioning. When a **PUL** command is issued, the selected contact will momentarily close or open depending on the output contact type (a or b). The **PUL** command momentarily energizes the coil and does not have any effect if the coil is already energized. The control outputs are OUT_*n*.Sta, where *n* = 01–05 for OUT01–OUT05.

Table 7.36 PUL OUT_n.Sta Command

Command	Description	Access Level
PUL OUT_*n*.Sta	Pulses output OUT*n* for 1 second.	2
PUL OUT_*n*.Sta *s*	Pulses output OUT*n* for *s* seconds.	2
Parameters		
n	A control output number (*n* = 01–05 for OUT01–OUT05).	
s	Time in seconds with a range of 1–30.	

QUIT Command

Use the **QUIT** command (see *Table 7.37*) to revert to Access Level 0.

Table 7.37 QUIT Command

Command	Description	Access Level
QUIT	Goes to Access Level 0.	0

Access Level 0 is the lowest access level; the SEL-851 performs no password check to descend to this level (or to remain at this level).

R_S Command (Restore Factory Defaults)

NOTE: In firmware versions R100-V3 and higher, the relay firmware retains the IP address, subnet mask, and default router settings after an **R_S** command is issued.

Use the **R_S** command (see *Table 7.38*) to restore the factory-default settings.

Table 7.38 R_S Command (Restore Factory-Defaults)

Command	Description	Access Level
R_S	Restores the factory-default settings and passwords and reboots the system.[a]	2

[a] Only available after a settings or critical RAM failure.

SER Command (Sequential Events Recorder Report)

Use the **SER** commands (see *Table 7.39*) to view and manage the Sequential Events Recorder report. See *Section 9: Analyzing Events* for further details on SER reports. If there is no SER report row stored, the relay responds with `No Data Available`.

Table 7.39 SER Command (Sequential Events Recorder Report)

Command	Description	Access Level
SER **SER *row1 row2*** **SER *date1 date2***	Displays a chronological progression of all available SER rows (as many as 1024 rows). Row 1 is the most recently triggered row and Row 1024 is the oldest.	1
SER C or **R**	Clears/resets the SER records.	1
Parameters		
row1	Append *row1* to return a chronological progression of the first *row1* rows. For example, use **SER 5** to return the first five rows.	
row1 row2	Append *row1* and *row2* to return all rows between *row1* and *row2*, beginning with row1 and ending with *row2*. Enter the smaller number first to display a numeric progression of rows through the report. Enter the larger number first to display a reverse numeric progression of rows. For example, use **SER 1 10** to return the first 10 rows in numeric order or **SER 10 1** to return these same items in reverse numeric order.	
date1	Append *date1* to return all rows with this date. For example, use **SER 1/1/2020** to return all records for January 1, 2020.	
date1 date2	Append *date1* and *date2* to return all rows between *date1* and *date2* beginning with *date1* and ending with *date2*. Enter the oldest date first to display a chronological progression through the report. Enter the newest date first to display a reverse chronological progression. Date entries are dependent on the date format setting Time.DateFormat. For example, use **SER 1/5/2020 1/7/2020** to return all records for January 5, 6, and 7, 2020.	

SET Command (Change Settings)

The **SET** command is for viewing or changing the relay settings (see *Table 7.40*).

Table 7.40 SET Command (Change Settings)

Command	Description	Access Level
SET *s* TERSE	Sets the protection class settings.	2
SET L *s* TERSE	Sets logic class settings for protection.	2
SET P *n s* TERSE	Sets communication port class settings. *n* specifies the **PORT** (**F**, **1**, or **2**); *n* defaults to the active port if not listed.	2
SET R *s* TERSE	Sets report class settings such as Sequential Events Recorder (SER) and event report settings.	2
SET H *s* TERSE	Sets HMI settings.	2
SET M *s* TERSE	Sets Modbus user map settings.	2
SET D *m s* TERSE	Sets DNP Map *m* settings (*m* = 1, 2, or 3).	2
Parameter	**Description**	
s	Append *s* to name the specific setting you want to view and to jump to this setting. If *s* is not entered, the relay starts at the first setting.	
TERSE	Append **TERSE** to skip the settings display after the last setting. Use this parameter to speed up the **SET** command. If you want to review the settings before saving, do not use the **TERSE** option. **TE** can be substituted for **TERSE**, e.g., **SET Sys.PhRot TE**).	

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 7.41*.

Table 7.41 SET Command Editing Keystrokes

Press Key(s)	Results
<Enter>	Retains the setting and moves to the next setting.
^ <Enter>	Returns to the previous setting.
< <Enter>	Returns to the previous setting category.
> <Enter>	Moves to the next setting category.
END <Enter>	Exits the editing session, then prompts you to save the settings.
<Ctrl+X>	Aborts the editing session without saving changes.

The relay checks each setting to ensure that it is within the allowed range. If the setting is not within the allowed range, the relay generates an `Out of Range` message and prompts you for the setting again.

When all the settings are entered, the relay displays the new settings and prompts you for approval to enable them. Answer **Y <Enter>** to enable the new settings. The relay is disabled for as long as one second while it saves the new settings. The Diag.Secu_Alm Relay Word bit is set momentarily and the **ENABLED** LED extinguishes while the relay is disabled.

SHOW Command (Show/View Settings)

When showing settings, the relay displays the settings label and the present value from nonvolatile memory for each setting class. See *Table 7.42* for the **SHOW** command settings and format.

Table 7.42 SHOW Command (Show/View Settings)

Command	Description	Access Level
SHO *s*	Shows protection class settings.	1
SHO L *s*	Shows logic class settings for protection.	1
SHO P *n s*	Shows communication port settings. *n* specifies the **PORT** (**F**, **1**, or **2**); *n* defaults to the active port if not listed.	1
SHO R *s*	Shows report class settings such as Sequential Events Recorder (SER) and event report settings.	1
SHO H *s*	Shows HMI settings.	1
SHO M *s*	Shows Modbus user map settings.	1
SHO D *m s*	Shows DNP Map *m* settings (*m* = 1, 2, or 3).	1
Parameter	**Description**	
s	Append *s* to name the specific setting you want to view and to jump to this setting. If *s* is not entered, the relay starts at the first setting.	

```
=>>SHO <Enter>

Protection Settings

Basic Settings
Dev.ID   := SEL-851
Dev.Loc  := FEEDER RELAY
Sys.FNom := 60            Sys.PhRot:= ABC           CTP.Rat  := 1000
CTP.NomSec:= 5            CTP.Pol  := NORMAL        CTN.Rat  := 100
CTN.NomSec:= 5            CTN.Pol  := NORMAL        VTP.Rat  := 100.00
VTP.Conn := WYE           Sys.VNom := 13.80         VTP.SingleV:= N

Configuration Settings
Time.DateFormat:= MDY
Meter.Fault:= 50P_01.PU OR 50Gnd_01.PU OR 51P_01.PU OR 51Gnd_01.PU
Meter.Thres_Min := Y

50P.Ena  := 1

Maximum Phase Overcurrent
50P_01.OpQty:= Fundamental
50P_01.PUVal:= 15.00      50P_01.PUDly:= 0.00
50P_01.TorqCtl:= 1

Per-Phase Overcurrent
50ABC.Ena:= OFF

Negative Sequence Overcurrent
50Neg.Ena:= OFF

Residual Ground Overcurrent
50Gnd.Ena:= 1

50Gnd_01.PUVal:= 2.50     50Gnd_01.PUDly:= 0.50
50Gnd_01.TorqCtl:= 1

Neutral Overcurrent
50N.Ena  := OFF

Maximum Phase Time-Overcurrent
51P.Ena  := 1
```

Figure 7.16 SHOW Command Response

```
51P_01.OpQty:= Fundamental
51P_01.PUVal:= 6.00       51P_01.Crv:= U3           51P_01.TmDial:= 3.00
51P_01.RstMod:= Instantaneous
51P_01.TorqCtl:= 1

Negative Sequence Time-Overcurrent
51Neg.Ena:= OFF

Residual Ground Time-Overcurrent
51Gnd.Ena:= 1

51Gnd_01.PUVal:= 2.50     51Gnd_01.Crv:= U3         51Gnd_01.TmDial:= 3.00
51Gnd_01.RstMod:= Instantaneous
51Gnd_01.TorqCtl:= 1

Neutral Time-Overcurrent
51N.Ena  := OFF

Phase-Phase Undervoltage
27PP.Ena := OFF

Phase-Phase Overvoltage
59PP.Ena := OFF

Residual Ground Overvoltage
59Gnd.Ena:= OFF

Loss of Potential
60LOP.Blk:= RB_001.Sta

Harmonic Blocking
HBlk.H2_Ena:= N

Reclosing Control
79.Ena   := N

Power Element Enable
32.Ena   := 2

3-Phase Power Element Settings
32_01.PUVal:= 50.0        32_01.OpQty:= -WATTS      32_01.PUDly:= 10.00
32_01.TorqCtl:= 1
32_02.PUVal:= 50.0        32_02.OpQty:= -WATTS      32_02.PUDly:= 10.00
32_02.TorqCtl:= 1


Power Factor Element Enable
55.Ena   := 2

Power Factor Element Settings
55_01.PUVal:= 0.80        55_01.Typ:= Lag           55_01.PUDly:= 1.00
55_01.TorqCtl:= 1
55_02.PUVal:= 0.80        55_02.Typ:= Lag           55_02.PUDly:= 1.00
55_02.TorqCtl:= 1

Frequency Settings
81.Ena   := OFF

Breaker Failure Settings
BF_01.Ena:= Y             BF_01.50P_PUVal:= 0.50
BF_01.Supv:= 0
BF_01.Init:= Trip_01.Sta
BF_01.SealinDly:= OFF     BF_01.RetripDly:= 0.05    BF_01.PUDly:= 0.50
BF_01.Trip_Init:= BF_01.TmOut
BF_01.UnltTrip:= 0

Arc-Flash Protection Settings
AFD.Ena  := N
```

Figure 7.16 SHOW Command Response (Continued)

```
Trip/Close Logic Settings
Trip_01.MinDur:= 0.5
Trip_01.Init:= 50.TmOut OR 51P_01.TmOut OR 51Gnd_01.TmOut OR 51Neg_01.TmOut OR
               (AFD.50P_PU OR AFD.50N_PU) AND (AFD.Sen01_PU OR AFD.Sen02_PU OR
               AFD.Sen03_PU OR AFD.Sen04_PU) OR Trip_01.InitX
Trip_01.InitX:= 0
Trip_01.LocInit:= IN_03.Sta
Trip_01.RemInit:= 0
Trip_01.Unlt:= NOT Bkr_01.52A_Sta
Bkr_01.52A_Sta:= RB_001.Sta
Ctl.RemSel:= 0
Close_01.LocInit:= IN_04.Sta
Close_01.RemInit:= 0
Close_01.FailDly:= 1.0
Close_01.Unlt:= 0

Warning List
(Enter up to 24 Relay Word bits, one per line.)
1: Diag.Hw_Alm

Output Settings
OUT_01.FailSafe:= Y
OUT_01.Sta:= Trip_01.Sta
OUT_02.FailSafe:= Y
OUT_02.Sta:= 0
OUT_03.FailSafe:= Y
OUT_03.Sta:= Close_01.Sta
OUT_04.FailSafe:= Y
OUT_04.Sta:= 0
OUT_05.FailSafe:= Y
OUT_05.Sta:= Diag.Hw_Alm OR Diag.Secu_Alm

Contact Input Settings
IN.VNom  := 125           IN.VTyp  := dc

Time and Date Management
Time.IRIG_CtlBits:= C37.118
Time.UTC_Ofs:= -5.00      Time.DST_StrMo:= NA

Demand Meter Settings
Meter.Dmd_Ena:= THM       Meter.Dmd_TmConst:= 5     Meter.Dmd_IP_PUVal:= OFF
Meter.Dmd_IGnd_PUVal:= OFF
Meter.Dmd_INeg_PUVal:= OFF

Data Reset Settings
Trip.TrgtRst:= 0
Meter.En_Rst:= 0
Meter.MaxMin_Rst:= 0
Meter.Dmd_Rst:= 0

Alarm Settings
Diag.Secu_Alm:= Diag.Secu_PassBad OR Diag.Secu_PassChg OR Diag.Secu_SetChg OR
                Diag.Secu_AccLev2 OR Diag.Secu_PassLO
Diag.Hw_Rst:= 0

IEC 61850 Mode Control
61850.Mod_Blk:= 0
61850.Mod_Test:= 0

=>>
```

Figure 7.16 SHOW Command Response (Continued)

STATUS Command (Relay Self-Test Status)

The **STA** command (see *Table 7.43*) displays the status report. See *Figure 7.17* for an example of a status report.

Table 7.43 STATUS Command (Relay Self-Test Status)

Command	Description	Access Level
STA *n*	Displays the relay self-test information *n* times (*n* = 1–32767). Defaults to 1 if *n* is not specified.	1
STA S	Displays the memory and execution utilization for the SELOGIC control equations.	1
STA C or **R**	Reboots the relay and clears the self-test warning and failure status results.	2

Refer to *Section 10: Testing and Troubleshooting* for self-test thresholds and corrective actions, as well as hardware configuration conflict resolution. *Table 7.44* shows the status report definitions and message formats for each test. Refer to *Figure 1.3* and for an example of the **STATUS** command response.

Table 7.44 STATUS Command Report and Definitions

STATUS Report Designator	Definition	Message Format
Serial Num	Serial number	Text Data
FID	Firmware identifier string	Text Data
CID	Firmware checksum identifier	Hex
PART NUM	Part number	Text Data
RAM	Volatile memory integrity	OK/FAIL
ROM	Firmware integrity	OK/FAIL
CR_RAM	Integrity of settings in RAM and code that runs in RAM	OK/FAIL
NON_VOL	Integrity of data stored in nonvolatile memory	OK/FAIL
HMI	Status of the HMI display	OK/WARN/FAIL
CLOCK	Clock functionality	OK/WARN
CLK_BAT	Clock battery voltage	OK/WARN
AF	Integrity of the arc-flash sensors	OK/WARN
PS	Integrity of the power supply	OK/FAIL
ETH	Integrity of the Ethernet port	OK/FAIL
Analog Module		
FPGA	FPGA programming unsuccessful or FPGA failed	OK/FAIL
DAQ	Indicates the self-test status of the data acquisition module	OK/FAIL

NOTE: The STA S report shows the available SELOGIC capacity of the relay. For example, Execution 90% means 90% of the execution capacity is still available.

Figure 7.17 shows the typical relay output for the **STATUS S** command, showing available SELOGIC control equation capability.

```
=>STA S <Enter>

SEL-851                                    Date: 04/09/2021   Time: 11:45:04.360
FEEDER RELAY                               Time Source: Internal

Serial Num = 000000000000101
FID = SEL-851-X033-V0-Z001001-D20210327         CID = FDA9
PART NUM = 085100011110130

Protection (%)     90
Logic (%)          92
Report (%)         90
Hmi (%)            96
Port 2 (%)         97

Execution (%)      96

=>
```

Figure 7.17 STATUS S Command Response

SUMMARY Command

The **SUM** command (see *Table 7.45*) displays an event summary in a readable format.

Table 7.45 SUMMARY Command

Command	Description	Access Level
SUM *n*	Displays the latest event summary. Use *n* to display a particular event summary (where *n* is either an event record or reference number).	1
SUM C or **R**	Clears the archive.	1

Each event summary report shows the date, time, current magnitudes (primary values), frequency, and, if the relay has the voltage option, voltage magnitudes (primary values). The relay reports the voltage and current when the largest current occurs during the event. The event summary report also shows the event type (e.g., arc-flash trip); refer to *Table 9.2* for a list of event types.

TARGET Command (Display Relay Word Bit Status)

The **TAR** command (see *Table 7.46*) displays the status of the Relay Word bits, whether the Relay Word bits are asserted or deasserted.

Table 7.46 TARGET Command (Display Relay Word Bit Status)

Command	Description	Access Level
TAR *name k* **TAR *n*** **TAR *n k***	Displays Relay Word Row 0 or the last displayed target row when used without parameters.	1
TAR R	Clears the front-panel tripping targets. Unlatches the trip logic for testing purposes. Shows Relay Word Row 0.	1
Parameter		
name	Displays the Relay Word row with Relay Word bit name.	
n	Shows Relay Word row number *n*.	
k	Repeats *k* times (1–32767).	

NOTE: The **TARGET R** command cannot reset the latched targets if a trip condition is present.

The elements are represented as Relay Word bits and are listed in rows of eight, called Relay Word rows. The first row includes the EnaLED.Sta and TripLED.Sta Relay Word bits and corresponds to the row shown in *Table 7.47*. All Relay Word rows are described in *Table H.1*.

Relay Word bits are used in SELOGIC control equations. See *Appendix H: Relay Word Bits*.

The **TAR** command does not remap the front-panel target LEDs, as is done in some previous SEL relays.

Table 7.47 Target LEDs and the TAR 0 Command

LEDs	7	6	5	4	3	2	1	0
TAR 0	EnaLED.Sta	TripLED.Sta	*[a]	*[a]	*[a]	*[a]	*[a]	*[a]

[a] Reserved for future use.

TEST DB Command

Use the **TEST DB** command to temporarily force the relay to send fixed analog and/or digital values over communications interfaces for protocol testing.

Table 7.48 TEST DB Commands

Command	Description	Access Level
TEST DB	Displays the present status of digital and analog overrides.	2
TEST DB A *name value*	Forces the protocol analog element *name* to override *value*.	2
TEST DB D *name value*	Forces the protocol digital element *name* to override *value*.	2
TEST DB *name* OFF	Clears (analog or digital) override for element *name*.	2
TEST DB A OFF	Clears all analog overrides.	2
TEST DB D OFF	Clears all digital overrides	2
TEST DB OFF	Clears all analog and digital overrides.	2

WARNING
To reduce the chance of a false operating decision when using the **TEST DB** command, ensure that protocol master device(s) flag the data as "forced or test data." One possible method is to monitor the Test.ForcData Relay Word bit.

The **TEST DB** command provides a method to override Relay Word bits or analog values to aid in the testing of the communications interfaces. The command overrides values in the communications interfaces (SEL Fast Message, DNP3, Modbus, and IEC 61850) only. The actual values used by the relay for protection and control are not changed. However, remote devices may use these analog and digital signals to make control decisions. Ensure that remote devices are properly configured to receive the overridden data before using the **TEST DB** command.

To override analog data in a communications interface, enter the following from Access Level 2:

NOTE: When using the **TEST DB** command to generate values for Fast Meter testing, you may need to override all current and voltage angles (IA.120ms_Ang, VA.120ms_Ang, etc.) to ensure the expected phase relationship.

```
=>>TEST DB A name value <Enter>
```

where *value* is a numerical value and *name* is an analog label from *Table I.1*, in which there is an "x" in the DNP3, Modbus, Fast Meter, or IEC 61850 column. For example, the **TEST DB** command can be used to force the value of the A-phase current magnitude transmitted to a remote device to 100 amperes:

NOTE: When using the **TEST DB** command, specifying a negative value may yield an unexpected display in some instances.

```
=>>TEST DB A IA.120ms_MagPri 100 <Enter>
```

To override digital data in an SEL Fast Message, Modbus, DNP3, or IEC 61850 communications interface, enter the following from Access Level 2:

```
=>>TEST DB D name value <Enter>
```

where *name* is a Relay Word bit (see *Table H.1*) and *value* is 1 or 0. For example, if Relay Word bit 51P_01.TmOut := logical 0, the **TEST DB** command can be used effectively to test the communications interface by forcing the communicated status of this Relay Word bit to logical 1:

```
=>>TEST DB D 51P_01.TmOut 1 <Enter>
```

Values listed in the SER.List setting cannot be overridden.

If the relay is not already in Test Mode, the relay responds to either the digital or analog override request with the following message:

```
WARNING:  TEST MODE is not a regular operation.
Communication outputs of the device will be overridden by simulated values.

Are you sure (Y/N)? Y <Enter>
```

NOTE: If the relay is already in IEC 61850 Test Mode, the relay will not accept **TEST DB** commands.

If you select **Y**, the relay responds:

```
Test Mode Active.  Use Test DB OFF command to exit Test Mode.
Override Added
```

Relay Word bit Test.ForcData will also assert to indicate that Test Mode is active. If the relay is already in the test mode (overrides are already active), the relay responds:

```
Override Added
```

The **TEST DB** command alone displays the present status of digital and analog overrides. An example **TEST DB** response of two analogs follows:

```
=>>TEST DB <Enter>

SEL-851                                    Date: 04/09/2021   Time: 12:04:31.744
FEEDER RELAY                               Time Source: Internal


NAME                     OVERRIDE VALUE
IA.120ms_MagPri          100.0000
Freq.120ms_Mag           55.0000

=>>
```

Individual overrides are cleared using the **TEST DB** command with the OFF parameter:

```
=>>TEST DB D or A name OFF <Enter>
```

Entering **TEST DB A OFF** clears all the analog overrides and **TEST DB D OFF** clears all the digital overrides. Entering **TEST DB OFF** without any parameters clears all the overrides. When there are no overrides, the relay automatically exits Test Mode and clears all the overrides if no **TEST DB** commands are entered for 30 minutes.

TIME Command (View/Change Time)

The **TIME** command (see *Table 7.49*) returns information about the SEL-851 internal clock. You can also set the clock if you specify hours and minutes (seconds data are optional). Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

Table 7.49 TIME Command (View/Change Time)

Command	Description	Access Level
TIME	Displays the present internal clock time.	1
TIME *hh*	Sets the internal clock to *hh*.	1
TIME *hh:mm*	Sets the internal clock to *hh:mm*.	1
TIME *hh:mm:ss*	Sets the internal clock to *hh:mm:ss*.	1

Use the **TIME *hh:mm*** and **TIME *hh:mm:ss*** commands to set the internal clock time. The value *hh* is for hours from 0–23; the value *mm* is for minutes from 0–59; the value *ss* is for seconds from 0–59. If you enter a valid time, the relay updates and saves the time in the nonvolatile clock and displays the time you just entered. If you enter an invalid time, the SEL-851 responds with `Invalid Time`.

TRIGGER Command (Trigger Event Report)

Use the **TRI** command (see *Table 7.50*) to trigger the SEL-851 to record data for high-resolution oscillography and event reports.

Table 7.50 TRIGGER Command (Trigger Event Report)

Command	Description	Access Level
TRI	Triggers an event report data capture.	1

When you issue the **TRI** command, the SEL-851 responds with `Triggered`. If the event is not triggered within one second, the relay responds with `Did not trigger`. See *Section 9: Analyzing Events* for further details on event reports.

VECTOR Command (Show Diagnostic Information)

Issue the **VEC** command under the direction of SEL. The information contained in a vector report is formatted for SEL in-house use only. Your SEL application engineer or the factory may request a **VEC** command capture to help diagnose a relay or system problem.

Table 7.51 VEC Command

Command	Description	Access Level
VEC D	Displays the diagnostic vector report.	2
VEC E	Displays the exception vector report.	2

Virtual File Interface

You can retrieve and send data as files through the relay virtual file interface. Devices with embedded computers can also use the virtual file interface. When using serial ports of virtual terminal links, use the **FILE DIR** command to access the file interface.

Send and receive files using the following three protocols:

Protocol	Port Availability
FTP	Ethernet only
MMS	Ethernet only
Ymodem	Serial and Ethernet

FTP and MMS File Structure

Ethernet FTP and IEC 61850 MMS have a two-level file structure. Files are available at the root level and in subdirectories. *Table 7.52* shows the directories and their contents.

Table 7.52 FTP and MMS Virtual File Structure

Directory	Contents
/ (Root)	CFG.TXT file, CFG.XML file, ERR.TXT file and SET_61850.CID and the SETTINGS, REPORTS, EVENTS, and COMTRADE[a] directories
/SETTINGS	Relay settings
/REPORTS	SER, PRO, SUM, and HIS reports
/EVENTS	COMTRADE and HIS reports
/COMTRADE[a]	COMTRADE events
/UPGRADE[b]	Digitally signed firmware upgrades

[a] The COMTRADE directory is only available in the MMS file structure.
[b] Directory is not available if Port 2 setting Port_O2.FwUpgrd_Ena := N.

Root Directory

The root directory (/) contains files and subdirectories as shown in *Table 7.52*.

CFG.TXT File (Read-Only)

The CFG.TXT file contains general configuration information about the relay and each settings class. External support software retrieves the CFG.TXT file to interact automatically with the relay. Calibration settings are included only when the file is read at Access Level C.

```
[INFO]
RELAYTYPE=SEL-851
FID=SEL-800-R100-V0-Z001001-D20210519
BFID=SLBT8XX-R100-V0-Z000000-D20210519
PARTNO=085100011010130
[CLASSES]
```

Figure 7.18 CFG.TXT File

```
"1","Protection","SET_1.TXT"
"L","Logic","SET_L.TXT"
"R","Report","SET_R.TXT"
"P1","Port 1","SET_P1.TXT"
"P2","Port 2","SET_P2.TXT"
"PF","Port F","SET_PF.TXT"
"M","Modbus","SET_M.TXT"
"D1","Dnp 1","SET_D1.TXT"
"D2","Dnp 2","SET_D2.TXT"
"D3","Dnp 3","SET_D3.TXT"
"H","HMI","SET_H.TXT"
```

Figure 7.18 CFG.TXT File (Continued)

CFG.XML File (Read-Only)

The CFG.XML file is supplementary to the CFG.TXT file. The CFG.XML file describes the IED configuration and any options such as the Ethernet port, and includes firmware identification, settings class names, and configuration file information.

ERR.TXT (Read-Only) and SET_61850.CID File

The SET_61850.CID file is present if the relay includes the IEC 61850 protocol option. The ERR.TXT file contents are based on the most recent SET_61850.CID file or settings file written to the relay. If there were no errors, the file is empty. If errors occurred, the relay logs these errors in the ERR.TXT file. The SET_61850.CID file contains the IEC 61850 configured IED description in XML. Architect generates and then downloads this file to the relay. See *Appendix F: IEC 61850 Communications* for more information.

Settings Directory (Available for FTP and MMS)

You can access the relay settings through files in the SETTINGS directory. It is recommended that you use support software to access the settings files, rather than directly accessing them via other means. Settings support software reads settings from all of these files to perform its functions. The relay only allows you to write to the individual SET_*cn* files, where *c* is the settings class code and *n* is the settings instance. Except for the SET_61850 CID file, changing settings with support software involves the following steps:

Step 1. Read the CFG.TXT and the SET_ALL.TXT files from the relay using a support software.

Step 2. Modify the settings for each settings class and send the corresponding SET_*cn*.TXT file to the relay using the support software.

Step 3. Read the ERR.TXT file from the relay. If the ERR.TXT file is empty, the relay detected no errors in the SET_*cn*.TXT file and it is accepted.

Step 4. For any detected errors, fix the SET_*cn*.TXT file as indicated by the ERR.TXT file and send the SET_*cn*.TXT file to the relay.

Step 5. Repeat *Step 2* to *Step 4* for each setting class that you want to modify.

Step 6. After all setting changes are complete, test and commission the relay.

SET_ALL.TXT File (Read-Only)

The SET_ALL.TXT file contains the settings for all of the settings classes in the relay. Calibration settings are included only when the file is read at Access Level C.

SET_cn.TXT Files (Read and Write)

There is a file for each instance of each setting class. *Table 7.53* summarizes the settings files. The settings class is designated by *c*, and the settings instance number is designated by *n*.

ERR.TXT (Read-Only)

The ERR.TXT file contents are based on the most recent SET_*cn*.TXT file written to the relay. If there were no errors, the file is empty. If errors occurred, the relay logs these errors in the ERR.TXT file.

Table 7.53 Settings Directory Files

File Name	Settings Description
SET_1.TXT	Protection
SET_D*n*.TXT	DNP3 Map; *n* in range 1–3
SET_H.TXT	HMI
SET_L.TXT	Logic
SET_M.TXT	Modbus Map
SET_P*n*.TXT	Port; *n* in range 1, 2, F
SET_R.TXT	Report
SET_ALL.TXT	All instances of all settings classes
ERR.TXT	Error log for most recently written settings file

Reports Directory (Read-Only) (Available for FTP and MMS)

Use the REPORTS directory to retrieve files that contain the reports shown in *Table 7.54*. Note that the relay provides a report file that contains the latest information each time you request the file. Each time you request a report, the relay stores its corresponding command response in the designated text file.

Table 7.54 Reports Directory Files

File Name	Description	Equivalent Command Response
CHISTORY.TXT	Compressed ASCII History Report	**CHI**
HISTORY.TXT	History Report	**HIS**
CPRO.TXT	Compressed Profile Data	**CPRO**
PRO.TXT	Profile Data	**PRO**
CSER.TXT	Compressed Sequence of Events	**CSER**
SER.TXT	Sequence of Events	**SER**
CSUM.TXT	Compressed Summary Report	**CSUM**
SUM.TXT	Summary Report	**SUM**

Events Directory (Read-Only) (Available for FTP and MMS)

The relay provides history and oscillography files in the EVENTS directory as shown in *Table 7.56*. Oscillography files are available in COMTRADE format (IEEE C37.111-2013). COMTRADE event files are also available to read as a batch. See *Batch File Access on page 7.55*.

Oscillography files are generated at the time the event is triggered (see *Triggering Data Captures and Event Reports on page 9.3*). The size of each oscillography file is determined by the Event.Len setting in effect at the time the event is triggered and by the Event.SampRate setting in effect at the time the event is downloaded from the relay.

The file names for the C37.111-2013 COMTRADE event files have the following format:

yymmdd,hhMMssmmm,0T,aaaaa,bbbbb,ccccc,ddd,nnnnn.ext

Table 7.55 C37.111-2013 COMTRADE Event File Names

Variable	Description
yy	The last two digits of the year
mm	The month (01 to 12)
dd	The day (01 to 31)
hh	The hour (00 to 23)
MM	The minute (00 to 59)
ss	The second (00 to 59)
mmm	The millisecond (000 to 999)
0t	Indicates that the time stamp is the event trigger time with a UTC offset of 0
aaaaa	The last five characters of the Dev.Loc setting (after removing spaces)
bbbbb	The last five characters of the Dev.Id setting (after removing spaces)
ccccc	The Dev.CoName setting
ddd	Event record type/time-domain report (TDR)
nnnnn	The unique serial number associated with the event file
ext	CFG (indicating configuration file) or DAT (indicating data file) or HDR (indicating header file)

The *yymmdd* and *hhMMss* values are based on the SOC (second of century) of the first triggered data point as specified in the COMTRADE C37.111 standard.

Spaces and characters **? " / \ < > * | : ; [ ] $ % { }** are not supported in the Dev.Id or Dev.Loc used in the C37.111-2013 filenames, and the relay will automatically remove them.

Table 7.56 EVENTS Directory Files (Sheet 1 of 2)

File	Usage
HISTORY.TXT	History file; read-only
CHISTORY.TXT	Compressed ASCII history file; read-only
SUM.TXT	Summary file; read-only
CSUM.TXT	Compressed ASCII summary file; read-only

Table 7.56 EVENTS Directory Files (Sheet 2 of 2)

File	Usage
yymmdd,hhMMss-mmm,0t,aaaaa,bbbbb,ccccc,ddd,nnnnn.CFG	Sample/Second C37.111-2013 COMTRADE configuration file, read-only
yymmdd,hhMMss-mmm,0t,aaaaa,bbbbb,ccccc,ddd,nnnnn.DAT	Sample/Second C37.111-2013 data file; read-only
yymmdd,hhMMss-mmm,0t,aaaaa,bbbbb,ccccc,ddd,nnnnn.HDR	Sample/Second C37.111-2013 COMTRADE header file; read-only

COMTRADE Directory (Available Only for MMS)

When using MMS file transfer, conveniently retrieve all of the COMTRADE files from the COMTRADE directory. Note that the COMTRADE files are also available in the EVENTS directory. Refer to *Table 7.57* for all the files available in the COMTRADE directory.

Upgrade Directory (Available Only for FTP)

Table 7.57 shows the file contents of the UPGRADE directory. The UPGRADE directory is only available via FTP at Access Level 2 and above on relays that support Ethernet firmware upgrades. The directory is not available if the Port 2 setting Port_02.FwUpgrd_Ena := N. The RELAY.ZDS and SLBT.ZDS are write-only files, whereas the ERR.TXT is a read-only file.

Table 7.57 UPGRADE Directory File Sample

File	Description
ERR.TXT	Digitally signed firmware upgrade error file, read-only
RELAY.ZDS	Digitally signed firmware upgrade file, write-only
SLBT.ZDS	SELBOOT firmware digitally signed upgrade file, write-only

Ymodem File Structure

All the files available (see *Table 7.58*) for Ymodem protocol are in the root directory. See *FILE Command on page 7.26* for a response to the **FILE DIR** command.

Table 7.58 Files Available for Ymodem Protocol (Sheet 1 of 2)

File Name	Description	Read Access Level	Write Access Level
CFG.TXT	See *Root Directory on page 7.49*	1, 2, C	N/A
ERR.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.50*	1, 2, C	N/A
SET_ALL.TXT[a]	See *Settings Directory (Available for FTP and MMS) on page 7.50*	1, 2, C	N/A
SET_1.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.50*	1, 2, C	2, C
SET_C.TXT[a]	See *Settings Directory (Available for FTP and MMS) on page 7.50*	C	C
SET_D*n*.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.50*	1, 2, C	2, C
SET_H.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.50*	1, 2, C	2, C
SET_L.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.50*	1, 2, C	2, C

Table 7.58 Files Available for Ymodem Protocol (Sheet 2 of 2)

File Name	Description	Read Access Level	Write Access Level
SET_M.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.50*	1, 2, C	2, C
SET_P*n*.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.50*	1, 2, C	2, C
SET_R.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.50*	1, 2, C	2, C
yymmdd,hhMMssmmm, 0t,aaaaa,bbbbb,ccccc,ddd, nnnnn.CFG	See *Events Directory (Read-Only) (Available for FTP and MMS) on page 7.52*	1, 2, C	N/A
yymmdd,hhMMssmmm, 0t,aaaaa,bbbbb,ccccc,ddd, nnnnn.DAT	See *Events Directory (Read-Only) (Available for FTP and MMS) on page 7.52*	1, 2, C	N/A
yymmdd,hhMMssmmm, 0t,aaaaa,bbbbb,ccccc,ddd, nnnnn.HDR	See *Events Directory (Read-Only) (Available for FTP and MMS) on page 7.52*	1, 2, C	N/A
CHISTORY.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.51*	1, 2, C	N/A
HISTORY.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.51*	1, 2, C	N/A
SUM.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.51*	1, 2, C	N/A
CSUM.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.51*	1, 2, C	N/A
CPRO.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.51*	1, 2, C	N/A
PRO.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.51*	1, 2, C	N/A
CSER.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.51*	1, 2, C	N/A
SER.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.51*	1, 2, C	N/A
RELAY.ZDS	See *Upgrade Directory (Available Only for FTP) on page 7.53*	2, C	N/A
SLBT.ZDS	See *Upgrade Directory (Available Only for FTP) on page 7.53*	2, C	N/A

[a] Calibration settings are included only when accessed at Access Level C.

Batch File Access

Files can be accessed as a batch by using the supported wild card character, *.

FTP and MMS Wild Card Usage

Table 7.59 shows examples using supported wild cards. Note that these wild cards may be appended to a directory path (e.g., /specified_directory/*.txt).

Table 7.59 FTP and MMS Wildcard Usage Examples

Usage	Description	Example	Note
*xyz	Lists all files and/or subdirectories in a specified directory whose name (including extension) ends with xyz.	/*.TXT	Lists all files with the .TXT extension.
abc*	Lists all files and/or subdirectories in a specified directory whose name begins with abc.	/SETTINGS/SET*	Lists all settings files that start with SET.
mno	Lists all files and/or subdirectories in a specified directory whose name contains mno.	/EVENTS/*_100*	Lists all events that contain _100 in the ID number.

Ymodem Wild Card Usage

NOTE: Ymodem protocol does not support wild cards for settings files.

Event, report, and diagnostic files can also be accessed as a batch using wild cards.

Table 7.60 Ymodem Wildcard Usage Examples

Usage	Description	Example	Note
*xyz	Lists all files that end with xyz.	FILE DIR HIS*.TXT	Lists all of the files that contain HIS in the name (HISTORY.TXT).
abc*	Lists all files whose name begins with abc.	FILE DIRyymmdd, hhMMssmmm, 0t,aaaaa,bbbbb, ccccc,ddd,nnnnn*	Lists all of the three files for the COMTRADE event *nnnnn* (DFG, DAT, and HDR).

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Section 8

HMI

Overview

The SEL-851 Feeder Protection Relay has a relay front-panel HMI that makes feeder monitoring, data collection, and control quick and efficient. Use the relay front panel to analyze the basic operating information, including whether the relay is enabled, is tripped, or has an alarm. A multifunction **TARGET RESET** pushbutton is also provided.

The SEL-851 features a straightforward menu-driven LCD. The LEDs on the HMI give a clear indication of the SEL-851 operational status. The SEL-851 front-panel features include the following:

- Reading metering, monitoring, and events data
- Inspecting targets
- Controlling relay operations
- Viewing diagnostics

The front panel has six pushbutton navigation keys, four control pushbuttons (**TRIP**, **CLOSE**, **LOCAL/REMOTE**, and **TARGET RESET**), and five function keys.

Relay Front Panel

Figure 8.1 identifies the following regions on the SEL-851 front-panel HMI.

- Function keys
- Navigation pushbuttons
- Control pushbuttons
- Tricolor target LEDs
- USB Type C serial port (Port F)

Figure 8.1 SEL-851 Front Panel

You can use the following features of the SEL-851 front panel to customize the relay to your application needs:

- Rotating display on the HMI
- Programmable tricolor target LEDs
- Slide-in configurable front-panel labels to change the identification of the target LEDs

The **ENABLED** LED indicates that the relay is powered correctly, is functional, and has no self-test failures. Trip events illuminate the **TRIP** LED. The prominent location of the **TRIP** LED in the top target area aids in recognizing trip events quickly. A **TRIP** LED can be ON for any of the conditions listed in *Table 9.2: Event Types*. The **WARNING** LED notifies you of warning conditions, and the default Warning.List setting includes the Diag.Hw_Alm Relay Word bit.

You can enter as many as 24 Relay Word bits in the Warning.List setting, 1 per line. Refer to *Section 4: Protection and Logic Functions* for warning list setting support.

Restoring Passwords and Port 1 Settings to Default Using the TARGET RESET Pushbutton on the Relay Front Panel

Press and hold the **TARGET RESET** pushbutton for 10 seconds while the relay is turning on to restore the default passwords and Port 1 settings. If the pushbutton is released before 10 seconds elapse, the relay continues with normal startup. All LEDs may be ON when the **TARGET RESET** pushbutton is pressed and held on startup. The **ENABLED** LED extinguishes to indicate that the relay recognizes that the **TARGET RESET** pushbutton has been pressed for the

10 seconds required to initiate the restoration of the passwords, security certificate, and Port 1 settings.

LCD Backlight Adjustment

The HMI display consists of four lines with twenty-one characters per line. In addition to the four lines, there are five text strings that correspond to the action to be taken by the five function keys. You can adjust the LCD screen backlight to suit your viewing angle and lighting conditions. To change the backlight, press and hold the **Left** and **Right Arrow** pushbuttons for approximately five seconds. The SEL-851 displays a backlight adjustment box. Pressing the **Up Arrow** pushbutton increases the brightness. Pressing the **Down Arrow** pushbutton decreases the brightness. When you are finished adjusting the screen backlight, press the **ESC** pushbutton.

HMI Automatic Display Messages

NOTE: You can program as many as eight rotating display points. Refer to Section 4: Protection and Logic Functions, HMI Settings (SET H Command) for details on display point settings.

The SEL-851 displays automatic messages, overriding the rotating display, under the conditions described in *Table 8.1*. Relay failure has the highest priority, followed by trip and warning when the HMI setting HMI.AutoMsg := OVERRIDE. Trip messages continue to be displayed until the **TARGET RESET** pushbutton is pressed (and the **TRIP** has cleared).

If the HMI setting HMI.AutoMsg := ROTATING, then the rotating display messages continue and any trip or warning message is added to the rotation.

Table 8.1 HMI Automatic Messages

Condition	HMI Display Message
Relay detects any self-test failure	Displays the type of latest failure (see *Section 10: Testing and Troubleshooting*).
Relay trip occurs	Displays the type or cause of the trip. Refer to *Table 9.2* for a list of trip display messages.
Relay warning condition occurs	Displays the type of warning.

HMI Menus and Screens

Navigating the Menus

The SEL-851 front panel gives you access to most of the information that the relay measures and stores. All of the front-panel functions are accessible through use of the six-button keypad and LCD. Use the keypad (shown in *Figure 8.2*) to maneuver within the front-panel menu structure, described in detail throughout the remainder of this section. *Table 8.2* describes the function of each navigation pushbutton.

Figure 8.2 HMI Navigation Pushbuttons

Table 8.2 Navigation Pushbutton Functions

Pushbutton	Function
Up Arrow	Move up within a menu or data list.
Down Arrow	Move down within a menu or data list.
Left Arrow	Used for backlight adjustment.
Right Arrow	Used for backlight adjustment.
ESC	Escape from the current menu or display.
ENT	Move from the rotating display to the main menu. Select the menu item at the cursor.

Table 8.3 SEL-851 Feeder Relay HMI Navigation (Sheet 1 of 2)

Main Menu	Submenu	Fields in Submenu	Subfields in Submenu
Meter			
	Fundamental	IA, IB, IC, IG, IN, IAVG, I1, 3I2,VAB, VBC, VCA, VA, VB, VC, 3V0, VAVG, V1, 3V2, Real Power kW, Reactive Power kVAR, Apparent Power kVA, Power Factor, Frequency Hz	
	RMS	IArms, IBrms, ICrms, INrms, VArms, VBrms, VCrms, VABrms, VBCrms, VCArms Note: Phase-to-phase values are reported when setting VTP.Conn = DELTA and phase-to-neutral values are reported when setting VTP.Conn = WYE.	
	Demand	Demand Display	IAD, IBD, ICD, IGndD, INegD, IAPD, IBPD, ICPD, IGndPD, INegPD, Last Demand Reset
		Demand Reset	Reset Demand? Yes or No
	Energy	Energy Display	MWh3P-Received, MWh3P-Delivered, MVARHh3P-Received, MVARh3P-Delivered, MVAh3P, Last Reset
		Energy Reset	Reset Energy? Yes or No
	Max/Min	Max/Min Display	IAMX, IAMN, IBMX, IBMN, ICMX, ICMN, INMX, INMN, IGMX, IGMN, VAMX, VAMN, VBMX, VBMN, VCMX, VCMN, KW3PMX, KW3PMN, KVAR3PMX, KVAR3PMN, KVA3PMX, KVA3PMN, FREQMX, FREQMN, Last reset Note: Phase-to-phase values are reported when setting VTP.Conn = DELTA and phase-to-neutral values are reported when setting VTP.Conn = WYE.
		Max/Min Reset	Reset Max/Min? Yes or No
	Harmonics	Fundamental quantities for voltages and currents and 2nd, 3rd, 4th, 5th harmonics as % of fundamental quantities, THDs for voltages and currents	
	Math Variables	Displays Math Variables if Enabled (see PMV.Ena setting in *Table 4.41*)	

Table 8.3 SEL-851 Feeder Relay HMI Navigation (Sheet 2 of 2)

Main Menu	Submenu	Fields in Submenu	Subfields in Submenu
	Remote Analogs	Displays 32 remote analogs	
	Light	Displays light sensor data (LS1, LS2, LS3, L4)	
Targets			
	Current Row	Displays 75 target rows with 8 Relay Word bits in each column. Use the Up and Down navigation keys to navigate between rows. Jump to target rows 15, 30, 45, or 60 using the corresponding soft keys.	
Status			
	Display Status	Serial number, FID, CID, part number, RAM, ROM, critical RAM, nonvolatile Flash, HMI, clock, clock battery, arc-flash sensors, power supply, FPGA, DAQ, relay status	
	Reboot Relay	Asks Yes or No for rebooting the relay	If Yes, relay reboots
	Arc-Flash Diagnostics	Asks Yes or No to run arc-flash diagnostics	If Yes, relay runs arc-flash diagnostics
Control			
	Trip Breaker	Trip Breaker? Yes/No	Confirmation (Yes/No?) is asked only if HMI.CtlBlk = ACK_EN
	Close Breaker	Close Breaker? Yes/No	Confirmation (Yes/No?) is asked only if HMI.CtlBlk = ACK_EN
Events			
	Display Events	Displays events stored in the relay with time stamp of its occurrence	
	Clear Events	Asks Yes or No for clearing events	
	Trigger Events	Asks Yes or No for triggering events	
Settings			
	Port Settings	IP Address, Default Router, MAC Address P1 Protocol, P1 Baud Rate	
	Basic Settings	Dev.Id, Dev.Loc, Sys.FNom, Sys.PhRot, CTP.Rat, CTP.NomSec, CTP.Pol, CTN.Rat, CTN.NomSec, CTN.Pol, VTP.Rat, VTP.Conn, Sys.VNom, VTP.SingleV	
	Protection Settings	50P, 50Gnd, 50ABC, 50Neg, 50N, 51P, 51Gnd, 51Neg, 51N	

Main Menu

Figure 8.3 shows the main menu screen. Using the **Up Arrow** or **Down Arrow** and **ENT** pushbuttons, you can navigate to specific menu item in the main menu. Alternatively, the menu items can be selected by pressing the function keys right below the corresponding function key grid text shown in *Figure 8.3*. Press the function key below MORE to toggle between all available menu items. Each menu item is explained in detail in the following paragraphs.

Figure 8.3 Main Menu

Meter Menu

Select `Meter` from the main menu, as shown in *Figure 8.4*, to view metering data. The `Meter` menu has menu items for viewing different types of metering data, such as `Fundamental`, `RMS`, `Demand`, etc. Select the type of metering and view the data using the **Up** or **Down Arrow** and **ENT** pushbuttons. See *Metering on page 5.2* for a description of the available data fields.

Figure 8.4 Main Menu and Meter Submenu

To view the demand metering data, select `Demand` from the `Meter` menu and then select `Demand Display`, as shown in *Figure 8.5*.

Figure 8.5 Meter Menu and Demand Submenu

Demand metering data can be reset from the HMI by selecting `Demand Reset` from the `Demand` menu. After selecting `Demand Reset` and confirming the reset, the relay displays as shown in *Figure 8.6*.

Figure 8.6 Relay Response When Demand Metering is Reset

Assume that the math variables are not enabled. In response to a request for math variable data (selecting `Math Variables`), the device displays the message shown in *Figure 8.7*.

Figure 8.7 Relay Responses When No Math Variables are Enabled

Targets Menu

Select `Targets` from the main menu, as shown in *Figure 8.8*, to view the binary state of the target rows. Each target row has eight Relay Word bits, as shown in *Appendix H: Relay Word Bits*.

Figure 8.8 Targets Menu Navigation

Status Menu

Select `Status` from the main menu, as shown in *Figure 8.9*, to access relay status data, reboot the relay, or run arc-flash diagnostics. See *STATUS Command (Relay Self-Test Status) on page 7.43* for the `STATUS` data field description. Refer to *Section 2: Installation* for information on the arc-flash diagnostics.

Figure 8.9 Main Menu and Status Submenu

Control Menu

Select `Control` from the main menu, as shown in *Figure 8.10*, to go to the `Control` menu.

Figure 8.10 Main Menu and Control Submenu

The `Control` menu has `Trip Breaker` and `Close Breaker` as its menu items.

Events Menu

Select `Events` from the main menu, as shown in *Figure 8.11*. The `Events` menu has `Display Events`, `Clear Events`, and `Trigger Event` as its menu items. Select `Display Events` to view events, `Clear Events` to delete all the events data, and `Trigger Event` to trigger an event.

Figure 8.11 Events Menu and Display Submenu

When you select `Display Events` and no event data are available, the relay displays as shown in *Figure 8.12*.

Figure 8.12 Relay Response When No Event Data Are Available

When you select `Clear Events` from the `Events` menu and confirm the selection, the relay displays as shown in *Figure 8.13*, after clearing the events data.

Figure 8.13 Relay Responses When Events Are Cleared

When you select `Trigger Event` from the `Events` menu and confirm the selection, the relay displays as shown in *Figure 8.14*, after triggering the event.

Figure 8.14 Relay Response When Event Is Triggered

Settings Menu

Select `Settings` from the main menu, as shown in *Figure 8.15*, to access the relay port, basic, and protection settings. The Port 1 baud rate and protocol and Port 2 IP address, default router, and MAC address are available under the `Port Settings` submenu.

Figure 8.15 Main Menu and Settings Submenu

Operation and Target LEDs

The SEL-851 front panel provides quick confirmation of relay conditions via operation and target LEDs. *Figure 8.16* shows this region with factory-default text on the front-panel configurable labels.

Figure 8.16 Factory-Default HMI LEDs

ENABLED and TRIP LEDs

The **ENABLED** LED indicates that the relay powered correctly, is functional, and has not self-test errors.

The **TRIP** LED illuminates for the events defined by protection trip equation Trip_01.Ini (see *Table 4.28* for more details). The prominent location of the **TRIP** LED aids in recognizing protection events quickly.

Programmable LEDs

You can reprogram all of these indicators (except for the **ENABLED** and **TRIP** LEDs) to reflect operating conditions other than the factory-default programming described in this subsection. See *Target LED Settings on page 4.92* for the SELOGIC control equations.

TLED_0*n*.Set settings are SELOGIC control equations that work with the corresponding TLED_0*n*.Latch latch settings to illuminate the LEDs shown in *Figure 8.16*. Parameter *n* is a number from 1–8 that indicates each LED. If the latch setting (TLED_0*n*.Latch) for a certain LED is set to N, then the LED will follow the status of the corresponding control equation (TLED_0*n*.Set). When the equation asserts, the LED will illuminate, and when the equation deasserts, the LED will extinguish. If the latch setting is set to Y, the LED will only assert if a trip condition occurs and the TLED_0*n*.Set equation is asserted at the time of the trip. At this point, the LED will latch in and can be reset using the **TARGET RESET** pushbutton or the **TAR R** command as long as the target conditions are absent. For a concise listing of the default programming on the HMI LEDs, see *Table 4.60*.

The SEL-851 front panel features slide-in labels for custom LED designations that match custom LED logic. Use the slide-in labels to mark the LEDs with these custom names. You can order the configurable labels kit accessory that comes with slide-in labels (1 sheet or 25 sheets) for custom LED designations. Use the slide-in labels to mark the LEDs with customer names. The configurable label template is available on the Product Literature CD and the product webpage.

Control Pushbuttons

TARGET RESET Pushbutton

For a TRIP event, the SEL-851 latches the **TRIP** LED. Press the **TARGET RESET** pushbutton to reset the latched **TRIP** LED. Pressing and holding the **TARGET RESET** pushbutton illuminates all the LEDs. Upon release of the **TARGET RESET** pushbutton, two possible situations can exist: the conditions that caused the relay to trip have cleared, or the trip conditions remain present at the relay inputs. If the trip conditions have cleared, the latched **TRIP** LED turns off. If the trip event conditions remain, the **TRIP** LED remains lit. The **TARGET RESET** pushbutton also removes the trip automatic message displayed on the LCD menu screens if the trip conditions have cleared.

LED Test

The **TARGET RESET** pushbutton also provides a front-panel LED test. Pressing and holding **TARGET RESET** illuminates all the front-panel LEDs, and these LEDs remain illuminated for as long as **TARGET RESET** is pressed. The LEDs cycle between red, green, and amber as long as the pushbutton is pressed. Each state lasts about five seconds. The LEDs return to the normal operational state after the release of the **TARGET RESET** pushbutton.

CLOSE, TRIP, and LOCAL/REMOTE Pushbuttons

The functionality of the **CLOSE**, **TRIP**, and **LOCAL/REMOTE** pushbuttons on the SEL-851 HMI are determined by the HMI.CtlBlk setting.

LOCAL/REMOTE Pushbutton: The HMI is considered to be the local control location. The local control location has the highest control authority. The HMI operator can select LOCAL and take over control or select REMOTE and relinquish control to a remote location. Press the **LOCAL/REMOTE** pushbutton

momentarily, irrespective of HMI.CtlBlk := ACK_EN or ACK_DIS, to toggle between LOCAL and REMOTE modes. However, when HMI.CtlBlk := BLK_CTRL, LOCAL/REMOTE control is blocked from the HMI.

CLOSE Pushbutton: As soon as the **CLOSE** pushbutton is pressed, the HMI processes the following conditions in the order shown.

- HMI.CtlBlk := ACK_EN, ACK_DIS, or BLK_CTRL
- The control is in Ctl.LocSta mode
- The relay is in the EnaLED.Sta state
- HMI.ClsDly := 0 or a value other than 0 (see *Table 4.53* for information on the HMI.ClsDly setting)

Based on the HMI.CtlBlk and HMI.ClsDly settings, the behavior of the HMI on a CLOSE request is captured in the following table.

HMI Control Mode Setting Value (HMI.CtlBlk)	HMI CLOSE Delay Setting Value (HMI.ClsDly)	Initiating a CLOSE
ACK_EN	0	When a CLOSE is performed from the HMI via either the **CLOSE** pushbutton or the control menu, it acknowledges with YES or NO options requiring the user to confirm the operation. The control must be in Ctl.LocSta mode to initiate a CLOSE by using the **CLOSE** pushbutton or the control menu.
	Any non-zero value	When a CLOSE operation is performed from the HMI via either the **CLOSE** pushbutton or the control menu, it will display the message "CLOSE delay active ESC or TRIP to cancel CLOSE in *xx* seconds," where *xx* is the CLOSE delay timer that is counting down. Note that when the close delay timer is set to a value, the HMI does not respond with YES or NO options for a CLOSE operation. The control must be in Ctl.LocSta mode to initiate a CLOSE by using the **CLOSE** pushbutton or the control menu.
ACK_DIS	0	When a CLOSE is performed from the HMI, the HMI initiates the command with just one press of the **CLOSE** pushbutton. The control must be in Ctl.LocSta mode to initiate a CLOSE by using the **CLOSE** pushbutton or the control menu.
	Any non-zero value	When a CLOSE operation is performed from the HMI, it will display the message "CLOSE delay active ESC or TRIP to cancel CLOSE in *xx* seconds," where *xx* is the close delay timer that is counting down. The control must be in Ctl.LocSta mode to initiate a CLOSE by using the **CLOSE** pushbutton or the control menu.
BLK_CTRL	NA	CLOSE is blocked from the HMI.

If the above conditions are satisfied, a CLOSE request gets initiated. Otherwise, the request is aborted.

Pressing the **TRIP** or **ESC** pushbutton during the delay wait time will cancel the CLOSE request.

TRIP Pushbutton: As soon as the **TRIP** pushbutton is pressed, the HMI verifies the following conditions in the order shown.

- HMI.CtlBlk := ACK_EN or ACK_DIS
- The control is in Ctl.LocSta or Ctl.RemSta mode
- The relay is enabled

Based on the HMI.CtlBlk and HMI.TripDly settings, the behavior of the HMI on a TRIP request is captured in the following table.

HMI Control Mode Setting Value (HMI.CtlBlk)	HMI TRIP Delay Setting Value (HMI.TripDly)	Initiating a TRIP Using the TRIP Pushbutton
ACK_EN	0	When a TRIP is performed from the HMI it acknowledges with YES or NO options requiring the user to confirm the operation. The control must be in LOCAL mode to initiate a TRIP by using the TRIP pushbutton.
	Any non-zero value	When a TRIP operation is performed from the HMI via either the TRIP pushbutton or the control menu, it will display the message "Trip Delay Active ESC or CLOSE to Cancel Trip in *xx* seconds" where *xx* is the trip delay timer that is counting down. Note that when the trip delay timer is set to a value, the HMI does not respond with YES or NO options for a TRIP operation. The control must be in TRIP mode to initiate a TRIP by using the TRIP pushbutton or the control menu.
ACK_DIS	0	When a TRIP operation is performed from the HMI, the HMI initiates the command with just one press of the TRIP pushbutton. The control must be in LOCAL mode to initiate a TRIP by using the TRIP pushbutton or the control menu.
	Any non-zero value	When a TRIP operation is performed from the HMI, it will display the message "Trip Delay Active ESC or CLOSE to Cancel Trip in *xx* seconds" where *xx* is the trip delay timer that is counting down. The control must be in TRIP mode to initiate a TRIP by using the TRIP pushbutton or the control menu.
BLK_CTRL	NA	TRIP is blocked from the HMI.

If the above conditions are satisfied, a TRIP request gets initiated. Otherwise, the request is aborted.

Pressing the CLOSE or ESC pushbutton during the delay wait time will cancel the TRIP request.

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Section 9

Analyzing Events

Overview

The SEL-851 Feeder Protection Relay features comprehensive power system data analysis capabilities. The relay provides these useful analysis tools:

- *Data Processing*
- *Raw and Filtered Data on page 9.1*
- *Triggering Data Captures and Event Reports on page 9.3*
- *Duration of Data Captures and Event Reports on page 9.3*
- *Oscillography on page 9.4*
- *Event History on page 9.10*

An event is a representation of the operating conditions of the power system at a specific time. Events include instances such as a relay trip, an abnormal situation in the power system that triggers a relay element, or an event capture command.

Information from oscillograms, relay event reports, and the Sequential Events Recorder (SER) report are very valuable if you are responsible for outage analysis, outage management, or relay settings coordination.

The SEL-851 features an IRIG-B (serial port) and supports SNTP for high-accuracy timing. When IRIG-B or SNTP is used, the SEL-851 synchronizes the data acquisition system to the received signal. Knowledge of the precise time of sampling (as shown in COMTRADE files) allows comparisons of data across the power system. Use a coordinated network of SEL-851 relays to create moment-in-time "snapshots" of the power system. These data are useful for determining power system dynamic voltage and current phasors, impedances, load flow, and system states.

Data Processing

The SEL-851 is a microprocessor-based relay that monitors power system conditions via the current and voltage inputs. The relay converts these analog inputs to digital information for processing to determine relaying quantities for protection and automation. The relay captures analytical data in high-resolution COMTRADE format.

Raw and Filtered Data

Figure 9.1 shows the path a power system signal takes through relay input processing. An analog input begins at hardware acquisition and sampling, continues through software filtering, and progresses to protection and automation processing. The initial hardware low-pass filter half-power or

–3 dB point is 2.6 kHz with the relay sampling the power system voltage or current at 10 kHz using a 24-bit A/D (analog-to-digital) converter. The relay stores data at 10 kHz and this is the tap point for high-resolution raw data captures. You can select 2 kHz, 5 kHz, and 10 kHz effective sampling rates for presentation of the high-resolution raw data COMTRADE format (see *Duration of Data Captures and Event Reports on page 9.3*).

Figure 9.1 SEL-851 Input Processing

Subsequent processing calculates one-cycle rms measurements, fundamental frequency phasors, and four harmonic components (second, third, fourth, and fifth). Except for rms measurements, all other quantities are calculated using the Fourier filter. These output quantities are calculated every 4 ms. The relay uses these measurements for various protection functions and stores them in the COMTRADE oscillography files.

The SEL-851 processes arc-flash elements (light and current) and the control inputs and outputs every 1 ms. The SEL-851 publishes the data to the COMTRADE oscillography and SER reports (**SER** command).

Triggering Data Captures and Event Reports

The SEL-851 displays power system data from oscillograms, event reports, event summaries, event histories, and SER data. For information on the SER, see *Sequential Events Recorder (SER)*. All of these features, except the SER, require sampled or filtered data from the power system, and are triggered both internally and externally depending on the event trigger that you program in the relay.

Use an event trigger to initiate capturing power system data. The trigger for data captures comes from three possible sources:

- Relay Word bit Trip_01.Init assertion
- SELOGIC control equation Event.Trg (Event Report Trigger)
- **TRI** command

Trip Initiate Relay Word Bit

Refer to *Figure 4.42*. If Relay Word bit Trip_01.Init asserts to logical 1, an event report is automatically generated. Thus, any Relay Word bit that causes a trip does not have to be entered in SELOGIC control equation setting Event.Trg.

Event Trigger SELOGIC Control Equation

The programmable SELOGIC control equation event report trigger setting Event.Trg is set to trigger event reports for conditions other than trip conditions (see *Target LEDs on page 4.92*). When setting Event.Trg detects a logical 0 to logical 1 transition, it generates an event report (if the SEL-851 is not already generating a report that encompasses the new transition). The factory setting is shown in *Event Report Settings on page 4.95*.

You can also use the falling-edge operator, F_TRIG, to initiate data captures. See SELOGIC *Control Equation Operators on page 4.73* for more information on falling edge operators.

TRI (Trigger Event Report) Command

Use the **TRI** command from any communications port to trigger and begin recording high-resolution raw data in the SEL-851. When testing with the **TRI** command, you can gain a glimpse of power system operating conditions that occur immediately after you issue the **TRI** command. See *TRIGGER Command (Trigger Event Report) on page 7.48* for more information on the **TRI** command.

Duration of Data Captures and Event Reports

To use the data capture functions, select the data capture times. Relay setting Event.Len determines the total length of the event report. You can set Event.Len to a value from 0.25 to 2.00 seconds in 0.01 increments.

The length of the data capture/event report (setting Event.Len) and the pretrigger or prefault time (setting Event.PreFlt) are related, as shown in *Figure 9.2*. The Event.Len setting is the overall length of the event report data capture; the Event.PreFlt setting determines the time reserved in the Event.Len period when the relay records pretrigger (prefault) data. Typically, you set the Event.PreFlt time to 20 percent of the total Event.Len period. The factory-default setting is shown in *Event Report Settings on page 4.95*.

Figure 9.2 Data Capture/Event Report Times

The relay stores all data captures to volatile RAM and then moves these data to nonvolatile memory storage. There is enough volatile RAM to store two maximum length captures (maximum Event.Len time). No data captures can be triggered while the volatile RAM is full; the relay must move at least one data capture to nonvolatile storage to reenable data capture triggering. The lower the setting value of Event.Len, the more data captures the relay can store.

Table 9.1 lists the maximum number of data captures/event reports the relay stores in nonvolatile memory for various report lengths. The relay automatically overwrites the oldest events with the newest events when the nonvolatile storage capacity is exceeded.

If you have selected Event.Len = one second, you can store six one-second reports. *Table 9.1* lists the storage capability of the SEL-851 for common event report lengths.

Table 9.1 Event Report Nonvolatile Storage Capability

Event Report Length	Maximum Number of Stored Reports
2.00 s	2
1.00 s	6
0.25 s	27

Oscillography

The SEL-851 creates high-resolution COMTRADE files with a sampling rate as fast as 10 kHz. These COMTRADE files contain raw and filtered voltage and current magnitudes, arc-flash quantities, frequency, Relay Word bits, settings at the time of event, and the summary report. Use raw data to view transient conditions in the power system that occur outside the relay digital filtering and to view the filtered data to analyze the operation of protection elements. These COMTRADE files also aid in testing and troubleshooting relay settings and protection schemes because these contain detailed data on voltage, current, and relay element statuses.

The SEL-851 stores high-resolution raw data oscillography in binary format and uses COMTRADE file types to output these data:

- .HDR—header file
- .CFG—configuration file
- .DAT—high-resolution raw data file

The .HDR file contains summary information about the event in ASCII format. The .CFG file is an ASCII configuration file that describes the layout of the .DAT file. The .DAT file is in binary format and contains the values for each input channel for each sample in the record. These data conform to the IEEE C37.111-2013 COMTRADE standard.

.HDR File

The .HDR file contains the summary and relay settings information that appears in the event report for the data capture. The settings portion is in a comma-delimited format as illustrated in *Figure 9.3*.

```
SEL-851                                   Date: 04/20/2021   Time: 14:51:36.130
FEEDER RELAY

Serial Number = 000000000000000
FID = SEL-851-X036-V0-Z001001-D20210413             CID = B69C
EVENT LOGS =   2
Event Number = 10002

Event:       Phase Inst OC Trip
Targets      1101100000
Freq (Hz)    60.00

Current Mag
            IA        IB        IC        IG        IN
(A)       327.73    326.64    329.31      2.44      0.006

Voltage Mag
            VA        VB        VC
(V)      8025.09   8012.73   8021.26
```

Summary Event Information

```
Protection Settings
Dev.Id,"SEL-851"
Dev.Loc,"FEEDER RELAY"
Dev.CoName,"CONM"
Sys.FNom,"60"
Sys.PhRot,"ABC"
CTP.Rat,"100"
CTP.NomSec,"5"
CTP.Pol,"Normal"
CTN.Rat,"50"
CTN.NomSec,"5"
CTN.Pol,"Normal"
VTP.Rat,"120.00"
VTP.Conn,"Wye"
Sys.VNom,"13.80"
VTP.SingleV,"N"
Time.DateFormat,"MDY"
Meter.Fault,"50P_01.PU OR 50Gnd_01.PU OR 51P_01.PU OR 51Gnd_01.PU"
Meter.Thres_Min,"Y"
50P.Ena,"1"
50P_01.OpQty,"Fundamental"
50P_01.PUVal,"3.00"
...
...
...
...
Profile.List02,"IB.120ms_MagPri"
Profile.List03,"IC.120ms_MagPri"
Profile.List04,""
Profile.List05,""
Profile.List06,""
Profile.List07,""
Profile.List08,""
Profile.List09,""
Profile.List10,""
Profile.List11,""
Profile.List12,""
Profile.List13,""
Profile.List14,""
Profile.List15,""
Profile.List16,""
```

Relay Settings

Figure 9.3 Sample COMTRADE .HDR Header File

.CFG File

The .CFG file contains data such as sample rates, number of channels, line frequency, channel information, and transformer ratios (see *Figure 9.4*). A <CR><LF> follows each line.

The configuration file has the following format:

- Relay name, device identification, COMTRADE standard year
- Number and type of channels
- Channel name units and conversion factors
- Line frequency
- Sample rate and number of samples
- Date and time of first data point
- Date and time of trigger point
- Data file type
- Time-stamp multiplication factor

SEL-851,SEL-851-X034-V0-Z001001-D20210401,2013	COMTRADE Standard
639,31A,608D	Total Channels, Analog, Digital
1,IA.Raw_Pri,A,,A,0.003744,-2.781729698,0,-2147483647,2147483647,100.0,1,P 2,IB.Raw_Pri,B,,A,0.003744,-0.190939724,0,-2147483647,2147483647,100.0,1,P 3,IC.Raw_Pri,C,,A,0.003744, 0.022463497,0,-2147483647,2147483647,100.0,1,P 4,IN.Raw_Pri,,,A,0.000037, 0.008236615,0,-2147483647,2147483647,1.0,1,P 5,VA.Raw_Pri,A,,V,0.007736,-23.625579834,0,-2147483647,2147483647,120.00,1,P 6,VB.Raw_Pri,B,,V,0.007736,-34.842700958,0,-2147483647,2147483647,120.00,1,P 7,VC.Raw_Pri,C,,V,0.007736,-27.354305267,0,-2147483647,2147483647,120.00,1,P 8,LightSen_01.Raw,,,%,0.000011920930,0,0,0,8388608,1,1,P 9,LightSen_02.Raw,,,%,0.000011920930,0,0,0,8388608,1,1,P 10,LightSen_03.Raw,,,%,0.000011920930,0,0,0,8388608, . . . 30,Freq.Mag,,,Hz,0.001,0,0,0,120000,1,1,P 31,FreqTrk.Mag,,,Hz,0.001,0,0,0,120000,1,1,P	Analog Channel Data
1,UNUSED1,,,0 2,UNUSED2,,,0 3,UNUSED3,,,0 4,UNUSED4,,,0 5,UNUSED5,,,0 6,UNUSED6,,,0 7,TripLED.Sta,,,0 8,EnaLED.Sta,,,0 9,TLED_08.Sta,,,0 10,TLED_07.Sta,,,0 . . . 607,UNUSED607,,,0 608,UNUSED608,,,0	Digital (Status) Channel Data
60	Line Frequency
1	
2000,1000	Sample Rate & Number of Samples
07/04/2021,10:43:04.336000	First Data Point
07/04/2021,10:43:04.346000	Trigger Point
BINARY32 1.0 0t,0 F,3	

Figure 9.4 COMTRADE .CFG Configuration File Data

.DAT File

The .DAT file follows the COMTRADE binary standard. The format of the binary data files is sample number, time stamp, data value for each analog channel, and grouped status channel data for each sample in the file. There are no data separators in the binary file, and the file contains no carriage return/line feed characters. The sequential position of the data in the binary

file determines the data translation. Refer to the *IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111-2013* for more information. SEL SYNCHROWAVE Event Software (SEL-5601-2) can read the binary COMTRADE files.

Generating Raw Data Oscillograms

To use high-resolution raw data oscillography, select the type of triggering event and use a trigger event method described in *Raw and Filtered Data on page 9.1*. Use the settings Event.Len and Event.PreFlt to set the SEL-851 for the appropriate data capture time (see *Duration of Data Captures and Event Reports on page 9.3*). Events are always captured by the relay at the 10 kHz sample rate. However, you can choose a lower resolution to download by changing the Event.SampleRate prior to downloading. Event.SampRate does not change resolution of the captured event. Event.SampRate only changes the resolution and size of the downloaded event.

Retrieving Raw Data Oscillograms

You can use SEL Grid Configurator Software or the web server to identify and download data captures (see *Section 3: PC Interface*). Ethernet File Transfer Protocol can also be used to retrieve the COMTRADE files from the relay (see *Communications Protocols*). In addition, you can use a computer terminal emulation program and the **FILE** commands at any communications port to retrieve the stored high-resolution raw data capture from the relay file structure. See *FILE Command on page 7.26* for additional information.

Viewing Event Oscillography

SEL SYNCHROWAVE Event Software (SEL-5601-2) can be used to view and analyze relay event reports. Use **View Combined Event Files** to simultaneously view separate events. To view the saved events using SYNCHROWAVE Event, click **Open Event**. When downloading events via SEL Grid Configurator Software or the web server, the event file will be saved with an .evzip extension. Files with an .evzip extension can be automatically opened by SEL Event Software by double-clicking on the file. *Figure 9.5* shows a sample COMTRADE oscillography.

Figure 9.5 Sample COMTRADE Report Viewed With SEL SYNCHROWAVE Event

Event Summaries and Event Histories

The SEL-851 records the filtered power system data that the relay uses in protection and automation processing. You can view filtered information about an event in either of the following forms.

- Event summary
- Event history

Event Summary

You can retrieve a shortened version of stored event reports as event summaries. These short-form reports present vital information about a triggered event. The relay generates an event report in response to power system faults and other trigger events (see *Triggering Data Captures and Event Reports*). See *Figure 9.6* for a sample event summary.

```
=>>SUM <Enter>

SEL-851                                    Date: 04/07/2021   Time: 15:56:44.817
FEEDER RELAY

Serial Number = 000000000000000
FID = SEL-851-X034-V0-Z001001-D20210401            CID = CCBC
EVENT LOGS =  10
Event Number = 10009

Event:       Gnd/Neut Inst OC Trip
Targets      1101100000
Freq (Hz)    60.00

Current Mag
             IA        IB        IC        IG        IN
(A)      1095.03    109.04    109.72    984.84      0.006

Voltage Mag
             VA        VB        VC
(V)     13137.32  13156.97  13189.99

=>>
```

Figure 9.6 Sample Event Summary Report

The event summary contains the following information:

- Standard report header
  - Relay and location identification
  - Event date and time
- Serial number
- Firmware identification
- Event number
- Event type
- Targets
- System frequency
- Current and voltage magnitudes

The relay displays the targets that asserted during the event on the front-panel to assist with fault analysis.

The SEL-851 reports the event type according to the output of the trip logic algorithm. *Table 9.2* lists event types in fault reporting priority. Fault event types (e.g., phase inst OC trip) have reporting priority over indeterminate fault

events. For example, you can trigger an event when there is no fault condition on the power system by using the **TRI** command. In this case, when there is no fault, the relay reports the event type as TRIG.

Table 9.2 Event Types

Type	Condition
Arc Flash Trip	(R_TRIG AFD.50P_PU OR R_TRIG AFD.50N_PU) AND (R_TRIG AFD.Sen01_PU OR R_TRIG AFD.Sen02_PU OR R_TRIG AFD.Sen03_PU OR R_TRIG AFD.Sen04_PU) AND Trip_01.Sta
Phase Inst OC Trip	(R_TRIG 50P_01.TmOut OR R_TRIG 50P_02.TmOut OR R_TRIG 50P_03.TmOut OR R_TRIG 50P_04.TmOut OR R_TRIG 50P_05.TmOut OR R_TRIG 50P_06.TmOut OR R_TRIG 50ABC_01.TmOut) AND Trip_01.Sta
Gnd/Neut Inst OC Trip	(R_TRIG 50Gnd_01.TmOut OR R_TRIG 50Gnd_02.TmOut OR R_TRIG 50N_01.TmOut OR R_TRIG 50N_02.TmOut) AND Trip_01.Sta
Neg Seq Inst OC Trip	(R_TRIG 50Neg_01.TmOut OR R_TRIG 50Neg_02.TmOut) AND Trip_01.Sta
Phase Time OC Trip	(R_TRIG 51P_01.TmOut OR R_TRIG 51P_02.TmOut) AND Trip_01.Sta
Gnd/Neut Time OC Trip	(R_TRIG 51Gnd_01.TmOut OR R_TRIG 51Gnd_02.TmOut OR R_TRIG 51N_01.TmOut OR R_TRIG 51N_02.TmOut) AND Trip_01.Sta
Neg Seq Time OC Trip	(R_TRIG 51Neg_01.TmOut OR R_TRIG 51Neg_02.TmOut) AND Trip_01.Sta
Undervoltage Trip	(R_TRIG 27PP_01.TmOut OR R_TRIG 27PP_02.TmOut) AND NOT 60LOP.PU AND Trip_01.Sta
Overvoltage Trip	(R_TRIG 59PP_01.TmOut OR R_TRIG 59PP_02.TmOut OR R_TRIG 59Gnd_01.TmOut OR R_TRIG 59Gnd_02.TmOut) AND Trip_01.Sta
Underfrequency Trip	(R_TRIG 81_*n*.TmOut AND Trip_01.Sta) when 81_*n*.PUVal < Sys.FNom setting, *n* = 1 or 2
Overfrequency Trip	(R_TRIG 81_*n*.TmOut AND Trip_01.Sta) when 81_*n*.PUVal > Sys.FNom setting, *n* = 1 or 2
Power Element Trip	(R_TRIG 32_01.TmOut OR R_TRIG 32_02.TmOut) AND Trip_01.Sta
Power Factor Trip	(R_TRIG 55_01.TmOut OR R_TRIG 55_02.TmOut) AND Trip_01.Sta
Breaker Failure Trip	(R_TRIG BF_01.TmOut OR R_TRIG BF_01.Trip) AND Trip_01.Sta
Trigger	Trigger command
Remote Trip	R_TRIG Trip_01.RemSta AND Trip_01.Sta
Local Trip	R_TRIG Trip_01.LocSta AND Trip_01.Sta
Undefined Trip	TRIP not defined above (e.g., trip due to external source)
Event Report Trigger	Assertion of the Event.Trg Relay Word bit

Viewing the Event Summary

Access the event summary from the communications ports. View and download summary reports from Access Level 1 and higher.

You can use the **SUM** command to retrieve event summaries by event number. (The relay labels each new event with a unique number as reported in the **HIS** command history report; see *Event History*.) *Table 9.3* lists the **SUM** commands. Additionally, you can access summaries by the order in which they occur, with the most recent summary being SUM 1.

Table 9.3 SUM Command

Command	Description
SUM	Return the most recent event summary.
SUM *n*	Return a particular *n* event summary.

CSUMMARY

The relay outputs a Compressed ASCII summary report for SCADA and other automation applications. Issue ASCII command **CSU** to view the Compressed ASCII summary report. A sample of the summary report appears in *Figure 9.7*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII summary report are similar to those included in the summary report, although the relay reports the items in a special order.

See *SEL Compressed ASCII Commands on page C.1* for more information on the Compressed ASCII command set.

```
=>CSUM 10 <Enter>
"MONTH","DAY","YEAR","04E5"
4,7,2021,"01B4"
"HOUR","MIN","SEC","MSEC","05E5"
5,29,4,496,"0227"
"SERIALNUMBER","03F9"
"000000000000000","0340"
"FID","CID","0283"
"SEL-851-X034-V0-Z001001-D20210401","CCBC","090D"
"EVENTLOGS","0327"
10,"008D"
"REF_NUM","029C"
10000,"011D"
"EVENT","01F2"
"Trigger","0344"
"TARGETS","028A"
"1001000000","0252"
"FREQ","019E"
60.00,"0120"
"IA","IB","IC","IG","IN","04F8"
0.00,0.01,0.01,0.02,0.006,"04CC"
"VA","VB","VC","0318"
0.28,1.01,1.00,"02CB"

=>
```

Figure 9.7 Sample Compressed ASCII Summary

Event History

The event history gives you a quick look at recent relay activity. The relay labels each new event with a unique number from 10000 to 42767. (At 42767, the top of the numbering range, the relay returns to 10000 for the next event number and then continues to increment.) See *Figure 9.8* for a sample event history.

The event history contains the following:

- Standard report header
  - Relay and location identification
  - Date and time of report
- Event number
- Event date and time
- Event type
- Maximum phase current from summary fault data
- Targets

Figure 9.8 is a sample event history from a terminal. The event types in the event history are the same as the event types in the event summary (see *Table 9.2* for event types).

```
=>HIS <Enter>

SEL-851                                    Date: 04/07/2021   Time: 16:49:41.356
FEEDER RELAY                               Time Source: Internal


FID = SEL-851-X034-V0-Z001001-D20210401

#          DATE         TIME          EVENT                    CURR   FREQ   TARGETS
10009   04/07/2021  15:56:44.817  Gnd/Neut Inst OC Trip  1095.0  60.00  1101100000
10008   04/07/2021  15:56:44.321  ER Trigger             1095.1  60.00  1001000000
10007   04/07/2021  15:56:12.449  Gnd/Neut Inst OC Trip   655.2  60.00  1101100100
10006   04/07/2021  15:56:11.953  ER Trigger              655.0  60.00  1101100100
10005   04/07/2021  15:51:55.271  Gnd/Neut Inst OC Trip  1095.2  60.00  1101100000
10004   04/07/2021  15:51:54.775  ER Trigger             1095.2  60.00  1001000000
10003   04/07/2021  15:38:02.117  Trigger                 111.0  60.00  1001000000
10002   04/07/2021  15:37:41.761  Trigger                 111.0  60.00  1001000000
10001   04/07/2021  10:43:04.346  Trigger                 110.3  60.00  1001000000
10000   04/07/2021  05:29:04.496  Trigger                   0.0  60.00  1001000000

=>
```

Event Number

Event Type

Figure 9.8 Sample Event History

Viewing the Event History

Access the history report from any of the ports. View and download history reports from Access Level 1 and higher. You can also clear or reset the history data from Access Level 1 and higher (with the **HIS C** and **HIS R** commands).

Use the **HIS** command from a terminal to obtain the event history. You can view event histories by date or by date range, or you can specify the number of the most recent events that the relay returns. See *HISTORY Command on page 7.32* for information on the **HIS** command. *Table 9.4* lists the **HIS** commands.

Table 9.4 HIS Command (Sheet 1 of 2)

Command	Description
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *k*	Return the *k* most recent event summaries with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *date1*	Return the event summaries on date *date1*[a].

Table 9.4 HIS Command (Sheet 2 of 2)

Command	Description
HIS ***date1 date2***	Return the event summaries from *date1* to *date2*, with *date1* at the bottom of the list and *date2* at the top of the list.
HIS C or **R**	Clear all event data without resetting the unique event number. The relay continues to assign a unique event number to each of the subsequent events.
HIS CA or **RA**	Clear all event data and reset the unique event number. The relay assigns a unique event number starting from 10000 to the subsequent events.

[a] Use the same date format as Global setting Time.DateFormat.

You can use the web server (see *Web Server on page 3.5*) or SEL Grid Configurator to view the relay event history. To view the event history in SEL Grid, click **System Explorer** > (**Online HMI: Live Device Information**) > **Reports** > **Event History**.

Figure 9.9 View Events Via SEL Grid

CHISTORY

The relay outputs a Compressed ASCII history report for SCADA and other automation applications. Issue the **CHI** command to view the Compressed ASCII history report. A sample of the report appears in *Figure 9.10*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of each history in the Compressed ASCII history report.

Items included in the Compressed ASCII history report are similar to those included in the history report, although the relay reports the items in a special order. See *SEL Compressed ASCII Commands on page C.1* for more information on the Compressed ASCII command set.

```
=>>CHI <Enter>

"FID","0143"
"FID=SEL-851-X034-V0-Z001001-D20210401","08A2"
"REC_NUM","REF_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","EVENT","CURR
","FREQ","TARGETS","17C5"
1,10009,4,7,2021,15,56,44,817,"Gnd/Neut Inst OC Trip",
1095.0,60.00,"1101100000","1210"
2,10008,4,7,2021,15,56,44,321,"ER Trigger",1095
.1,60.00,"1001000000","0E7D"
3,10007,4,7,2021,15,56,12,449,"Gnd/Neut Inst OC Tri
p",655.2,60.00,"1101100100","11E0"
4,10006,4,7,2021,15,56,11,953,"ER Trigger",65
5.0,60.00,"1101100100","0E55"
5,10005,4,7,2021,15,51,55,271,"Gnd/Neut Inst OC Tr
ip",1095.2,60.00,"1101100000","1209"
6,10004,4,7,2021,15,51,54,775,"ER Trigger",
1095.2,60.00,"1001000000","0E87"
7,10003,4,7,2021,15,38,2,117,"Trigger",111.0,60
.00,"1001000000","0D56"
8,10002,4,7,2021,15,37,41,761,"Trigger",111.0,60.00,"100
1000000","0D8D"
9,10001,4,7,2021,10,43,4,346,"Trigger",110.3,60.00,"1001000000",
"0D55"
10,10000,4,7,2021,5,29,4,496,"Trigger",0.0,60.00,"1001000000","0CF5"

=>>
```

Figure 9.10 Sample Compressed ASCII History Report

Sequential Events Recorder (SER)

The SEL-851 SER gives you detailed information on relay states and relay element operation. The SER captures and time-tags state changes of element Relay Word bits and relay conditions. The conditions include power-up, settings changes, and clearing of the SER. The SEL-851 stores the latest 1024 SER entries to nonvolatile memory. *Figure 9.11* is a sample SEL-851 SER report. The SER report contains the following:

- Standard report header
  - Relay and location identification
  - Date and time of report
- SER number
- SER date and time
- Relay element or condition
- Element state

```
=>SER <Enter>

SEL-851                                    Date: 04/08/2021   Time: 08:21:44.284
FEEDER RELAY                               Time Source: Internal

Serial Number : 000000000000000
FID=SEL-851-X034-V0-Z001001-D20210401      CID=CCBC

  #     DATE          TIME          ELEMENT                STATE
 15   04/07/2021   15:56:39.831   SER archive cleared
 14   04/07/2021   15:56:44.817   50Gnd_01.TmOut          Asserted
 13   04/07/2021   15:56:44.817   Trip_01.Init            Asserted
 12   04/07/2021   15:56:44.817   Trip_01.Sta             Asserted
 11   04/07/2021   15:56:44.817   OUT_01.Sta              Asserted
 10   04/07/2021   15:56:45.405   51Gnd_01.TmOut          Asserted
  9   04/07/2021   15:56:45.937   50Gnd_01.TmOut          Deasserted
  8   04/07/2021   15:56:45.937   51Gnd_01.TmOut          Deasserted
  7   04/07/2021   15:56:45.937   Trip_01.Init            Deasserted
  6   04/07/2021   16:56:13.873   Diag.Secu_Alm           Asserted
  5   04/07/2021   16:56:15.125   Diag.Secu_Alm           Deasserted
  4   04/07/2021   17:04:45.508   Trip_01.LocSta          Asserted
  3   04/07/2021   17:04:46.010   Out_01.Sta              Asserted
  2   04/08/2021   08:18:57.817   Diag.Secu_Alm           Asserted
  1   04/08/2021   08:18:58.921   Diag.Secu_Alm           Deasserted

=>
```

SER Number — Relay Element or Condition

Figure 9.11 Sample SER Report

In the SER report, the oldest information has the highest number. The newest information is always #1.

Viewing the SER Report

The relay displays the SER records in ASCII and binary formats. For more information on binary SER messaging, see *Interleaved ASCII and Binary Messages on page C.2*.

Access the SER report from the communications ports at Access Level 1 and higher. To clear all SER data on a serial port, use the **SER C** or **SER R** command.

Use an ASCII terminal, the web server, or SEL Grid Configurator Software to examine SER records. You can use the **SER** command to view the SER report by date, date range, SER number, or SER number range. The relay labels each new SER record with a unique number. See *Table 9.5* for more information on the **SER** command.

Table 9.5 SER Commands (Sheet 1 of 2)

Command[a]	Description
SER	Return a chronological progression of all the available SER rows (as many as 1024 rows). Row 1 is the most recently triggered row and Row 1024 is the oldest.
SER *k*	Return the *k* most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *m n*	Return the SER records from *m* to *n*. If *m* is greater than *n*, records appear with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list. If *m* is less than *n*, records appear with the most recent (lowest number) at the top of the list and the oldest (highest number) at the bottom of the list.
SER *date1*[b]	Return the SER records on date *date1*.

Table 9.5 SER Commands (Sheet 2 of 2)

Command[a]	Description
SER ***date1 date2***	Return the SER records from *date1* at the top of the list to *date2* at the bottom of the list.
SER C or **R**	Clear SER records on the present port.

[a] The parameters m and n indicate SER numbers that the relay assigns at each SER trigger.
[b] Use the same date format as configuration setting Time.DateFormat.

You can retrieve SER records with SEL Grid Configurator Software. Click on the **Online HMI** tab in the Device Explorer view and select the **Reports** tab. Select **SER** to display the SER report. In addition, SER records are accessible from the web server (see *Section 3: PC Interface*).

Figure 9.12 SER Report Via SEL Grid

SER Aliases

You can rename as many as 10 of the SER trigger conditions using the alias settings. For instance, the factory-default SER.Alias01 setting renames Relay Word bit Bkr_01.52A_Sta for reporting in the SER:

```
SER.Alias01:= Bkr_01.52A_Sta BREAKER CLOSED OPEN
```

When Relay Word bit Bkr_01.52A_Sta is asserted, the SER report will show the date and time of the 52A SELOGIC equation. When Relay Word bit Bkr_01.52A_Sta is deasserted, the SER report will show the date and time of the 52A SELOGIC equation. With this and other alias assignments, the SER record is easier for the operator to review. See *Relay Word Bit Aliases on page 4.94* for additional details.

Setting SER Point

You program the relay elements that trigger an SER record. You can select as many as 96 elements. These triggers, or points, include all available Relay Word bits. Use the **SET R** command from a terminal, or use the SEL Grid Configurator software **SER Trigger List** option under the **Report** branch of the **Settings** grid view to enter SER points. Use the text-edit line mode settings method to enter or delete SER elements.

Text-Edit Mode Line Editing

Some SEL-851 settings present multiple input lines to your terminal; you use basic line text editing commands to construct the setting. For display, the relay references each line of the setting by line number, not by the setting name.

While in the text-edit mode, you see a prompt consisting of the line number and the present setting for that line. You can keep the setting, enter a new setting, or delete the setting. *Table 9.6* lists the commands for text-edit mode.

Table 9.6 Actions at Text-Edit Mode Prompts Action Relay Response

Action	Response
?<Enter>	Accept the setting and move to the next line; if at the last line or at a blank line, exit settings.
>*n* <Enter>	Move to line *n*. If this is beyond the end of the list, move to a blank line following the last line.
^ <Enter>	Move to the previous line; if at the first line, stay at the present line.
< <Enter>	Move to the first line.
> <Enter>	Move to a blank line following the last line.
LIST <Enter>	List all settings and return to the present action prompt.
DELETE [*n*] <Enter>	Delete the present line and subsequent lines for a total of *n* lines; *n* = 1 if not provided. Lines after deletion shift upward by the number of lines deleted.
INSERT <Enter>	Insert a blank line at the present location; the present line and subsequent lines shift downward.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the "Save settings (Y, N) ?" prompt.
<Ctrl+X>	Abort editing session without saving changes.

Use commas to separate the items in a text-edit mode setting when you are entering multiple items per line. After you enter each line, the relay checks the validity of the setting. If the entered setting is invalid, the relay responds with an error message and prompts you again for the setting.

Section 10

Testing and Troubleshooting

Overview

Relay testing is typically divided into two categories:

- Tests performed at the time the relay is installed or commissioned
- Tests performed periodically once the relay is in service

This section provides information on both types of testing for the SEL-851 Feeder Protection Relay. Because the SEL-851 is equipped with extensive self-tests, traditional periodic test procedures may be eliminated or greatly reduced.

Should a problem arise during either commissioning or periodic tests, the section on *Troubleshooting on page 10.14* provides a guide to isolating and correcting the problem.

Testing Tools

Web Server

The following web server screens assist you during relay testing.

The Meter Fundamental (METER) shows the ac currents and voltages (magnitude and phase angle) presented to the relay in primary values. In addition, it shows power system frequency. Compare these quantities against other devices of known accuracy. The METER fundamental is also available via the serial port, SEL Grid Configurator Software, and HMI display (see *Section 7: Communications* and *Section 8: HMI*).

In the SEL-851, the length of the event reports generated in response to faults or disturbances is measured in seconds and can be set to hundredths of a second between 0.25 and 2.00 seconds. 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 report is also available via SEL Grid Configurator Software (see *Section 3: PC Interface*) and the serial port (see *Section 9: Analyzing Events*).

The relay provides a Sequential Events Recorder (SER) 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 also available via SEL Grid Configurator Software and the serial port (see *Section 9: Analyzing Events*).

Use the **TARGET** command to view the state of relay control inputs, relay outputs, and relay elements individually during a test. The **TARGET** command is also available via SEL Grid Configurator Software, the serial

port, and the HMI display (see *Section 7: Communications* and *Section 8: HMI*). The present state of all the Relay Word bits can also be viewed via web server.

Commissioning Tests

SEL performs a complete functional check and calibration of each SEL-851 before it is shipped. This helps to ensure that you receive a relay that operates correctly and accurately. Commissioning tests confirm that the relay is properly connected to the feeder and all auxiliary equipment, and they verify control signal inputs and outputs.

The following connection tests help you enter settings into the SEL-851 and verify that the relay is properly connected. Brief functional tests ensure that the relay settings are correct. It is unnecessary to test every element, timer, and function in these tests. Modify the procedure as necessary to conform to your standard practices. Use the procedure at initial relay installation; you should not need to repeat it unless major changes are made to the relay electrical connections.

Required Equipment

- The SEL-851, installed and connected according to your protection design
- A PC with Ethernet port (standard Ethernet cable) or serial port (communication cable)
- Terminal emulation software
- Document with settings appropriate to your application and protection design
- The ac and dc elementary schematics and wiring diagrams for this relay installation
- A continuity tester
- A protective relay ac test source; three-phase voltage and current with phase angle control

Connection Tests

Step 1. Remove control voltage and ac signals from the SEL-851 by opening the appropriate breaker(s) or removing fuses.

Step 2. Isolate the relay contact assigned to be the **TRIP** output.

Step 3. Verify correct ac and dc connections by performing point-to-point continuity checks on the associated circuits.

Step 4. Apply ac or dc control voltage to the relay.

After the relay is energized, the green **ENABLED** LED should illuminate.

Step 5. Use the appropriate Ethernet or serial cable to connect a PC to the relay.

Step 6. Establish communication with the relay.

Refer to *Section 7: Communications* for more information on serial port communication.

Step 7. Set the correct relay time and date by using the web server, SEL Grid Configurator Software, or the serial port commands.

Step 8. Enter the relay settings from the settings sheets for your application.

Step 9. Verify the relay ac connections.

Step 10. Connect the ac test source current or voltage to the appropriate relay terminals.

NOTE: Make sure the current transformer secondary windings are shorted before they are disconnected from the relay.

a. Disconnect the current transformer and voltage transformer (if present) secondaries from the relay prior to applying test source quantities.

b. If you set the relay to accept phase-to-ground voltages (VTP.Conn := WYE), set the current and/or voltage phase angles as shown in *Figure 10.1*.

c. If you set the relay to accept delta voltages (VTP.Conn := DELTA), set the current and/or voltage phase angles as shown in *Figure 10.2*.

When setting Sys.PhRot := ABC, set angle V_A = angle I_A = 0°
set angle V_B = angle I_B = −120°
set angle V_C = angle I_C = 120°

When setting Sys.PhRot := ACB, set angle V_A = angle I_A = 0°
set angle V_B = angle I_B = 120°
set angle V_C = angle I_C = −120°

Figure 10.1 Three-Phase Wye AC Connections

When setting Sys.PhRot := ABC, set angle I_A = 0°
set angle I_B = −120°
set angle I_C = 120°
set angle V_{AB} = +30°
set angle V_{CB} = +90°

When setting Sys.PhRot := ACB, set angle I_A = 0°
set angle I_B = −120°
set angle I_C = 120°
set angle V_{AB} = −30°
set angle V_{CB} = −90

Figure 10.2 Three-Phase Open-Delta AC Connections

Step 11. Apply rated full-load current (secondary).

Step 12. If the relay is equipped with voltage inputs, apply rated voltage for your application.

Step 13. Use the METER fundamental to verify that the relay is measuring the magnitude and phase angle of both voltage and current correctly; it takes into account the relay VTP.Rat and CTP.Rat settings and the fact that the quantities are displayed in primary units.

Step 14. Verify control input connections. Using Relay Word bits, check the control input status in the relay.

As you assert each input, the position Relay Word bits corresponding to that input should change from zero (0) to one (1).

Step 15. Verify output contact operation.

a. For each output contact, set the input to logical 1. This causes the output contact to close. For example, setting OUT_01.Sta = 1 causes the output **OUT01** contact to close.

b. Repeat the process for all contact outputs.

Make sure that each contact closure does what you want it to do in the annunciation, control, or trip circuit associated with that contact closure.

Step 16. Perform any desired protection element tests. Perform only enough tests to prove that the relay operates as intended; exhaustive element performance testing is not necessary for commissioning.

Step 17. Connect the relay for tripping duty.

Step 18. Verify that any settings changed during the tests performed in *Step 15* and *Step 16* are changed back to the correct values for your application.

Step 19. Clear the relay data buffers (Clear Signal Profile, Clear SERs, Clear Event Report History). For corresponding serial port commands, see *Table 10.1* and prepare the relay for operation.

This prevents data generated during commissioning testing from being confused with operational data collected later.

Table 10.1 Serial Port Commands That Clear Relay Data Buffers

Serial Port Command	Task Performed
PRO C	Clears signal-profile data
SER R	Resets Sequential Events Recorder buffer
SUM R	Resets event report and summary command buffers

Step 20. When it is safe to do so, energize the feeder.

Step 21. Verify the following ac quantities by using the METER fundamental.

- ➢ Phase current magnitudes should be nearly equal.
- ➢ Phase current angles should be balanced, have proper phase rotation, and have the appropriate phase relationship to the phase voltages.

Step 22. If your relay is equipped with voltage inputs, check the following:

- ➢ Phase voltage magnitudes should be nearly equal.
- ➢ Phase voltage phase angles should be balanced and have proper phase rotation.

The SEL-851 is now ready for continuous service.

Functional Tests

Phase Current Measuring Accuracy

Step 1. Connect the current source to the relay, as shown in *Figure 10.3*.

Figure 10.3 Current Source Connections

Step 2. Record the CTP.Rat and Sys.PhRot setting values.

Step 3. Set the phase current angles to apply balanced three-phase currents in accordance with the Sys.PhRot setting (refer to *Figure 10.1*).

Step 4. Set each phase current magnitude equal to the values listed in the first column of *Table 10.2*. Meter fundamental should display the applied current magnitude times the CTP.Rat setting.

Table 10.2 Phase Current Measuring Accuracy

|I| Applied (A)	Expected Reading CTP.Rat • |I|	A-Phase Reading (A primary)	B-Phase Reading (A primary)	C-Phase Reading (A primary)
0.2 • CTP.NomSec				
0.9 • CTP.NomSec				
1.6 • CTP.NomSec				

Current Unbalance Metering Accuracy

Step 1. Connect the current source to the relay, as shown in *Figure 10.3*.

Step 2. Record the CTP.Rat and Sys.PhRot setting values.

Step 3. Set the phase current angles to apply balanced three-phase currents in accordance with the Sys.PhRot setting (refer to *Figure 10.1*).

Step 4. Apply the appropriate magnitude for each phase current, as shown in Column 1 of *Table 10.3*.

Table 10.3 Current Unbalance Measuring Accuracy

|I| Applied (A)	Expected Reading (%)	Actual Reading (%)
|IA| = 0.9 • CTP.NomSec |IB| = CTP.NomSec |IC| = CTP.NomSec	7%	
|IA| = 0.75 • CTP.NomSec |IB| = CTP.NomSec |IC| = CTP.NomSec	17%	
|IA| = CTP.NomSec |IB| = 1.2 • CTP.NomSec |IC| = 1.2 • CTP.NomSec	12%	
|IA| = 0.9 • CTP.NomSec |IB| = 1.1 • CTP.NomSec |IC| = 1.1 • CTP.NomSec	13%	

Power and Power Factor Measuring Accuracy

Wye-Connected Voltages

Perform the following steps to test wye-connected voltages.

Step 1. Connect the current source to the relay, as shown in *Figure 10.3*.

Step 2. Connect the voltage source to the relay, as shown in *Figure 10.4*. Make sure that VTP.Conn := WYE.

Figure 10.4 Wye Voltage Source Connections

Step 3. Record the CTP.Rat, VTP.Rat, and Sys.PhRot setting values.

Step 4. Apply the current and voltage quantities shown in Column 1 of *Table 10.4*.

Values are given for Sys.PhRot := ABC and Sys.PhRot := ACB.

Step 5. Use the METER fundamental to verify the results.

Table 10.4 Power Quantity Accuracy—Wye Voltages

Applied Currents and Voltages	Real Power (kW)	Reactive Power (kVAR)	Power Factor (pf)
Sys.PhRot := ABC Ia = 2.5 ∠-26 Ib = 2.5 ∠–146 Ic = 2.5 ∠+94	**Expected:** P = 0.4523 • CTP.Rat • VTP.Rat	**Expected:** Q = 0.2211 • CTP.Rat • VTP.Rat	**Expected:** pf = 0.90 lag
Va = 67 ∠0 Vb = 67 ∠–120 Vc = 67 ∠+120	**Measured:**	**Measured:**	**Measured:**
Sys.PhRot := ACB Ia = 2.5 ∠–26 Ib = 2.5 ∠+94 Ic = 2.5 ∠–146	**Expected:** P = 0.4523 • CTP.Rat • VTP.Rat	**Expected:** Q = 0.2211 • CTP.Rat • VTP.Rat	**Expected:** pf = 0.90 lag
Va = 67 ∠0 Vb = 67 ∠+120 Vc = 67 ∠–120	**Measured:**	**Measured:**	**Measured:**

Delta-Connected Voltages

Perform the following steps to test delta-connected voltages.

Step 1. Connect the current source to the relay, as shown in *Figure 10.3*.

Step 2. Connect the voltage source to the relay, as shown in *Figure 10.5*. Make sure that VTP.Conn := DELTA.

Figure 10.5 Delta Voltage Source Connections

Step 3. Record the CTP.Rat, VTP.Rat, and Sys.Rot setting values.

Step 4. Apply the current and voltage quantities shown in the first column of *Table 10.5*.

Values are given for Sys.PhRot := ABC and Sys.PhRot := ACB.

Step 5. Use the METER fundamental to verify the results.

Table 10.5 Power Quantity Accuracy—Delta Voltages

Applied Currents and Voltages	Real Power (kW)	Reactive Power (kVAR)	Power Factor (pf)
Sys.PhRot := ABC Ia = 2.5 ∠–26 Ib = 2.5 ∠–146 Ic = 2.5 ∠+94 Vab = 120 ∠+30 Vbc = 120 ∠–90	**Expected:** P = 0.4677 • CTP.Rat • VTP.Rat **Measured:**	**Expected:** Q = 0.2286 • CTP.Rat • VTP.Rat **Measured:**	**Expected** pf = 0.90 lag **Measured:**
Sys.PhRot := ACB Ia = 2.5 ∠–26 Ib = 2.5 ∠+94 Ic = 2.5 ∠–146 Vab = 120 ∠–30 Vbc = 120 ∠+90	**Expected:** P = 0.4677 • CTP.Rat • VTP.Rat **Measured:**	**Expected:** Q = 0.2286 • CTP.Rat • VTP.Rat **Measured:**	**Expected:** pf = 0.90 lag **Measured:**

Arc-Flash Protection Tests

Follow the procedures described in *Section 2: Installation* to complete the installation of the arc-flash detection (AFD) fiber-optic sensors in the switchgear equipment to be protected. Make sure the switchgear doors, panels, etc., are closed and in the final operating configuration. This ensures that the ambient light as measured by the sensors is indicative of the normal operating condition. DO NOT ENERGIZE the switchgear for the commissioning tests described in the following text. The relay must have the application settings as necessary, be energized, and be in the ENABLED state. Refer to *Application Guide AG2011-01: Using the SEL-751 and SEL-751A for Arc-Flash Detection* for more details. The SEL-4520 Arc-Flash Test module provides a convenient way to test the operation of arc-flash detection relays installed in metal-clad and metal-enclosed switchgear. The SEL-4520 is used to test the SEL-851 Feeder Protection Relay and other arc-flash detection relays that use light and overcurrent to sense an arc-flash event.

Arc-Flash Detection (AFD) System Continuous Self-Testing

The SEL-851 continuously tests (periodic) and monitors all four arc-flash sensor subsystems and reports the status. The test period of constant, set to 10 minutes.

1. Point-Sensor AFD Self-Test

   Each point-sensor AFD subsystem on the relay has a Transmit LED channel and a Light Detector channel. The LED periodically sends a light pulse through the transmit fiber cable, which is "coupled" into the receive fiber cable in the point sensor. The light travels back to the light detector on the relay. The relay uses the light measurement by the detector to determine the integrity of the point-sensor AFD loop and report PASS/FAIL status.

2. Clear-Jacketed Fiber Sensor AFD Self-Test

   The clear-jacketed fiber sensor is basically a loop, starting from the Transmit LED and returning to the Light Detector. The relay self-test involves sending a light pulse around the loop and measuring the light received at the detector. The light measurement by the detector is used to determine the integrity of the clear-jacketed fiber sensor AFD loop and report PASS/FAIL status.

NOTE: The point-sensor diagnostics signal does not affect the response time of the sensor. The clear-jacketed fiber-sensor diagnostics signal can cause a 1 ms delay if the arc-flash event occurs at the same time as the diagnostics test. The clear-jacketed fiber-sensor diagnostic test injects a 1 ms pulse through the fiber once every 10 minutes.

Meter Light Report

Use the serial port ASCII command **METER L** to view the meter light report as shown in *Figure 5.9*.

The report shows the light intensity measurements in percent of full scale (%) for the four AFD channels. This measurement represents the "background" or the "ambient" light in the switchgear areas being monitored for arc-flash. Use this measurement to determine the time-overlight AFD.Sen01_PUVal to AFD.Sen04_PUVal settings for arc-flash protection (refer to *Section 4: Protection and Logic Functions* for details). If there is excessive background light (any of the Relay Word bits AFD.Sen0*n*_AmbLight picks up) or if there is a diagnostic failure (any of the Relay Word bits AFD.Sen0*n*_DiagFail picks up), the AFD.Alm Relay Word bit picks up and gives a WARNING on the relay front panel and asserts the PULSE ALARM output contact.

Command AFD (Arc-Flash Test)

The relay performs the arc-flash self-test periodically as discussed previously. Additionally, by using the serial port ASCII command **AFD**, the relay performs the self-test on demand in all four channels and reports the status of each channel. This same test is also available from the relay front-panel STATUS sub-menu. Refer to *Figure 7.10* for the **AFD** command response example. The response shows the light measurements in percent of full scale and the PASS/FAIL status. The PASS indication means the channel is healthy and ready to detect an arc-flash event. The FAIL indication means the channel in question is not healthy and needs repair and testing when a convenient outage is available for maintenance.

Testing the Arc-Flash Time-Overlight Elements AFD.Sen01_PU to AFD.Sen04_PU

Test the time-overlight elements once the relay has been set, as described in *Section 4: Protection and Logic Functions* for the arc-flash protection elements. You should add the AFD.Sen01_PU–AFD.Sen04_PU Relay Word

bits to the **SER** (sequence of events report) settings so that the relay can capture the time-overlight element assertion and dropout. Apply a bright light source near the light sensor (POINT or FIBER type) in the switchgear cabinet and note that the appropriate time-overlight element Relay Word bit picks up and drops out as expected.

The arc-flash test can also be captured as a COMTRADE event report by triggering the event report with the AFD.Sen0*n*_PU Relay Word bit. The COMTRADE (raw data) event report should be viewed with SEL-5601-2 SYNCHROWAVE Event Software. You can view the % light intensity analog quantity together with the AFD.Sen0*n*_PU Relay Word bit to verify the correct operation.

Testing the Arc-Flash Overcurrent Elements AFD.50P_PU and AFD.50N_PU

These current elements are similar to the phase and neutral overcurrent elements, except they use "raw" current input samples and act instantaneously to achieve fast response. You can test these elements similarly to the phase and neutral overcurrent elements. You can use the COMTRADE report as described previously to analyze the event.

Testing the Complete Arc-Flash Protection System

⚠CAUTION
Before placing the arc-flash protection system in service, first make sure all the sensors are correctly installed, and then execute the **AFD** command to initiate a self-test.

It is necessary to verify the complete protection subsystem even though the relay is tested at the factory before shipping as it is a critical protection function. If a synchronized light and current pulse test source is available to simulate an arc, you can use it to exercise the arc-flash protection AFD.Sen0*n*_PU elements together with the AFD.50P_PU or the AFD.50N_PU elements. If the relay has been set for the arc-flash protection including the tripping logic, the test could exercise the breaker tripping (unenergized state). You can capture the total event with appropriate event report trigger settings and use SYNCHROWAVE Event to view and analyze the COMTRADE (raw data) report. The COMTRADE report shows the analog currents and light channels together with the Relay Word bits so that you can analyze and qualify the response. *Figure 10.6* shows an example event report for a simulated arc-flash incident.

Figure 10.6 COMTRADE Light Event Capture Example

Periodic Tests (Routine Maintenance)

Because the SEL-851 is equipped with extensive self-tests, the most effective maintenance task is to monitor the self-tests after a self-test failure. In addition, each relay event report generated by a fault should be reviewed. Such reviews frequently reveal problems with equipment external to the relay, such as instrument transformers and control wiring.

The SEL-851 does not require specific routine tests, but your operation standards may require some degree of periodic relay verification. If you need or want to perform periodic relay verification, the following checks are recommended.

Table 10.6 Periodic Relay Checks

Test	Description
Relay Status	Use the front-panel or serial port **STATUS** command to verify that the relay self-tests have not detected any WARN or FAIL conditions.
Meter	Verify that the relay is correctly measuring current and voltage (if included) by comparing the relay meter readings to separate external meters.
Arc-Flash Detection (AFD) Status	Use the serial port **AFD** command to verify that the AFD channel self-tests have not detected a FAIL condition in any of the channels.
Control Input	Using the Relay Word bits, check the control input status in the relay. As you assert each input, the Relay Word bit corresponding to that input should change from zero (0) to one (1).
Contact Output	For each output contact, set the input to Logic 1. This causes the output contact to close. For example, setting OUT_01.Sta := 1 causes the output **OUT01** contact to close. Repeat the process for all contact outputs. Make sure that each contact closure does what you want it to do in the annunciation, control, or trip circuit associated with that contact closure.

Self-Test

The SEL-851 runs a variety of self-tests. You may know when a self-test failure has occurred by configuring an output contact to create a diagnostic alarm as explained in *Section 4: Protection and Logic Functions*. By using the metering functions, you may know if the analog front-end (not monitored by relay self-test) is functional. The relay takes the following corrective actions for out-of-tolerance conditions (see *Table 10.7*):

- Protection Disabled: The relay disables protection and control elements and trip/close logic. All output contacts are de-energized. The **ENABLED** LED is extinguished.
- ALARM Output: Two Relay Word bits, Diag.Hw_Alm and Diag.Secu_Alm, signal self-test problems. Refer to *Table 4.39* for the factory-default SELOGIC setting, Diag.Secu_Alm. The Diag.Secu_Alm Relay Word bit asserts based on the programmed software conditions in the Diag.Secu_Alm SELOGIC control equation. Diag.Hw_Alm is pulsed for hardware self-test warnings. Diag.Hw_Alm is continuously asserted (set to logical 1) for hardware self-test failures. A

diagnostic alarm may be configured as explained in *Section 4: Protection and Logic Functions*. In the Alarm Status column of *Table 10.7*, Latched indicates that Diag.Hw_Alm is continuously asserted, Not Latched indicates that Diag.Hw_Alm is pulsed for five seconds, and NA indicates that Diag.Hw_Alm is not asserted. Program Diag.Hw_Rst (refer to *Table 4.39*) to reset hardware alarm conditions.

- The relay generates automatic STATUS reports at the serial port for warnings and failures (ports with setting Port_01.AutoEve_Ena = Y).
- The relay displays failure messages on the relay front-panel display for failures.
- For certain failures, the relay will automatically restart as many as three times. In many instances, this will correct the failure. The failure message might not be fully displayed before automatic restart occurs. Indication that the relay restarted will be recorded in the SER.

Use the serial port **STATUS** command or HMI to view relay self-test status. Based on the self-test type, issue the **STA C** command as directed in the Corrective Action column. Contact SEL if this does not correct the problem. The **Clear Self-Tests and Reboot** button on the web server interface allows you to clear any self-test failures and reboot the relay. Note that pressing the **Clear Self-Tests and Reboot** button does not clear a nonvolatile failure present in the relay.

Table 10.7 Relay Self-Tests (Sheet 1 of 2)

Self-Test	Description	Normal Range	Protection Disabled on Failure	Alarm Status	Auto-Message on Failure	Front-Panel Message on Failure	Corrective Action
Watchdog Timer Periodic Resetting (1/32 cycle)			Yes	De-energized	No	No	
Main Board FPGA (Run Time)	Fail on lack of data acquisition interrupts or on detection of a CRC error in the FPGA code		Yes	Latched	Yes	Status Fail FPGA Failure	Automatic restart. Contact SEL if failure returns.
External RAM (Power Up)	Performs a read/write test on system RAM		Yes	Latched	No	No	
External RAM (Run Time)	Performs a read/write test on system RAM		Yes	Latched	Yes	Status Fail RAM Failure	Automatic restart. Contact SEL if failure returns.
Internal RAM (Power Up)	Performs a read/write test on system CPU RAM		Yes	Latched	No	No	
Internal RAM (Run Time)	Performs a read/write test on system CPU RAM		Yes	Latched	Yes	Status Fail RAM Failure	Automatic restart. Contact SEL if failure returns.
Code Flash (Power Up)	SELBOOT qualifies code with a checksum		NA	NA	NA	NA	
Data Flash (C)	Checksum is computed on critical data		Yes	Latched	Yes	Status Fail Non_Vol Fail	
Data Flash (Run Time)	Checksum is computed on critical data		Yes	Latched	Yes	Status Fail Non_Vol Fail	

Table 10.7 Relay Self-Tests (Sheet 2 of 2)

Self-Test	Description	Normal Range	Protection Disabled on Failure	Alarm Status	Auto-Message on Failure	Front-Panel Message on Failure	Corrective Action
Critical RAM (Settings)	Performs a checksum test on the active copy of settings		Yes	Latched	Yes	Status Fail CR_RAM Fail	Automatic restart. Contact SEL if failure returns.
Critical RAM (Run Time)	Verify instruction matches Flash image		Yes	Latched	Yes	Status Fail CR_RAM Fail	Automatic restart. Contact SEL if failure returns.
Data Acquisition	Fail on lack of data acquisition		Yes	Latched	Yes	Status Fail Data Acq Failure	Automatic restart. Contact SEL if failure returns.
Arc Flash Diagnostics	Monitors arc-flash sensor health once every 10 minutes		No	Not Latched	Yes	Yes	
Offset Warn Measure	DC offset at each input channel	<50 mV	No	Not Latched	Yes	NA	
+0.675 V Fail Monitor	+0.675 V power supply	0.58 to 0.76 V	No	Not Latched	Yes	Yes	
+12.0 V Fail Monitor	+12.0 V power supply	8.4 to 12.0 V	No	Not Latched	Yes	Yes	
Clock Battery	Monitor clock battery 5.00 V 4.3 to 5.7 3.30 V 2.8 to 3.8 2.50 V 2.2 to 2.8 1.35 V 1.3 to 1.5 1.10 V 1.0 to 1.2	1.8 to 2.2 V	No	Not Latched	Yes	NA	STA C Contact SEL if failure returns.
Clock	Unable to communicate with clock or fails time keeping test		No	Not Latched	Yes	NA	STA C Contact SEL if failure returns.
Exception Vector	CPU error		Yes	Latched	NA	Vector *nnn*	Automatic restart. Contact SEL if failure returns.

Troubleshooting

Table 10.8 Troubleshooting

Symptom/Possible Cause	Diagnosis/Solution
The relay ENABLED LED is dark.	
Input power unavailable or fuse blown	Verify that input power is present. Check fuse continuity.
Self-test failure	View the self-test failure message on the HMI display.
The relay does not accurately measure voltages or currents.	
Wiring error	Verify input wiring.
Incorrect CTP.Rat or VTP.Rat setting	Verify instrument transformer ratios, connections, and associated settings.
The relay does not respond to commands from a device connected to the serial port.	
Cable disconnected	Verify the cable connections.
Incorrect cable type	Verify the cable pinout.
Incorrect baud rate or mismatched parameter	Verify device software setup.
The relay serial port receives an XOFF, halting communications	Type **<Ctrl+Q>** to send the relay XON and restart communications.
The relay does not respond to faults.	
Improperly set relay	Verify the relay settings.
Improper test source settings	Verify the test source settings.
Current or voltage input wiring error	Verify input wiring.
Failed relay self-test	Use the HMI `RELAY STATUS` function to view self-test results.
The user is unable to communicate with the relay via serial port.	
Incorrect password or incorrect Port 1 settings	Press and hold the **TARGET RESET** pushbutton for 10 seconds or longer while the relay is powering up to restore the default passwords and Port 1 settings.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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Appendix A

Firmware, ICD, and Manual Versions

Firmware

Determining the Firmware Version

To determine the firmware version, view the status report by using the serial port **STATUS** command or the front panel STATUS pushbutton. The status report displays the firmware identification (FID) string.

The firmware version will be either a standard release or a point release. A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device FID string.

Existing firmware:

FID=SEL-851-**R100**-V0-Z001001-D2021*xxxx*

Standard release firmware:

FID=SEL-851-**R101**-V0-Z001001-D2021*xxxx*

A point release is identified by a change in the V-number of the device FID number.

Existing firmware:

FID=SEL-851-R106-**V0**-Z001001-D2021*xxxx*

Point release firmware:

FID=SEL-851-R106-**V1**-Z001001-D2021*xxxx*

The date code is after the D. For example, the following is firmware version number R100, date code June 30, 2021.

FID=SEL-851-R100-V0-Z001001-**D20210630**

Revision History

Table A.1 lists the firmware versions, revision descriptions, and corresponding instruction manual date codes. The most recent firmware version is listed first.

Starting with revisions published after March 1, 2022, changes that address security vulnerabilities are marked with “[Cybersecurity]”. Other improvements to cybersecurity functionality that should be evaluated for potential cybersecurity importance are marked with “[Cybersecurity Enhancement]”.

Table A.1 SEL-851 Firmware Revision History (Sheet 1 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-851-R101-V0-Z002001-D20240412	➤ [Cybersecurity] Resolved an issue where issuing the **VEC** command could disable the relay. ➤ Increased the upper range limit of the pickup setting range of the 27PP and 59PP elements from 300.0 V to 520.00 V for wye-connected PT applications. This increase is intended for solidly grounded power system applications only. The pickup setting range resolution was increased from one to two decimal places for the delta and wye input setting ranges. ➤ Added the option to disable the small signal cutoff threshold minimum for current and voltage metering via the Meter.Thres_Min setting. ➤ Resolved an issue where the Port_02.FailForcOV setting used the incorrect Relay Word bit. ➤ Enhanced the relay firmware to retain the configuration settings for the IP address, subnet mask, and default router for Ethernet Port 2. ➤ Resolved an issue where leaving a display point value field blank, caused the subsequent enabled display points to not be displayed on the relay HMI. ➤ Resolved an issue where the three COMTRADE report files (CFG, DAT, HDR) were not generated when a period was included in the Dev.Id setting. ➤ Resolved an issue where clearing the event history via the web browser also reset the unique event number (REF_NUM). ➤ Resolved an issue where the relay could incorrectly transmit GOOSE messages when the Port 2 operating mode was set to SWITCHED. ➤ Resolved an issue where the GOOSE messages did not use the correct MAC address after the MAC address was updated. ➤ Resolved an issue with the processing of Bridge Protocol Data Unit (BPDU) packets when the relay was configured in SWITCHED mode. ➤ Resolved an issue where the relay inconsistently transmitted a gratuitous address resolution protocol (ARP). ➤ Resolved an issue with the behavior of the display points. ➤ Resolved an issue with the processing of the arc-flash integrity alarm (AFD.Alm) Relay Word bit. ➤ Resolved an issue where some of the setting defaults did not match the defaults shown in SEL-5037 Grid Configurator.	20240412
SEL-851-R100-V3-Z001001-D20240412	Includes all the functions of SEL-851-R100-V2-Z001001-D20230821 with the following addition: ➤ [Cybersecurity] Resolved an issue where issuing the VEC command could disable the relay. ➤ Resolved an issue where leaving a display point value field blank, caused the subsequent enabled display points to not be displayed on the relay HMI. ➤ Resolved an issue where the three COMTRADE report files (CFG, DAT, HDR) were not generated when a period was included in the Dev.Id setting. ➤ Resolved an issue where clearing the event history via the web browser also reset the unique event number (REF_NUM). ➤ Resolved an issue where the relay could incorrectly transmit GOOSE messages when the Port 2 operating mode was set to SWITCHED.	20240412

Table A.1 SEL-851 Firmware Revision History (Sheet 2 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Resolved an issue where the GOOSE messages did not use the correct MAC address after the MAC address was updated. ➤ Resolved an issue with the processing of Bridge Protocol Data Unit (BPDU) packets when the relay was configured in SWITCHED mode. ➤ Resolved an issue where the relay inconsistently transmitted a gratuitous address resolution protocol (ARP). ➤ Resolved an issue with the behavior of the display points. ➤ Resolved an issue with the processing of the arc-flash integrity alarm (AFD.Alm) Relay Word bit. ➤ Resolved an issue where some of the setting defaults did not match the defaults shown in SEL-5037 Grid Configurator.	
SEL-851-R100-V2-Z001001-D20230821	Includes all the functions of SEL-851-R100-V1-Z001001-D20220513 with the following additions: ➤ Added support for the IEC 61850 service tracking feature. ➤ Resolved an issue where the math variables (PMV) were not clipped to the minimum and maximum values of –16777215.99 and +16777215.99, respectively. ➤ Resolved an issue where the relay became disabled when any number was divided by zero.	20230821
SEL-851-R100-V1-Z001001-D20220513	Includes all the functions of SEL-851-R100-V0-Z001001-D20210630 with the following additions: ➤ Resolved an issue where the HMI screen locked up and the navigational pushbuttons became nonfunctional when the TRIP or CLOSE pushbutton was pressed while on the Targets screen. ➤ Resolved an issue where the relay failed to process a TRIP or CLOSE pushbutton command following the cancellation of a local trip or close operation. ➤ Resolved an issue with the dc offset calculation upon turn on. ➤ Resolved an issue with the self-test diagnostics of the Ethernet port in models with one Ethernet port in the model option table (MOT). ➤ Resolved an issue with the arc-flash diagnostics in models without voltage inputs in the MOT.	20220513
SEL-851-R100-V0-Z001001-D20210630	➤ Initial version.	20210630

SELBOOT Firmware Version and Relay Firmware Compatibility

The SELBOOT version and the compatible relay firmware versions are listed in *Table A.2*. SELBOOT firmware ensures that the relay firmware upgrade file is digitally signed by SEL using a secure hash algorithm and that the file has been provided by SEL and that its contents have not been altered.

Table A.2 SELBOOT Firmware Revision History

Boot Firmware Identification Number	Summary of Revisions	Firmware Version Supported	Release Date
SLBT800-R100-V0-Z000000-D20210630	➤ Initial version.	R100	20210630

ICD File

Determining the ICD File Version

To find the ICD revision number in your relay, view the configVersion by using the **ID** command. The configVersion is the last item displayed in the information returned from the **ID** command.

configVersion=ICD-851-R100-V0-Z000000-D2021*xxxx*

The ICD revision number follows the R (e.g., 100) and the release date follows the D. This revision number is not related to the relay firmware revision number. The configVersion revision displays the ICD file version used to create the CID file that is loaded in the relay.

The configVersion contains other useful information. The Z-number consists of six digits. The first three digits following the Z represent the minimum IED firmware required to be used with the ICD (e.g., 000). The second three digits represent the ICD ClassFileVersion (e.g., 000). The ClassFileVersion increments when there is a major addition or change to the IEC 61850 implementation of the relay.

Table A.9 lists the ICD file versions, a description of modifications, and the instruction manual date code that corresponds to the versions. The most recent version is listed first.

Table A.3 SEL-851 ICD File Revision History

configVersion	Summary of Revisions	Relay Firmware Compatibility	ClassFile Version	ACSELERATOR Architect File Description	Manual Date Code
ICD-851-R101-V0-Z100006-D20230821	➤ Added the IEC 61850 LTRK logical node for service tracking. ➤ Conformance certification changes.	R100 or later	006	SEL851 Edition 2	20230821
ICD-851-R100-V0-Z100006-D20210630	➤ Initial ICD file release.	R100	006	SEL851 Edition 2	20210630

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date. *Table A.4* lists the instruction manual versions and revision descriptions. The most recent instruction manual version is listed first.

Table A.4 Instruction Manual Revision History (Sheet 1 of 3)

Date Code	Summary of Revisions
20240412	Section 1 ➤ Updated *Specifications*. Section 2 ➤ Updated *Relay Mounting*, *Horizontal Mount* with *Figure 2.4: SEL-851 Horizontal Mount With Front-Cover Dimensions*. ➤ Updated *Digital Outputs (1 Form C and 4 Form A [2 Hybrid and 2 Standard Contacts]) Connections (Terminal Block B)* with *Figure 2.4: SEL-851 Horizontal Mount With Front-Cover Dimensions*. ➤ Updated *Ground Terminal Connection*. ➤ Updated *Point-Sensor Installation* and added *Figure 2.32: Window Point-Sensor Dimensions* and *Figure 2.33: Window Point-Sensor Installation*.

Table A.4 Instruction Manual Revision History (Sheet 2 of 3)

Date Code	Summary of Revisions
	Section 3 ➤ Updated *SEL Grid Configurator Software*. Section 4 ➤ Updated *Configuration Settings*, *Table 4.3: Configuration Settings*. ➤ Updated *Under- and Overvoltage Functions*, *Table 4.15: Phase-to-Phase Undervoltage Function* and *Table 4.16: Phase-to-Phase Overvoltage Function*. ➤ Updated *Power Elements*, including *Figure 4.33: Three-Phase Power Elements Logic*. ➤ Updated *Warning List*. ➤ Updated *Port 2*, *Table 4.51: Ethernet Port Settings* and *Target LED Settings*, *Table 4.60: Target LED Settings*. Section 5 ➤ Updated *Small Signal Cutoff Metering*. Section 6 ➤ Updated *Figure 6.5: SEL Grid Configurator Settings Editor–Displays Error if Invalid Settings Entered*. Section 7 ➤ Updated *Ethernet Port*, including *Table 7.3: Ethernet Port Configuration Settings*, *Figure 7.6: Simple Ethernet Network Configuration*, *Figure 7.7: Ethernet Network Configuration With Dual Redundant Connection (Failover Mode)*, and *Figure 7.8: Ethernet Network Configuration With Ring Structure (Switched Mode)*. ➤ Added *FGS (Fixed GOOSE) Command*. ➤ Updated *GOOSE Command* with *Table 7.20: Warning and Error Codes for GOOSE Subscriptions*. ➤ Updated *R_S Command (Restory Factory Defaults)* with a note on the **R_S** command. ➤ Updated *Figure 7.15: SHOW Command Response*. ➤ Updated *Upgrade Directory (Available Only for FTP)*, including *Table 7.54: UPGRADE Directory File Sample*. Section 8 ➤ Updated *ENABLED and TRIP LEDs*. Section 9 ➤ Updated *Figure 9.3: Sample COMTRADE .HDR Header File*. ➤ Updated *Table 9.4: HIS Command*, *Figure 9.9: View Events Via SEL Grid*, and *Figure 9.12: SEL Report Via SEL Grid*. Section 10 ➤ Updated *Self-Test*. Appendix A ➤ Updated for firmware versions R100-V3 and R101-V0. Appendix B ➤ Updated *Upgrade the SELboot Firmware Loader Using a Terminal Emulator*. Appendix D ➤ Updated *Figure D.5: Analog Input Map Entry in SEL Grid Configurator Software*, *Figure D.6: AI Point, Scaling and Deadband in SEL Grid Configurator Software*, *Figure D.8: Analog Output Map Entry in SEL Grid Configurator Software*, and *Figure D.10: Binary Output Map Entry in SEL Grid Configurator Software*. Appendix E ➤ Updated *Table E.23: Modbus Quantities Table*. Appendix F ➤ Updated *Simulation Mode*. ➤ Updated *Table F.30: Logical Device: PRO (Protection)*, *Table E.33: Logical Device: ANN (Annunciation)*, and *Table E.34: Logical Device: CFG (Configuration)*. Appendix H ➤ Updated *Table H.1: Relay Word Bits*.
20230821	Section 2 ➤ Updated *19-Inch Horizontal Rack Mount With Adapter Plate*, including *Figure 2.6: Relay Dimensions for Mounting an SEL-851 With an Adapter Plate* and *Figure 2.9: Relay Dimensions for an SEL-851 Ganged Rack Mount*. ➤ Added *Figure 2.7: SEL-851 19-Inch Horizontal Rack-Mount Assembly*.

Table A.4 Instruction Manual Revision History (Sheet 3 of 3)

Date Code	Summary of Revisions
	Appendix A ➤ Updated for firmware version R100-V2 and ICD file version R101-V0. Appendix F ➤ Added *Service Tracking*. ➤ Updated *Table F.34: Logical Device: CFG (Configuration)*, *Table F.38: MMS Service Supported Conformance*, and *Table F.50: ACSI Models Conformance Statement*.
20220513	Section 1 ➤ Updated *Figure 1.3: STA Command Response*. ➤ Updated *Specifications*, including *General* and *Metering Accuracy*. Section 2 ➤ Updated *19-Inch Horizontal Rack Mount With Adapter Plate*. Section 4 ➤ Updated *Overcurrent Elements* and *Setting 79.RstTmLO*. Section 5 ➤ Updated *Table 5.1: Measured Fundamental Meter Values*. Section 7 ➤ Updated *Table 7.2: EIA-232/EIA-485 Serial Port Pin Functions* and *Table 7.41: STATUS Command Report and Definitions*. Appendix A ➤ Updated for firmware version R100-V1.
20220201	Section 1 ➤ Updated *Output Contacts*, *Optoisolated Control Inputs*, and *Operating Environment*. ➤ Updated *Product Standards* and *Type Tests*. Section 2 ➤ Updated *Figure 2.1: SEL-851 Horizontal Mount Dimensions, Panel Cutout, and Drill Plan* and *Figure 2.4: SEL-851 Dimensions, Panel Cutout, and Drill Plan*. ➤ Updated *Figure 2.2: SEL-851 Front-Panel, Horizontal Mount Version*, *Figure 2.3: SEL-851 Horizontal Mount With Front Cover*, *Figure 2.5: SEL-851 Front-Panel, Panel Mount Version*, *Figure 2.7: SEL-851 Horizontal Rack Mount With the Adapter Plate*, *Figure 2.11: SEL-851 Ganged Rack Mount (Left) With L-Shaped Bracket*, and *Figure 2.12: SEL-851 Ganged Rack Mount (Right) With L-Shaped Bracket*. ➤ Updated *Voltage Connections*. Section 4 ➤ Updated *General Settings*. Section 9 ➤ Updated *Viewing Event Oscillography*. Appendix G ➤ Updated *Channel Monitoring* and *Table G.4: MIRRORED BITS Protocol Settings*.
20210630	➤ Initial version.

Appendix B

Firmware Upgrade Instructions

Overview

These instructions guide you through the process of upgrading firmware in the device. The firmware upgrade will be either a standard release or a point release. A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device FID string.

Existing firmware:

FID=SEL-851-**R100**-V0-Z001001-D*xxxxxxxx*

Standard release firmware:

FID=SEL-851-**R101**-V0-Z001001-D*xxxxxxxx*

A point release is identified by a change in the V-number of the device FID number.

Existing firmware:

FID=SEL-851-R100-**V0**-Z001001-D*xxxxxxxx*

Point release firmware:

FID=SEL-851-R100-**V1**-Z001001-D*xxxxxxxx*

SEL occasionally offers firmware upgrades to improve the performance of your relay. Because the SEL-851 relays store firmware in flash memory, changing physical components is unnecessary. Upgrade the relay firmware by downloading a file from a personal computer to the relay via one of the methods described in *Table B.1*.

Table B.1 Firmware Upgrade Methods

Port	Firmware Upgrade Method
USB Type C Serial Port F	Upgrade the relay firmware using the **FILE** command.
Rear Serial Port 1	Upgrade the relay firmware using the **L_D** and **FILE** commands.
Ethernet Port 2A	Upgrade the relay firmware using the web server, the File Transfer Protocol (FTP), or the **FILE** command via Telnet.

For relays with the IEC 61850 option, verify the IEC 61850 protocol after the upgrade (see *Protocol Verification for Relays With IEC 61850 Option*).

Digitally Signed Firmware Files

The SEL-851 supports digitally signed firmware files for firmware upgrades. These firmware upgrade files are in compressed form to reduce file transfer times and are digitally signed by SEL using a secure hash algorithm. The signature ensures that the file has been provided by SEL and that its contents have not been altered. Once uploaded to the relay, the signature of the firmware is verified with a public key number that is stored on the relay from the factory. If the relay cannot verify the signature, it rejects the file.

The name of the digitally signed firmware file is of the form r*xxx*851.zds, where r*xxx* is the firmware revision number, 851 indicates the relay type, and .zds is the file extension reserved for digitally signed files.

Upgrade the SELBOOT Firmware Loader Using a Terminal Emulator

NOTE: Make sure the relay and SELBOOT firmware revisions are compatible. Refer to Appendix A: Firmware, ICD, and Manual Versions in this manual.

The process for upgrading SELBOOT is similar to *Upgrade the Relay Firmware Using a Terminal Emulator*. To determine if SELBOOT must be updated, do the following:

Step 1. Establish communication between the relay and a personal computer, as described in *Step 2* of *Upgrade the Relay Firmware Using a Terminal Emulator*.

Step 2. From the computer, type **ID <Enter>**.

The relay responds with the following:

```
=>>ID <Enter>
"FID=SEL-851-X027-V0-Z001001-D20210309","08AB"
"BFID=SLBT800-X102-V0-Z000000-D20210309","0903"
"CID=463","021A"
"DEVID=SEL-851","03C8"
"DEVCODE=86","0315"
"PARTNO=085100011010130","0566"
"SERIALNO=3210760091","05A3"
"CONFIG=11112201","03EC"
"iedName=","036O"
"type=","026F"
"configVersion=","0609"
=>>
```

Step 3. Locate the Boot Firmware Identification String (BFID).

Step 4. Find the SELBOOT revision number in the BFID (R*xxx*). If the revision number is lower than the one you see on the firmware CD, follow the process mentioned below. Otherwise, upgrade the relay firmware using one of the methods mentioned later in the section.

Step 5. To upgrade SELBOOT, locate the new SELBOOT file (r*xxx*8*xx*.zds) on the disk provided with the firmware upgrade materials. Follow the instructions under *Upgrade the Relay Firmware Using a Terminal Emulator*. In *Step 6* replace the **REC** command with **REC BOOT** and follow the prompts.

Step 6. When the relay prompts: `Press any key to begin transfer and then start transfer at the terminal`. press **<Enter>** and select the SELBOOT file.

Step 7. When the SELBOOT upgrade is successful, the relay prompts:

`Erasing` SELBOOT. `Writing` SELBOOT.

SELBOOT `upload completed successfully. Restarting` SELBOOT.

Step 8. Type **EXI <Enter>** at the SELBOOT `!>` prompt to exit SELBOOT. The relay should display the = prompt.

If the relay does not return the SELBOOT `!>` prompt within two minutes after displaying `Restarting SELboot`, cycle the relay power. The relay should restart and display the = prompt.

Once the SELBOOT upgrade is complete, select a firmware upgrade method as discussed later in the section. It is not necessary to save the relay settings and other data again if you did this before upgrading SELBOOT.

Upgrade SELBOOT Using the Web Server

The process for upgrading SELBOOT is similar to *Upgrade the Relay Firmware Using the Web Server*. To upgrade SELBOOT, do the following:

Step 1. Establish communication between the relay and a personal computer, as described by *Step 1* in *Upgrade the Relay Firmware Using the Web Server*.

Step 2. After saving the relay settings and other data, proceed with the SELBOOT upgrade process.

a. Click **System > File Management** from the left navigation pane of the webpage.

b. Click the **Choose File** button to select the SELBOOT version you want to send to the relay.

c. Click **Upgrade Firmware** to start the upgrade process.

Step 3. Click **Yes – Upgrade** if you want to upgrade SELBOOT using the file selected. Follow *Step 3* and *Step 4* from *Upgrade the Relay Firmware Using the Web Server*.

Step 4. To check that the relay SELBOOT version matches the version that was used for the upgrade, open any terminal emulator software and issue the **ID** command—the string that follows BFID should match the SELBOOT version that was used for the upgrade.

Upgrade the Relay Firmware Using the Web Server

NOTE: The relay pulses the Diag.Secu_Alm bit and writes an entry to the relay SER log whenever a firmware upgrade is attempted over Ethernet. Monitoring the Diag.Secu_Alm bit and reviewing the SER log can help identify possible unauthorized firmware upgrade attempts.

The web server offers a convenient method for upgrading relay firmware. Located on the left navigation pane of the screen, the **System** menu contains four categories: **File Management**, **Passwords**, **Date/Time**, and **Device Reset**. **File Management** allows you to upgrade firmware in the relay.

When preparing to upgrade relay firmware, you must first have the new relay firmware. The firmware is designated with a .zds extension.

Refer to *Section 3: PC Interface* for connecting and logging on to the SEL-851 web server using the Ethernet port.

To upgrade relay firmware using the web server, set the Port 2 setting Port_02.HTTP_AccLev := 2 and Port_02.FwUpgrd_Ena := Y. If Port_02.FwUpgrd_Ena is set to N, you cannot upgrade the firmware over Ethernet, regardless of the Port_02.HTTP_AccLev setting.

Step 1. Save the current relay settings and other data.

a. Click **System > File Management** from the left navigation pane of the webpage.

b. Select the category from the **Settings** list to export and save settings from the relay before starting the upgrade process.

c. Save the various reports by clicking **Reports** on the left navigation pane of the webpage.

Refer to *Reports on page 3.5* for more details on saving different reports.

Step 2. After saving the relay settings and other data, proceed with the firmware upgrade process.

a. Click **System > File Management** from the left navigation pane of the webpage.

b. Click the **Choose File** button to select the firmware you want to send to the relay.

c. Click **Upgrade Firmware** to start the upgrade process.

Step 3. Click **Yes - Upgrade** if you want to upgrade using the file selected.

Once the upgrade process is in progress, the relay acknowledges with the message, **Transferring firmware**. **Please wait**.

After the relay finishes the firmware transfer, an acknowledgment message appears and the relay reboots.

NOTE: After the relay reboots, if the **ENABLED** LED on the front panel of the relay is not illuminated or if the HMI shows a STATUS FAIL or Non_Vol Failure, then open a terminal emulator using the serial port and use the following procedure to restore the factory-default settings. Refer to Upgrade the Relay Firmware Using a Terminal Emulator for terminal emulator setup and connections.

a. Set the communications software settings to 115200 bps, 8 data bits, and 1 stop bit.

b. Enter Access Level 2 by issuing the **2AC** command.

c. Issue the **R_S** command to restore the factory default.

The relay will reboot and come up ENABLED.

Note that the port settings will be restored to the default settings due to the **R_S** command.

Step 4. After the relay reboots, the Login screen appears on the web server. Log in to the relay to verify completion of the firmware upgrade process.

An acknowledgment message appears that verifies a successful firmware upgrade.

Step 5. Check that the relay firmware version matches the version that was used for the upgrade and that the relay is enabled.

Click on **Relay Status** > **Self-Tests** to view the status report.

Table B.2 shows messages displayed in the web browser and the message meaning.

Table B.2 Ethernet Firmware Upgrade User Messages (Sheet 1 of 2)

User Message	Relay Condition
Firmware upgrade succeeded.	The previous firmware upgrade with a .zds file was successful.
Invalid upgrade file.	The .zds file was not successfully received or validated by the relay.

Table B.2 Ethernet Firmware Upgrade User Messages (Sheet 2 of 2)

User Message	Relay Condition
Upgrade in progress on another interface.	A firmware upgrade is presently being performed through another connection.
Errors during Upgrade File Transfer.	Upgrade failed due to errors during file transfer.

Upgrade SELBOOT Using File Transfer Protocol

To upgrade the relay SELBOOT using FTP, set the Port 2 setting Port_02.FTP_AccLev := 2 or C and Port_02.FwUpgrd_Ena := Y. If Port_2.FwUpgrd_Ena is set to N, you cannot upgrade the firmware over Ethernet, regardless of the Port_02.FTP_AccLev setting. The following instructions assume you have a working knowledge of the Windows command prompt.

Step 1. Connect the PC to the Ethernet port and enter Access Level 2.

Step 2. Save the present relay settings (follow instructions as described in *Step 2* of *Upgrade the Relay Firmware Using File Transfer Protocol*).

Step 3. Create an FTP session to connect to the relay using the relay IP address and enter the FTP username and password.

Step 4. Rename the SLBT-800-*xxxx*.zds as SLBT.zds and save the file on your PC. Note the file location.

Step 5. Issue the **CD UPGRADE** command to switch the present relay directory to the UPGRADE directory.

Step 6. Issue the **PUT <computer file location>\SLBT.zds** command to place the SLBT.zds file in the UPGRADE directory and send the file to the relay.

When the upgrade is complete, the relay reboots and the **ENABLED** LED illuminates.

Upgrade the Relay Firmware Using File Transfer Protocol

NOTE: Make sure that the relay and SELBOOT firmware revisions are compatible. Refer to Firmware, ICD, and Manual Versions in this manual. If needed, upgrade the SELBOOT firmware prior to upgrading the relay firmware.

NOTE: The relay pulses the Diag.Secu_Alm bit and writes an entry to the relay SER log whenever a firmware upgrade is attempted over Ethernet. Monitoring the Diag.Secu_Alm bit and reviewing the SER log can help identify possible unauthorized firmware upgrade attempts.

To upgrade relay firmware using FTP, set the Port 2 settings Port_02.FTP_AccLev := 2 or C and Port_02.FwUpgrd_Ena := Y. If Port_02.FwUpgrd_Ena is set to N, you cannot upgrade the firmware over Ethernet, regardless of the Port_02.FTP_AccLev setting.

The following instructions assume you have a working knowledge of the Windows command prompt.

Step 1. If the relay is in service, open the relay control circuits.

Step 2. Connect the PC to the Ethernet port and enter Access Level 2.

NOTE: To save the calibration settings, perform **SHO C** from the terminal by logging into Access Level C using the Access Level C password. The factory-default password for Access Level C is CLARKE.

NOTE: File name RELAY.zds is not case sensitive.

Step 3. Save the present relay settings.

You can use the PC software (see *Section 3: PC Interface*) to save and restore settings, or you can use the following steps:

a. Issue the following commands at the ASCII prompt: **SHO**, **SHO L**, **SHO P**, **SHO H**, **SHO R**, **SHO C**, etc.

b. Record all the settings for possible re-entry after the firmware upgrade.

We recommend that you save all stored data in the relay, including events, before the upgrade.

Step 4. Rename the r*xxx*-v*x*851.zds file as RELAY.zds.

Step 5. Create an FTP session to connect to the relay using the relay IP address.

Step 6. Enter your FTP username and password.

Step 7. Issue the **CD UPGRADE** command to switch the present relay directory to the UPGRADE directory.

Step 8. Issue the **PUT RELAY.ZDS** command to place the RELAY.zds file in the UPGRADE directory and to send the file to the relay.

When the download is complete, the relay reboots and comes up enabled.

During this upgrade process, you will lose the FTP connection, and you must reestablish the FTP connection after the upgrade is complete. Then navigate to the relay UPGRADE directory and review the ERR.txt file for any error messages. If the firmware upgraded properly, no errors occurred during the upgrade process and the file is empty. If messages are contained within the file, see *Table B.2* for the error message and a description.

Figure B.1 shows the entire upgrade process via Windows command prompt.

```
Microsoft Windows [Version 10.0.17763.805]
(c) 2018 Microsoft Corporation. All rights reserved.

Y:\>FTP 10.39.94.180 <Enter>
Connected to 10.39.94.180.
220 FTP SERVER
550 NOOP requested action not taken.
User (10.39.94.180:(none)): xxxxxx <Enter>
331 User name okay, need password.
Password: xxxxxx <Enter>
230 User logged in, proceed.
ftp> CD UPGRADE <Enter>
250 CWD  requested file action okay, completed.
ftp> PUT RELAY.ZDS <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
Connection closed by remote host.
ftp>
```

Figure B.1 Firmware Upgrade Via FTP

Upgrade the Relay Firmware Via Terminal Emulator Using the FILE Command

NOTE: Make sure that the relay and SELBOOT firmware revisions are compatible. Refer to Firmware, ICD, and Manual Versions in this manual. If needed, upgrade the SELBOOT firmware prior to upgrading the relay firmware.

NOTE: The relay pulses the Diag.Secu_Alm bit and writes an entry to the relay SER log whenever a firmware upgrade is attempted over Ethernet. Monitoring the Diag.Secu_Alm bit and reviewing the SER log can help identify possible unauthorized firmware upgrade attempts.

The SEL-851 allows you to upgrade the firmware using the **FILE** command via all available ports.

To upgrade relay firmware using the **FILE** command over Ethernet, establish a Telnet connection and set the Port 2 settings Port_02.FTP_AccLev := 2 or C and Port_02.FwUpgrd_Ena := Y. If Port_02.FwUpgrd_Ena is set to N, you cannot upgrade the firmware over Ethernet, regardless of the Port_02.FTP_AccLev setting.

The following procedure assumes that you have a working knowledge of the software being used to upgrade the firmware via **FILE** command.

Step 1. If the relay is in service, open the relay control circuits.

Step 2. Connect the PC to the USB Type C, serial, or Ethernet port and enter Access Level 2.

Step 3. Save the present relay settings.

NOTE: To save the calibration settings, perform **SHO C** from the terminal by logging into Access Level C using the Access Level C password. The factory-default password for Access Level C is CLARKE.

NOTE: File name RELAY.zds is not case sensitive.

You can use the PC software (see *Section 3: PC Interface*) to save and restore settings, or you can use the following steps:

a. Issue the following commands at the ASCII prompt: **SHO**, **SHO L**, **SHO P**, **SHO H**, **SHO R**, **SHO C**, etc.

b. Record all the settings for possible re-entry after the firmware upgrade.

We recommend that you save all stored data in the relay, including events, before the upgrade.

Step 4. Rename the r*xxx*-v*x*851.zds file as RELAY.zds.

Step 5. Save the RELAY.zds file to a directory.

Step 6. Update the active directory to be the directory where the RELAY.zds file is saved.

Step 7. Issue the **FILE WRITE RELAY.ZDS** command to the relay.

Step 8. Send the RELAY.zds file to the relay via Ymodem transfer.

When the upgrade is complete, the relay reboots and comes up enabled.

During the upgrade process via the Ethernet port, you will lose the Telnet connection, and you must reestablish the Telnet connection after the upgrade is complete. Then navigate to the relay UPGRADE directory and review the ERR.txt file for any error messages. If the firmware upgraded properly, no errors occurred during the upgrade process and the file is empty. If messages are contained within the file, see *Table B.2* for the error message and a description.

Upgrade the Relay Firmware Using a Terminal Emulator

NOTE: Make sure that the relay and SELBOOT firmware revisions are compatible. Refer to Firmware, ICD, and Manual Versions in this manual. If needed, upgrade the SELBOOT firmware prior to upgrading the relay firmware.

NOTE: The front-panel Port F cannot be used for relay firmware upgrades.

The following instructions assume that you have a working knowledge of your personal computer terminal emulation software. In particular, you must be able to modify your serial communications parameters (baud rate, data bits, parity, etc.), select transfer protocol (Xmodem/CRC or 1k Xmodem/CRC), and transfer files (for example, send and receive binary files).

Step 1. If the relay is in service, open the relay control circuits.

Step 2. Connect the PC to serial Port 1 using an SEL-C478A or C478N Cable (with IRIG-B) and an SEL-C662 Cable and enter Access Level 2.

Step 3. Save the current relay settings and other data.

PC software (described in *Section 3: PC Interface*) can be used to save and restore settings easily. Otherwise, use the following steps.

NOTE: To save the calibration settings, perform the **SHO C** command from the terminal by logging into the CAL level using the CAL level password. The factory-default password for CAL level is CLARKE.

a. Issue the following commands at the ASCII prompt: **SHO**, **SHO L**, **SHO P**, **SHO H**, **SHO R**, **SHO C**, etc.

b. Record all the settings for possible re-entry after the firmware upgrade.

c. We recommend that you save all stored data in the relay, including events, before the upgrade.

Step 4. Start the firmware upgrade.

a. Issue the **L_D** command to the relay.

b. Type **Y <Enter>** at the following prompt:

```
Disable relay to receive firmware (Y/N)?
```

c. Type **Y <Enter>** at the following prompt:

```
Are you sure (Y,N)?
```

The relay will send the `!>` prompt.

Step 5. Change the baud rate, if necessary.

a. Type **BAU 115200 <Enter>**.

This will change the baud rate of the communications port to 115200.

b. Change the baud rate of the PC to 115200 to match the relay.

Step 6. Begin the transfer of new firmware to the relay by issuing the **REC** command.

Step 7. Type **Y** to erase the existing firmware or press **<Enter>** to abort.

Step 8. Press any key (for example, **<Enter>**) when the relay sends a prompt.

Step 9. Start the file transfer.

Select the send file option in your communications software. Use the Xmodem-1K protocol and send the file that contains the new firmware (e.g., rxxx851.zds).

The file transfer takes less than 5–15 minutes at 115200 bps, depending on the product. After the transfer is complete, the relay will reboot and return to Access Level 0. *Figure B.2* shows the entire process, including checking the **ID** command and **STA** command responses.

```
=>>L_D <Enter>
Disable relay to receive firmware (Y,N)? Y <Enter>
Are you sure (Y,N)?  Y <Enter>
Relay Disabled


!>BAU 115200 <Enter>

!>

!>REC <Enter>
Receive New Firmware Y/N? Y <Enter>

This command uploads new firmware.
When new firmware is uploaded successfully, IED will erase old firmware,
load new firmware and reboot.

Are you sure you want to erase the existing firmware(Y,N)? Y <Enter>
Press any key to begin transfer and then start transfer at the terminal.CC
Erasing firmware.
Erase successful.
Writing new firmware.
Upload completed successfully. Attempting a restart.


=

=

=ACC <Enter>
Password: ? *****
```

Figure B.2 Firmware File Transfer Process

```
=>2AC <Enter>
Password: ? *****

=>>ID <Enter>
"FID=SEL-851-X049-V0-Z001001-D20210202","08A1"
"BFID=SLBT800-X100-V0-Z000000-D20210108","08FE"
"CID=93E","022E"
"DEVID=SEL-851","03C8"
"DEVCODE=78","0316"
"PARTNO=085100011000130","0565"
"SERIALNO=3180660218","050D"
"CONFIG=11102201","03EB"
"iedName=","0360"
"type=","026F"
"configVersion=","0609"

=>>STA <Enter>

SEL-851                                    Date: 02/04/2021   Time: 13:43:51.217
FEEDER RELAY                               Time Source: Internal


Serial Num = 3180660218
FID = SEL-851-X049-V0-Z001001-D20210202         CID = 93E
PART NUM = 085100011000130

SELF TESTS (W=Warn)
  RAM     ROM     CR_RAM  NON_VOL HMI     CLOCK   CLK_BAT AF      PS
  OK      OK      OK      OK      OK      OK      OK      OK      OK

Analog Module
  FPGA    DAQ
  OK      OK

  Relay Enabled

=>>
```

Figure B.2 Firmware File Transfer Process (Continued)

Step 10. The relay illuminates the **ENABLED** front-panel LED if the relay settings were retained through the download.

If the **ENABLED** LED is illuminated, proceed to *Step 11*.

If the **ENABLED** LED is not illuminated or the HMI displays `STATUS FAIL` or `Non_Vol Failure`, use the following procedure to restore the factory-default settings:

a. Set the communications software settings to 115200 bps, 8 data bits, and 1 stop bit.

b. Enter Access Level 2 by issuing the **2AC** command.

c. Issue the **R_S** command to restore the factory-default settings.

The relay will reboot and come up ENABLED.

Note that the port settings will be restored to the default settings due to the **R_S** command.

d. Restore relay settings back to the settings saved in *Step 3*.

Step 11. Change the baud rate of the PC to match that of the relay prior to *Step 5*, and enter Access Level 2.

Step 12. Issue the **STATUS** command; verify all relay self-test results are OK.

Step 13. Apply current and voltage signals to the relay.

Step 14. Issue the **METER** command; verify that the current and voltage signals are correct.

Step 15. Autoconfigure the SEL communications processor port if you have a communications processor connected.

This step re-establishes automatic data collection between the SEL communications processor and the SEL relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

Protocol Verification for Relays With IEC 61850 Option

NOTE: A relay with optional IEC 61850 protocol requires 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 relay 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 a relay 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 relay firmware upgrade.

a. Establish an FTP connection to the relay Ethernet port.

b. Open the ERR.TXT file.

If the ERR.TXT file is empty, the relay found no errors during CID file processing and IEC 61850 should be enabled. Go to *Step c* if ERR.TXT is empty.

If the ERR.TXT file contains error messages relating to CID file parsing, the relay has disabled the IEC 61850 protocol. Use ACSELERATOR Architect SEL-5032 Software to convert the existing CID file and make it compatible again.

i. Install the ACSELERATOR Architect Software upgrade that supports your required CID file version.

ii. Run ACSELERATOR Architect and open the project that contains the existing CID file for the relay.

iii. Download the CID file to the relay.

Upon connecting to the relay, ACSELERATOR Architect detects the upgraded relay firmware and prompts 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.

c. In the Telnet session, type **GOO <Enter>**.

d. View the GOOSE status and verify that the transmitted and received messages are as expected.

The relay is now ready for your commissioning procedure.

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Appendix C

SEL Communications Processors

SEL Communications Protocols

The SEL-851 Feeder Protection Relay supports the SEL 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 receive binary control commands.
SEL Fast SER	Use this protocol to receive binary Sequential Events Recorder unsolicited responses.
SEL Fast Message	Use this protocol to write Remote Analog data via unsolicited writes.

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 customizing 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
BNA	ASCII names of Fast Meter status bits	0
CAS	Configuration data of all Compressed ASCII commands available at access levels > 0	0
CHI	List of events	1
CPRO	Signal-profile data	1
CMET	Metering data, including fundamental, thermal demand, peak demand, energy, max/min, rms, analog inputs, and math variables	1
CSER	Sequence of events data	1
CST	Relay status	1
CSU	Summary of an event report	1
DNA	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 communication with the relay consists of ASCII character commands and reports that you view through use of 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 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-851 communicates with an SEL communications processor. These SEL communications processors perform autoconfiguration 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, you can use the binary data stream to connect transparently to the SEL-851 and use the ASCII data stream for commands and responses.

SEL Fast Meter, Fast Operate, Fast SER, and Unsolicited Write

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 and receive unsolicited SEL Fast Messages (used in the SEL-851 for Remote Analogs). 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.

SEL Communications Processor

SEL offers SEL communications processors, powerful tools for system integration and automation. The SEL-3530 Real-Time Automation Controller (RTAC) has Ethernet ports as well as serial ports to connect to your SEL relay. 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
- Distribution of IRIG-B time-synchronization signal to IEDs based on external IRIG-B input, internal clock, or protocol interface
- Simultaneous collection of SCADA data and engineering connection to SEL IEDs over a single cable
- Automated dial-out on alarms

The SEL communications processors have 16 or more 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 substation 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* when connected to the SEL-851.

Table C.3 SEL Communications Processors Protocol Interfaces

Protocol	Interface
C37.118	Client Ethernet/Serial
DNP3	Client Ethernet/Serial/Telnet Tunneled Serial
IEC 61850 MMS and GOOSE	Ethernet
Modbus	Client Ethernet/Serial/Telnet Tunneled Serial
SEL	Client Serial/Telnet Tunneled Serial

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 utilizing SEL communications processors involve either developing a star network or enhancing a multidrop network.

Developing Star Networks

The simplest architecture using both the SEL-851 and an SEL communications processor is shown in *Figure C.3*. In this architecture, the SEL communications processor collects data from the SEL-851 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 utilization efficiency on each link. A system that uses an SEL communications processor to provide a protocol interface to an RTU has 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 any 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.

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 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.

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

SEL Communications Processor Example

This example demonstrates the data and control points available in the SEL communications processor when you connect an SEL-851. The physical configuration used in this example is shown in *Figure C.4*. In this example, the communications processor is an RTAC that is connected to the SEL-851 using SEL Protocol via ACSELERATOR RTAC Software. For more information regarding the RTAC and ACSELERATOR RTAC Software, refer to selinc.com.

Figure C.4 Example of an SEL Relay and SEL Communications Processor Configuration

Table C.4 shows the Port 1 settings for the RTAC.

Table C.4 RTAC Port 1 Settings (Sheet 1 of 2)

Setting	Range	Value
Communications		
SERIAL COMMUNICATIONS PORT	The number of ports depends on the RTAC MOT.	Com_01
SERIAL COMMUNICATIONS PORT TYPE	EIA-232, EIA-485/EIA-422	EIA232
BAUD RATE	Auto-Baud, 300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	115200
DATA BITS	8	8
PARITY BIT	None	None
STOP BIT	1	1
RTS_CTS	True, False	False
XON/XOFF	True, False	True
LEVEL 1 PASSWORD	0–32 characters	**********
LEVEL 2 PASSWORD	0–32 characters	**********
ENABLE PASSWORD MONITOR	True, False	False
POLL CASCII RETRIES	0–255	3
POLL CASCII INACTIVITY TIMEOUT	100–65535 ms	8000
POLL BINARY RETRIES	0–255	3
POLL BINARY INACTIVITY TIMEOUT	<min>–65535 ms	2500

Table C.4 RTAC Port 1 Settings (Sheet 2 of 2)

Setting	Range	Value
SLOW POLL MODE MULTIPLIER	1–65535	5
TRANSMIT FAST UNSOLICITED WRITE MESSAGING ON STARTUP	True, False	False
Date-Time		
UTC OFFSET	–720 to 840 minutes	0
DST ENABLED	True, False	True
Event		
ENABLE EVENT COLLECTION	True, False	False
ENABLE COMTRADE COLLECTION	True, False	False
LIST OF EVENT TYPES TO BE COLLECTED		HR
SEL		
VIRTUAL PORT NUMBER	1–254	1

After these settings are configured to align with the Port 1 settings of the SEL-851, the RTAC will auto-configure the connection. Refer to *Figure C.5* to see what a healthy connection looks like after auto-configuration is complete. Note that ENO and EN are TRUE and that Offline is FALSE.

Figure C.5 Healthy Communications Between an RTAC and an SEL-851

Data Collection

In this example, the RTAC is configured to collect data from the SEL-851 via SEL Protocol, using the list in *Table C.5*.

Table C.5 RTAC Data Collection Automessages

Message Name	Message Type	Command	Poll Period
History	Compressed ASCII	CHI	0
Load Data	Compressed ASCII	CLDP	0
SER	Compressed ASCII	CSE	0
Status	Compressed ASCII	CST	0
Demand Meter	Fast Meter	D2	0
Meter	Fast Meter	D1	1000
Peak Meter	Fast Meter	D3	0

You have the ability to set the poll period for each of the commands in *Table C.5*.

Control Points

The RTAC can automatically pass control messages, called Fast Operate messages, to the SEL-851. To do this, the SEL-851 FastOp_Ena setting needs to be set to Y. See *Figure C.6*.

```
==>>SHO P 1 <Enter>

Port 1 Settings

Protocol Selection
Port_01.Proto:= SEL       Port_01.CommIntfType:= 232

Communications Settings
Port_01.Spd:= 115200      Port_01.DataBits:= 8     Port_01.Prty:= N
Port_01.StopBits:= 1      Port_01.HndShk:= N       Port_01.TmOut:= 0

SEL Protocol Settings
Port_01.AutoMsg_Ena:= N   Port_01.FastOp_Ena:= Y
```

Figure C.6 Fast Operate Messages Accepted on Port 1

The RTAC automatically sends messages to the relay for changes in remote bits RB_001.Sta–RB016.Sta on the corresponding RTAC port. For example, if you set RB_001.Sta on Port 1 in the RTAC, it automatically sets RB_001.Sta in the SEL-851.

SEL Communications Processor to SEL-851 Unsolicited Write Remote Analog Example

There are two settings that need to be configured in the RTAC if you need to write to remote analogs in the SEL-851. In this example, the required settings needed to write to RA_001.Val and RA_002.Val are provided. The first set of settings is under the Tx UW Messages tab. See *Figure C.7*.

Unsolicited Write TX	Unsolicited Write TX Period	Unsolicited Write TX Port	Unsolicited Write TX Start Address
1	1000	Com_001	0xf800
2	1000	Com_001	0xf802

Figure C.7 Unsolicited Write Remote Analogs Tx UW Messages Settings

In the settings, note the unsolicited write Tx starting addresses. After these two settings are properly configured, Tx UW Message 1 needs to be configured. See Figure C.8. Note the Tag Types being MV and the Datatype being REAL. A similar setup can be used to write to all of the remote analogs.

Drag a column header here to group by that column

Enable	Tag Name	Tag Type	Tag Alias	Address Range Start	Address Range Stop	Bit Index	Treat As	Status Value
True	SEL_851_1_SEL.Tx_UW_1_F800	MV		0xf800	0xf801		REAL	
True	SEL_851_1_SEL.Tx_UW_1_F802	MV		0xf802	0xf803		REAL	

Figure C.8 Tag Type and Datatype for RA_001.Val–RA_032.Val

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Appendix D

DNP3 Communications

Overview

The SEL-851 Feeder Protection Relay provides a Distributed Network Protocol Version 3.0 (DNP3) Level 2 Outstation interface for direct serial and LAN/WAN network connections to the device.

This section covers the following topics:

- *Introduction to DNP3 on page D.1*
- *DNP3 in the SEL-851 on page D.6*
- *DNP3 Documentation on page D.13*

Introduction to DNP3

A supervisory control and data acquisition (SCADA) manufacturer developed the first versions of DNP from the lower layers of IEC 60870-5. Originally designed for use in telecontrol applications, Version 3.0 of the protocol has also become popular for local substation data collection. DNP3 is one of the protocols included in the IEEE Recommended Practice for Data Communications Between Remote Terminal Units and Intelligent Electronic Devices in a Substation.

The DNP Users Group maintains and publishes DNP3 standards. See the DNP Users Group website, www.dnp.org, for more information on standards, implementers, and tools for working with DNP3.

DNP3 Specifications

DNP3 is a feature-rich protocol with many ways to accomplish tasks, defined in an eight-volume series of specifications. Volume 8 of the specification, called the Interoperability Specification, simplifies DNP3 implementation by providing four standard interoperable implementation levels. The levels are listed in *Table D.1*.

Table D.1 DNP3 Implementation Levels

Level	Description	Equipment Types
1	Simple: limited communication requirements	Meters, simple IEDs
2	Moderately complex: monitoring and metering devices and multifunction devices that contain more data	Protective relays, RTUs
3	Sophisticated: devices with great amounts of data or complex communication requirements	Large RTUs, SCADA masters
4	Enhanced: additional data types and functionality for more complex requirements	Large RTUs, SCADA masters

Each level is a proper superset of the previous lower-numbered level. A higher-level device can act as a master to a lower-level device, but can only use the data types and functions implemented in the lower level device. For example, a typical SCADA master is a Level 3 device and can use Level 2 (or lower) functions to poll a Level 2 (or lower) device for Level 2 (or lower) data. Similarly, a lower-level device can poll a higher-level device, but the lower level device can only access the features and data available to its level.

In addition to the eight-volume DNP3 specification, the protocol is further refined by conformance requirements, optional features, and a series of technical bulletins. The technical bulletins supplement the specifications with discussions and examples of specific features of DNP3.

Data Handling

Objects

DNP3 uses a system of data references called objects, defined by the Basic 4 standard object library. Each subset level specification requires a minimum implementation of object types and recommends several optional object types. DNP3 object types, commonly referred to as objects, are specifications for the type of data the object carries. An object can include a single value or more complex data. Some objects serve as shorthand references for special operations, including collections of data, time synchronization, or even all data within the DNP3 device.

If there can be more than one instance of a type of object, then each instance of the object includes an index that makes it unique. For example, each binary status point (Object 1) has an index. If there are 16 binary status points, these points are Object 1, Index 0 through Object 1, Index 15.

Each object also includes multiple versions called variations. For example, Object 1 (binary inputs) has three variations: 0, 1, and 2. You can use Variation 0 to request all variations, Variation 1 to specify binary input values only, and Variation 2 to specify binary input values with status information.

Each DNP3 device has both a list of objects and a map of object indices. The list of objects defines the available objects, variations, and qualifier codes. The map defines the indices for objects that have multiple instances and defines what data or control points correspond with each index.

A master initiates all DNP3 message exchanges except unsolicited data. DNP3 terminology describes all points from the perspective of the master. Binary points for control that move from the master to the outstation are called binary outputs, while binary status points within the outstation are called binary inputs.

Function Codes

Each DNP3 message includes a function code. Each object has a limited set of function codes that a master can use to manipulate the object. The object listing for the device shows the permitted function codes for each type of object. The most common DNP3 function codes are listed in *Table D.2*.

Table D.2 Selected DNP3 Function Codes

Function Code	Function	Description
1	Read	Request data from the outstation
2	Write	Send data to the outstation
3	Select	First part of a Select-Before-Operate operation
4	Operate	Second part of a Select-Before-Operate operation
5	Direct operate	One-step operation with reply
6	Direct operate, no reply	One-step operation with no reply

Qualifier Codes and Ranges

DNP3 masters use qualifier codes and ranges to make requests for specific objects by index. Qualifier codes specify the style of range, and the range specifies the indices of the objects of interest. DNP3 masters use qualifier codes to compose the shortest, most concise message possible when requesting points from a DNP3 outstation.

For example, the qualifier code 01 specifies that the request for points includes a start address and a stop address. Each of these two addresses uses two bytes. An example request using qualifier code 01 might have the four hexadecimal byte range field, 00h 04h 00h 10h, which specifies points in the range 4 to 16.

Access Methods

DNP3 has many features that help obtain maximum possible message efficiency. DNP3 masters send requests with the least number of bytes using special objects, variations, and qualifiers that reduce the message size. Other features eliminate the continual exchange of static (unchanging) data values. These features optimize use of bandwidth and maximize performance over a connection of any speed.

DNP3 event data collection eliminates the need to use bandwidth to transmit values that have not changed. Event data are time-stamped records that show when observed measurements changed. For binary points, the remote device (DNP3 outstation) logs changes from logical 1 to logical 0 and from logical 0 to logical 1. For analog points, the outstation device logs changes that exceed a deadband. DNP3 outstation devices collect event data in a buffer that either the master can request or the device can send to the master without a request message. Data sent from the outstation to the master without a polling request are called unsolicited data.

DNP3 data fit into one of four event classes: 0, 1, 2, or 3. Class 0 is reserved for reading the present value data (static data). Classes 1, 2, and 3 are event data classes. The meaning of Classes 1 to 3 is arbitrary and defined by the application at hand. With outstations that contain great amounts of data or in large systems, the three event classes provide a framework for prioritizing different types of data. For example, you can poll once a minute for Class 1 data, once an hour for Class 2 data, and once a day for Class 3 data.

DNP3 also supports static polling: simple polling of the present value of data points within the outstation. By combining event data, unsolicited polling, and static polling, you can operate your system in one of the four access methods shown in *Table D.3*.

The access methods listed in *Table D.3* are listed in order of increasing communication efficiency. With various trade-offs, each method is less demanding of communication bandwidth than the previous one. For example,

unsolicited report-by-exception consumes less communication bandwidth than polled report-by-exception because that method does not require polling messages from the master. To properly evaluate which access method provides optimum performance for your application, you must also consider overall system size and the volume of data communication expected.

Table D.3 DNP3 Access Methods

Access Method	Description
Polled static	Master polls for present value (Class 0) data only
Polled report-by-exception	Master polls frequently for event data and occasionally for Class 0 data
Unsolicited report-by-exception	Outstation devices send unsolicited event data to the master, and the master occasionally polls for Class 0 data
Quiescent	Master never polls and relies on unsolicited reports only

Binary Control Operations

DNP3 masters use Object 12, control device output block, to perform DNP3 binary control operations. The control device output block has both a trip/close selection and a code selection. The trip/close selection allows a single DNP3 index to operate two related control points such as trip and close or raise and lower. Trip/close pair operation is not recommended for new DNP3 devices, but is often included for interoperability with older DNP3 master implementations.

The control device output block code selection specifies either a latch or pulse operation on the point. In many cases, DNP3 outstations have only a limited subset of the possible combinations of the code field. Sometimes, DNP3 outstations assign special operation characteristics to the latch and pulse selections. *Table D.11* describes control point operation for the SEL-851.

Conformance Testing

In addition to the protocol specifications, the DNP Users Group has approved conformance-testing requirements for Level 1 and Level 2 devices. Some implementers perform their own conformance specification testing, while some contract with independent companies to perform conformance testing.

Conformance testing does not always guarantee that a master and outstation are fully interoperable (that is, work together properly for all implemented features). Conformance testing does help to standardize the testing procedure and move the DNP3 implementers toward a higher level of interoperability.

DNP3 Serial Network Issues

Data Link Layer Operation

DNP3 employs a three-layer version of the seven-layer OSI (Open System Interconnection) model called the enhanced performance architecture. The layer definition helps to categorize functions and duties of various software components that make up the protocol. The middle layer, the Data Link Layer, includes several functions for error checking and media access control.

A feature called data link confirmation is a mechanism that provides positive confirmation of message receipt by the receiving DNP3 device. While this feature helps you recognize a failed device or failed communications link quickly, it also adds significant overhead to the DNP3 conversation. Consider whether you require this link integrity function in your application at the expense of overall system speed and performance.

The DNP3 technical bulletin (*DNP Confirmation and Retry Guidelines 9804-002*) on confirmation processes recommends against using data link confirmations because these processes can add to traffic in situations where communications are marginal. The increased traffic reduces connection throughput further, possibly preventing the system from operating properly.

Network Medium Contention

When more than one device requires access to a single (serial) network medium, you must provide a mechanism to resolve the resulting network medium contention. For example, unsolicited reporting results in network medium contention if you do not design your serial network as a star topology of point-to-point connections or use carrier detection on a multidrop network.

To avoid collisions among devices trying to send messages, DNP3 includes a collision avoidance feature. Before sending a message, a DNP3 device listens for a carrier signal to verify that no other node is transmitting data. The device transmits if there is no carrier or waits for a random time before transmitting. However, if two nodes both detect a lack of carrier at the same instant, these two nodes could begin simultaneous transmission of data and cause a data collision. If your serial network allows for spontaneous data transmission including unsolicited event data transmissions, you also must use application confirmation to provide a retry mechanism for messages lost in data collisions.

DNP3 LAN/WAN Overview

The main process for carrying DNP3 over an Ethernet network (LAN/WAN) involves encapsulating the DNP3 data link layer data frames within the transport layer frames of the IP suite. This allows the IP stack to deliver the DNP3 data link layer frames to the destination in place of the original DNP3 physical layer.

The DNP User Group Technical Committee has recommended the following guidelines for carrying DNP3 over a network:

NOTE: Link layer confirmations are explicitly disabled for DNP3 LAN/WAN. The IP suite provides a reliable delivery mechanism, which is backed up at the application layer by confirmations when required.

- DNP3 shall use the IP suite to transport messages over a LAN/WAN
- Ethernet is the recommended physical link, though you can use others
- TCP must be used for WANs
- TCP is strongly recommended for LANs
- UDP can be used for highly reliable single-segment LANs
- UDP is necessary if broadcast messages are required
- The DNP3 protocol stack shall be retained in full
- Link layer confirmations shall be disabled

The technical committee has registered a standard port number, 20000, for DNP3 with the Internet Assigned Numbers Authority (IANA). This port is used for either TCP or UDP.

TCP/UDP Selection

The committee recommends the selection of TCP or UDP protocol as per the guidelines in *Table D.4*.

Table D.4 TCP/UDP Selection Guidelines

Use in the case of...	TCP	UDP
Most situations	X	
Non-broadcast or multicast	X	
Mesh Topology WAN	X	
Broadcast		X
Multicast		X
High-reliability single-segment LAN		X
Pay-per-byte, non-mesh WAN, for example, Cellular Digital Packet Data (CDPD)		X
Low priority data, for example, data monitor or configuration information		X

DNP3 in the SEL-851

The SEL-851 is a DNP3 Level 2 remote (outstation) device, without dual end point.

Data Access

Table D.5 lists DNP3 data access methods along with their corresponding SEL-851 settings. You must select a data access method and configure each DNP3 master for polling as specified.

NOTE: Because unsolicited messaging is problematic in most circumstances, SEL recommends using the polled report-by-exception access method to maximize performance and minimize risk of configuration problems.

NOTE: In the settings in Table D.5, the suffix n represents the DNP3 session number from 1 to 3 for the Ethernet port (Port 2). Additionally, the SEL-851 supports 1 session on the serial port (Port 1). All settings with the same numerical suffix comprise the complete DNP3 session configuration.

Table D.5 Configuring DNP3 Access Methods

Access Method	Master Polling	SEL-851 Settings
Polled static	Class 0	Set Port_02/DNP*n*_BinEveClass, Port_02.DNP*n*_CntEveClass, Port_02.DNP*n*_AnaEveClass to 0; Port_02.DNP*n*_UnsolEna to No
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set Port_02.DNP*n*_BinEveClass, Port_02.DNP*n*_CntEveClass, Port_02.DNP*n*_AnaEveClass to the desired event class; Port_02.DNP*n*_UnsolEna to No
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently; mainly relies on unsolicited messages	Set Port_02.DNP*n*_BinEveClass, Port_02.DNP*n*_CntEveClass, Port_02.DNP*n*_AnaEveClass to the desired event class; set Port_02.DNP*n*_UnsolENa to Yes and Port_02.DNP*n*_UnsolPwrUpEna to Yes or No
Quiescent	Class 0, 1, 2, 3 never; relies completely on unsolicited messages	Set Port_02.DNP*n*_BinEveClass, Port_02.DNP*n*_CntEveClass, Port_02.DNP*n*_AnaEveClass to the desired event class; set Port_02.DNP*n*_UnsolEna and Port_02.DNP*n*_UnsolPwrUpEna to Yes.

The SEL-851 is an outstation device without dual end point. For a TCP connection, the relay sends out unsolicited messages only if a DNP3 master has already established a session and enabled unsolicited messaging for that session. However, for a Serial/Modem/UDP connection, the relay automatically dials out and sends unsolicited messages as defined by the settings.

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table D.5*, you must make a selection for the Port_02.DNP*n*_UnsolPwrUpEna setting. This setting enables or disables unsolicited data reporting when the device is turned on. If your DNP3 master can send a message to enable unsolicited reporting on the SEL-851, set Port_02.DNP*n*_UnsolPwrUpEna to No.

While automatic unsolicited data transmission on power up is convenient, this can cause problems if your DNP3 master is not prepared to start receiving data immediately on power up. If the master does not acknowledge the unsolicited data with an Application Confirm, the device resends the data until it is acknowledged. On a large system, or in systems where the processing power of the master is limited, you can have problems when several devices simultaneously begin sending data and waiting for acknowledgment messages.

The SEL-851 allows you to set the conditions for transmitting unsolicited event data on a class-by-class basis. It also allows you to assign points to event classes on a point-by-point basis (see *DNP3 Documentation on page D.13*). You can prioritize data transmission with these event class features. For example, you might place high-priority points in event Class 1 and set it with low thresholds (Port_02.DNP*n*_NumEve and Port_02.DNP*n*_AgeEve settings) so that changes to these points are sent to the master quickly. You can then place low priority data in event Class 2 with higher thresholds.

If the SEL-851 does not receive an Application Confirm in response to unsolicited data, it waits for Port_02.DNP*n*_CnfrmTmOut seconds and then repeats the unsolicited message. To prevent clogging of the network with unsolicited data retries, the SEL-851 uses the Port_02.DNP*n*_UnsolRetry and Port_02.DNP*n*_SlowCnfrmTmOut settings to increase retry time when the number of retries set in Port_02.DNP*n*_UnsolRetry is exceeded. After Port_02.DNP*n*_UnsolRetry has been exceeded, the SEL-851 pauses Port_02.DNP*n*_SlowCnfrmTmOut seconds and then transmits the unsolicited data again. *Figure D.1* provides an example with Port_02.DNP*n*_UnsolRetry = 2.

Figure D.1 Application Confirmation Timing With Port_02.DNP*n*_UnsolRetry = 2

Collision Avoidance

If your application uses unsolicited reporting on a serial network, you must select a half-duplex medium or a medium that includes carrier detection to avoid data collisions. EIA-485 two-wire networks are half-duplex. EIA-485

four-wire networks do not provide carrier detection, while EIA-232 systems can support carrier detection. DNP3 LAN/WAN uses features of the IP suite for collision avoidance, so does not require these settings.

The SEL-851 uses Application Confirmation messages to guarantee delivery of unsolicited event data before erasing the local event data buffer. Data collisions are typically resolved when messages are repeated until confirmed.

The SEL-851 pauses for a random delay between the settings Port_01.MaxDly and Port_01.MinDly when it detects a carrier through data on the receive line or the CTS pin. For example, if you use the settings of 0.10 seconds for Port_01.MaxDly and 0.05 seconds for Port_01.MinDly, the SEL-851 inserts a random delay of 50 to 100 ms between the end of carrier detection and the start of data transmission (see *Figure D.2*).

Figure D.2 Message Transmission Timing

Transmission Control

NOTE: Port_01.PreDly and Port_01.PstDly settings are only available for EIA-232 and EIA-485 serial port sessions.

If you use a media transceiver (for example, EIA-232 to EIA-485) or a radio system for your DNP network, you may need to adjust data transmission properties. Use the Port_01.PreDly and Port_01.PstDly settings to provide a delay between RTS signal control and data transmission (see *Figure D.2*). For example, an EIA-485 transceiver typically requires 10 to 20 ms to change from receive to transmit. If you set the pre-delay to 30 ms, you avoid data loss resulting from the data transmission beginning at the same time as the RTS signal assertion.

Event Data

DNP3 event data objects contain change-of-state and time-stamp information that the SEL-851 collects and stores in a buffer. Points assigned in the Binary Input Map that are also assigned in the Sequential Events Recorder (SER) settings carry the time stamp of actual occurrence. Binary input points not assigned in the SER settings carry a time stamp based on the DNP map scan time. This may be significantly delayed from when the original source changed and should not be used for sequence-of-events determination. The DNP map is scanned approximately once per second to generate events. You can configure the SEL-851 to either report the data without a polling request from the master (unsolicited data) or hold the data until the master requests it with an event poll message.

With the event class settings Port_02.DNP*n*_BinEveClass, Port_02.DNP*n*_CntEveClass, and Port_02.DNP*n*_AnaEveClass, you can set the event class for binary, counter, and analog inputs for Session *n*. You can use the classes as a simple priority system for collecting event data. The SEL-851 does not treat data of different classes differently with respect to message scanning, but it does allow the master to perform independent class polls.

NOTE: Most RTUs that act as substation DNP3 masters perform an event poll that collects event data of all classes simultaneously. You must confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the SEL-851.

For event data collection you must also consider and enter appropriate settings for deadband and scaling operation on analog points shown in *Table D.7*. You can either:

- set and use default deadband and scaling according to data type, or
- use a custom data map to select deadbands on a point-by-point basis.

See *DNP3 Documentation on page D.13* for a discussion of how to set scaling and deadband operation on a point-by-point basis. You can modify deadbands for analog inputs at run-time by writing to Object 34.

The settings Port_02.DNP*n*_AmpDb, Port_02.DNP*n*_VoltDb, and Port_02.DNP*n*_MiscDb control default dead-band operation for each type of analog data. Because DNP3 Objects 30 and 32 use integer data, you must use scaling to send digits after the decimal point and avoid rounding to a simple integer value.

With no scaling, the value of 12.632 would be sent as 12. With a scaling setting of 1, the value transmitted is 126. With a scaling setting of 3, the value transmitted is 12632. You must make certain that the maximum value does not exceed 32767 if you are polling the default 16-bit variations for Objects 30 and 32, but you can send some decimal values using this technique. You must also configure the master to perform the appropriate division on the incoming value to display it properly.

You can set the default analog value scaling with the Port_02.DNP*n*_AmpSca, Port_02.DNP*n*_VoltSca, and Port_02.DNP*n*_MiscSca settings. Application of event reporting deadbands occurs after scaling. For example, if you set Port_02.DNP*n*.AmpSca to 2 and Port_02.DNP*n*_AmpDb to 10, a measured current of 10.14 Amps would be scaled to the value 1014 and would have to increase to more than 1024 or decrease to less than 1004 (a change in magnitude of ± 0.1 Amps) for the device to report a new event value.

The SEL-851 uses the Port_02.DNP*n*_NumEve and Port_02.DNP*n*_AgeEve settings to decide when to send unsolicited data to the master. The device sends an unsolicited report when the total number of events accumulated in the event buffer for Master *n* reaches Port_02.DNP*n*_NumEve. The device also sends an unsolicited report if the age of the oldest event in the master n buffer exceeds Port_02.DNP*n*_AgeEve. The SEL-851 has the buffer capacities listed in *Table D.6*.

Table D.6 SEL-851 Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	100
Counters	32

Binary Controls

The SEL-851 provides more than one way to control individual points. The SEL-851 maps incoming control points either to remote bits or to internal command bits that cause circuit breaker operations. *Table D.11* lists control points and control methods available in the SEL-851.

A DNP3 technical bulletin (*Control Relay Output Block Minimum Implementation 9701-002*) recommends that you use one point per Object 12,

control block output device. You can use this method to perform Pulse On, Pulse Off, Latch On, and Latch Off operations on selected remote bits.

If your master does not support the single-point-per-index messages or single operation database points, you can use the trip/close operation or use the code field in the DNP3 message to specify operation of the points shown in *Control Point Operation on page D.21*.

Time Synchronization

The accuracy of DNP3 time synchronization is insufficient for most protection and oscillography needs. DNP3 time synchronization provides backup time synchronization in the event the device loses primary synchronization through the IRIG-B input. You can enable time synchronization with the Port_02.DNP*n*_TmReq setting and then use Object 50, Variation 1, and Object 52, Variation 2, to set the time via the Session *n* DNP3 master (Object 50, Variation 3 for DNP3 LAN/WAN).

By default, the SEL-851 accepts and ignores time set requests (Port_02.DNP*n*_TmReq= I for "ignore"). (This mode allows the SEL-851 to use a high accuracy, IRIG time source, but still interoperate with DNP3 masters that send time-synchronization messages.) You can set the SEL-851 to request time synchronization periodically by setting the Port_02.DNP*n*_TmReq setting to the desired period. You can also set it to not request, but accept, time synchronization (Port_02.DNP*n*_TmReq = M for "master").

The SEL-851 prioritizes its time-synchronization sources. These time sources fall under one of two categories: primary time sources and secondary time sources. IRIG-B (serial port) and SNTP are primary time sources. All other time sources such as DNP3, Modbus, and serial port time and date commands are secondary time sources.

If an IRIG-B time source is available, the SEL-851 synchronizes its time with that time source regardless of what other time sources are available. If IRIG-B is not available, but SNTP is, the SEL-851 synchronizes its time with that SNTP time source even if other time sources are available. And finally, if IRIG-B and SNTP are not available, the SEL-851 synchronizes with the remaining time sources that could be available. These include DNP3, Modbus, or serial port time and date commands. These four time sources take on the same priority. At any given time, the relay synchronizes with the one that most recently established synchronization with the relay. In summary, time-synchronization prioritization starts with IRIG-B, followed by SNTP, followed by DNP3, Modbus, or serial port time and date commands.

Note that when an IRIG-B time source is available, any remaining time sources can only be used to update the year.

Modem Support

The SEL-851 DNP implementation includes modem support for serial ports. Your DNP3 master can dial-in to the SEL-851 and establish a DNP3 connection. The SEL-851 can automatically dial out and deliver unsolicited DNP3 event data.

When the device dials out, it waits for the "CONNECT" message from the local modem and for assertion of the device CTS line before continuing the DNP transaction. This requires a connection from the modem DCD to the device CTS line.

You can either connect the modem to a computer and configure it before connecting it to the SEL-851, or program the appropriate modem setup string in the modem startup string setting Port_01.Modm_Str. Use the Port_01.Modm_PhonNum1 and (optional) Port_01.Modm_PhonNum2

NOTE: Contact SEL for information on serial cable configurations and requirements for connecting your SEL-851 to other devices.

NOTE: To enable hardware handshaking, set the modem settings to Y if you are using a Null modem cable for DOP protocol implementation.

settings to set the phone numbers that you want the SEL-851 to call. The SEL-851 automatically sends the ATDT modem dial command and then the contents of the Port_01.Modm_PhonNum1 setting when dialing the modem. If Port_01.Modm_PhonNum2 is set, use the Port_01.Modm_Retry1 setting to configure the number of times the SEL-851 tries to dial Port_01.Modm_PhonNum1 before dialing Port_01.Modm_PhonNum2. Similarly, the Port_01.Modm_Retry2 setting is the number of attempts the SEL-851 tries to dial Port_01.Modm_PhonNum2 before trying Port_01.Modm_PhonNum1. Port_01.Modm_HngupTm sets the length of time from initiating the call to declaring it failed because of no connection, and Port_01.Modm_DialIntv sets the time between dial-out attempts.

NOTE: RTS/CTS hardware flow control is not available for a DNP3 modem connection. You must use either X-ON/X-OFF software flow control or set the port data speed slower than the effective data rate of the modem.

The settings Port_01.Modm_PhonNum1 and Port_01.Modm_PhonNum2 must conform to the AT modem command set dialing string standard, including:

- A comma (,) inserts a four second pause
- If necessary, use a 9 to reach an outside line
- Include a 1 and the area code if the number requires long distance access
- Add any special codes your telephone service provider designates to block call waiting and other telephone line features.

DNP3 Settings

The DNP3 port configuration settings available on the SEL-851 are shown in *Table D.7*. You can enable DNP3 on Ethernet Port 2 or serial Port 1, to a maximum of four concurrent DNP3 sessions. Each session defines the characteristics of the connected DNP3 Master, to which you assign one of the three available custom maps. Some settings only apply to DNP3 LAN/WAN, and are visible only when configuring the Ethernet port. For example, you only have the ability to define multiple sessions on Port 2, the Ethernet port. Likewise, settings applicable to serial DNP3 are visible only when configuring a serial port.

Table D.7 Port DNP3 Protocol Settings (Sheet 1 of 3)

Name	Description	Range	Default
Port_02.DNP.Ena[a]	Enable DNP3 sessions	0–3	0
Port_02.DNP_PortNum[a]	DNP3 TCP and UDP port	1–65534	20000
Port_02.DNP_Addr[b]	DNP3 address	0–65519	0
Session 1 Settings			
Port_02.DNP1_TransProto[a]	Transport protocol	UDP, TCP	TCP
Port_02.DNP1_IPAddr[a,c]	DNP3 Master 1 IP address (zzz.yyy.xxx.www)	15 characters	“”
Port_01.DNP1_UDPPort[a]	UDP response port	REQ, 1–65534	20000
Port_02.DNP1_MastAddr[b]	DNP3 address to report to	0–65519	1
Port_01.DNP1_MapNum[b]	DNP3 map	1–3	1
Port_02.DNP1_AnaVar[b]	Analog input default variation	1–6	4
Port_02.DNP1_CtlEna[b]	Enable control operations	Y, N	Y
Port_02.DNP1_BinEveClass[b]	Class for binary event data, 0 disables	0–3	1
Port_02.DNP1_CntEveClass[b]	Class for counter event data, 0 disables	0–3	0
Port_02.DNP1_AnaEveClass[b]	Class for analog event data, 0 disables	0–3	2
Port_02.DNP1_AmpSca[b]	Currents scaling decimal places	0–3	1

Table D.7 Port DNP3 Protocol Settings (Sheet 2 of 3)

Name	Description	Range	Default
Port_02.DNP1_VoltSca[b]	Voltages scaling decimal places	0–3	1
Port_02.DNP1_MiscSca[b]	Misc data scaling decimal places	0–3	1
Port_02.DNP1_AmpDb[b]	Amps reporting deadband counts; hidden if Port_02.DNP1_AnaEveClass set to 0	0–32767	100
Port_02.DNP1_VoltDb[b]	Volts reporting deadband counts; hidden if Port_02.DNP1_AnaEveClass set to 0	0–32767	100
Port_02.DNP1_MiscDb[b]	Misc data reporting deadband counts; hidden if Port_02.DNP1_AnaEveClass and Port_02.DNP1_CntEveClass set to 0	0–32767	100
Port_02.DNP_TmReq[b]	Time for request interval, minutes (M = Disables time sync requests, but still accepts and applies time syncs from Master; I = Ignores (does not apply) time syncs from Master)	I, M, 1–32767	I
Port_02.DNP_SBOTmOut[b]	Select/Operate time-out, seconds	0.0–30.0	1.0
Port_02.DNP1_DataLinkHrtbt[a,d]	Send Data Link Heartbeat, seconds; hidden if Port_02.DNP1_TransProto set to UDP	0.0–7200	120
Port_02.DNP1_CnfrmTmOut[b]	Event message confirm time-out, seconds	1–50	5
Port_02.DNP1_UnsolEna[b]	Enable unsolicited reporting; hidden and set to N if Port_02.DNP1_BinEveClass, Port_02.DNP1_CntEveClass, and Port_02.DNP1_AnaEveClass set to 0	Y, N	N
Port_02.DNP1_UnsolPwrUpEna[b]	Enable unsolicited reporting at turn on; hidden and set to N if Port_02.DNP1_UnsolEna set to N	Y, N	N
Port_02.DNP1_NumEve[b]	Number of events to transmit on	1–200	10
Port_02.DNP1_AgeEve[be]	Oldest event to transmit on, seconds	0.0–99999.0	2.0
Port_02.DNP1_UnsolRetry[be]	Unsolicited messages maximum retry attempts	2–10	3
Port_02.DNP1_SlowCnfrmTmOut[be]	Unsolicited messages offline time-out, seconds	1–5000	60
Session 2 Settings			
Port_02.DNP2_IPAddr[a,c]	DNP3 Master 2 IP address (zzz.yyy.xxx.www)	15 characters	“”
Port_02.DNP2_TransProto[a]	Transport protocol	UDP, TCP	TCP
• • •			
Port_02.DNP2_UnsolRetry[a,e]	Unsolicited messages maximum retry attempts	2–10	3
Port_02.DNP2_SlowCnfrmTmOut[a,e]	Unsolicited messages offline time-out, seconds	1–5000	60
Session 3 Settings			
Port_02.DNP3_IPAddr[a,c]	DNP3 Master 3 IP address (zzz.yyy.xxx.www)	15 characters	“”
Port_02.DNP3_TransProto[a]	Transport protocol	UDP, TCP	TCP
• • •			
Port_02.DNP3_UnsolRetry[a,e]	Unsolicited messages maximum retry attempts	2–10	3
Port_02.DNP3_SlowCnfrmTmOut[a,e]	Unsolicited messages offline time-out, seconds	1–5000	60
Serial Port Settings			
Port_01.MinDly	Minimum time from DCD to TX, seconds	0.00–1.00	0.05
Port_01.MaxDly	Maximum time from DCD to TX, seconds	0.00–1.00	0.10

Table D.7 Port DNP3 Protocol Settings (Sheet 3 of 3)

Name	Description	Range	Default
Port_01.PreDly	Settle time from RTS On to TX; Off disables Port_01.PstDly	OFF, 0.00–30.00	0.00
Port_01.PstDly	Settle time from TX to RTS Off; hidden if Port_01.PreDly set to Off	0.00–30.00	0.00
Port_01.DNP_DataLinkRetry	Data link retries	0–15	0

[a] Available only on Ethernet ports.
[b] Available on the Ethernet ports and the serial port.
[c] Set Port_02.DNP*n*_IPAddr = 0.0.0.0 to accept connections from any DNP master when Port_02.DNP1_TransProto = TCP.
[d] Port_02.DNP*n*_DataLinkHrbt allows the user to set the wait time to detect a bad TCP connection. The relay closes the unused TCP connection after the Port_02.DNP*n*_DataLinkHrtbt response timeout. It is recommended you set this value to less than 20 seconds. Disabling Port_02.DNP*n*_DataLinkHrtbt violates the DNP3 standard and should only be done for testing.
[e] Hidden if Port_02.DNP*n*_UnsolEna is set to N.

The modem settings in *Table D.8* are available only for DNP3 serial port sessions.

Table D.8 Serial Port DNP3 Modem Settings

Name	Description	Range	Default
Port_01.Modm_Ena	Modem connected to port; all following settings are hidden if Port_01.Modm_Ena set to N	Y, N	N
Port_01.Modm_Str	Modem startup string	As many as 30 characters	"E0X0& D0S0 = 4"
Port_01.Modm_PhonNum1	Primary phone number for dial-out	As many as 30 characters	""
Port_01.Modm_PhonNum2	Secondary phone number for dial-out	As many as 30 characters	""
Port_01.Modm_Retry1	Retry attempts for Phone 1 dial-out; hidden and unused if Port_01.Modm_PhonNum1 set to ""	1–20	5
Port_01.Modm_Retry2	Retry attempts for Phone 2 dial-out; hidden and unused if Port_01.Modm_PhonNum2 set to ""	1–20	5
Port_01.Modm_HngupTm	Time to attempt dial, seconds	5–300	60
Port_01.Modm_DialIntv	Time between dial-out attempts	5–3600	120

DNP3 Documentation

Object List

Table D.9 lists the objects and variations with supported function codes and qualifier codes available in the SEL-851. The list of supported objects conforms to the format laid out in the DNP specifications and includes both supported and unsupported objects for DNP3 implementation Level 2 and higher and non-supported objects for DNP3 implementation Level 2 only. Those that are supported include the function and qualifier codes. The objects that are not supported are shown without any corresponding function and qualifier codes.

Table D.9 SEL-851 DNP3 Object List (Sheet 1 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
0	211	Device Attributes—User-specific sets of attributes	1	0	129	0,17
0	212	Device Attributes—Master data set prototypes	1	0	129	0,17
0	213	Device Attributes—Outstation data set prototypes	1	0	129	0,17
0	214	Device Attributes—Master data sets	1	0	129	0,17
0	215	Device Attributes—Outstation data sets	1	0	129	0,17
0	216	Device Attributes—Max binary outputs per request	1	0	129	0,17
0	219	Device Attributes—Support for analog output events	1	0	129	0,17
0	220	Device Attributes—Max analog output index	1	0	129	0,17
0	221	Device Attributes—Number of analog outputs	1	0	129	0,17
0	222	Device Attributes—Support for binary output events	1	0	129	0,17
0	223	Device Attributes—Max binary output index	1	0	129	0,17
0	224	Device Attributes—Number of binary outputs	1	0	129	0,17
0	225	Device Attributes—Support for frozen counter events	1	0	129	0,17
0	226	Device Attributes—Support for frozen counters	1	0	129	0,17
0	227	Device Attributes—Support for counter events	1	0	129	0,17
0	228	Device Attributes—Max counter index	1	0	129	0,17
0	229	Device Attributes—Number of counters	1	0	129	0,17
0	230	Device Attributes—Support for frozen analog inputs	1	0	129	0,17
0	231	Device Attributes—Support for analog input events	1	0	129	0,17
0	232	Device Attributes—Max analog input index	1	0	129	0,17
0	233	Device Attributes—Number of analog inputs	1	0	129	0,17
0	234	Device Attributes—Support for double-bit events	1	0	129	0,17
0	235	Device Attributes—Max double-bit binary index	1	0	129	0,17
0	236	Device Attributes—Number of double-bit binaries	1	0	129	0,17
0	237	Device Attributes—Support for binary input events	1	0	129	0,17
0	238	Device Attributes—Max binary input index	1	0	129	0,17
0	239	Device Attributes—Number of binary inputs	1	0	129	0,17
0	240	Device Attributes—Max transmit fragment size	1	0	129	0,17
0	241	Device Attributes—Max receive fragment size	1	0	129	0,17
0	242	Device Attributes—Device manufacturer’s software version	1	0	129	0,17
0	243	Device Attributes—Device manufacturer’s hardware version	1	0	129	0,17
0	245	Device Attributes—User-assigned location name	1	0	129	0,17
0	246	Device Attributes—User assigned ID code/number	1	0	129	0,17
0	247	Device Attributes—User assigned ID code/number	1	0	129	0,17
0	248	Device Attributes—Device serial number	1	0	129	0,17

Table D.9 SEL-851 DNP3 Object List (Sheet 2 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
0	249	Device Attributes—DNP subset and conformance	1	0	129	0,17
0	250	Device Attributes—Device manufacturer's product name and model	1	0	129	0,17
0	252	Device Attributes—Device manufacturer's name	1	0	129	0,17
0	254	Device Attributes—Non-specific all attributes request	1	0	129	0,17
0	255	Device Attributes—List of attribute variations	1	0	129	0,17
1	0	Binary Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
1	1	Binary Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
1	2[e]	Binary Input With Status	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
2	0	Binary Input Change—All Variations	1	6, 7, 8		
2	1	Binary Input Change Without Time	1	6, 7, 8	129	17, 28
2	2[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28
2	3	Binary Input Change With Relative Time	1	6, 7, 8	129	17, 28
10	0	Binary Output—All Variations	1	0, 1, 6, 7, 8		
10	1	Binary Output				
10	2[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1
12	0	Control Block—All Variations				
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern Control Block	3, 4, 5, 6	7	129	echo of request
12	3	Pattern Mask	3, 4, 5, 6	0, 1	129	echo of request
20	0	Binary Counter—All Variations	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28		
20	1	32-Bit Binary Counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	2	16-Bit Binary Counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	6[e]	16-Bit Binary Counter Without Flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	7	32-Bit Delta Counter Without Flag				
20	8	16-Bit Delta Counter Without Flag				
21	0	Frozen Counter—All Variations				
21	1	32-Bit Frozen Counter				
21	2	16-Bit Frozen Counter				
21	3	32-Bit Frozen Delta Counter				
21	4	16-Bit Frozen Delta Counter				
21	5	32-Bit Frozen Counter With Time of Freeze				
21	6	16-Bit Frozen Counter With Time of Freeze				

Table D.9 SEL-851 DNP3 Object List (Sheet 3 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
21	7	32-Bit Frozen Delta Counter With Time of Freeze				
21	8	16-Bit Frozen Delta Counter With Time of Freeze				
21	9	32-Bit Frozen Counter Without Flag				
21	10	16-Bit Frozen Counter Without Flag				
21	11	32-Bit Frozen Delta Counter Without Flag				
21	12	16-Bit Frozen Delta Counter Without Flag				
22	0	Counter Change Event—All Variations	1	6, 7, 8		
22	1	32-Bit Counter Change Event Without Time	1	6, 7, 8	129	17, 28
22	2[e]	16-Bit Counter Change Event Without Time	1	6, 7, 8	129, 130	17, 28
22	3	32-Bit Delta Counter Change Event Without Time				
22	4	16-Bit Delta Counter Change Event Without Time				
22	5	32-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	6	16-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	7	32-Bit Delta Counter Change Event With Time				
22	8	16-Bit Delta Counter Change Event With Time				
23	0	Frozen Counter Event—All Variations				
23	1	32-Bit Frozen Counter Event Without Time				
23	2	16-Bit Frozen Counter Event Without Time				
23	3	32-Bit Frozen Delta Counter Event Without Time				
23	4	16-Bit Frozen Delta Counter Event Without Time				
23	5	32-Bit Frozen Counter Event With Time				
23	6	16-Bit Frozen Counter Event With Time				
23	7	32-Bit Delta Counter Change Event With Time				
23	8	16-Bit Delta Counter Change Event With Time				
30[f]	0	Analog Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
30[f]	1	32-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	2	16-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	4	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	5	Short Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	6	Long Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
31	0	Frozen Analog Input—All Variations				
31	1	32-Bit Frozen Analog Input				
31	2	16-Bit Frozen Analog Input				
31	3	32-Bit Frozen Analog Input With Time of Freeze				
31	4	16-Bit Frozen Analog Input With Time of Freeze				

Table D.9 SEL-851 DNP3 Object List (Sheet 4 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
31	5	32-Bit Frozen Analog Input Without Flag				
31	6	16-Bit Frozen Analog Input Without Flag				
31	7	Short Floating Point Frozen Analog Input				
31	8	Long Floating Point Frozen Analog Input				
32	0	Analog Change Event—All Variations	1	6, 7, 8		
32[f]	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32[f]	2	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28
32[f]	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[f]	4	16-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[f]	5	Short Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32[f]	6	Long Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32[f]	7	Short Floating Point Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[f]	8	Long Floating Point Analog Change Event With Time	1	6, 7, 8	129	17, 28
33	0	Frozen Analog Event—All Variations				
33	1	32-Bit Frozen Analog Event Without Time				
33	2	16-Bit Frozen Analog Event Without Time				
33	3	32-Bit Frozen Analog Event With Time				
33	4	16-Bit Frozen Analog Event With Time				
33	5	Short Floating Point Frozen Analog Event				
33	6	Long Floating Point Frozen Analog Event				
33	7	Short Floating Point Frozen Analog Event With Time				
33	8	Long Floating Point Frozen Analog Event With Time				
34	0	Analog Deadband—All Variations				
34	1[e]	16-Bit Analog Input Reporting Deadband Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	2	32-Bit Analog Input Reporting Deadband Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	3	Floating Point Analog Input Reporting Deadband Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
40	0	Analog Output Status—All Variations	1	0, 1, 6, 7, 8	129	
40	1	32-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	2[e]	16-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	3	Short Floating Point Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	4	Long Floating Point Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
41	0	Analog Output Block—All Variations				
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	2[e]	16-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	3	Short Floating Point Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
50	0	Time and Date—All Variations				
50	1	Time and Date	1, 2	7, 8 index=0	129	07, quantity=1

Table D.9 SEL-851 DNP3 Object List (Sheet 5 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
50	2	Time and Date With Interval				
50	3	Time and Date Last Recorded	2	7 quantity = 1	129	
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO			129	07, quantity=1
52	0	Time Delay—All Variations				
52	1	Time Delay, Coarse				
52	2	Time Delay, Fine			129	7, quantity=1
60	0	All Classes of Data	1, 20, 21	6, 7, 8		
60	1	Class 0 Data	1, 20, 21	6, 7, 8		
60	2	Class 1 Data	1	6, 7, 8		
60	3	Class 2 Data	1, 20, 21	6, 7, 8		
60	4	Class 3 Data	1, 20, 21	6, 7, 8		
70	1	File Identifier				
70	2	Authentication Object				
70	3	File Command Object				
70	4	File Command Status Object				
70	5	File Transport Object				
70	6	File Transport Status Object				
70	7	File Descriptor Object				
80	1	Internal Indications	2	0, 1 index=7		
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				
100	3	Extended Floating Point				
101	1	Small Packed Binary-Coded Decimal				
101	2	Medium Packed Binary-Coded Decimal				
101	3	Large Packed Binary-Coded Decimal				
110	all	Octet String				
111	all	Octet String Event				
112	All	Virtual Terminal Output Block				

Table D.9 SEL-851 DNP3 Object List (Sheet 6 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
113	All	Virtual Terminal Event Data				
N/A		No object required for the following function codes: 13 cold start 14 warm start 23 delay measurement	13, 14, 23			

[a] Supported in requests from master.
[b] May generate in response to master.
[c] Decimal.
[d] Hexadecimal.
[e] Default variation.
[f] Default variation specified by serial port setting Port_01.DNP_AnaVar (or Port_02.DNPn_AnaVar for Ethernet Session n [n = 1, 2, 3, 4, or 5]).

Device Profile

The DNP3 Device Profile document, available on the supplied CD or as a download from the SEL website, contains the standard device profile information for the SEL-851. This information is also available in XML format. Please refer to this document for complete information on DNP3 Protocol support in the SEL-851.

Reference Data Map

Table D.10 shows the SEL-851 reference data map. The reference map shows the data available to a DNP3 master. You can use the custom DNP3 mapping functions of the SEL-851 to retrieve only the points required by your application.

NOTE: Deadband changes via Object 34 are not stored in nonvolatile memory. Make sure to reissue the Object 34 deadbands after a warm (**STA C**) or cold start (power cycle).

The SEL-851 scales analog values by the indicated settings or fixed scaling indicated in the description. Analog deadbands for event reporting use the indicated settings, or Port_01.DNP_MiscDb if you have not specified a setting.

NOTE: Although the reference maps do not include Relay Word bit labels, you can use these labels in creating custom maps.

Table D.10 DNP3 Reference Data Map (Sheet 1 of 2)

Object	Labels	Description
Binary Inputs		
01, 02	STFAIL	Relay diagnostic failure (Diag.Hw_AlmLt is latched)
	STWARN	Relay diagnostic warning (Diag.Hw_AlmPul is pulsed)
	STSET	Relay settings change or restart
	EnaLED.Sta–TLED_08.Sta	Relay Word Elements Target Row 0 and Row 1 (see *Table H.1*)
	TLED_01.Set–Meter.Fault	Relay Word elements (see *Table H.1*)
	PF.120ms_LdLg	Power factor leading for three-phase currents
	0	Logical 0
	1	Logical 1

Table D.10 DNP3 Reference Data Map (Sheet 2 of 2)

Object	Labels	Description
Binary Outputs		
10, 12	RB_001.Sta–RB_016.Sta	Remote bits RB_001.Sta–RB_016.Sta
	RB_001.Sta:RB_002.Sta RB_003.Sta:RB_004.Sta ... RB_013.Sta:RB_0014.Sta RB_015.Sta:RB_016.Sta	Remote bit pairs RB_001.Sta–RB_016.Sta
	Comm.TripCmd	Trip breaker command, pulse to trip the breaker
	Comm.ClsCmd	Closer breaker command, pulse to close the breaker
	Comm.TripCmd: Comm.ClsCmd	Trip/close breaker pair
Counters		
20, 22	PCN*x*.CV	SELOGIC counter values (*x* = 001–016)
Analog Inputs		
30, 32, 34	IA.120ms_MagPri–RA_032.Val	Analog quantities from *Appendix I* with an "x" in the DNP3 column
	Dev.SerNum	Serial number
	0	Numeric 0
	1	Numeric 1
Analog Outputs		
40, 41	RA_*x*.Val	Remote analogs (RA_001.Val to RA_032.Val)
	NOOP	No operation, no error

NOTE: All fault information analog inputs contain data from the latest captured event (see Appendix I: Analog Quantities).

Device Attributes (Object 0)

Table D.9 includes the supported Object 0 device attributes and variations. In response to Object 0 requests, the SEL-851 sends attributes that apply to that particular DNP3 session. Because the SEL-851 supports custom DNP3 maps, these values are likely to be different for each session. The SEL-851 uses its internal settings for the following variations:

- Variation 242—FID string
- Variation 243—Part Number
- Variation 245—Dev.Loc setting
- Variation 246—Dev.Id setting
- Variation 247—Dev.Id setting
- Variation 248—Serial Number

Variation 249 shall contain the DNP subset and conformance, "2:2009". Variation 250 shall contain the product model, "SEL-851" and Variation 252 shall contain "SEL."

Binary Inputs

Binary inputs (Objects 1 and 2) are supported. The default variation for both static and event inputs is 2. Only the Read function code (1) is allowed with these objects. All variations are supported. Object 2, variation 3 will be responded to, but will contain no data.

Binary inputs are scanned approximately once per second to generate events. When time is reported with these event objects, it is the time at which the scanner observed the bit change. This can be significantly delayed from when

the original source changed and should not be used for sequence-of-events determination. Binary inputs registered with SER are derived from the SER and carry the time stamp of actual occurrence. Some additional binary inputs are available only to communication protocols such as DNP.

For example, STWARN and STFAIL are derived from the diagnostic task data. Another binary input, STSET, is derived from the SER and carries the time stamp of actual occurrence. Static reads of this input will always show 0.

Binary Outputs

Binary output status (Object 10, Variation 2) is supported. Static reads of points RB_001.Sta–RB_016.Sta and Comm.TripCmd/Comm.ClsCmd respond with the on-line bit set and the state of the requested bit. Reads from control-only binary output points respond with the online bit set and a state of 0.

The SEL-851 supports Control Relay Output Block objects (Object 12, Variation 1). The control relays correspond to the remote bits and other functions as shown previously. Each DNP Control message contains a Trip/Close code (TRIP, CLOSE, or NUL) and an Operation type (PULSE ON, LATCH ON, LATCH OFF, or NUL). The Trip/Close code works with the Operation Type to produce set, clear, and pulse operations.

Control operations differ slightly for single-point controls compared to paired outputs. Paired outputs correspond to the complementary two-output model, and single-point controls follow the complementary latch or activation model. In the complementary two-output model, paired points only support Trip or Close operations, which, when issued, Pulse On the first or second point in the pair, respectively. An operation in progress can be canceled by issuing a NUL Trip/Close Code with a NUL Operation Type. Single output points support both Pulse and Latch operations. See *Control Point Operation on page D.21* for details on control operations.

The Status field is used exactly as defined. All other fields are ignored. A pulse operation is asserted for a single processing interval. Exercise caution if sending multiple remote bit pulses in a single message (i.e., point count > 1), because this can result in some of the pulse commands being ignored and the return of an already active status message. The SEL-851 only honors the first 10 points in an Object 12, Variation 1 request. Any additional points in the request returns the DNP3 status code TOO_MANY_OBJS.

The SEL-851 also supports Pattern Control Blocks (Object 12, Variations 2 and 3) to control multiple binary output points. Variation 2 defines the control type (Trip/Close, Set/Clear, or Pulse) and the range of points to operate. Variation 3 provides a pattern mask that indicates which points in that range should be operated. Object 12, Variations 2 and 3 define the entire control command: the DNP3 master must send both for a successful control. For example, the DNP3 master sends an Object 12, Variation 2 message to request a Trip of the range of indices 0–7. The DNP3 master then sends an Object 12, Variation 3 message with a hexadecimal value of “BB” as the pattern mask (converted to binary notation: 10111011). Read right to left in increasing bit order, the Pattern Block Control command results in a TRIP of indexes 0, 1, 3 to 5, and 7. Multiple binary output point control operations are not guaranteed to occur during the same processing interval.

Control Point Operation

Use the Trip and Close, Latch On/Off and Pulse On operations with Object 12 control relay output block command messages to operate the points shown in *Table D.11*. Pulse operations provide a pulse with duration of one protection processing interval.

Table D.11 SEL-851 Object 12 Control Operations

Label	Close/Pulse On	Trip/Pulse On	Nul/Latch On	Nul/Latch Off	Nul/Pulse On
RB_001.Sta–RB_016.Sta	Pulse Remote Bit RB_001.Sta–RB_016.Sta	Pulse Remote Bit RB_001.Sta–RB_016.Sta	Set Remote Bit RB_001.Sta–RB_016.Sta	Clear Remote Bit RB_001.Sta–RB_016.Sta	Pulse Remote Bit RB_001.Sta–RB_016.Sta
RB_*xxx*.Sta: RB_*yyy*.Sta	Pulse RB_*yyy*.Sta RB_001.Sta–RB_016.Sta	Pulse RB_*xxx*.Sta RB_001.Sta–RB_016.Sta	Pulse RB_*yyy*.Sta RB_001.Sta–RB_016.Sta	Pulse RB_*xxx*.Sta RB_001.Sta–RB_016.Sta	Pulse RB_*yyy*.Sta RB_001.Sta–RB_016.Sta
Comm.TripCmd	Trip Breaker (Pulse Comm.TripCmd)	Trip Breaker (Pulse Comm.TripCmd)	Trip Breaker (Pulse Comm.TripCmd)	No action	Trip Breaker (Pulse Comm.TripCmd)
Comm.ClsCmd	Close Breaker (Pulse Comm.ClsCmd)	Close Breaker (Pulse Comm.ClsCmd)	Close Breaker (Pulse Comm.ClsCmd)	No action	Close Breaker (Pulse Comm.ClsCmd)
Comm.TripCmd: Comm.ClsCmd	Close Breaker (Pulse Comm.ClsCmd)	Trip Breaker (Pulse Comm.TripCmd)	Close Breaker (Pulse Comm.ClsCmd)	Trip Breaker (Pulse Comm.TripCmd)	Close Breaker (Pulse Comm.ClsCmd)

Analog Inputs

Analog Inputs (30) and Analog Change Events (32) are supported as defined in *Table D.9* and *Table D.10*. The Port_02.DNP1_AnaVar (Port_02.DNP*n*_AnaVar for DNP3 LAN/WAN Session *n*) setting defines the default variation for both static and event inputs. Only the Read function code (1) is allowed with these objects.

NOTE: Deadband changes via Object 34 are not stored in nonvolatile memory. Be sure to reissue the Object 34 deadband changes you want to retain after changing DNP port settings, issuing a **STA C** command, or cold-starting the relay (power-cycle).

Unless otherwise indicated, analog values are reported in primary units. See *Appendix I: Analog Quantities* for a list of all available analog inputs.

For all currents, the default scaling is the Port_01.DNP_AmpSca setting on magnitudes and scale factor of 100 on angles. The default deadband for currents is Port_01.DNP_AmpDb on magnitudes and Port_01.DNP_MiscDb on angles. For all voltages, the default scaling is the Port_01.DNP_VoltSca setting on magnitudes and scale factor of 100 on angles. The default deadband for voltages is Port_01.DNP_VoltDb on magnitudes and Port_01.DNP_MiscDb on angles. For all powers and energies, the default scaling is the Port_01.DNP_MiscSca setting and default deadband is Port_01.DNP_MiscDb. For all other quantities, the default scaling is 1 and default deadband is Port_01.DNP_MiscDb.

Default scaling and deadbands can be overridden by per-point scaling and deadband. See *Configurable Data Mapping on page D.22* for more information. Deadbands for analog inputs can also be modified by writing to Object 34.

A deadband check is done after any scaling has been applied. Event class messages are generated whenever an input changes beyond the value given by the appropriate deadband setting. The voltage and current phase angles only generate an event if, in addition to their deadband check, the corresponding magnitude changes beyond its own deadband. Analog inputs are scanned at approximately a one-second rate. All events generated during a scan use the time the scan was initiated.

Configurable Data Mapping

One of the most powerful features of the SEL-851 implementation is the ability to remap DNP3 data and, for analog values, specify per-point scaling and deadbands. Remapping is the process of selecting data from the reference map and organizing it into a data subset optimized for your application. The SEL-851 uses object and point labels, rather than point indices, to streamline the remapping process. This enables you to quickly create a custom map without having to search for each point index in a large reference map.

You can use any of the three available DNP3 maps simultaneously with as many as four unique DNP3 masters. You can map the points to create a custom map with as many as:

- 100 Binary Inputs
- 32 Binary Outputs
- 100 Analog Inputs
- 32 Analog Outputs
- 32 Counters

NOTE: SEL recommends that you configure the Modbus Register Map using SEL Grid Configurator Software or the web server. If you use the ASCII command **SET M**, the setting values are case sensitive.

You can use the **SHOW DNP *x* <Enter>** command to view the DNP data map settings, where *x* is the DNP3 map number from 1 to 3. See *Figure D.3* for an example display of Map 1.

```
=>>SHO DNP 1 <Enter>

DNP Map 1 Settings

Binary Input Map
0: EnaLED.Sta
1: TripLED.Sta
…
12: IN_03.Sta
13: IN_04.Sta

Binary Output Map
0: RB_001.Sta
1: RB_002.Sta
…
14: RB_015.Sta
15: RB_016.Sta

Analog Input Map
0: IA.120ms_MagPri
1: IB.120ms_MagPri
2: IC.120ms_MagPri
3: IGnd.120ms_MagPri
4: IN.120ms_MagPri
5: Freq.120ms_Mag

Analog Output Map
0: RA_001.Val
1: RA_002.Val
…
6: RA_007.Val
7: RA_008.Val

Counter Map
0: PCN_001.CV
1: PCN_007.CV
2: PCN_010.CV

=>>
```

Figure D.3 Sample Response to SHO DNP Command

You can use the command **SET DNP *x***, where ***x*** is the map number, to edit or create custom DNP3 data maps. You can also use SEL Grid Configurator or the web server, which are recommended for this purpose.

Scaling factors allow you to overcome the limitations imposed by the integer nature of the default variations of Objects 30 and 32. For example, the device rounds a value of 11.4 A to 11 A. You can use scaling to include decimal point values by multiplying by a number larger than one. If you use 10 as a scaling factor, 11.4 A is transmitted as 114. You must divide the value by 10 in the master to see the original value including one decimal place.

You can also use scaling to avoid overflowing the 16-bit maximum integer value of 32767. For example, if you have a value that can reach 157834, you cannot send it using DNP3 16-bit analog object variations. You could use a scaling factor of 0.1 so that the maximum value reported is 15783. You can

then multiply the value by 10 in the master to see a value of 157830. You lose some precision as the last digit is rounded off in the scaling process, but you can transmit the scaled value using standard DNP3 Objects 30 and 32.

You can customize the DNP3 analog input map with per-point scaling, and deadband settings. Per-point customization is not required, but class scaling (Port_01.DNP_AmpSca, Port_01.DNP_VoltSca, and Port_01.DNP_MiscSca) and deadband (Port_01.DNP_AmpDb, Port_01.DNP_VoltDb, and Port_01.DNP_MiscDb) settings are applied to indices that do not have per-point entries. Unlike per-point scaling described above, class-level scaling is specified by an integer in the range 0–3 (inclusive), which indicates the number of decimal place shifts. In other words, select 0 to multiply by 1, 1 for 10, 2 for 100, or 3 for 1000.

If it is important to maintain tight data coherency (that is, all data read of a certain type was sampled or calculated at the same time), then group those data together within your custom map. For example, if you want all the currents to be coherent, group points IA.120ms_MagPri, IB.120ms_MagPri, IC.120ms_MagPri, and IGnd.MagPri together in the custom map. If points are not grouped together, they might not come from the same data sample.

The following example describes how to create a custom DNP3 map by point type. The example demonstrates the SEL ASCII command **SET DNP** for each point type, but the entire configuration can be completed without saving changes between point types. To do this, you simply continue entering data and save the entire map at the end. Alternatively, you can use SEL Grid Configurator or the web server to simplify custom data map creation.

Consider a case where you want to set the AI points in a map, as shown in *Table D.12*.

Table D.12 Sample Custom DNP3 AI Map

Desired Point Index	Description	Label	Scaling	Deadband
0	Current, A-phase, magnitude, 120 ms avg	IA.120ms_MagPri	default	default
1	Current, B-phase, magnitude, 120 ms avg	IB.120ms_MagPri	default	default
2	Current, C-phase, magnitude, 120 ms avg	IC.120ms_MagPri	default	default
3	Current, calculated-residual, magnitude, 120 ms avg	IGnd,120ms_MagPri	2	1
4	Current, neutral, magnitude, 120 ms avg	IN.120ms_MagPri	10	1
5	Frequency, 120 ms avg	Freq.120ms_Mag	100	1
6	Real power, 120 ms avg	P.120ms_Mag	0.1	100

To set these points as part of custom Map 1, you can use the command **SET DNP 1 AI_00 TERSE <Enter>** command as shown in *Figure D.4*.

```
=>>SET DNP 1 AI_OO TERSE <Enter>

DNP Map 1 Settings

Analog Input Map

O: NA
 ? IA.12Oms_MagPri

1: NA
 ? IB.12Oms_MagPri
2: NA
 ? IC.12Oms_MagPri
3: NA
 ? IGnd.12Oms_MagPri:2:1
4: NA
 ? IN.12Oms_MagPri:1O:1
5: NA
 ? Freq.12Oms_Mag:1OO:1
6:
 ? P.12Oms_Mag:0.1:1OO
7:
 ? end
Save Changes (Y,N)? y
Settings Saved

=>>
```

Figure D.4 Sample Custom DNP3 AI Map Settings

You can also use SEL Grid Configurator to enter the above AI map settings as shown in the screen capture in *Figure D.5*. Enter scaling and deadband settings in the same pop-up dialog used to select the AI point, as shown in *Figure D.6*.

Figure D.5 Analog Input Map Entry in SEL Grid Configurator Software

Index	Element	Deadband	Scale	Description
0	IA.120ms_Ma...			Current, A-phase, magnitude, 120 ms avg (A pri)
1	IB.120ms_M...			Current, B-phase, magnitude, 120ms avg (A pri)
2	IC.120ms_Ma...			Current, C-phase, magnitude, 120 ms avg (A pri)
3	IGnd.120ms_...			Current, Calculated-residual, magnitude, 120 ms avg (A pri)
4	IN.120ms_M...			Current, Neutral, magnitude, 120 ms avg (A pri)
5	Freq.120ms_...			Frequency, 120 ms avg (Hz)
6	P.120ms_Mag	15	1.000	3-phase real power, 120 ms avg (kW pri)
7				
8				
9				
10				
11				

Figure D.6 AI Point, Scaling and Deadband in SEL Grid Configurator Software

The **SET DNP *x* AO_00<Enter>** command allows you to populate the DNP analog output map with any of the 32 remote analogs (RA_001.Val–RA_032.Val) or the NOOP variable as shown in *Figure D.7*.

```
=>>SET DNP 1 AO_OO TERSE <Enter>

DNP Map 1 Settings

Analog Output Map

O: NA
 ? RA_OO1.Val
1: NA
 ? RA_OO3.Val
2: NA
 ? NOOP
3: NA
 ? RA_O1O.Val
4: NA
 ? end
Save Changes (Y,N)? y
Settings Saved

=>>
```

Figure D.7 Sample Custom DNP3 AO Map Settings

You can also use SEL Grid Configurator to enter the AO map settings as shown in the screen capture in *Figure D.8*.

Figure D.8 Analog Output Map Entry in SEL Grid Configurator Software

The **SET DNP *x* CO_00 <Enter>** command allows you to populate the DNP counter map with per-point deadbands. Entering these settings is similar to defining the analog input map settings.

Use the command **SET DNP *x* BO_00 TERSE <Enter>** to change the binary output Map *x* as shown in *Figure D.9*. You can populate the custom BO map with any of the 16 remote bits (RB_001.Sta–RB_016.Sta). Define bit pairs in BO maps by including a colon (:) between the bit labels.

```
=>>SET DNP 1 BO_00 TERSE <Enter>

DNP Map 1 Settings

Binary Output Map

0: RB_001.Sta
 ?
1: RB_002.Sta
 ?
2: RB_003.Sta
 ? END

=>>
```

Figure D.9 Sample Custom DNP3 BO Map Settings

You can also use SEL Grid Configurator to enter the BO map settings as shown in the screen capture in *Figure D.10*.

Figure D.10 Binary Output Map Entry in SEL Grid Configurator Software

The binary input (BI) maps are modified in a similar manner, but pairs are not allowed.

Appendix E

Modbus Communications

Overview

This appendix describes the Modbus RTU and TCP communications features supported by the SEL-851 Feeder Protection Relay. Complete specifications for the Modbus protocol are available from the Modbus user's group website at modbus.org.

The SEL-851 allows as many as two simultaneous Modbus sessions on the Ethernet port and one on the serial ports. The SEL-851 Modbus communication allows a Modbus master device to do the following:

- Acquire metering, monitoring, and event data from the relay.
- Control SEL-851 output contacts and remote bits.
- Read and set the time and date.
- Reset targets, demand and peak data, and event history data.

Enable Modbus TCP protocol with the Ethernet port setting Port_02.Modbus_Ena. The master IP address for each session is selected with the Ethernet port settings Port_02.Modbus_MastIP1 and Port_02.Modbus_MastIP2. The Master IP address 0.0.0.0 is a valid entry and is used to accept a connection from any master. Use caution when using this address as any Modbus master may connect to the Ethernet port through this connection. When a Modbus TCP master attempts to connect, the relay will first search the valid master IP addresses. If no matching Modbus master IP address is found, and one of the Port_02.Modbus_MastIP*x* addresses is 0.0.0.0, the master will be allowed to connect through that connection. The TCP port number is the Modbus TCP registered Port 502. Modbus TCP uses the device IP address as the Modbus identifier and accesses the data in the relay using the same function codes and data maps as Modbus RTU. The time-out settings, Port_02.Modbus_TmOut1 and Port_02.Modbus_TmOut2, will cause the relay to close a Modbus session if no communication is received from the master within the setting time.

Modbus RTU is a binary protocol that permits communication between a single master device and multiple slave devices. The communication is half duplex—only one device transmits at a time. The master transmits a binary command that includes the address of the desired slave device (port setting Port_01.Modbus_SlaveID). All of the slave devices receive the message, but only the slave device with the matching address responds.

Enable Modbus RTU protocol with the serial port settings. When Modbus RTU protocol is enabled, the relay switches the port to Modbus RTU protocol and deactivates the ASCII protocol.

Communications Protocol

Modbus RTU Queries

Modbus master devices initiate all exchanges by sending a query. The query format for Modbus RTU consists of the fields shown in *Table E.1*.

Table E.1 Modbus Query Fields

Field	Number of Bytes
Slave Device Address	1 byte
Function Code	1 byte
Data Region	0–251 bytes
Cyclic Redundancy Check (CRC)	2 bytes

The SEL-851 serial port Port_01.Modbus_SlaveID setting defines the device address. Set this value to a unique number for each device on the Modbus network. For Modbus RTU communication to operate properly, no two slave devices may have the same address.

The cyclic redundancy check detects errors in the received data. If an error is detected, the relay discards the packet.

Modbus TCP Queries

The Modbus request or response is encapsulated when carried on a Modbus TCP/IP network. A dedicated header used on TCP/IP identifies the Modbus Application Data Unit (ADU). The header, called the MBAP (Modbus Application Protocol header), contains the fields shown in *Table E.2*.

Table E.2 Modbus TCP Header Fields

Field	Number of Bytes
Transaction Identifier	2 Bytes
Protocol Identifier	2 Bytes (0 = MODBUS protocol)
Length	2 Bytes
Unit Identifier	1 Byte

The Modbus TCP Message consists of the MBAP Header, followed by the Modbus function code and the data supporting the function code. The Modbus TCP message does not contain the 2 byte CRC that is included in the RTU message, as the error checking is accomplished through TCP. Otherwise the data following the MBAP header is identical to the Modbus RTU message.

The remainder of this section will cover the Modbus Function codes in terms of the Modbus RTU protocol.

Modbus Responses

The slave device sends a response message after it performs the action the query specifies. If the slave cannot execute the query command for any reason, it sends an error response. Otherwise, the slave device response is formatted similarly to the query and includes the slave address, function code, data (if applicable), and a cyclic redundancy check value.

Supported Modbus Function Codes

The SEL-851 supports the Modbus function codes shown in *Table E.3*.

Table E.3 SEL-851 Modbus Function Codes

Codes	Description
01h	Read Discrete Output Coil Status
02h	Read Discrete Input Status
03h	Read Holding Registers
04h	Read Input Registers
05h	Force Single Coil
06h	Preset Single Register
08h	Diagnostic Command
10h	Preset Multiple Registers

Modbus Exception Responses

The SEL-851 sends an exception code under the conditions described in *Table E.4*.

Table E.4 SEL-851 Modbus Exception Codes

Exception Code	Error Type	Description
1	Illegal Function Code	The received function code is either undefined or unsupported.
2	Illegal Data Address	The received command contains an unsupported address in the data field.
3	Illegal Data Value	The received command contains a value that is out of range.
4	Device Error	The SEL-851 is in the wrong state for the function a query specifies. The relay is unable to perform the action specified by a query (i.e., cannot write to a read-only register, device is disabled, etc.).
6	Busy	The device is unable to process the command at this time because of a busy resource.

In the event that any of the errors listed occur, the relay assembles a response message that includes the exception code in the data field. The relay sets the most significant bit in the function code field to indicate to the master that the data field contains an error code, instead of the required data.

Cyclic Redundancy Check

The SEL-851 calculates a 2-byte CRC value through use of the device address, function code, and data region. It appends this value to the end of every Modbus RTU response. When the master device receives the response, it recalculates the CRC. If the calculated CRC matches the CRC sent by the SEL-851, the master device uses the data received. If there is no match, the check fails and the message is ignored. The devices use a similar process when the master sends queries.

01h Read Discrete Output Coil Status Command

Use function code 01h to read the On/Off status of the selected bits (coils) (see the Output Coils shown in *Table E.15*). The SEL-851 coil addresses start at 0. The coil status is packed one coil per bit of the data field. The Least Significant Bit (LSB) of the first data byte contains the starting coil address in the query. The other coils follow towards the high order end of this byte and from low order to high order in subsequent bytes.

Table E.5 01h Read Discrete Output Coil Status Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (01h)
2 bytes	Address of the first bit
2 bytes	Number of bits to read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (01h)
1 byte	Bytes of data (*n*)
n bytes	Data
2 bytes	CRC-16

To build the response, the SEL-851 calculates the number of bytes required to contain the number of bits requested. If the number of bits requested is not evenly divisible by eight, the device adds one more byte to maintain the balance of bits, padded by zeros to make an even byte. *Table E.15* includes the coil number and lists all possible coils (identified as Outputs and Remote bits) available in the device. The relay responses to errors in the query are shown in *Table E.6*.

Table E.6 Responses to 01h Read Discrete Output Coil Query Errors

Error	Error Code Returned	Communications Counter Increments
Invalid bit to read	Illegal Data Address (02h)	Invalid Address
Invalid number of bits to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

02h Read Input Status Command

Use function code 02h to read the On/Off status of the selected bits (inputs), as shown in *Table E.7*. Input addresses start at 0. The input status is packed one input per bit of the data field. The LSB of the first data byte contains the starting input address in the query. The other inputs follow towards the high order end of this byte, and from low order to high order in subsequent bytes.

Table E.7 02h Read Input Status Command (Sheet 1 of 2)

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (02h)
2 bytes	Address of the first bit

Table E.7 02h Read Input Status Command (Sheet 2 of 2)

Bytes	Field
2 bytes	Number of bits to read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (02h)
1 byte	Bytes of data (*n*)
n bytes	Data
2 bytes	CRC-16

To build the response, the device calculates the number of bytes required to contain the number of bits requested. If the number of bits requested is not evenly divisible by eight, the device adds one more byte to maintain the balance of bits, padded by zeros to make an even byte.

In each row, the input numbers are assigned from the right-most input to the left-most input (i.e., input address 15 is TLED_01.Sta and input address 7 is EnaLED.Sta). Input addresses start at 0000. *Table E.8* includes the input address in decimal and hexadecimal and lists all possible inputs (Relay Word bits) available in the device.

Table E.8 02h SEL-851 Inputs[a] (Sheet 1 of 3)

Discrete Input Address in Decimal	Discrete Input Address in Hex	Function Code Supported	Discrete Address Description	Notes
0–7	0–7	2	Relay Element Status Row 0	The Address numbers are assigned from the right-most Address to the left-most Address in the Relay row as shown in the SEL-851 example below. Address 7 = EnaLED.Sta Address 6 = TripLED.Sta Address 5 = * Address 4 = * Address 3 = * Address 2 = * Address 1 = * Address 0 = *
8–15	8–F	2	Relay Element Status Row 1	Address 15 = TLED_01.Sta Address 14 = TLED_02.Sta Address 13 = TLED_03.Sta Address 12 = TLED_04.Sta Address 11 = TLED_05.Sta Address 10 = TLED_06.Sta Address 9 = TLED_07.Sta Address 8 = TLED_08.Sta
16–23	10–17	2	Relay Element Status Row 2	
24–31	18–1F	2	Relay Element Status Row 3	
32–39	20–27	2	Relay Element Status Row 4	
40–47	28–2F	2	Relay Element Status Row 5	
48–55	30–37	2	Relay Element Status Row 6	
56–63	38–3F	2	Relay Element Status Row 7	

Table E.8 02h SEL-851 Inputs[a] (Sheet 2 of 3)

Discrete Input Address in Decimal	Discrete Input Address in Hex	Function Code Supported	Discrete Address Description	Notes
64–71	40–47	2	Relay Element Status Row 8	
72–79	48–4F	2	Relay Element Status Row 9	
80–87	50–57	2	Relay Element Status Row 10	
88–95	58–5F	2	Relay Element Status Row 11	
96–103	60–67	2	Relay Element Status Row 12	
104–111	68–6F	2	Relay Element Status Row 13	
112–119	70–77	2	Relay Element Status Row 14	
120–127	78–7F	2	Relay Element Status Row 15	
128–135	80–87	2	Relay Element Status Row 16	
136–143	88–8F	2	Relay Element Status Row 17	
144–151	90–97	2	Relay Element Status Row 18	
152–159	98–9F	2	Relay Element Status Row 19	
160–167	A0–A7	2	Relay Element Status Row 20	
168–175	A8–AF	2	Relay Element Status Row 21	
176–183	B0–B7	2	Relay Element Status Row 22	
184–191	B8–BF	2	Relay Element Status Row 23	
192–199	C0–C7	2	Relay Element Status Row 24	
200–207	C8–CF	2	Relay Element Status Row 25	
208–215	D0–D7	2	Relay Element Status Row 26	
216–223	D8–DF	2	Relay Element Status Row 27	
224–231	E0–E7	2	Relay Element Status Row 28	
232–239	E8–EF	2	Relay Element Status Row 29	
240–247	F0–F7	2	Relay Element Status Row 30	
248–255	F8–FF	2	Relay Element Status Row 31	
256–263	100–107	2	Relay Element Status Row 32	
264–271	108–10F	2	Relay Element Status Row 33	
272–279	110–117	2	Relay Element Status Row 34	
280–287	118–11F	2	Relay Element Status Row 35	
288–295	120–127	2	Relay Element Status Row 36	
296–303	128–12F	2	Relay Element Status Row 37	
304–311	130–137	2	Relay Element Status Row 38	
312–319	138–13F	2	Relay Element Status Row 39	
320–327	140–147	2	Relay Element Status Row 40	
328–335	148–14F	2	Relay Element Status Row 41	
336–343	150–157	2	Relay Element Status Row 42	
344–351	158–15F	2	Relay Element Status Row 43	
352–359	160–167	2	Relay Element Status Row 44	
360–367	168–16F	2	Relay Element Status Row 45	
368–375	170–177	2	Relay Element Status Row 46	
376–383	178–17F	2	Relay Element Status Row 47	
384–391	180–187	2	Relay Element Status Row 48	
392–399	188–18F	2	Relay Element Status Row 49	

Table E.8 02h SEL-851 Inputs[a] (Sheet 3 of 3)

Discrete Input Address in Decimal	Discrete Input Address in Hex	Function Code Supported	Discrete Address Description	Notes
400–407	190–197	2	Relay Element Status Row 50	
408–415	198–19F	2	Relay Element Status Row 51	
416–423	1A0–1A7	2	Relay Element Status Row 52	
424–431	1A8–1AF	2	Relay Element Status Row 53	
432–439	1B0–1B7	2	Relay Element Status Row 54	
440–447	1B8–1BF	2	Relay Element Status Row 55	
448–455	1C0–1C7	2	Relay Element Status Row 56	
456–463	1C8–1CF	2	Relay Element Status Row 57	
464–471	1D0–1D7	2	Relay Element Status Row 58	
472–479	1D8–1DF	2	Relay Element Status Row 59	
480–487	1E0–1E7	2	Relay Element Status Row 60	
488–495	1E8–1EF	2	Relay Element Status Row 61	
496–503	1F0–1F7	2	Relay Element Status Row 62	
504–511	1F8–1FF	2	Relay Element Status Row 63	
512–519	200–207	2	Relay Element Status Row 64	
520–527	208–20F	2	Relay Element Status Row 65	
528–535	210–217	2	Relay Element Status Row 66	
536–543	218–21F	2	Relay Element Status Row 67	Reserved for future use
544–551	220–227	2	Relay Element Status Row 68	Reserved for future use
552–559	228–22F	2	Relay Element Status Row 69	Reserved for future use
560–567	230–237	2	Relay Element Status Row 70	Reserved for future use
568–575	238–23F	2	Relay Element Status Row 71	Reserved for future use
576–583	240–247	2	Relay Element Status Row 72	Reserved for future use
584–591	248–24F	2	Relay Element Status Row 73	Reserved for future use
592–599	250–257	2	Relay Element Status Row 74	Reserved for future use
600–607	258–25F	2	Relay Element Status Row 75	Reserved for future use

[a] See Appendix H: Relay Word Bits for relay element row numbers and definitions.

The relay responses to errors in the query are shown in *Table E.9*.

Table E.9 Responses to 02h Read Input Query Errors

Error	Error Code Returned	Communications Counter Increments
Invalid bit to read	Illegal Data Address (02h)	Invalid Address
Invalid number of bits to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

03h Read Holding Register Command

Use function code 03h to read directly from the Modbus Register Map shown in *Table E.23*. Use the **SET M** command (see *User-Defined Modbus Data Region and SET M Command*) to configure the map using the register label names shown in *Table E.23*. You can read a maximum of 125 registers at once with this function code. Most masters use 4X references with this function code.

Table E.10 03h Read Holding Register Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (03h)
2 bytes	Starting Register Address
2 bytes	Number of Registers to Read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (03h)
1 byte	Bytes of data (*n*)
n bytes	Data (2–250)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.11*.

Table E.11 Responses to 03h Read Holding Register Query Errors

Error	Error Code Returned	Communications Counter Increments
Illegal register to read	Illegal Data Address (02h)	Invalid Address
Illegal number of registers to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

04h Read Input Register Command

Use function code 04h to read directly from the Modbus Register Map shown in *Table E.23*. Use the **SET M** command (see *User-Defined Modbus Data Region and SET M Command*) to configure the map using the register label names shown in *Table E.23*. You can read a maximum of 125 registers at once with this function code. Most masters use 3X references with this function code.

Table E.12 04h Read Input Register Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (04h)
2 bytes	Starting Register Address
2 bytes	Number of Registers to Read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (04h)
1 byte	Bytes of data (*n*)
n bytes	Data (2–250)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.13*.

Table E.13 Responses to 04h Read Input Register Query Errors

Error	Error Code Returned	Communications Counter Increments
Illegal register to read	Illegal Data Address (02h)	Invalid Address
Illegal number of registers to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

05h Force Single Coil Command

Use function code 05h to set or clear a coil. The command response is identical to the command request shown in *Table E.14*.

Table E.14 05h Force Single Coil Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (05h)
2 bytes	Coil Reference
1 byte	Operation Code (FF for bit set, 00 for bit clear)
1 byte	Placeholder (00)
2 bytes	CRC-16

Table E.15 lists the coil numbers supported by the SEL-851. The physical coils (coils 00–03) are self-resetting. Pulsing a Set remote bit (decimal addresses 12 through 19) causes the remote bit to be cleared at the end of the pulse.

Table E.15 01h, 05h SEL-851 Output Coils (Sheet 1 of 3)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Description	Coil Function	Duration
0	0	1,5	OUT_01.Sta[a]	Pulse	1 second
1	1	1,5	OUT_02.Sta [a]	Pulse	1 second
2	2	1,5	OUT_03.Sta [a]	Pulse	1 second
3	3	1,5	OUT_04.Sta [a]	Pulse	1 second
4	4	1,5	OUT_05.Sta [a]	Pulse	1 second
5	5	1,5	RB_001.Sta	Set/Clear	
6	6	1,5	RB_002.Sta	Set/Clear	
7	7	1,5	RB_003.Sta	Set/Clear	
8	8	1,5	RB_004.Sta	Set/Clear	
9	9	1,5	RB_005.Sta	Set/Clear	
10	A	1,5	RB_006.Sta	Set/Clear	
11	B	1,5	RB_007.Sta	Set/Clear	
12	C	1,5	RB_008.Sta	Set/Clear	
13	D	1,5	RB_009.Sta	Set/Clear	
14	E	1,5	RB_010.Sta	Set/Clear	
15	F	1,5	RB_011.Sta	Set/Clear	
16	10	1,5	RB_012.Sta	Set/Clear	
17	11	1,5	RB_013.Sta	Set/Clear	

Table E.15 01h, 05h SEL-851 Output Coils (Sheet 2 of 3)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Description	Coil Function	Duration
18	12	1,5	RB_014.Sta	Set/Clear	
19	13	1,5	RB_015.Sta	Set/Clear	
20	14	1,5	RB_016.Sta	Set/Clear	
21	15	1,5	RB_001.Sta	Pulse[b]	Pulse RB_001.Sta (1 SELOGIC processing interval)
22	16	1,5	RB_002.Sta	Pulse[b]	Pulse RB_002.Sta (1 SELOGIC processing interval)
23	17	1,5	RB_003.Sta	Pulse[b]	Pulse RB_003.Sta (1 SELOGIC processing interval)
24	18	1,5	RB_004.Sta	Pulse[b]	Pulse RB_004.Sta (1 SELOGIC processing interval)
25	19	1,5	RB_005.Sta	Pulse[b]	Pulse RB_005.Sta (1 SELOGIC processing interval)
26	1A	1,5	RB_006.Sta	Pulse[b]	Pulse RB_006.Sta (1 SELOGIC processing interval)
27	1B	1,5	RB_007.Sta	Pulse[b]	Pulse RB_007.Sta (1 SELOGIC processing interval)
28	1C	1,5	RB_008.Sta	Pulse[b]	Pulse RB_008.Sta (1 SELOGIC processing interval)
29	1D	1,5	RB_009.Sta	Pulse[b]	Pulse RB_009.Sta (1 SELOGIC processing interval)
30	1E	1,5	RB_010.Sta	Pulse[b]	Pulse RB_010.Sta (1 SELOGIC processing interval)
31	1F	1,5	RB_011.Sta	Pulse[b]	Pulse RB_011.Sta (1 SELOGIC processing interval)
32	20	1,5	RB_012.Sta	Pulse[b]	Pulse RB_012.Sta (1 SELOGIC processing interval)
33	21	1,5	RB_013.Sta	Pulse[b]	Pulse RB_013.Sta (1 SELOGIC processing interval)
34	22	1,5	RB_014.Sta	Pulse[b]	Pulse RB_014.Sta (1 SELOGIC processing interval)
35	23	1,5	RB_015.Sta	Pulse[b]	Pulse RB_015.Sta (1 SELOGIC processing interval)
36	24	1,5	RB_016.Sta	Pulse[b]	Pulse RB_016.Sta (1 SELOGIC processing interval)
37	25	1,5	Comm.ClsCmd		CLOSE command over communications (1 SELOGIC processing interval)
38	26	1,5	Comm.TripCmd		TRIP command over communications (1 SELOGIC processing interval)
39	27	1,5	Trip.TrgtRstSta		Reset targets
40	28	1,5	Event.Rst		Reset event history
41	29	1,5	Meter.Dmd_Rst		Reset demand and peak demand data
42	2A	1,5	Meter.MaxMin_Rst		Reset max/min data
43	2B	1,5	Meter.En_Rst		Reset energy data
44	2C	1,5	Diag.Hw_Rst		Reset hardware alarm
45	2D	1,5	Reserved		
46	2E	1,5	Reserved		
47	2F	1,5	Reserved		

Table E.15 01h, 05h SEL-851 Output Coils (Sheet 3 of 3)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Description	Coil Function	Duration
48	30	1,5	Reserved		
49	31	1,5	Reserved		
50	32	1,5	Reserved		
51	33	1,5	Reserved		
52	34	1,5	Reserved		
53	35	1,5	Reserved		

[a] Coils are also controlled by the SELOGIC control equation of the same name.
[b] Pulsing a remote bit that is already set will cause the remote bit to be cleared at the end of the pulse.

The device responses to errors in the query are shown in *Table E.16*.

Table E.16 Responses to 05h Force Single Coil Query Errors

Error	Error Code Returned	Communications Counter Increments
Invalid bit (coil)	Illegal Data Address (02h)	Invalid Address
Invalid bit state requested	Illegal Data Value (03h)	Illegal Register
Format Error	Illegal Data Value (03h)	Bad Packet Format

06h Preset Single Register Command

The SEL-851 uses this function to allow a Modbus master to write directly to a database register. Refer to the Modbus Quantities Table in *Table E.23* for a list of registers that can be written by using this function code. The command response is identical to the command request shown in *Table E.17*.

Table E.17 06h Preset Single Register Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (06h)
2 bytes	Register Address
2 bytes	Data
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.18*.

Table E.18 Responses to 06h Preset Single Register Query Errors

Error	Error Code Returned	Communications Counter Increments
Illegal register address	Illegal Data Address (02h)	Invalid Address Illegal Write
Illegal register value	Illegal Data Value (03h)	Illegal Write
Format error	Illegal Data Value (03h)	Bad Packet Format

08h Loopback Diagnostic Command

The SEL-851 uses this function to allow a Modbus master to perform a diagnostic test on the Modbus communications channel and relay. When the subfunction field is 0000h, the relay returns a replica of the received message.

Table E.19 08h Loopback Diagnostic Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field (identical to data in Master request)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.20*.

Table E.20 Responses to 08h Loopback Diagnostic Query Errors

Error	Error Code Returned	Communications Counter Increments
Illegal subfunction code	Illegal Data Value (03h)	Illegal Function Code/Op Code
Format error	Illegal Data Value (03h)	Bad Packet Format

10h Preset Multiple Registers Command

This function code works much like code 06h, except that it allows you to write multiple registers at once, to as many as 100 per operation.

Table E.21 10h Preset Multiple Registers Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (10h)
2 bytes	Starting Address
2 bytes	Number of Registers to Write
1 byte	Number of Bytes of Data (*n*)
n bytes	Data
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (10h)
2 bytes	Starting Address
2 bytes	Number of Registers
2 bytes	CRC-16

The relay responses to errors in the query are shown *Table E.22*.

Table E.22 10h Preset Multiple Registers Query Error Messages

Error	Error Code Returned	Communications Counter Increments
Illegal register to set	Illegal Data Address (02h)	Invalid Address Illegal Write
Illegal number of registers to set	Illegal Data Value (03h)	Illegal Register Illegal Write
Incorrect number of bytes in query data region	Illegal Data Value (03h)	Bad Packet Format Illegal Write
Invalid register data value	Illegal Data Value (03h)	Illegal Write

Bit Operations Using Function Codes 06h and 10h

The SEL-851 includes registers for controlling some of the outputs or resetting data within the relay. See Log.Cmd and Dev.RstDat in *Table E.23*. Use Modbus function codes 06h or 10h to write appropriate flags. Remember that when writing to the Logic command register with output contacts, it is not a bit operation. All the bits in that register need to be written together to reflect the state you want for each of the outputs.

User-Defined Modbus Data Region and SET M Command

The SEL-851 Modbus Register Map defines an area of 250 contiguous addresses whose contents are defined by user-settable labels. This feature allows you to take 250 discrete values from anywhere in the Modbus Quantities Table (*Table E.23*) and place them in contiguous registers that you can then read in a single command. Use the ASCII command **SET M** (or the Modbus User Map settings in SEL Grid Configurator Software or the web server) to define the user map addresses. A default map is provided with the relay. If the default Modbus map is not appropriate or more data are desired, edit the map as required for your application.

NOTE: SEL recommends that you configure the Modbus Register Map using SEL Grid Configurator Software or the web server. If you use the ASCII command **SET M**, the setting values are case sensitive.

To use the user-defined data region, perform the following steps:

Step 1. Define the list of desired quantities (as many as 250). Arrange the quantities in any order that is convenient for you to use.

Step 2. Refer to *Table E.23* for a list of the Modbus labels for each quantity.

Step 3. Use the **SET M** command from the command line or SEL Grid Configurator Modbus User Map to map user registers 001 to 250 (MOD_001 to MOD_250) using the labels in *Table E.23*.

Step 4. Use Modbus function code 03h or 04h to read the desired quantities from addresses 0 through 249 (decimal).

Note that the Modbus addresses begin with zero, which corresponds to **SET M** setting MOD_001.

NOTE: If your master uses 5- or 6-digit address references, add the appropriate number to the Modbus Address provided in Table E.23 when configuring your master. For example, if your master uses 5-digit addressing, add 40001 for holding register operations. For Input register functions, add 30001. If your master uses 6-digit addressing, add 400001 for holding register operations or 300001 for input register functions. The actual address that appears in the address field of the message will be the Modbus Address shown in Table E.23. For example, User Register 1 is address 0000 (see Table E.23 for Modbus register addresses). A master using 6-digit addresses to read a holding register may be configured for address 400001. However, the data address field of the message from the master will contain address 0000.

As each label is entered in a register via the **SET M** command, the relay will increment to the next valid register.

If a label is entered for a 32-bit quantity register (e.g., P.120ms_Mag, Q.120ms_Mag, S.120ms_Mag, PMV_001.Val), the relay will not allow the user to enter a label in the following register. In the example, User Register 15 was previously set to INeg.120ms_MagPri, which is a 16-bit value and consumes one register. By changing the register label to P.120ms_Mag, a 32-bit value, the next register available for setting is User Register 17. User Register 16 needs to be set to NA to proceed and to avoid any error messages.

```
=>>SET M <Enter>
Modbus Settings

User Map Register Settings

15: INeg.12Oms_MagPri
  ? P.12Oms_Mag
16: VC.12Oms_MagPri
  ?
Modbus register not available.
16: VC.12Oms_MagPri
  ? NA
17: PMV_OO1.Val
  ?
18:
  ? NA
19:
  ? IA.12Oms_MagPri
20:
  ?

=>>
```

Table E.23 Modbus Quantities Table (Sheet 1 of 10)

Description	Valid Function Codes	SET M Point Label/ Enums	Default	Number of 16-Bit Registers	Value		Scaling (X1 unless specified)
					Min	Maxs	
Special Quantities							
Constants							
Constant Value	03	0	0	0	0	0	1
Constant Value	03	1	1	0	1	1	1
Relay Information							
Relay Firmware Revision	03	Dev.FwRev	0	1	0	9999	1
Relay Firmware Point Release Version	03	Dev.FwVer	0	1	0	9999	1
Relay Serial Number, Lowest 4 digits	03	Dev.SerNumLow	0	1	0	9999	1
Relay Serial Number, Middle 4 digits	03	Dev.SerNumMid	0	1	0	9999	1
Relay Serial Number, Highest 4 digits	03	Dev.SerNumHi	0	1	0	9999	1
Modbus Device Code	03	Dev.Code	78	1	0	65535	1
Miscellaneous							
No Operation	03/06	NOOP		na	0	65535	1
Reset Bits							
Reset Data Bit 0 = Reset Targets Bit 1 = Reset History Data Bit 2 = Reset Demands Bit 3 = Reset Max/Min Data Bit 4 = Reset Energy Data Bit 5 = Reset Hardware Alarm Bit 6 = Reset Comm Counters Bits 7–15 = Reserved[b]	06	Dev.RstDat[a]	0	1	0	65535	
Date/Time Set							
Set Seconds	03/06	Time.Modbus_s[a]	0	1	0	59	1
Set Minutes	03/06	Time.Modbus_Mn[a]	0	1	0	59	1
Set Hour	03/06	Time.Modbus_Hr[a]	0	1	0	23	1

Table E.23 Modbus Quantities Table (Sheet 2 of 10)

Description	Valid Function Codes	SET M Point Label/ Enums	Default	Number of 16-Bit Registers	Value		Scaling (X1 unless specified)
					Min	Maxs	
Set Day	03/06	Time.Modbus_Day[a]	1	1	1	31	1
Set Month	03/06	Time.Modbus_Mo[a]	1	1	1	12	1
Set Year	03/06	Time.Modbus_Yr[a]	2000	1	2000	2550	1
Historical Data							
No. EVENT LOGS	03	Event.NumOfEve	0	1	0	50	1
FAULT EVENT PRESENT	03	Event.Sta[a]	0	1	0	1	1
LATEST FAULT EVENT ID	03	Event.Id[a]	0	1	0	65535	1
EVENT LOG SEL	03/06	Event.Sel[a]	0	1	0	65535	1
EVENT TIME ss	03	Event.s[a]	0	1	0	59999	1000
EVENT TIME mm	03	Event.Mn[a]	0	1	0	59	1
EVENT TIME hh	03	Event.Hr[a]	0	1	0	23	1
EVENT DAY dd	03	Event.Day[a]	1	1	0	31	1
EVENT DAY mm	03	Event.Mo[a]	1	1	0	12	1
EVENT DAY yy	03	Event.Yr[a]	2000	1	0	9999	1
EVENT TYPE	03	Event.Typ[a]	0	1	0	35	
Bit 0 = TRIP*		Bit 15 = Trigger					
Bit 1 = Arc Flash Trip		Bit 16 = Remote Trip					
Bit 2 = Phase Inst OC Trip		Bit 17 = Local Trip					
Bit 3 = Ground/Neutral Inst OC Trip		Bit 18 = Event Report Trigger					
Bit 4 = Neg Sequence Inst OC Trip		Bit 19 = Undefined Trip					
Bit 5 = Phase Time OC Trip		Bit 20–27 = Reserved					
Bit 6 = Ground/Neutral Time OC Trip							
Bit 7 = Neg Sequence TOC Trip							
Bit 8 = Undervoltage Trip							
Bit 9 = Overvoltage Trip							
Bit 10 = Underfrequency Trip							
Bit 11 = Overfrequency Trip							
Bit 12 = Power Element Trip							
Bit 13 = Power Factor Trip							
Bit 14 = Breaker Failure Trip							
Event Targets	03	Event.Trgt[a]	0	1	0	65535	
Bit 0–5 = Reserved[b]							
Bit 6 = TRIP_LED							
Bit 7 = ENABLED							
Bit 8 = TLED_08							
Bit 9 = TLED_07							
Bit 10 = TLED_06							
Bit 11 = TLED_05							
Bit 12 = TLED_04							
Bit 13 = TLED_03							
Bit 14 = TLED_02							
Bit 15 = TLED_01							
EVENT IA	03	Event.IA_MagPri[a]	0	1	0	65535	1
EVENT IB	03	Event.IB_MagPri[a]	0	1	0	65535	1
EVENT IC	03	Event.IC_MagPri[a]	0	1	0	65535	1

Table E.23 Modbus Quantities Table (Sheet 3 of 10)

Description	Valid Function Codes	SET M Point Label/ Enums	Default	Number of 16-Bit Registers	Value		Scaling (X1 unless specified)
					Min	Maxs	
EVENT IG	03	Event.IGnd_MagPri[a]	0	1	0	65535	1
EVENT IN	03	Event.IN_MagPri[a]	0	1	0	65535	1
EVENT VAB/VAN	03	Event.VAB_MagPri[a]	0	1	0	65535	1
EVENT VBC/VBN	03	Event.VBC_MagPri[a]	0	1	0	65535	1
EVENT VCA/VCN	03	Event.VCA_MagPri[a]	0	1	0	65535	1
EVENT DELTA/WYE 0 = DELTA 1 = WYE	03	Event.VTP_Conn[a]	0	1	0	1	
Event Freq	03	Event.Freq_Mag[a]	6000	1	2000	7000	100
I/O Status							
I/O Status Bit 0 = IN01 STATUS Bit 1 = IN02 STATUS Bit 2 = IN03 STATUS Bit 3 = IN04 STATUS Bit 4 = IN05 STATUS Bit 5 = IN06 STATUS Bit 6 = IN07 STATUS Bit 7 = IN08 STATUS Bit 8 = IN09 STATUS Bit 9 = IN10 STATUS Bit 10 = OUT01 STATUS Bit 11 = OUT02 STATUS Bit 12 = OUT03 STATUS Bit 13 = OUT04 STATUS Bit 14 = OUT05 STATUS Bit 15 = Reserved	03	BIBO.Sta	0	1	0	65535	
Control I/O Commands							
Logic Command Bit 0 = Trip Bit 1 = Close Bits 2–15 = Reserved[b]	06	Comm.Cmd	0	na	0	65535	
Current Data[c]							
IA Current	03	IA.120ms_MagPri	0	1	0	65535	1
IA Angle	03	IA.120ms_Ang	0	1	–1800	1800	10
IB Current	03	IB.120ms_MagPri	0	1	0	65535	1
IB Angle	03	IB.120ms_Ang	0	1	–1800	1800	10
IC Current	03	IC.120ms_MagPri	0	1	0	65535	1
IC Angle	03	IC.120ms_Ang	0	1	–1800	1800	10
IN Current	03	IN.120ms_MagPri	0	1	0	65535	1
IN Angle	03	IN.120ms_Ang	0	1	–1800	1800	10
IG Current	03	IGnd.120ms_MagPri	0	1	0	65535	1
IG Angle	03	IGnd.120ms_Ang	0	1	–1800	1800	10
Pos. Seq. Current I1	03	IPos.120ms_MagPri	0	1	0	65535	1
I1 Angle	03	IPos.120ms_Ang	0	1	–1800	1800	10

Table E.23 Modbus Quantities Table (Sheet 4 of 10)

Description	Valid Function Codes	SET M Point Label/ Enums	Default	Number of 16-Bit Registers	Value		Scaling (X1 unless specified)
					Min	Maxs	
Neg. Seq. Current 3I2	03	INeg.120ms_MagPri	0	1	0	65535	1
I2 Angle	03	INeg.120ms_Ang	0	1	–1800	1800	10
Average Current	03	IAvg.120ms_MagPri	0	1	0	65535	1
Voltage Data							
VAB	03	VAB.120ms_MagPri	0	1	0	65535	1
VAB Angle	03	VAB.120ms_Ang	0	1	–1800	1800	10
VBC	03	VBC.120ms_MagPri	0	1	0	65535	1
VBC Angle	03	VBC.120ms_Ang	0	1	–1800	1800	10
VCA	03	VCA.120ms_MagPri	0	1	0	65535	1
VCA Angle	03	VCA.120ms_Ang	0	1	–1800	1800	10
VAN	03	VA.120ms_MagPri	0	1	0	65535	1
VAN Angle	03	VA.120ms_Ang	0	1	–1800	1800	10
VBN	03	VB.120ms_MagPri	0	1	0	65535	1
VBN Angle	03	VB.120ms_Ang	0	1	–1800	1800	10
VCN	03	VC.120ms_MagPri	0	1	0	65535	1
VCN Angle	03	VC.120ms_Ang	0	1	–1800	1800	10
3V0 Voltage	03	VGnd.120ms_MagPri	0	1	0	65535	1
3V0 Angle	03	VGnd.120ms_Ang	0	1	–1800	1800	10
Pos. Seq. V1	03	VPos.120ms_MagPri	0	1	0	65535	1
V1 Angle	03	VPos.120ms_Ang	0	1	–1800	1800	10
Neg. Seq. Voltage V2	03	VNeg.120ms_MagPri	0	1	0	65535	1
3V2 Angle	03	VNeg.120ms_Ang	0	1	–1800	1800	10
Average Voltage[d]	03	VAvg.120ms_MagPri	0	1	0	65535	1
Power Data							
Real Power	03	P.120ms_Mag	0	2	–2147483648	2147483647	1
Reactive Power	03	Q.120ms_Mag	0	2	–2147483648	2147483647	1
Apparent Power	03	S.120ms_Mag	0	2	–2147483648	2147483647	1
Power Factor	03	PF.120ms_Mag	0	1	–100	100	100
Frequency	03	Freq.120ms_Mag	6000	1	1500	7000	100
Rate of Change of Frequency, 120 ms avg	03	Freq.120ms_DFDMag	0	1	1500	7000	100
RMS Data							
IA RMS	03	IA.RMS_120ms_Pri	0	1	0	65535	1
IB RMS	03	IB.RMS_120ms_Pri	0	1	0	65535	1
IC RMS	03	IC.RMS_120ms_Pri	0	1	0	65535	1
IN RMS	03	IN.RMS_120ms_Pri	0	1	0	65535	1
VA RMS	03	VA.RMS_120ms_Pri	0	1	0	65535	1
VB RMS	03	VB.RMS_120ms_Pri	0	1	0	65535	1
VC RMS	03	VC.RMS_120ms_Pri	0	1	0	65535	1
VAB RMS	03	VAB.RMS_120ms_Pri	0	1	0	65535	1
VBC RMS	03	VBC.RMS_120ms_Pri	0	1	0	65535	1
VCA RMS	03	VCA.RMS_120ms_Pri	0	1	0	65535	1

Table E.23 Modbus Quantities Table (Sheet 5 of 10)

Description	Valid Function Codes	SET M Point Label/ Enums	Default	Number of 16-Bit Registers	Value		Scaling (X1 unless specified)
					Min	Maxs	
Light Data							
LSENS1	03	Light_01.1ms_Mag	0	1	0	1000	1
LSENS2	03	Light_02.1ms_Mag	0	1	0	1000	1
LSENS3	03	Light_03.1ms_Mag	0	1	0	1000	1
LSENS4	03	Light_04.1ms_Mag	0	1	0	1000	1
Energy Data							
REAL ENERGY, 3-PHASE OUT OF BUS	03	MWh.Del	0	2	0	4294967295	1
REAL ENERGY, 3-PHASE RECEIVED	03	MWh.Rec	0	2	0	4294967295	1
REACTIVE ENERGY, 3-PHASE IN TO BUS	03	MVARh.Rec	0	2	0	4294967295	1
REACTIVE ENERGY, 3-PHASE OUT OF BUS	03	MVARh.Del	0	2	0	4294967295	1
APPARENT ENERGY, 3-PHASE	03	MVAh.Mag	0	2	0	4294967295	1
ENERGY RST TIME ss	03	Meter.En_LastRst_s	0	1	0	59999	4
ENERGY RST TIME mm	03	Meter.En_LastRstMn	0	1	0	59	1
ENERGY RST TIME hh	03	Meter.En_LastRstHr	0	1	0	23	1
ENERGY RST TIME dd	03	Meter.En_LastRstDay	1	1	0	31	1
ENERGY RST TIME mm	03	Meter.En_LastRstMo	1	1	0	12	1
ENERGY RST TIME yy	03	Meter.En_LastRstYr	2000	1	0	9999	1
Demand and Peak Demand Data							
IA Demand	03	IA.Dmd	0	1	0	65535	1
IB Demand	03	IB.Dmd	0	1	0	65535	1
IC Demand	03	IC.Dmd	0	1	0	65535	1
Calculated-Residual Current Demand	03	IGnd.Dmd	0	1	0	65535	1
Negative-Sequence Current Demand	03	INeg.Dmd	0	1	0	65535	1
IA Peak Demand	03	IA.PkDmd	0	1	0	65535	1
IB Peak Demand	03	IB.PkDmd	0	1	0	65535	1
IC Peak Demand	03	IC.PkDmd	0	1	0	65535	1
Calculated-Residual Current Peak Demand	03	IGnd.PkDmd	0	1	0	65535	1
Negative-Sequence Current Peak Demand	03	INeg.PkDmd	0	1	0	65535	1
Demand RST Time ss	03	Meter.PkDmd_LastRst_s	0	1	0	59999	1000
Demand RST Time mm	03	Meter.PkDmd_LastRstMn	0	1	0	59	1
Demand RST Time hh	03	Meter.PkDmd_LastRstHr	0	1	0	23	1
Demand RST Time dd	03	Meter.PkDmd_LastRstDay	1	1	0	31	1
Demand RST Time mm	03	Meter.PkDmd_LastRstMo	1	1	0	12	1
Demand RST Time yy	03	Meter.PkDmd_LastRstYr	2000	1	0	9999	1

Table E.23 Modbus Quantities Table (Sheet 6 of 10)

Description	Valid Function Codes	SET M Point Label/ Enums	Default	Number of 16-Bit Registers	Value		Scaling (X1 unless specified)
					Min	Maxs	
MAX/MIN Data							
IA MAX	03	IA.MaxMagPri	0	1	0	65535	1
IB MAX	03	IB.MaxMagPri	0	1	0	65535	1
IC MAX	03	IC.MaxMagPri	0	1	0	65535	1
IN MAX	03	IN.MaxMagPri	0	1	0	65535	1
IG MAX	03	IGnd.MaxMagPri	0	1	0	65535	1
IA MIN	03	IA.MinMagPri	0	1	0	65535	1
IB MIN	03	IB.MinMagPri	0	1	0	65535	1
IC MIN	03	IC.MinMagPri	0	1	0	65535	1
IN MIN	03	IN.MinMagPri	0	1	0	65535	1
IG MIN	03	IGnd.MinMagPri	0	1	0	65535	1
VAB MAX	03	VAB.MaxMagPri	0	1	0	65535	1
VBC MAX	03	VBC.MaxMagPri	0	1	0	65535	1
VCA MAX	03	VCA.MaxMagPri	0	1	0	65535	1
VA MAX	03	VA.MaxMagPri	0	1	0	65535	1
VB MAX	03	VB.MaxMagPri	0	1	0	65535	1
VC MAX	03	VC.MaxMagPri	0	1	0	65535	1
VAB MIN	03	VAB.MinMagPri	0	1	0	65535	1
VBC MIN	03	VBC.MinMagPri	0	1	0	65535	1
VCA MIN	03	VCA.MinMagPri	0	1	0	65535	1
VA MIN	03	VA.MinMagPri	0	1	0	65535	1
VB MIN	03	VB.MinMagPri	0	1	0	65535	1
VC MIN	03	VC.MinMagPri	0	1	0	65535	1
KVA3P MAX	03	S.MaxMag	0	2	–2147483648	2147483647	1
KW3P MAX	03	P.MaxMag	0	2	–2147483648	2147483647	1
KVAR3P MAX	03	Q.MaxMag	0	2	–2147483648	2147483647	1
KVA3P MIN	03	S.MinMag	0	2	–2147483648	2147483647	1
KW3P MIN	03	P.MinMag	0	2	–2147483648	2147483647	1
KVAR3P MIN	03	Q.MinMag	0	2	–2147483648	2147483647	1
FREQ MAX	03	Freq.MaxMag	0	1	1500	7000	100
FREQ MIN	03	Freq.MinMag	0	1	1500	7000	100
MAX/MIN RST TIME ss	03	Meter.MaxMin_LastRst_s	0	1	0	59999	1000
MAX/MIN RST TIME mm	03	Meter.MaxMin_LastRstMn	0	1	0	59	1
MAX/MIN RST TIME hh	03	Meter.MaxMin_LastRstHr	0	1	0	23	1
MAX/MIN RST TIME dd	03	Meter.MaxMin_LastRstDay	1	1	0	31	1
MAX/MIN RST TIME mm	03	Meter.MaxMin_LastRstMo	1	1	0	12	1
MAX/MIN RST TIME yy	03	Meter.MaxMin_LastRstYr	2000	1	0	9999	1
Harmonic Metering Data							
IA THD	03	IA.THD_120ms_Pct		1	0	995	1
IB THD	03	IB.THD_120ms_Pct		1	0	995	1
IC THD	03	IC.THD_120ms_Pct		1	0	995	1
VA THD	03	VA.THD_120ms_Pct		1	0	995	1

Table E.23 Modbus Quantities Table (Sheet 7 of 10)

Description	Valid Function Codes	SET M Point Label/ Enums	Default	Number of 16-Bit Registers	Value		Scaling (X1 unless specified)
					Min	Maxs	
VB THD	03	VB.THD_120ms_Pct		1	0	995	1
VC THD	03	VC.THD_120ms_Pct		1	0	995	1
VAB THD	03	VAB.THD_120ms_Pct		1	0	995	1
VBC THD	03	VBC.THD_120ms_Pct		1	0	995	1
VCA THD	03	VCA.THD_120ms_Pct		1	0	995	1
Device Status 0 = OK 1 = WARN 2 = FAIL							
RAM Status	03	Diag.RAM	0	1	0	2	
ROM Status	03	Diag.ROM	0	1	0	2	
CR_RAM Status	03	Diag.CritRAM	0	1	0	2	
NON_VOL Status	03	Diag.NVM	0	1	0	2	
HMI Status	03	Diag.HMI	0	1	0	2	
CLOCK Status	03	Diag.Clk	0	1	0	2	
CLK_BAT Status	03	Diag.ClkBat	0	1	0	2	
AF Status	03	Diag.AFD	0	1	0	2	
PS Status	03	Diag.PwrSup	0	1	0	2	
FPGA Status	03	Diag.FPGA	0	1	0	2	
DAQ Status	03	Diag.DAQ	0	1	0	2	
IA Status	03	Diag.IA	0	1	0	2	
IB Status	03	Diag.IB	0	1	0	2	
IC Status	03	Diag.IC	0	1	0	2	
IN Status	03	Diag.IN	0	1	0	2	
VA Status	03	Diag.VA	0	1	0	2	
VB Status	03	Diag.VB	0	1	0	2	
VC Status	03	Diag.VC	0	1	0	2	
Relay Status 0 = Enabled 1 = Disabled	03	Diag.Dev	0	1	0	1	
Protection Math Variables							
Math Variable PMV_001	03	PMV_001.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_002	03	PMV_002.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_003	03	PMV_003.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_004	03	PMV_004.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_005	03	PMV_005.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_006	03	PMV_006.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_007	03	PMV_007.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_008	03	PMV_008.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_009	03	PMV_009.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_010	03	PMV_010.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_011	03	PMV_011.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_012	03	PMV_012.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_013	03	PMV_013.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_014	03	PMV_014.Val	0	2	–1677721599	1677721599	100

Table E.23 Modbus Quantities Table (Sheet 8 of 10)

Description	Valid Function Codes	SET M Point Label/ Enums	Default	Number of 16-Bit Registers	Value		Scaling (X1 unless specified)
					Min	Maxs	
Math Variable PMV_015	03	PMV_015.Val	0	2	–1677721599	1677721599	100
Math Variable PMV_016	03	PMV_016.Val	0	2	–1677721599	1677721599	100
Protection Counters							
Counter PCN_001	03	PCN_001.CV	0	1	0	65000	1
Counter PCN_002	03	PCN_002.CV	0	1	0	65000	1
Counter PCN_003	03	PCN_003.CV	0	1	0	65000	1
Counter PCN_004	03	PCN_004.CV	0	1	0	65000	1
Counter PCN_005	03	PCN_005.CV	0	1	0	65000	1
Counter PCN_006	03	PCN_006.CV	0	1	0	65000	1
Counter PCN_007	03	PCN_007.CV	0	1	0	65000	1
Counter PCN_008	03	PCN_008.CV	0	1	0	65000	1
Counter PCN_009	03	PCN_009.CV	0	1	0	65000	1
Counter PCN_010	03	PCN_010.CV	0	1	0	65000	1
Counter PCN_011	03	PCN_011.CV	0	1	0	65000	1
Counter PCN_012	03	PCN_012.CV	0	1	0	65000	1
Counter PCN_013	03	PCN_013.CV	0	1	0	65000	1
Counter PCN_014	03	PCN_014.CV	0	1	0	65000	1
Counter PCN_015	03	PCN_015.CV	0	1	0	65000	1
Counter PCN_016	03	PCN_016.CV	0	1	0	65000	1
Remote Analogs							
Remote Analog RA001	03/06	RA_001.Val	0	2	–9999999	9999999	100
Remote Analog RA002	03/06	RA_002.Val	0	2	–9999999	9999999	100
Remote Analog RA003	03/06	RA_003.Val	0	2	–9999999	9999999	100
Remote Analog RA004	03/06	RA_004.Val	0	2	–9999999	9999999	100
Remote Analog RA005	03/06	RA_005.Val	0	2	–9999999	9999999	100
Remote Analog RA006	03/06	RA_006.Val	0	2	–9999999	9999999	100
Remote Analog RA007	03/06	RA_007.Val	0	2	–9999999	9999999	100
Remote Analog RA008	03/06	RA_008.Val	0	2	–9999999	9999999	100
Remote Analog RA009	03/06	RA_009.Val	0	2	–9999999	9999999	100
Remote Analog RA010	03/06	RA_010.Val	0	2	–9999999	9999999	100
Remote Analog RA011	03/06	RA_011.Val	0	2	–9999999	9999999	100
Remote Analog RA012	03/06	RA_012.Val	0	2	–9999999	9999999	100
Remote Analog RA013	03/06	RA_013.Val	0	2	–9999999	9999999	100
Remote Analog RA014	03/06	RA_014.Val	0	2	–9999999	9999999	100
Remote Analog RA015	03/06	RA_015.Val	0	2	–9999999	9999999	100
Remote Analog RA016	03/06	RA_016.Val	0	2	–9999999	9999999	100
Remote Analog RA017	03/06	RA_017.Val	0	2	–9999999	9999999	100
Remote Analog RA018	03/06	RA_018.Val	0	2	–9999999	9999999	100
Remote Analog RA019	03/06	RA_019.Val	0	2	–9999999	9999999	100
Remote Analog RA020	03/06	RA_020.Val	0	2	–9999999	9999999	100
Remote Analog RA021	03/06	RA_021.Val	0	2	–9999999	9999999	100
Remote Analog RA022	03/06	RA_022.Val	0	2	–9999999	9999999	100

Table E.23 Modbus Quantities Table (Sheet 9 of 10)

Description	Valid Function Codes	SET M Point Label/ Enums	Default	Number of 16-Bit Registers	Value		Scaling (X1 unless specified)
					Min	Maxs	
Remote Analog RA023	03/06	RA_023.Val	0	2	–9999999	9999999	100
Remote Analog RA024	03/06	RA_024.Val	0	2	–9999999	9999999	100
Remote Analog RA025	03/06	RA_025.Val	0	2	–9999999	9999999	100
Remote Analog RA026	03/06	RA_026.Val	0	2	–9999999	9999999	100
Remote Analog RA027	03/06	RA_027.Val	0	2	–9999999	9999999	100
Remote Analog RA028	03/06	RA_028.Val	0	2	–9999999	9999999	100
Remote Analog RA029	03/06	RA_029.Val	0	2	–9999999	9999999	100
Remote Analog RA030	03/06	RA_030.Val	0	2	–9999999	9999999	100
Remote Analog RA031	03/06	RA_031.Val	0	2	–9999999	9999999	100
Remote Analog RA032	03/06	RA_032.Val	0	2	–9999999	9999999	100
Modbus Communication Counters							
Num Messages Received	03	MSGRCD[b]	0	1	0	65535	1
Num Msgs to Other devices (Other ID)	03	MSGOID[b]	0	1	0	65535	1
Illegal Address	03	ILLADDR[b]	0	1	0	65535	1
Bad CRC	03	BADCRC[b]	0	1	0	65535	1
Uart Error	03	UARTER[b]	0	1	0	65535	1
Illegal Function	03	ILLFUNC[b]	0	1	0	65535	1
Illegal Register	03	ILLREG[b]	0	1	0	65535	1
Illegal Data	03	ILLDATA[b]	0	1	0	65535	1
Bad Packet Format	03	BADPF[b]	0	1	0	65535	1
Bad Packet Length	03	BADPL[b]	0	1	0	65535	1
Relay Elements[e]							
ROW 0—ROW 75	03	ROW_0–ROW_75	0	1	0	255	
Fixed GOOSE Analogs							
Fixed GOOSE Analog FG1RA01	03	FG_P2_01.RxAna01	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG1RA02	03	FG_P2_01.RxAna02	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG1RA03	03	FG_P2_01.RxAna03	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG1RA04	03	FG_P2_01.RxAna04	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG1RA05	03	FG_P2_01.RxAna05	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG1RA06	03	FG_P2_01.RxAna06	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG1RA07	03	FG_P2_01.RxAna07	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG1RA08	03	FG_P2_01.RxAna08	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG2RA01	03	FG_P2_02.RxAna01	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG2RA02	03	FG_P2_02.RxAna02	0	2	–2147483648	2147483647	0.01

Table E.23 Modbus Quantities Table (Sheet 10 of 10)

Description	Valid Function Codes	SET M Point Label/ Enums	Default	Number of 16-Bit Registers	Value		Scaling (X1 unless specified)
					Min	Maxs	
Fixed GOOSE Analog FG2RA03	03	FG_P2_02.RxAna03	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG2RA04	03	FG_P2_02.RxAna04	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG2RA05	03	FG_P2_02.RxAna05	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG2RA06	03	FG_P2_02.RxAna06	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG2RA07	03	FG_P2_02.RxAna07	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG2RA08	03	FG_P2_02.RxAna08	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG3RA01	03	FG_P2_03.RxAna01	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG3RA02	03	FG_P2_03.RxAna02	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG3RA03	03	FG_P2_03.RxAna03	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG3RA04	03	FG_P2_03.RxAna04	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG3RA05	03	FG_P2_03.RxAna05	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG3RA06	03	FG_P2_03.RxAna06	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG3RA07	03	FG_P2_03.RxAna07	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG3RA08	03	FG_P2_03.RxAna08	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG4RA01	03	FG_P2_04.RxAna01	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG4RA02	03	FG_P2_04.RxAna02	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG4RA03	03	FG_P2_04.RxAna03	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG4RA04	03	FG_P2_04.RxAna04	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG4RA05	03	FG_P2_04.RxAna05	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG4RA06	03	FG_P2_04.RxAna06	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG4RA07	03	FG_P2_04.RxAna07	0	2	–2147483648	2147483647	0.01
Fixed GOOSE Analog FG4RA08	03	FG_P2_04.RxAna08	0	2	–2147483648	2147483647	0.01

[a] These analogs may only be assigned to a single register. Relay will respond with the error message, "Value may only appear in the map once," if an attempt is made to assign one of the analogs to multiple registers.
[b] Reserved bits shall accept 0 or 1.
[c] The following data are a list of Modbus analogs and their attributes. These analogs can be set via the SET M command to an address in the user region.
[d] This register gives the average phase voltage for wye-connected VTs and the average phase-to-phase voltage for delta-connected VTs.
[e] See Appendix H: Relay Word Bits for element information in the Relay Word rows.

Table E.24 Default Modbus Map

Modbus Address	User Map Register	Mapped Register Label
000	MOD_001	IA.120ms_MagPri
001	MOD_002	IB.120ms_MagPri
002	MOD_003	IC.120ms_MagPri
003	MOD_004	IGnd.120ms_MagPri
004	MOD_005	IN.120ms_MagPri
005	MOD_006	IAvg.120ms_MagPri
006	MOD_007	INeg.120ms_MagPri
007	MOD_008	Freq.120ms_Mag
008	MOD_009	IA.RMS_120ms_Pri
009	MOD_010	IB.RMS_120ms_Pri
010	MOD_011	IC.RMS_120ms_Pri
011	MOD_012	IN.RMS_120ms_Pri

Additional Modbus Registers (Dev.ID, Dev.Loc, Dev.PartNum)

The SEL-851 Modbus Register Map has separate register addresses assigned for labels Dev.ID, Dev.Loc, and Dev.PartNum. These labels cannot be mapped in the Modbus Map. You can poll for these labels using the register addresses specified in *Table E.25*.

Table E.25 Dev.ID, Dev.Loc, and Dev.PartNum Registers

Description	Register Address	Valid Function Codes	Default	Number of 16-Bit Registers	Value	
					Min	Max
Dev.ID	1001–1016[a]	03	0	1	0	65535
Dev.Loc	1017–1032[a]	03	0	1	0	65535
Dev.PartNum	1033–1040	03	0	1	0	65535

[a] Modbus Addresses 1001 through 1032 contain string data. Strings are packed 2 characters per register with the MSB containing the character closest to the beginning of the string.

Reading Event Data Using Modbus

The SEL-851 provides a feature that allows relay event history data to be retrieved via Modbus. The Event History registers are listed in *Table E.23* under the Historical Data description heading. To read the history data, set the Modbus Map to contain the Event.Sel label, along with the other Fault History related labels. The following example shows some of the available history data labels in the Modbus Map:

```
=>>SHO M

Modbus Settings

User Map Register Settings

1: Event.Sel
2: Event.s
3: Event.Mn
4: Event.Hr
5: Event.Day
6: Event.Mo
7: Event.Yr
8: Event.Typ
9: Event.Trgt

=>>
```

Use Modbus function code 03 or 04 to read the Modbus registers. The Event.NumofEve label will contain the number of events listed in the event history, **HIS** command, and response. To read relay event history data using Modbus, use function code 06 to write the event number, which is the relative ID (1–50) or the unique event number (between 10000 and 42767), to the Modbus register containing the Event.Sel label. The relay will return the history data using the unique event number as long as that event is currently in the history data. The SEL-851 will populate the other event related registers with the data related to the event number specified in the Event.Sel label address. Issue a Modbus function code 03 or 04 command to read the registers containing the history data.

For example, use the following relay response to the **HIS** command:

```
=>>HIS

SEL-851                                    Date: 02/26/2021   Time: 21:44:28.904
FEEDER RELAY                               Time Source: Internal

FID = SEL-851-X024-V0-Z001001-D20210225

#        DATE        TIME     EVENT                        CURR  FREQ  TARGETS
10004 02/26/2021 21:44:16.283 Gnd/Neut Time OC Trip        68.9  59.99 1101100000
10003 02/26/2021 21:44:11.728 Event Report Trigger         68.9  59.99 1011010100
10002 02/26/2021 21:42:16.485 Trigger                      0.1   60.00 1100110100
10001 02/26/2021 21:42:01.042 Trigger                      5.0   59.99 1101010100
10000 02/26/2021 21:41:33.030 Trigger                      22.2  59.99 1101010100
```

Retrieve the history data in this example for event number 4, using the map shown above, by setting register address 0001 to the value of 4 using a function code 06 command. (Note: The Modbus Map is indexed beginning with 1, which corresponds to register address 0 in Modbus). If a value is written to the Event.Sel register for an event that does not currently exist in the history data, the SEL-851 will respond with an exception code 03.

Following the function code 06 command, issue a function code 03 or 04 command to read registers 0–9 as shown in the previous **SHO M** capture. The data returned in registers 2–9 would contain the event time, event date, and event type associated with event number 4.

When the history data are cleared in the relay, either from the **HIS C** command or from a remote control point, the Event.NumofEve register will contain the value of 0, indicating there are no events that can be read using Modbus. After a power cycle, the history data registers show the history data corresponding to the latest event. This information updates dynamically; whenever there is a new event, the history data registers update automatically with new event data. If specific event number data have been retrieved using a

write to the Event.Sel register, the event data registers stay frozen with that specific event history. These registers return the latest event history data when a zero is written to the event selection register from a prior nonzero selection.

Appendix F

IEC 61850 Communications

Features

The SEL-851 uses Ethernet and IEC 61850 to support the following features:

- **SCADA**—Connect as many as seven simultaneous IEC 61850 Manufacturing Message Specification (MMS) client sessions. The SEL-851 also supports as many as seven buffered and seven unbuffered report control blocks. See *Table F.32* for Logical Node mapping that enables SCADA control via an MMS browser. Controls support direct control with normal security, direct control with enhanced security, and select before operate (SBO) control with enhanced security control models.
- **Peer-to-Peer Real-Time Status and Control**—Use GOOSE with as many as 16 incoming (receive) and 8 outgoing (transmit) messages. Virtual bits (VB_001.Sta–VB_032.Sta) and Remote Analogs (RA_001.Val–RA_032.Val) can be mapped from incoming GOOSE messages. Use Fixed GOOSE with 4 incoming (receive) messages and 1 outgoing (transmit) message. Relay Word bits FG_P2_*n*.RxBin*x* and analog quantities FG_P2_*n*.RxAna*x* (where *n* = 01–04 and *x* = 01–08) maps the received Fixed GOOSE messages.
- **Configuration**—Use FTP client software or ACSELERATOR Architect SEL-5032 Software to transfer the Substation Configuration Language (SCL) Configured IED Description (CID) file to the relay.
- **Commissioning and Troubleshooting**—Use software such as AX-S4 from Sisco, Inc., to browse the relay logical nodes and verify functionality.

NOTE: The SEL-851 ships with a default CID file installed that supports basic IEC 61850 functionality. A new CID file should be loaded if a change in the relay configuration is required. If an invalid CID file is transferred, the relay will reject the file and revert to the previous valid CID file.

This appendix presents the information you need to use the IEC 61850 features of the SEL-851:

- *IEC 61850 Introduction*
- *IEC 61850 Operation*
- *IEC 61850 Configuration*
- *Logical Nodes*
- *Protocol Implementation Conformance Statement*
- *ACSI Conformance Statements*

IEC 61850 Introduction

In the early 1990s, the Electric Power Research Institute (EPRI) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE) began to define a Utility Communications Architecture (UCA). They initially focused on inter-control center and substation-to-control center communications and produced the Inter-Control Center Communications Protocol (ICCP) specification. This specification, later adopted by the IEC as 60870-6 TASE.2, became the standard protocol for real-time exchange of data between databases.

In 1994, EPRI and IEEE began work on UCA 2.0 for Field Devices (simply referred to as UCA2). In 1997, they combined efforts with Technical Committee 57 of the IEC to create a common international standard. Their joint efforts created the current IEC 61850 standard.

The IEC 61850 standard, a superset of UCA2, contains most of the UCA2 specification, plus additional functionality. The standard describes client/server and peer-to-peer communications, substation design and configuration, testing, and project standards. The IEC 61850 standard consists of the parts listed in *Table F.1*.

These parts were first published between 2001 and 2004, and they are often referred to as IEC 61850 Edition 1 (Ed1). Selected parts of these standards were released in 2011 and tagged as Edition 2 (Ed2). The SEL-851 is compliant with Ed2.

It is possible and even likely, that an installation can have a mixture of devices that conform to either Ed1 or Ed2. The standard supports backwards compatibility, i.e., Ed2 devices can send and receive messages to and from Ed1 devices. However, there are important considerations to be made when adding Ed2 devices to an existing Ed1 system. Refer to *Potential Client and Automation Application Issues With Edition 2 Upgrades on page F.61* for more information.

Table F.1 IEC 61850 Document Set (Sheet 1 of 2)

IEC 61850 Sections	Definitions
IEC 61850-1	Introduction and overview
IEC 61850-2	Glossary
IEC 61850-3	General requirements
IEC 61850-4	System and project management
IEC 61850-5	Communications requirements
IEC 61850-6	Configuration description language for substation IEDs
IEC 61850-7-1	Basic communications structure for substations and feeder equipment—Principles and models
IEC 61850-7-2	Basic communications structure for substations and feeder equipment—Abstract Communication Service Interface (ACSI)
IEC 61850-7-3	Basic communications structure for substations and feeder equipment—Common data classes
IEC 61850-7-4	Basic communications structure for substations and feeder equipment—Compatible logical node (LN) classes and data classes
IEC 61850-8-1	SCSM-Mapping to MMS (ISO/IEC 9506-1 and ISO/IEC 9506-2 over ISO/IEC 8802-3)
IEC 61850-9-1	SCSM-Sampled values over serial multidrop point-to-point link

Table F.1 IEC 61850 Document Set (Sheet 2 of 2)

IEC 61850 Sections	Definitions
IEC 61850-9-2	SCSM-Sampled values over ISO/IEC 8802-3
IEC 61850-10	Conformance testing

The IEC 61850 document set, available directly from the IEC at www.iec.ch, contains information necessary for successful implementation of this protocol. SEL strongly recommends that anyone involved with the design, installation, configuration, or maintenance of IEC 61850 systems be familiar with the appropriate sections of these documents.

IEC 61850 Operation

Ethernet Networking

IEC 61850 and Ethernet networking are available as options in the SEL-851. In addition to IEC 61850, the Ethernet port provides support protocols and data exchange, including FTP and Telnet. Access the SEL-851 Port 2 settings to configure all of the Ethernet settings, including IEC 61850 enable settings.

The SEL Ethernet port supports IEC 61850 services, including transport of logical node objects, over TCP/IP. The Ethernet port can coordinate a maximum of seven concurrent IEC 61850 sessions.

Object Models

The IEC 61850 standard relies heavily on the Abstract Communication Service Interface (ACSI) model to define a set of services and the responses to those services. In terms of network behavior, abstract modeling enables all IEDs to act identically. You can use these abstract models to create objects (data items) and services that exist independently of any underlying protocols. These objects are in conformance with the common data class (CDC) specification IEC 61850-7-3, which describes the type and structure of each element within a logical node. CDCs for status, measurements, controllable analogs and statuses, and settings all have unique CDC attributes. Each CDC attribute belongs to a set of functional constraints that groups the attributes into specific categories such as status (ST), description (DC), and substituted value (SV). Functional constraints, CDCs and CDC attributes are used as building blocks for defining Local Nodes.

UCA2 uses GOMSFE (Generic Object Models for Substation and Feeder Equipment) to present data from station IEDs as a series of objects called models or bricks. The IEC working group has incorporated GOMSFE concepts into the standard, with some modifications to terminology; one change was the renaming of bricks to logical nodes. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function. For example, the MMXU logical node (polyphase measurement unit) contains measurement data and other points associated with three-phase metering including voltages and currents. Each IED can contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

You can organize logical nodes into logical devices that are similar to directories on a computer disk. As represented in the IEC 61850 network, each physical device can contain many logical devices, and each logical device can contain many logical nodes. Many relays, meters, and other IEC 61850 devices contain one primary logical device where all models are organized.

IEC 61850 devices are capable of self-description. You do not need to refer to the specifications for the logical nodes, measurements, and other components to request data from another IEC 61850 device. IEC 61850 clients can request and display a list and description of the data available in an IEC 61850 server device. This process is similar to the autoconfiguration process used within SEL communications processors (SEL-3530, SEL-2032, and SEL-2030). Simply run an MMS browser to query devices on an IEC 61850 network and discover what data are available. Self-description also permits extensions to both standard and custom data models. Instead of having to look up data in a profile stored in its database, an IEC 61850 client can simply query an IEC 61850 device and receive a description of all logical devices, logical nodes, and available data.

Unlike other Supervisory Control and Data Acquisition (SCADA) protocols that present data as a list of addresses or indices, IEC 61850 presents data with descriptors in a composite notation made up of components. *Table F.2* shows how the A-phase current expressed as MMXUAphsA$cVal is broken down into its component parts.

Table F.2 Example IEC 61850 Descriptor Components

Components		Description
MMXU	Logical Node	Polyphase measurement unit
A	Data Object	Phase-to-ground amperes
PhsA	Sub-Data Object	A-phase
cVal	Data Attribute	Complex value

Data Mapping

Device data are mapped to IEC 61850 logical nodes (LN) according to rules SEL has defined. Refer to IEC 61850-5:2013(E) and IEC 61850-7-4:2010(E) for the mandatory content and usage of these LNs. The SEL-851 logical nodes are grouped under Logical Devices for organization based on function. See *Table F.3* for descriptions of the Logical Devices in an SEL-851. See Logical Nodes for a description of the LNs that make up these Logical Devices.

Table F.3 SEL-851 Logical Devices

Logical Device	Description
ANN	Annunciator elements—alarms, status values
CFG	Configuration elements—datasets and report control blocks
CON	Control elements—remote bits
MET	Metering or Measurement elements—currents, voltages, power, etc.
PRO	Protection elements—protection functions and breaker control

Functional Naming

Substation design typically starts with a one-line diagram and progresses down to the assignment of functions to IEDs. In this top-down approach, the functions are identified and named independently from the IEDs to which they are assigned.

Because a logical device is a grouping of logical nodes that perform a certain high-level function at a substation, the associated name often indicates the assigned function. The functional naming feature allows users to name a logical device based on the function it provides independent of the name of the IED to which the function is assigned. The alternative is product naming,

NOTE: Functional naming is not supported by all MMS clients and GOOSE subscribers. Verify support for this feature before configuring functional names in a publishing IED.

which prepends the IED name to the logical device instance to create the logical device name. The functional name is used on the communications interface for all references to data in the logical device.

SEL-851 supports functional naming of logical devices. You can add functional names in Architect for supported Edition 2 relays. To enable it in Architect, navigate to **Edit > Project Settings** and select the **Enable functional name editing on Server Model tab of supporting IEDs** check box, as shown in *Figure F.1*.

Figure F.1 Enabling Functional Naming in Architect

To provide functional names to the logical devices, navigate to the Server Model tab for the IED. Because datasets and control blocks are in the CFG logical device, any functional name given to the CFG logical device instance is used in dataset references, control block references, and in published GOOSE messages, as shown in *Figure F.2*. The IED Server Model also allows the user to change the default logical node prefix and instance values.

Figure F.2 Server Model View in Architect

MMS

MMS provides services for the application-layer transfer of real-time data within a substation LAN. MMS was developed as a network independent data exchange protocol for industrial networks in the 1980s and standardized as ISO 9506.

In theory, you can map IEC 61850 to any protocol. However, it can be unwieldy and quite complicated to map objects and services to a protocol that only provides access to simple data points via registers or index numbers. MMS supports complex named objects and flexible services that enable mapping to IEC 61850 in a straightforward manner. This was why the UCA users group used MMS for UCA from that start, and why the IEC chose to keep it for IEC 61850.

Settings files, event files, and reports are also available through MMS. See *File Transfer Protocol (FTP) and MMS File Transfer on page 7.12*.

If MMS authentication is enabled, the device authenticates each MMS association by requiring the client to provide the password authentication parameter with a value that is equal to the Access Level 2 password of the SEL-851.

- If the correct password authentication parameter is not received, the device returns a not authenticated error code.
- If the correct password authentication parameter value is received, the device gives a successful association response.

Once an authenticated association is established, the device allows access to all supported MMS services for that association.

File Services

The Ethernet file system allows reading or writing data as files. The file system supports FTP and MMS file transfer. The file system provides:

- A means for the devices to transfer data as files
- A hierarchical file structure for the device data

The SEL-851 supports MMS file transfer with or without authentication; the service is intended to support the following:

- CID file download and upload
- Settings Files download and upload
- Retrieval of events, and reports

MMS file services are enabled or disabled via Port 2 settings. See *Virtual File Interface on page 7.49* for details on the files available for MMS file services.

SCL Files

Substation Configuration Language (SCL) is an XML-based configuration language used to support the exchange of database configuration data between different tools, which may come from different manufacturers. There are four types of SCL files:

- IED Capability Description file (.ICD)
- System Specification Description (.SSD) file
- Substation Configuration Description file (.SCD)
- Configured IED Description file (.CID)

The ICD file described the capabilities of an IED, including information on LN and GOOSE support. The SSD file describes the single-line diagram of the substation and the necessary LNs. The SCD file contains information on all IEDs, communications configuration data, and a substation description. The CID file, of which there may be several, describes a single instantiated IED within the project, and includes address information.

Datasets

Datasets are configured using ACSELERATOR Architect and contain data attributes that represent real data values within the SEL-851 device. See Logical Nodes for the logical node tables that list the available data attributes for each logical node and the Relay Word bit mapping for these data attributes. The datasets listed in *Figure F.3* are the defaults for an SEL-851 device. Datasets BRDSet01–BRDSet07 and URDSet01–URDSet07 are preconfigured with common FCDAs to be used for reporting. These datasets can be configured to represent the data you want to monitor. Dataset GPDSet01, which contains breaker status and control data attributes, is used in the default Goose Control Publication.

Figure F.3 SEL-851 Datasets

Within Architect, IEC 61850 datasets have two main purposes:

- GOOSE: You can use predefined or edited datasets, or create new datasets for outgoing GOOSE transmission.
- Reports: Fourteen predefined datasets (BRDSet01–BRDSet07 and URDSet01–URDSet07) correspond to the default seven buffered and seven unbuffered reports, respectively. Note that you cannot change the number (14) or type of reports (buffered or unbuffered) within Architect. However, you can alter the data attributes that a dataset contains and so define what data an IEC 61850 client receives with a report.
- MMS: You can use predefined or edited datasets, or create new datasets to be monitored by MMS clients.

NOTE: Do not edit the dataset names used in reports. Changing or deleting any of those dataset names will cause a failure in generating the corresponding report.

Reports

The SEL-851 supports buffered and unbuffered report control blocks in the report model as defined in IEC 61850-8-1:2004(E). The predefined reports shown in *Figure F.4* are available by default via IEC 61850. There are 14 report control blocks, seven buffered reports and seven unbuffered.

Reports

Type	Name	ID	Dataset	Description
Buffered	BRep01	BRep01	BRDSet01	Predefined Buffered Report 01
Buffered	BRep02	BRep02	BRDSet02	Predefined Buffered Report 02
Buffered	BRep03	BRep03	BRDSet03	Predefined Buffered Report 03
Buffered	BRep04	BRep04	BRDSet04	Predefined Buffered Report 04
Buffered	BRep05	BRep05	BRDSet05	Predefined Buffered Report 05
Buffered	BRep06	BRep06	BRDSet06	Predefined Buffered Report 06
Buffered	BRep07	BRep07	BRDSet07	Predefined Buffered Report 07
Unbuffered	URep01	URep01	URDSet01	Predefined Unbuffered Report 01
Unbuffered	URep02	URep02	URDSet02	Predefined Unbuffered Report 02
Unbuffered	URep03	URep03	URDSet03	Predefined Unbuffered Report 03
Unbuffered	URep04	URep04	URDSet04	Predefined Unbuffered Report 04
Unbuffered	URep05	URep05	URDSet05	Predefined Unbuffered Report 05
Unbuffered	URep06	URep06	URDSet06	Predefined Unbuffered Report 06
Unbuffered	URep07	URep07	URDSet07	Predefined Unbuffered Report 07

Figure F.4 SEL-851 Predefined Reports

For each report control block, there can be just one client association, i.e., only one client can be associated to a report control block (BRCB or URCB) at any given time. The number of reports (14) and the type of reports (buffered or unbuffered) cannot be changed. However, by using Architect, you can reallocate data within each report dataset to present different data attributes for each report beyond the predefined datasets. For buffered reports, connected clients can edit the report parameters shown in *Table F.4*.

Table F.4 Buffered Report Control Block Client Access

RCB Attribute	User changeable (Report Disabled)	User changeable (Report Enabled)	Default Values
RptId	YES		BRep01–BRep07
RptEna	YES	YES	FALSE
OptFlds	YES		seqNum timeStamp dataSet configRef reasonCode dataRef
BufTm	YES		500
TrgOp	YES		dchg qchg
IntgPd	YES		0
GI		YES[a]	FALSE
PurgeBuf	YES[a]		FALSE
EntryId	YES		0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted, returns to zero. Always read as zero.

Similarly, for unbuffered reports, connected clients can edit the report parameters shown in *Table F.5*.

Table F.5 Unbuffered Report Control Block Client Access

RCB Attribute	User changeable (Report Disabled)	User changeable (Report Enabled)	Default Values
RptId	YES		URep01–URep07
RptEna	YES	YES	FALSE
Resv	YES		FALSE
OptFlds	YES		seqNum timeStamp dataSet configRef reasonCode dataRef
BufTm	YES		250
TrgOps	YES		dchg qchg
IntgPd	YES		0
GI		YES[a]	

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted, returns to zero. Always read as zero.

For Buffered Reports, only one client can enable the RptEna attribute of the BRCB at a time resulting in a client association for that BRCB. Once enabled, the associated client has exclusive access to the BRCB until the connection is closed or the client disables the RptEna attribute. Once enabled, all unassociated clients have read only access to the BRCB.

For Unbuffered Reports, as many as seven clients can enable the RptEna attribute of the URCB at a time, resulting in multiple client associations for that URCB. Once enabled, each client has independent access to a copy of that URCB. The Resv attribute is writable, however, the SEL-851 does not support reservations. Writing any field of the URCB causes the client to obtain its own copy of the URCB-in essence, acquiring a reservation.

Reports are serviced at a 2 Hz rate. The client can set the IntgPd to any value with a resolution of 1 ms. However, the integrity report is only sent when the period has been detected as having expired. The report service rate of 2 Hz results in a report being sent within 500 ms of expiration of the IntgPd. The new IntgPd begins at the time that the current report is serviced.

Supplemental Software

Examine the data structure and value of the supported IEC 61850 LNs with an MMS browser such as MMS Object Explorer and AX-S4 MMS from Sisco, Inc. The settings necessary to browse an SEL-851 with an MMS browser are as follows:

OSI-PSEL (Presentation Selector)	00000001
OSI-SSEL (Session Selector)	0001
OSI-TSEL (Transport Selector)	0001

Time Stamps and Quality

In addition to the various data values, the two attributes quality and t (time stamp) are available at any time. The relay determines the time stamp when it detects a change in quality or data.

The relay applies a time stamp to all data and quality attributes (Boolean, Bstrings, Analogs, etc.) in the same fashion as when it detects a data or quality change. However, there is a difference in how the relay detects the change between the different attribute types. For points that are assigned as SER points, i.e., programmed in the SER report, the relay detects the change as the receipt of an SER record (which contains the SER time stamp) within the relay.

For all other Booleans or Bstrings, the relay detects the change via the scanner, which compares the last state against the previous state to detect the change. For analogs, the scanner looks at the amount of change relative to the deadband configured for the point to indicate a change and apply the time stamp. In all cases, the relay uses these time stamps for the reporting model.

Functionally Constrained Data Attributes mapped to points assigned to the SER report have 4 ms SER-accurate time stamps for data change events (the Relay Word bits corresponding to the digital inputs and arc-flash elements [AFR.Sen0*x*_PU, AFD.50*x*_PU, and OUT_0*n*.Sta] have 1/16 of the power system cycle SER-accurate time stamps). To ensure that you get SER-quality time stamps for changes to certain points, you must include those points in the SER report. All other FCDAs are scanned for data changes on a 1/2-second interval and have 1/2-second time-stamped accuracy. See *SER Trigger Lists on page 4.94* for information on programming the SER report.

The SEL-851 uses GOOSE quality attributes to indicate the quality of the data in its transmitted GOOSE messages. Under normal conditions, all attributes are zero, indicating good quality data. *Figure F.5* shows the GOOSE quality attributes available to devices that subscribe to GOOSE messages from SEL-851 datasets that contain them. Internal status indicators provide the information necessary for the device to set these attributes.

For example, if the device becomes disabled, as shown via status indications (e.g., an internal self-test failure), the SEL-851 sets the Validity attribute to invalid and the Failure attribute to TRUE. Note that the SEL-851 does not set any of the other quality attributes. These attributes always indicate FALSE (0). See the Architect online help for additional information on GOOSE Quality attributes.

Figure F.5 GOOSE Quality

Control

IEC 61850 Controls

An IEC 61850 server may allow a client to manipulate data related to its outputs, external devices, or internal functions. This is accomplished by the IEC 61850 control model, which provides services to execute control commands. The control models are defined in IEC 61850-7-2 and the mapping to the MMS (Manufacturing Message Specification) application protocol is defined in IEC 61850-8-1. The former describes control functionality while the latter maps the IEC 61850 control primitives to MMS. The SEL-851 supports four different control models:

- Status Only
- Direct with Normal Security
- Direct with Enhanced Security
- SBO with Enhanced Security

The SEL-851 supports the above control models for SPC and DPC controllable common data classes (CDCs) as defined in IEC 61850-8-1:2004. Other controllable CDCs defined in the standard are either unsupported or must be configured with the status-only control model. Supported CDCs include remote bits RBGGIO*n* in the CON Logical Device (LD), and breaker and disconnect controls *xx*XCBR*nn* and *xx*XSWI*nn* in the PRO LD. One control model must be selected during initial IED configuration in Architect and is applied throughout the CID file. This control model will apply to all controls in the IED.

Direct Control Models

The "Direct" control models provide the simplest means to initiate actions on the server. In these models, the client issues a control request via MMS, the server validates the request. Once validated, the server attempts to act upon the request. Note that if multiple clients are trying to perform control actions, the server will do nothing to prevent this.

SBO Control Model

The SBO control model supports the Select or SelectWithValue Service and can be used to prevent multiple clients from performing simultaneous control actions. In this mode, a client has to "reserve" the control object by sending a "select" control command. Once an object is selected, only the client that made the selection is allowed to perform control actions on it. If that client does not send a valid operate request for the object by the time the ten-second selection timer runs out, the object becomes available for selection again. The relay will support as many as ten pending control object selections at any time.

NOTE 1: When an IED is configured with the SBO with Enhanced Security control model, the sboTimeout attribute of the controllable CDCs in the CID file is set to ten seconds. The time-out is not configurable via Architect.

The attribute stSeld (selected status) of the controllable CDC is set to TRUE when a client successfully selects the control object. The attribute is reset to FALSE when either the control (operate) command is successfully executed, an error occurs, or no operate command is received within the select time-out period. The stSeld attribute may trigger a report just like any data attribute with trigger option.

Security in Control Models

"Security" in the control model context refers to additional supervision of the status value by the control object. The "enhanced security" models report additional error information on failed operations to the requesting client than

the models with “normal security”. Enhanced security control models also provide a command termination report indicating if the control actually reached the new state as commanded within a configurable time-out period.

NOTE: The maximum time required for a control operation to be completed should be less than the configured time-out period to avoid erroneous command termination reports indicating failure.

The time-out period between the execution of a control and the generation of a command termination report indicating failure has a default value of 1 s and is configurable via the CID file. This time-out is not configurable via Architect.

Optional Control Configurations

The SEL-851 does not support (by default) the pulse configuration option specified in Clause 6.7 of IEC 61850-7-3. However, control objects may be configured to be pulsed by direct modification of the CID file of the device.

The SEL-851 does not support the concept of local/remote control authority defined in Annex B of IEC 61850-7-4:2010. However, a similar behavior can be achieved by associating some variable device data with the appropriate originator categories (orCats) by direct modification of the CID file of the device.

Contact the factory if any of these features are necessary for your application.

Control Requests

IEC 61850 control services are implemented by reading and writing to pseudovariables in the relay in response to MMS requests. Similar to how client requests are generated and mapped to MMS read or write service requests, server actions are also mapped to internal commands, read and write actions and MMS information report messages. In the case of an unsuccessful control request, the relay will send the appropriate response PDU indicating that there was a problem and an MMS information report that contains more detailed information about the problem that occurred.

When writing controls, the client must select and write the entire Oper, SBOw, or Cancel structure to the relay. See *Figure F.6* for the attributes of the CON Logical Device and ST and CO functional constraints (FC) of LN RBGGIO1 used for controls of RB_001.Sta through RB_008.Sta.

Figure F.6 MMS Client View of the CON Logical Device

Control Error Messages

If a control request results in an error condition, the relay will respond with an AddCause value in an MMS information report. See Clause 20.5.2.9 of IEC 61850-7-2 for additional information on the AddCause values. The SEL-851 supports the AddCause values in *Table F.6* as part of the LastApplError information report.

Table F.6 AddCause Descriptions (Sheet 1 of 2)

AddCause Enumeration	AddCause Description	Error Condition
0	Unknown	No other AddCause value defined within this section applies
2	Blocked-by-switching-hierarchy	Logical node is set to local mode, i.e. Loc.stVal = true
3	Select-failed	Originator category not allowed to issue control commands or SelectWithValue operation fails
4	Invalid-position	For controls with enhanced security, an AddCause of “Invalid-position” (4) will be sent if the control status changes to an unexpected value. If no control status change is detected after the operate time-out period, an AddCause of “Time-limit-over” (16) will be sent.
5	Position-reached	Control status is already at the desired state
6	Parameter-change-in-execution	Control object is already selected by the client, and 1. Logical node is set to local mode i.e., Loc.stVal = true, or 2. Originator category not hallowed to issue control commands
8	Blocked-by-mode	Mode of logical device or node is not ON

Table F.6 AddCause Descriptions (Sheet 2 of 2)

AddCause Enumeration	AddCause Description	Error Condition
12	Command-already-in-execution	Execution of a previous control is not completed
13	Blocked-by-health	Health of logical device or node is not OK
16	Time-limit-over	CommandTermination gives a negative response. (The control failed to reach its intended state prior to time-out.)
18	Object-not-selected	Cancel operation fails

Any AddCause value not specified above is not supported. Control CDC data attributes which are associated with unsupported AddCause values and are not part of a control structure will be accepted but ignored. For example, the attribute CmdBlk.stVal which is associated with the AddCause value "blocked-by-command" and is not part of a SBOw, Oper, or Cancel structure will be ignored.

Service Tracking

The IEC 61850 standard defines many services to be provided by an IED (server). These services include control services, reporting services, logging services, and group switch control services. IEC 61850 Edition 2 defines the service tracking feature to allow these services to be reported or logged, whether they succeed or fail.

The SEL-851 supports the service tracking feature for control commands and report control block edits. You can report these services.

Tracking of these services is enabled by data objects in the service tracking logical node LTRK. *Table F.7* lists the service tracking data objects. Their data attributes mirror those in the service request or in the control block that was the target of the service request.

Table F.7 Service Tracking Data Objects

Data Object	CDC	Description
SpcTrk	CTS	Tracks control service requests targeted at a controllable single-point object
DpcTrk	CTS	Tracks control service requests targeted at a controllable double-point object
EncTrk	CTS	Tracks control service requests targeted at a controllable enumerated status object
UrcbTrk	UTS	Tracks unbuffered report control block edits
BrcbTrk	BTS	Tracks buffered report control block edits

Refer to *Table F.34* for information regarding the available attributes in each tracking data object.

Each tracking data object includes the data attributes objRef, serviceType, and errorCode. The attribute objRef provides the reference to the control object or control block instance that was the target of the service request. The attribute serviceType provides an enumerated value for the specific service requested or executed. *Table F.8* defines the service type enumerations.

Table F.8 IEC 61850 Service Type Enumeration

Service Type	Service Name	Description
24	SetBRCBValues	Write request on one or more of the following buffered report control block attributes: RptID, RptEna, OptFlds, BufTm, TrgOps, IntgPd, PurgeBuf, EntryID, or GI
26	SetURCBValues	Write request on one or more of the following unbuffered report control block attributes: RptID, RptEna, OptFlds, BufTm, TrgOps, IntgPd, Resv, or GI
44	SelectWithValue	Select control request
45	Cancel	Cancel control request
46	Operate	Operate control request
47	CommandTermination	Control processing completed on a control object configured with enhanced security control model
54	InternalChange	Report control block has been automatically disabled, i.e., RptEna is set to False after a loss of association with the client

The attribute errorCode provides the error code that indicates whether the service was successful or unsuccessful. *Table F.9* lists the codes and the corresponding ACSI errors.

Table F.9 IEC 61850 ACSI Service Error

Error Code	ACSI Error
0	no-error
1	instance-not-available
3	access-violation
5	parameter-value-inappropriate
6	parameter-value-inconsistent
7	class-not-supported
8	instance-locked-by-other-client
10	type-conflict
11	failed-due-to-communications-constraint
12	failed-due-to-server-constraint

When creating datasets to track the services through information reporting, it is important to include the tracking data objects as a whole object (FCD—functionally constrained data), and not as individual data attributes (FCDA—functional constrained data attribute). Only the objRef attribute has a trigger option (dupd—data update) and can trigger a report. The dupd trigger option must also be enabled in the report control block that is reporting changes in the tracking data objects.

GOOSE

The Generic Object Oriented Substation Event (GOOSE) object within IEC 61850 is for high-speed control messaging. IEC 61850 GOOSE automatically broadcasts messages containing status, controls, and measured values onto the network for use by other devices. IEC 61850 GOOSE sends the messages several times, increasing the likelihood that other devices receive the messages.

IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network. Configure SEL devices to respond to GOOSE messages from other networks with Architect software. Also, configure outgoing GOOSE messages for SEL devices in Architect. See the Architect online help for more information.

Each IEC 61850 GOOSE sender includes a text identification string (GOOSE Control Block Reference) in each outgoing message and an Ethernet multicast group address. Devices that receive GOOSE messages use the text identification and multicast group to identify and filter incoming GOOSE messages.

NOTE: Virtual bits and remote analogs mapped to GOOSE subscriptions retain their state until they are overwritten, a new CID file is loaded, or the device is restarted. To reset the virtual bits and remote analogs by restarting the device, issue an **STA C** command or remove and then restore power to the device.

Virtual bits (VB_001.Sta–VB_032.Sta) are control inputs that you can map to GOOSE receive messages by using the Architect software. See the VB_*nnn*.Sta bits in *Table F.33* for details on which logical nodes and names are used for these bits. This information can be useful when searching through device data with MMS browsers. If you intend to use any SEL-851 virtual bits for controls, you must create SELOGIC control equations to define these operations. The Virtual Bit Logical Nodes only contain Virtual Bit status, and only those Virtual Bits that are assigned to an SER report are able to track bit transitions (via reporting) between LN data update scans.

The relay is capable of receiving analog values via peer-to-peer GOOSE messages. Remote Analogs (RA_001.Val–RA_032.Val) are analog inputs that you can map to values from incoming GOOSE messages.

GOOSE Processing

SEL devices support GOOSE processing as defined by IEC 61850-7-1:2011(E), IEC 61850-7-2:2010(E), and IEC 61850-8-1:2011(E) via the installed Ethernet port. Outgoing GOOSE messages are processed within the following constraints:

- You can define as many as eight outgoing GOOSE messages consisting of any Data Attribute (DA) from any logical node. You can map a single DA to one or more outgoing GOOSE, or one or more times within the same outgoing GOOSE. You can also map a single GOOSE dataset to multiple GOOSE control blocks.
- The relay transmits all configured GOOSE immediately upon successful initialization. If a GOOSE message is not retriggered; then, following the initial transmission, the relay retransmits that GOOSE based on the minimum time and maximum time configured for that GOOSE message. The first transmission occurs immediately on triggering of an element within the GOOSE dataset. The second transmission occurs Min. Time later. The third transmission occurs Min. Time after the second transmission. The fourth transmission occurs twice Min. Time after the third transmission. All subsequent transmissions occur at the Max Time interval. For example, a message with a Min. Time of 4 ms and Max. Time of 1000 ms is transmitted upon triggering, then retransmitted at intervals of 4 ms, 4 ms, 8 ms, and then at 1000 ms indefinitely or until another change triggers a new GOOSE message (see IEC 61850-8-1, Sec. 18.1). The default Min. Time value is 8 ms. This is also the suggested Min. Time value.
- GOOSE transmission is squelched (silenced) after a permanent (latching) self-test failure.

- Each outgoing GOOSE includes communications parameters (VLAN, Priority, and Multicast Address) and is transmitted entirely in a single network frame.
- The SEL-851 maintains the configuration of outgoing GOOSE through a power cycle and device reset.

Incoming GOOSE messages are processed within the following constraints:

- You can configure the SEL-851 to subscribe to as many as 16 incoming GOOSE messages.

  The SEL-851 recognizes incoming GOOSE messages as valid based on the following content. Any GOOSE message that fails these checks is rejected.

  - Source broadcast MAC address
  - Dataset Reference
  - Application ID
  - GOOSE Control Reference
- Rejection of all DA contained in an incoming GOOSE, based on the accumulation of the following error indications created by inspection of the received GOOSE:
  - **Configuration Mismatch**: the configuration number of the incoming GOOSE changes.
  - **Needs Commissioning**: this Boolean parameter of the incoming GOOSE is true.
  - **Test Mode**: this Boolean parameter of the incoming GOOSE is true.
  - **Decode Error**: the format of the incoming GOOSE is not as configured.
- The SEL-851 discards incoming GOOSE under the following conditions:
  - after a permanent (latching) self-test failure
  - when the relay is disabled
  - when Port_02.Goose_Ena is set to No

Link-layered priority tagging and virtual LAN is supported as described in Annex C of IEC 61850-8-1:2004(E).

Fixed GOOSE

Fixed GOOSE is a simple and fast peer-to-peer communication method that uses the fixed length GOOSE format described in Annex A of IEC 61850-8-1:2011/A1:2020. The SEL-851 supports one outgoing (transmit) Fixed GOOSE message and four incoming (receive) Fixed GOOSE messages. Each Fixed GOOSE message can contain as many as eight analogs and eight digitals. Various settings required to configure Fixed GOOSE messages are shown in *Table F.20*.

To enable Fixed GOOSE publications, set Port_02.FG_TxEna equal to 1. The Port_02.FG1_TxBin*x* and Port_02.FG1_TxAna*x* (where *x* = 01–08) settings allow you to configure the list of digitals and analogs to be transmitted. If an analog or digital is not configured in the settings, its value is reported as 0. Fixed GOOSE messages are triggered when there are changes in the values of

transmit data configured in the settings. The first transmission occurs immediately following a change in the values of the configured Fixed GOOSE data set. The second transmission occurs Port_02.FG1_TxMinTm later. The third transmission occurs Port_02.FG1_TxMinTm after the second. The fourth transmission occurs twice Port_02.FG1_TxMinTm after the third. All subsequent transmissions occur until the Port_02.FG1_TxMaxTm interval. Each Fixed GOOSE message contains the configured APP ID, VLAN ID, and priority defined by the settings Port_02.FG1_TxAppId, Port_02.FG1_TxVLANId, and Port_02.FG1_TxVLANPri. The number of Fixed GOOSE messages that can be subscribed to is defined by Port_02.FG_RxEna. Use the Port_02.FG*n*_RxMAC (where *n* = 1–4) and Port_02.FG1_TxMAC settings to set the subscription and publication MAC addresses, respectively. It is expected that the MAC addresses be changed in the settings from the defaults based on the user's system configuration.

Relay Word bits FG_P2_*n*.RxBin*x* and analog quantities FG_P2_*n*.RxAna*x* (where *n* = 01–04 and *x* = 01–08) map the received Fixed GOOSE message data based on the number of Fixed GOOSE messages. The SEL-851 transmits Fixed GOOSE messages within 4 ms of the data transition and updates analogs and digitals within 4 ms of the message reception. *Figure F.7* illustrates the inherent delays in the analog quantity update when communicated via Fixed GOOSE. The SEL-851 processes and updates analogs at their defined rates. Selection of the analog quantity for publication determines the analog quantity update rate. See *Appendix I: Analog Quantities* for more information on analog quantity update rates. See *FGS (Fixed GOOSE) Command on page 7.26* for more information on Fixed GOOSE communication statistics.

Note: Network latency not-to-scale.

Note: Binary Fixed GOOSE data have similar time delays to those illustrated in the figure, except that binary data are evaluated at every processing interval (4 ms) and do not have analog quantity update rate delays.

Figure F.7 Timing Diagram for Analog Quantity Communicated Via Fixed GOOSE

Simulation Mode

The SEL-851 can be configured to operate in simulation mode. In this mode, the SEL-851 continues to process normal GOOSE messages until a simulated GOOSE message is received for a subscription. Once a simulated GOOSE message is received, only simulated GOOSE messages are processed for that subscription. The simulated mode only terminates when 61850.Sim is returned to FALSE. When the relay is not in the simulation mode, only normal GOOSE messages are processed for all subscriptions. You can place the SEL-851 in simulation mode by setting 61850.Sim (CFG.DevIDLPHD1.Sim.stVal) to true via MMS messaging.

IEC 61850 Mode/Behavior

The IEC 61850-7-4:2010 standard defines the behavior of the different modes to facilitate testing. The different modes are only available in IEDs with IEC 61850 Edition 2 support.

SEL-851 relays support the following modes:

- On
- Blocked
- Test
- Test/Blocked
- Off

IEC 61850 Behavior is determined by the logical device mode and its logical node mode according to the IEC 61850 standard. For SEL-851 relays, the selected IEC 61850 Mode/Behavior applies to the entire IED, including all the logical devices and all the logical nodes. The behavior of the IED is always the same as the selected mode. *Table F.10* describes the available services based on the mode/behavior of the IED.

Table F.10 IEC 61850 Services Based on Mode/Behavior

Mode	MMS	GOOSE Publication and Subscription
On	Available	Available
Blocked	Available	Available
Test	Available	Available
Test/Blocked	Available	Available
Off	No services[a]	Publication[b]

[a] All MMS control requests to change the mode with Test = false will be processed.
[b] GOOSE publication in Off mode is disabled if Port_02.GOOSE_TxOffModEna = N.

The analog quantity 61850.Mod is an enumerated number that corresponds to mode and behavior as shown in *Table F.11*. You can view the value of this analog quantity by assigning it to a math variable.

Table F.11 Analog Quantity 61850.Mod Status Based on the Selected IEC 61850 Mode/Behavior

61850.Mod	IEC 61850 Mode/Behavior
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off

Mode/Behavior Control

Enable Mode/Behavior Control

IEC 61850 Mode/Behavior, by default, is disabled in SEL-851 relays. To enable IEC 61850 Mode/Behavior, you must set the Port 2 setting Port_02.61850_Ena equal to Y. To enable IEC 61850 Mode/Behavior Control,

you must set Port setting Port_02.61850_ModCtrlEna equal to Y and the CID file setting controllableModeSupported to True. You can set the controllableModeSupported setting by selecting **Enable control of IEC 61850 Mode/Behavior** when adding an IED to an ACSELERATOR Architect SEL-5032 Software project, as shown in *Figure F.8*.

Figure F.8 Set controllableModeSupported = True

Enhanced Secure Mode Control

Relay setting Port_02.61850_ModCtrlEna and CID file setting controllableModeSupported provide security to prevent accidental switching into an unplanned IEC 61850 Mode/Behavior during normal operations. For example, following IED testing, a technician can disable unplanned switching of IEC 61850 Mode/Behavior by setting Port_02.61850_ModCtrlEna to N after switching the relay back to On mode.

Change Mode Via MMS or SELOGIC

If IEC 61850 Mode/Behavior is set as controllable, you can control the IEC 61850 Mode/Behavior via MMS writes to the LLN0 logical node mode data object (Mod.ctlVal) in logical device CFG. Note that Mod.ctVal in other logical devices does not accept MMS writes. See *Table F.12* for the list of writable values.

Table F.12 IEC 61850 Mode/Behavior List of Writable Values

Write Values to Mod.ctVal in Logical Device CFG	Selected IEC 61850 Mode/Behavior
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off

You can also control IEC 61850 Mode/Behavior through use of the **SET G** command with protection SELOGIC variables 61850.Mod_Test and 61850.Mode_Blk on the left side of the SELOGIC control equations. These variables are the SELOGIC controls for the Test and Blocked modes, respectively.

Table F.13 IEC 61850 Mode/Behavior Evaluated States of 61850.Mod_Test and 61850.Mod_Blk

61850.Mod_Test	61850.Mod_Blk	Selected IEC 61850 Mode/Behavior
0	0	See note[a]
1	0	Test
0	1	Blocked
1	1	Test/Blocked
See note[b]	See note[b]	Off

[a] The SELOGIC controls have higher priority than MMS clients in controlling the Test and Blocked modes. When 61850.Mod_Test and 61850.Mod_Blk both evaluate to 0 (false), IEC 61850 Mode/Behavior control is available to MMS clients. If either 61850.Mod_Test or 61850.Mod_Blk evaluates to 1 (true), SELOGIC determines the IEC 61850 Mode/Behavior of the IED regardless of MMS control values.

[b] You cannot control Off mode by using 61850.Mod_Test and 61850.Mod_Blk. When an MMS client causes the IED to be in Off mode, the SELOGIC controls are disabled and 61850.Mod_Test and 61850.Mod_Blk are not evaluated.

Example F.1 Change Mode Via SELOGIC

In this example, RB_001.Sta controls 61850.Mod_Test and RB_002.Sta controls 61850_Mod_Blk. If you issue the CON RB_001.Sta S command, the relay enters Test mode. If you issue the CON RB_002.Sta S command, the relay transitions from Test mode into Test/Blocked mode. Issue CON RB_001.Sta C and CON RB_002.Sta C to reset Test and Blocked modes, respectively.

```
=>>SHO G <Enter>

IEC 61850 Mode/Behavior Configuration
61850.Mod_Blk     := RB_002.Sta
61850.Mod_Test    := RB_001.Sta
```

Regardless of mode (On, Blocked, Test, Test/Blocked, Off), the Mod, Beh, and Health quality bitstring will always be quality.validity = Good, quality.failure = False, and quality.test = False. This behavior is not the same when using the **TEST DB** command. The **TEST DB** command behavior is independent of this.

Incoming Messages Processing

IEC 61850 incoming data processing is jointly determined by quality validity, test, and operatorBlocked. SEL-851 relays, by default, check if the quality operatorBlocked equals False; if not, the relays treat the messages as invalid. You can disable the default check by changing the quality mask of GOOSE subscriptions. *Figure F.9* illustrates the default quality check for GOOSE subscription in SEL-851 relays.

Figure F.9 Default Quality Check on GOOSE Subscription if Quality Is Present

Relay Operation for Different IEC 61850 Modes/Behaviors

Mode: On

In On mode, the relay operates as normal; it reports IEC 61850 Mode/Behavior status as On and processes all inputs and outputs as normal. If the quality of the subscribed GOOSE messages satisfies the GOOSE processing (see *GOOSE Processing on page F.16*), the relay processes the received GOOSE messages as valid. *Table F.14* and *Table F.15* illustrate how the relay handles incoming and outgoing messages while in On mode.

Table F.14 IEC 61850 Incoming Message Handling in On Mode

IEC 61850 Messages	Incoming Message With Quality Test Bit Set to False (0)	Incoming Message With Quality Test Bit Set to True (1)
MMS	Processed	Processed as invalid
GOOSE	Processed	Processed as invalid

Table F.15 IEC 61850 Outgoing Message Handling in On Mode

IEC 61850 Messages	Outgoing Message Quality Test Bit Status
MMS	False
GOOSE	False

Figure F.10 illustrates the On Mode/Behavior.

Figure F.10 Relay Operations in On Mode

Mode: Blocked

Blocked mode is similar to On mode, but in Blocked mode, none of the physical contact outputs are operated. However, it does continue to operate control bits, such as remote bits and output contact bits. *Figure F.11* illustrates the Blocked Mode/Behavior.

Figure F.11 Relay Operations in Blocked Mode

Mode: Test

In Test mode, the relay processes valid incoming test signals or normal messages and operates physical contact outputs, if triggered. In this Mode/Behavior, outgoing MMS and GOOSE messages have the quality test bit set to True if the quality test bit is present. If the quality of the subscribed GOOSE messages satisfies the user-defined quality type definition (regardless of whether the quality test bit is set to True or False—see *GOOSE Processing on page F.16*), the relay processes the received GOOSE messages as valid. *Table F.16* and *Table F.17* illustrate how the relay handles incoming and outgoing messages while in Test mode.

Table F.16 IEC 61850 Incoming Message Handling in Test Mode

IEC 61850 Messages	Incoming Message With Quality Test Bit Set to False (0)	Incoming Message With Quality Test Bit Set to True (1)
MMS	Not Processed	Processed
GOOSE	Processed	Processed

Table F.17 IEC 61850 Outgoing Message Handling in Test Mode

IEC 61850 Messages	Outgoing Message Quality Test Bit Status
MMS	True
GOOSE	True

Figure F.12 illustrates the Test Mode/Behavior.

Figure F.12 Relay Operations in Test Mode

Mode: Test/Blocked

In Test/Blocked mode, the relay processes valid incoming test signals or normal messages but blocks any physical contact outputs from operating. In this Mode/Behavior, outgoing MMS and GOOSE messages have the quality test bit set to True if the quality test bit is present. If the quality of the subscribed GOOSE messages satisfies the user-defined quality type definition (regardless of whether the quality test bit is set to True or False— see *GOOSE Processing on page F.16*), the relay processes the received GOOSE messages as valid.

Figure F.13 illustrates the Test/Blocked Mode/Behavior.

Figure F.13 Relay Operations in Test/Blocked Mode

Mode: Off

In Off mode, the relay no longer processes incoming GOOSE messages. The relay processes MMS control requests to change the IEC 61850 Mode/Behavior if the quality Test bit is set to False. In this mode, the relay is in a disabled state and it no longer trips any physical contact outputs. The Relay Word bit ENABLED is set to False. The device processes MMS control requests to change the active mode of IEC 61850 Mode/Behavior if the quality test bit of the control is set to False. If Port_02.GOOSE_TxOffModEna is set to Y, the relay continues to transmit GOOSE messages with the quality test bit set to False (0) and the validity set to Invalid (01) if the quality bit is present in the messages. If Port_02.GOOSE_TxOffModEna is set to N, the relay does not transmit GOOSE messages in this mode. *Table F.18* and *Table F.19* describe how the relay handles incoming and outgoing messages while in Off mode.

Table F.18 IEC 61850 Incoming Message Handling in Off Mode

IEC 61850 Messages	Incoming Message With Quality Test Bit Set to False (0)	Incoming Messages With Quality Test Bit Set to True (1)
MMS	Relay Only Processes Messages to Control the Mode	Not Processed
GOOSE	Not Processed	Not Processed

Table F.19 IEC 61850 Outgoing Message Handling in Off Mode

IEC 61850 Messages	Outgoing Message Quality Validity Bit
MMS	Invalid
GOOSE	Invalid

Figure F.14 illustrates the Off Mode/Behavior.

Figure F.14 Relay Operations in Off Mode

IEC 61850 Configuration

Settings

Table F.20 lists IEC 61850 settings. IEC 61850 settings are only available if your device includes the optional IEC 61850 protocol. Configure all other IEC 61850 settings, including subscriptions to incoming GOOSE messages, with Architect.

Table F.20 IEC 61850 Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE IEC 61850 PROTOCOL	Y, N	Port_02.61850_Ena := N
ENABLE IEC 61850 GSE[a]	Y[b], N	Port_02.Goose_Ena := N
ENABLE MMS FILE SERVICES[a]	Y[b], N	Port_02.MMS_FileSvcEna := N
ENABLE IEC 61850 MODE/BEHAVIOR CONTROL	Y, N	Port_02.61850_ModCtrlEna := N
ENABLE GOOSE TX IN OFF MODE	Y, N	Port_02.Goose_TxOffModEna := N
ENABLE FIXED GOOSE PUBLICATIONS	0–1	Port_02.FG_TxEna := 0
FIXED GOOSE TX DESTINATION MAC ADDRESS	*mm–nn* *mm*: 00-FF *nn*: 00-FF	Port_02.FG1_TxMAC := 00-01
FIXED GOOSE TX MIN TIME	4–60000 ms	Port_02.FG1_TxMinTm := 4
FIXED GOOSE TX MAX TIME	4–60000 ms	Port_02.FG1_TxMaxTm := 1000
FIXED GOOSE TX APPID	0–255	Port_02.FG1_TxAppId := 1
FIXED GOOSE TX VLAN ID	0–255	Port_02.FG1_TxVLANId := 1
FIXED GOOSE TX VLAN PRIORITY	0–7	Port_02.FG1_TxVLANPrio := 4
ENABLE FIXED GOOSE SUBSCRIPTIONS	0–4	Port_02.FG_RxEna := 0
FIXED GOOSE RX MSG*p*[c] DESTINATION MAC ADDRESS	*mm–nn* *mm*: 00-FF *nn*: 00-FF	Port_02.FG*p*_RxMAC := 00-01

[a] Settings Port_02.Goose_Ena and Port_02.MMS_FileSvcEna are hidden when Port_02.61850_Ena is set to N.
[b] Requires that Port_02.61850_Ena be set to Y.
[c] p = 1–4.

Fixed GOOSE Transmit Digitals

Enter as many as eight Relay Word bits. The Fixed GOOSE transmit digital entries are text-edit mode settings.

Default Relay Word bits are:

Port_02.FG_TxBin:	51P_01.TmOut
Trip_01.Sta	51Gnd_01.TmOut
50P_01.TmOut	51N_01.TmOut
50Gnd_01.TmOut	Bkr_01.52A_Sta
50N_01.TmOut	

Fixed GOOSE Transmit Analogs

Enter as many as eight analog quantities. The Fixed GOOSE transmit analog entries are text-edit mode settings.

Default analog quantities are:

Port_02.FG_TxAna:	IN.120ms_MagPri
IA.120ms_MagPri	IPos.120ms_MagPri
IB.120ms_MagPri	INeg.120ms_MagPri
IC.120ms_MagPri	Freq.120ms_Mag
IGnd.120ms_MagPri	

Architect Software

The Architect software enables users to design and commission IEC 61850 substations containing SEL IEDs. Users can use Architect to do the following:

- Organize and configure all SEL IEDs in a substation project.
- Configure incoming and outgoing GOOSE messages.
- Edit and create GOOSE datasets.
- Read non-SEL IED Capability Description (ICD) and Configured IED Description (CID) files and determine the available IEC 61850 messaging options.
- Use or edit preconfigured datasets for reports.
- Load IEC 61850 CID files into SEL IEDs.
- Generate ICD and CID files that provide SEL IED descriptions to other manufacturers' tools so they can use SEL GOOSE messages and reporting features.
- Edit deadband settings for measured values.

NOTE: Other manufacturers' ICD and CID files must have IEC 61850 outgoing GOOSE messages with Application IDs (APPIDs) of exactly four characters and VLAN IDs of exactly three characters so that the relay can successfully subscribe to them. If you attempt to configure a relay to subscribe to a GOOSE message that does not meet this criteria, the relay will reject the CID file upon download. Edit other manufacturers' ICD and CID files prior to importing them into Architect by adding leading zeros to the APPID and VLAN ID of outgoing GOOSE messages, as necessary.

Architect provides a graphical user interface (GUI) for users to select, edit, and create IEC 61850 GOOSE messages important for substation protection, coordination, and control schemes. Typically, the user first places icons representing IEDs in a substation container, then edits the outgoing GOOSE messages or creates new ones for each IED. The user can also select incoming GOOSE messages for each IED to receive from any other IEDs in the domain.

Some measured values are reported to IEC 61850 only when the value changes beyond a defined deadband value. Architect allows a deadband to be changed during the CID file configuration. Check and set the deadband values for your particular application when configuring the CID file for a device.

Architect can read ICD and CID files from other manufacturers, enabling the user to map the data seamlessly into SEL IED logic. See the Architect online help for more information.

SEL ICD File Versions

Architect version R.1.1.69.0 and later supports multiple ICD file versions for each type of IED in a project. Because relays with different firmware versions may require different CID file versions, users can manage the CID files of all IEDs within a single project.

Please ensure that you work with the appropriate version of Architect relative to your current configuration, existing project files, and ultimate goals. If you want the best available IEC 61850 functionality for your SEL relay, obtain the latest version of Architect and select the appropriate ICD version(s) for your needs. Architect generates CID files from ICD files, so the ICD file version Architect uses also determines the CID file version generated.

The Logical Nodes description detailed in this manual revision corresponds to the SEL-851 006 ICD file.

Logical Nodes

Each logical device (LD) has a set of common data objects at the top level LN0. These represent the current state of the device, as well as some informational data. These data objects are: Mod (Mode), Beh (Behavior), Health, and NamPlt. See the following sections for a brief description of each object.

Mode

The SEL-800 series relays include at the top-level LN0 within each LD the following enumerations for Mod.stVal:

Mod.stVal Enumeration	Description
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off
0	IEC 61850 Mode/Behavior disabled

The top-level logical node of each LD also includes the following Mod attributes:

Mod.q represents quality.

Mod.t represents time stamps.

Mod.stVal represents the current Mode/Behavior.

You can control IEC 61850 Mode/Behavior via LLN0COMod$Oper in your CFG logical device.

Behavior

SEL-800 series relays LNs include the following enumerations for Beh stVal:

Beh stVal Enumeration	Description
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off

Logical nodes also include the following Beh attributes:

Beh q and **Beh t** according to the *Time Stamps and Quality* section.

Health

The SEL-800 series relays include at the top-level LN0 within each LD the following enumerations for Health stVal:

Health stVal Enumeration	Health stVal Value	Description
1	OK	Relay Word bit = 1
3	Alarm	Relay Word bit = 0

The top-level logical node of each LD also includes the following Health attributes:

Health q and **Health t** according to the *Time Stamps and Quality* section.

NamPlt

The top-level LN0 of each LD includes the following NamPlt attributes:

- NamPlt vendor which is set to “SEL”.
- NamPlt swRev which contains the relay FID string value.
- NamPlt d, which is the LD description.

Logical Node Extensions

The following Logical Nodes and Data Classes were created in this device as extensions to the IEC 61850 standard, in accordance with the IEC 61850 guidelines.

Table F.21 New Logical Node Extensions

Logical Node	IEC 61850	Description or Comments
Arc Flash Detection	PAFD	This LN shall be used to represent Arc Flash Detection status.
Demand Metering Statistics	MDST	This LN shall be used for calculation of demand currents in a three-phase system. This shall not be used for billing purposes.

Table F.22 defines the data class Arc-Flash Detection. This class represents Arc-Flash Detection status.

Table F.22 Arc-Flash Detection Logical Node Class Definition

PAFD Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2).		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Status Information				
Str	ACD	Start		E
Op	ACT	Operate	T	E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Table F.23 defines the data class Demand Metering Statistics. This class is a collection of demand currents and energy.

Table F.23 Demand Metering Statistics Logical Node Class Definition

MDST Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Measured Values				
DmdA	WYE	Phase Demand Currents		E
DmdAnseq	MV	Negative-Sequence Demand Current		E
PkDmdA	WYE	Peak Demand Currents		E
PkDmdAnseq	MV	Negative-Sequence Peak Demand Current		E
SupWh	BCR	Real energy supply (default supply direction: energy flow towards busbar)		E
SupVArh	BCR	Reactive energy supply (default supply direction: energy flow towards busbar)		E
DmdWh	BCR	Real energy demand (default demand direction: energy flow from busbar away)		E
DmdVArh	BCR	Reactive energy demand (default demand direction: energy flow from busbar away)		E
TotVAh	BCR	Apparent energy demand		E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension

The following logical nodes have been extended with extra data.

Table F.24 Compatible Logical Nodes With Extensions

Logical Node	IEC 61850	Description or comments
Metering Statistics	MSTA	This LN is used for metering statistics.
Generic Process I/O	GGIO	This LN is used for remote analog data.
Physical Communication Channel Supervision	LCCH	This LN is used for supervision of physical communication channels.
GOOSE Subscription	LGOS	This LN is used for GOOSE subscription statistics.
Time Master Supervision	LTMS	This LN is used for time synchronization master supervision.

Table F.25 defines the data class Metering Statistics. This class is a collection of power system metering statistics.

Table F.25 Metering Statistics Logical Node Class Definition

MSTA Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Measured and Metered Values				
AvAmps	MV	Average current		O
AvVolts	MV	Average voltage		O
MaxVA	MV	Maximum apparent power		O
MinVA	MV	Minimum apparent power		O
MaxW	MV	Maximum real power		O
MinW	MV	Minimum real power		O
MaxVAr	MV	Maximum reactive power		O
MinVAr	MV	Minimum reactive power		O
MaxA	WYE	Maximum phase currents		E
MinA	WYE	Minimum phase currents		E
MaxPhV	WYE	Maximum phase-to-ground voltages		E
MinPhV	WYE	Minimum phase-to-ground voltages		E
MaxP2PV	DEL	Maximum phase-to-phase voltages		E
MinP2PV	DEL	Minimum phase-to-phase voltages		E
MaxFreq	MV	Maximum frequency		E
MinFreq	MV	Minimum frequency		E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Table F.26 Generic Process I/O Logical Node Class Definition (Sheet 1 of 2)

GGIO Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix, and the LN-Instance-ID (according to IEC 61850-7-2).		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M

Table F.26 Generic Process I/O Logical Node Class Definition (Sheet 2 of 2)

GGIO Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
Data Objects				
Measured Values				
AnIn	MV	Analog input		O
Ra	MV	Remote analog		E
Controls				
SPCSO	SPC	Single point controllable status output		O
Status Information				
Ind	SPS	General indication (binary input)		O

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Table F.27 LCCH Physical Communication Channel Supervision

LCCH Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22.		
Data objects				
Common Logical Node Information				
Beh	ENS	Behavior		M
NamPlt	LPL	Name plate		O
Status Information				
ChLiv	SPS	Physical channel status		M
RedChLiv	SPS	Physical channel status of redundant channel		C
FerCh	INS	Frame error rate on this channel		O
RedFerCh	INS	Frame error rate on redundant channel		O
Measured and Metered Values				
RxCnt	BCR	Number of received messages		O
RedRxCnt	BCR	Number of received messages on redundant channel		O
TxCnt	BCR	Number of sent messages		O
Controls				
RsStat	SPC	Reset device statistics		E
Settings				
NetMod	ENG	Network mode		E

[a] M: Mandatory; O: Optional; C: Conditional; E: Extension.
[b] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.

Table F.28 LGOS GOOSE Subscription (Sheet 1 of 2)

LGOS Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22		
Data Objects				
Common Logical Node Information				
Beh	ENS	Behavior		M
NamPlt	LPL	Name plate		O
Status Information				
NdsCom	SPS	Subscription needs commissioning		O
St	SPS	Status of the subscription		M
SimSt	SPS	Status showing really that Sim messages are received and accepted		O
LastStNum	INS	Last state number received		O
LastSqNum	INS	Last sequence number received		E
LastTal	INS	Last time-allowed-to-live received		E
ConfRevNum	INS	Expected configuration revision number		O
RxConfRev-Num	INS	Configuration revision number of the received messages		O
ErrSt	ENS	Current error status of the subscription		E
OosCnt	INS	Number of out-of-sequence (OOS) errors		E
TalCnt	INS	Number of time-allowed-to-live violations		E
DecErrCnt	INS	Number of messages that failed decoding		E
BufOvflCnt	INS	Number of messages lost due to buffer overflow		E
MsgLosCnt	INS	Number of messages lost due to OOS errors (estimated)		E
MaxMsgLos	INS	Max. number of sequential messages lost due to OOS error (estimated)		E
InvQualCnt	INS	Number of mapped incoming GOOSE data with invalid quality		E
Measured and Metered Values				
TotDwnTm	MV	Total downtime in seconds		E
MaxDwnTm	MV	Maximum continuous downtime in seconds		E
Controls				
RsStat	SPC	Reset/clear statistics		E
Settings				
GoCBRef	ORG	Reference to the subscribed GOOSE control block		O

Table F.28 LGOS GOOSE Subscription (Sheet 2 of 2)

LGOS Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
DatSet	ORG	Configured dataset reference		E
GoID	VSG	Configured GOOSE ID		E
Addr	VSG	Configured multicast MAC address		E
VlanID	ING	Configured VLAN ID		E
VlanPri	ING	Configured VLAD priority		E
AppID	ING	Configured APPID		E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Table F.29 LTMS Time Master Supervision

LTMS Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22		
Data Objects				
Common Logical Node Information				
Beh	ENS	Behavior		M
NamPlt	LPL	Name plate		O
Status Information				
TmAcc	INS	Number of significant bits in fraction of second in the time accuracy part of the time stamp		O
TmSrc	VSS	Current time source identity		M
SelTmSrcTyp	ENS	Type of the clock source		E
SelTmSyn	ENS	Actual time synchronization applied		E
SelTmSynLkd	ENS	Locked status of clock synchronization		E
Measured and Metered Values				
SelTmTosPer	MV	Duration, in milliseconds, between two consecutive top-of-second points on the synchronized time		E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Device Logical Nodes

The following tables, *Table F.30* through *Table F.34*, show the Logical Nodes (LN) supported in the SEL-851 and the associated Relay Word bits or measured quantities.

Table F.30 shows the LN associated with protection elements defined as Logical Device PRO.

Table F.30 Logical Device: PRO (Protection) (Sheet 1 of 5)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
BkCSWI1	Pos.Oper.ctlVal	Comm.ClsCmd: Comm.TripCmd[a]	Breaker close/open command
Functional Constraint = DC			
PROLPHD1	PhyNam.model	Dev.PartNum	Part number
PROLPHD1	PhyNam.serNum	Dev.SerNum	Serial number
LLN0	NamPlt.swRev	FID	Firmware revision
TOL1PAFD1	NamPlt.swRev	FID	Firmware revision
TOL2PAFD2	NamPlt.swRev	FID	Firmware revision
TOL3PAFD3	NamPlt.swRev	FID	Firmware revision
TOL4PAFD4	NamPlt.swRev	FID	Firmware revision
Functional Constraint = ST			
BkRBRF1	OpEx.general	BF_01.Trip	Breaker failure trip logic output
BkRBRF1	Str.general	BF_01.Init	Breaker failure initiate SELOGIC control equation
BkXCBR1	BlkCls.stVal	0	Breaker close blocking not configured by default
BkXCBR1	BlkOpn.stVal	0	Breaker open blocking not configured by default
BkXCBR1	CBOpCap.stVal	None	Breaker/Contactor physical operation capabilities not known to relay
BkXCBR1	Loc.stVal	Ctl.LocSta	Breaker control in Local mode
BkXCBR1	OpCnt.stVal	0	Breaker internal operation counter not configured by default
BkXCBR1	Pos.stVal	Bkr_01.52A_Sta?1:2[b]	Breaker position (52A = false, breaker opened; 52 = true, breaker closed)
BkCSWI1	OpCls.general	Comm.ClsCmd	Close command issued over communication protocols
BkCSWI1	OpOpn.general	Comm.TripCmd	Trip command issued over communication protocols
BkCSWI1	Loc.stVal	Ctl.LocSta	Breaker control in Local mode
BkCSWI1	Pos.stVal	Bkr_01.52A_Sta?1:2	Breaker position (52A = false, breaker opened; 52A = true, breaker closed)
HzPTOF1	Op.general	81_01.TmOut	Frequency element trip, Level 01
HzPTOF1	Str.general	81_01.PU	Frequency element trip, Level 01
HzPTOF1	Str.dirGeneral	unknown	Direction undefined
HzPTOF2	Op.general	81_02.TmOut	Frequency element trip, Level 02
HzPTOF2	Str.general	81_02.PU	Frequency element trip, Level 02
HzPTOF2	Str.dirGeneral	unknown	Direction undefined
FLTRDRE1	RcdMade.stVal	Event.Sta	Event report present
FLTRDRE1	FltNum.stVal	Event.Id	Unique identification number of the latest event
GndPIOC1	Op.general	50Gnd_01.TmOut	Residual ground definite-time overcurrent element trip, Level 01
GndPIOC1	Str.general	50Gnd_01.PU	Residual ground definite-time overcurrent element pickup, Level 01
GndPIOC1	Str.dirGeneral	unknown	Direction undefined
GndPTOC1	Op.general	51Gnd_01.TmOut	Residual ground time-overcurrent element trip, Level 01
GndPTOC1	Str.general	51Gnd_01.PU	Residual ground time-overcurrent element pickup, Level 01

Table F.30 Logical Device: PRO (Protection) (Sheet 2 of 5)

Logical Node	Attribute	Data Source	Comment
GndPTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
GndPTOV1	Op.general	59Gnd_01.TmOut	Residual ground definite-time overvoltage element trip, Level 01
GndPTOV1	Str.general	59Gnd_01.PU	Residual ground definite-time overvoltage element pickup, Level 01
GndPTOV1	Str.dirGeneral	unknown	Direction undefined
GndPIOC2	Op.general	50Gnd_02.TmOut	Residual ground definite-time overcurrent element trip, Level 02
GndPIOC2	Str.general	50Gnd_02.PU	Residual ground definite-time overcurrent element pickup, Level 02
GndPIOC2	Str.dirGeneral	unknown	Direction undefined
GndPTOC2	Op.general	51Gnd_02.TmOut	Residual ground time-overcurrent element trip, Level 02
GndPTOC2	Str.general	51Gnd_02.PU	Residual ground time-overcurrent element pickup, Level 02
GndPTOC2	Str.dirGeneral	unknown	Direction unknown due to settings
GndPTOV2	Op.general	59Gnd_02.TmOut	Residual ground definite-time overvoltage element trip, Level 02
GndPTOV2	Str.general	59Gnd_02.PU	Residual ground definite-time overvoltage element pickup, Level 02
GndPTOV2	Str.dirGeneral	unknown	Direction undefined
LOPPTUV1	Op.general	60LOP.PU	Loss of potential element pickup
LOPPTUV1	Str.general	60LOP.PU	Loss of potential element pickup
LOPPTUV1	Str.dirGeneral	unknown	Direction undefined
EFPIOC1	Op.general	50N_01.TmOut	Neutral definite-time overcurrent element trip, Level 01
EFPIOC1	Str.general	50N_01.PU	Neutral definite-time overcurrent element pickup, Level 01
EFPIOC1	Str.dirGeneral	unknown	Direction undefined
EFPTOC1	Op.general	51N_01.TmOut	Neutral time-overcurrent element trip, Level 01
EFPTOC1	Str.general	51N_01.PU	Neutral time-overcurrent element pickup, Level 01
EFPTOC1	Str.dirGeneral	unknown	Direction undefined
EFPIOC2	Op.general	50N_02.TmOut	Neutral definite-time overcurrent element trip, Level 02
EFPIOC2	Str.general	50N_02.PU	Neutral definite-time overcurrent element pickup, Level 02
EFPIOC2	Str.dirGeneral	unknown	Direction undefined
EFPTOC2	Op.general	51N_02.TmOut	Neutral time-overcurrent element trip, Level 02
EFPTOC2	Str.general	51N_02.PU	Neutral time-overcurrent element pickup, Level 02
EFPTOC2	Str.dirGeneral	unknown	Direction undefined
Ph3PIOC1	Str.general	50ABC_01.PU	Per-phase definite-time overcurrent element pickup, phase A, B, or C, Level 01
Ph3PIOC1	Op.general	50ABC_01.TmOut	Per-phase definite-time overcurrent element trip, Phase A, B, or C, Level 01
Ph3PIOC1	Op.phsA	50ABC_01.TmOut_A	Per-phase definite-time overcurrent element trip, Phase A, Level 01
Ph3PIOC1	Op.phsB	50ABC_01.TmOut_B	Per-phase definite-time overcurrent element trip, Phase B, Level 01

Table F.30 Logical Device: PRO (Protection) (Sheet 3 of 5)

Logical Node	Attribute	Data Source	Comment
Ph3PIOC1	Op.phsC	50ABC_01.TmOut_C	Per-phase definite-time overcurrent element trip, Phase C, Level 01
Ph3PIOC1	Str.dirGeneral	unknown	Direction undefined
EFPAFD1	Op.general	AFD.50N_PU	Sample-based residual overcurrent element for arc-flash detection
EFPAFD1	Str.general	AFD.50N_PU	Sample-based residual overcurrent element for arc-flash detection
EFPAFD1	Str.dirGeneral	unknown	Direction undefined
PhPIOC1	Op.general	50P_01.TmOut	Maximum phase definite-time overcurrent element trip, Level 01
PhPIOC1	Str.general	50P_01.PU	Maximum phase definite-time overcurrent element pickup, Level 01
PhPIOC1	Str.dirGeneral	unknown	Direction undefined
PhPTOC1	Op.general	51P_01.TmOut	Maximum phase time-overcurrent element trip, Level 01
PhPTOC1	Str.general	51P_01.PU	Maximum phase time-overcurrent element pickup, Level 01
PhPTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
PhPIOC2	Op.general	50P_02.TmOut	Maximum phase definite-time overcurrent element trip, Level 02
PhPIOC2	Str.general	50P_02.PU	Maximum phase definite-time overcurrent element pickup, Level 02
PhPIOC2	Str.dirGeneral	unknown	Direction undefined
PhPTOC2	Op.general	51P_02.TmOut	Maximum phase time-overcurrent element trip, Level 02
PhPTOC2	Str.general	51P_02.PU	Maximum phase time-overcurrent element pickup, Level 02
PhPTOC2	Str.dirGeneral	unknown	Direction unknown due to settings
PhPIOC3	Op.general	50P_03.TmOut	Maximum phase definite-time overcurrent element trip, Level 03
PhPIOC3	Str.general	50P_03.PU	Maximum phase definite-time overcurrent element pickup, Level 03
PhPIOC3	Str.dirGeneral	unknown	Direction undefined
PhPIOC4	Op.general	50P_04.TmOut	Maximum phase definite-time overcurrent element trip, Level 04
PhPIOC4	Str.general	50P_04.PU	Maximum phase definite-time overcurrent element pickup, Level 04
PhPIOC4	Str.dirGeneral	unknown	Direction undefined
PhPIOC5	Op.general	50P_05.TmOut	Maximum phase definite-time overcurrent element trip, Level 05
PhPIOC5	Str.general	50P_05.PU	Maximum phase definite-time overcurrent element pickup, Level 05
PhPIOC5	Str.dirGeneral	unknown	Direction undefined
PhPIOC6	Op.general	50P_06.TmOut	Maximum phase definite-time overcurrent element trip, Level 06
PhPIOC6	Str.general	50P_06.PU	Maximum phase definite-time overcurrent element pickup, Level 06
PhPIOC6	Str.dirGeneral	unknown	Direction undefined

Table F.30 Logical Device: PRO (Protection) (Sheet 4 of 5)

Logical Node	Attribute	Data Source	Comment
PhPAFD1	Op.general	AFD.50P_PU	Sample-based phase overcurrent element for arc-flash detection
PhPAFD1	Str.general	AFD.50P_PU	Sample-based phase overcurrent element for arc-flash detection
PhPAFD1	Str.dirGeneral	unknown	Direction undefined
PPPTOV1	Op.general	59PP_01.TmOut	Phase-phase definite-time overvoltage element trip, Level 01
PPPTOV1	Str.general	59PP_01.PU	Phase-phase definite-time overvoltage element pickup, Level 01
PPPTOV1	Str.dirGeneral	unknown	Direction undefined
PPPTUV1	Op.general	27PP_01.TmOut	Phase-phase definite-time undervoltage element trip, Level 01
PPPTUV1	Str.general	27PP_01.PU	Phase-phase definite-time undervoltage element pickup, Level 01
PPPTUV1	Str.dirGeneral	unknown	Direction undefined
PPPTOV2	Op.general	59PP_02.TmOut	Phase-phase definite-time overvoltage element trip, Level 02
PPPTOV2	Str.general	59PP_02.PU	Phase-phase definite-time overvoltage element pickup, Level 02
PPPTOV2	Str.dirGeneral	unknown	Direction undefined
PPPTUV2	Op.general	27PP_02.TmOut	Phase-phase definite-time undervoltage element trip, Level 02
PPPTUV2	Str.general	27PP_02.PU	Phase-phase definite-time undervoltage element pickup, Level 02
PPPTUV2	Str.dirGeneral	unknown	Direction undefined
PhPDOP1	Op.general	32_01.TmOut	32 directional power element timeout, Level 01.
PhPDOP1	Str.general	32_01.PU	32 directional power element pickup, Level 01
PhPDOP1	Str.dirGeneral	unknown	Direction undefined
PhPDUP1	Op.general	32_01.TmOut	32 directional power element timeout, Level 01
PhPDUP1	Str.general	32_01.PU	32 directional power element pickup, Level 01
PhPDUP1	Str.dirGeneral	unknown	Direction undefined
PhPDOP2	Op.general	32_02.TmOut	32 directional power element timeout, Level 02
PhPDOP2	Str.general	32_02.PU	32 directional power element pickup, Level 02
PhPDOP2	Str.dirGeneral	unknown	Direction undefined
PhPDUP2	Op.general	32_02.TmOut	32 directional power element timeout, Level 02
PhPDUP2	Str.general	32_02.PU	32 directional power element pickup, Level 02
PhPDUP2	Str.dirGeneral	unknown	Direction undefined
NgSeqPIOC1	Op.general	50Neg_01.TmOut	Negative sequence definite-time overcurrent element trip, Level 01
NgSeqPIOC1	Str.general	50Neg_01.PU	Negative sequence definite-time overcurrent element pickup, Level 01
NgSeqPIOC1	Str.dirGeneral	unknown	Direction undefined
NgSeqPIOC2	Op.general	50Neg_02.TmOut	Negative sequence definite-time overcurrent element trip, Level 02
NgSeqPIOC2	Str.general	50Neg_02.PU	Negative sequence definite-time overcurrent element pickup, Level 02

Table F.30 Logical Device: PRO (Protection) (Sheet 5 of 5)

Logical Node	Attribute	Data Source	Comment
NgSeqPIOC2	Str.dirGeneral	unknown	Direction undefined
NgSeqPTOC1	Op.general	51Neg_01.TmOut	Negative sequence time-overcurrent element trip, Level 01
NgSeqPTOC1	Str.general	51Neg_01.PU	Negative sequence time-overcurrent element pickup, Level 01
NgSeqPTOC1	Str.dirGeneral	unknown	Direction undefined
NgSeqPTOC2	Op.general	51Neg_02.TmOut	Negative sequence time-overcurrent element trip, Level 02
NgSeqPTOC2	Str.general	51Neg_02.PU	Negative sequence time-overcurrent element pickup, Level 02
NgSeqPTOC2	Str.dirGeneral	unknown	Direction undefined
PFPUPF1	Op.general	55_01.TmOut	Power factor element trip, Level 01
PFPOPF1	Str.general	55_01.PU	Power factor element pickup, Level 01
PFPUPF1	Str.dirGeneral	unknown	Direction undefined
PFPUPF2	Op.general	55_02.TmOut	Power factor element trip, Level 02
PFPOPF2	Str.general	55_02.PU	Power factor element pickup, Level 02
PFPUPF2	Str.dirGeneral	unknown	Direction undefined
TOL1PAFD1	Op.general	AFD.Sen01_PU[c]	Arc-Flash Light Input Element 01 pickup
TOL1PAFD1	Str.general	AFD.Sen01_PU[c]	Arc-Flash Light Input Element 01 pickup
TOL1PAFD1	Str.dirGeneral	unknown	Direction undefined
TOL2PAFD2	Op.general	AFD.Sen02_PU[c]	Arc-Flash Light Input Element 02 pickup
TOL2PAFD2	Str.general	AFD.Sen02_PU[c]	Arc-Flash Light Input Element 02 pickup
TOL2PAFD2	Str.dirGeneral	unknown	Direction undefined
TOL3PAFD3	Op.general	AFD.Sen03_PU[c]	Arc-Flash Light Input Element 03 pickup
TOL3PAFD3	Str.general	AFD.Sen03_PU[c]	Arc-Flash Light Input Element 03 pickup
TOL3PAFD3	Str.dirGeneral	unknown	Direction undefined
TOL4PAFD4	Op.general	AFD.Sen04_PU[c]	Arc-Flash Light Input Element 04 pickup
TOL4PAFD4	Str.general	AFD.Sen04_PU[c]	Arc-Flash Light Input Element 04 pickup
TOL4PAFD4	Str.dirGeneral	unknown	Direction undefined
TripPTRC1	Tr.general	Trip_01.Sta	Trip issued
Functional Constraint = SP			
LLN0	GrRef.setSrcRef	IdName	Functional name

[a] Writing a 0 to Pos.Oper.ctlVal will cause the Open control bit to assert and writing any other value will cause the Close control bit to assert.
[b] If the breaker/disconnect switch is closed, value = 10(2). If the breaker/disconnect switch is open, value = 01(1).
[c] Valid data depends on the installed arc-flash card.

Table F.31 shows the LN associated with measuring elements defined as Logical Device MET.

Table F.31 Logical Device: MET (Metering) (Sheet 1 of 4)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = DC			
METLPHD1	PhyNam.model	Dev.PartNum	Part number
METLPHD1	PhyNam.serNum	Dev.SerNum	Serial number

Table F.31 Logical Device: MET (Metering) (Sheet 2 of 4)

Logical Node	Attribute	Data Source	Comment
LLN0	NamPlt.swRev	FID	Firmware revision
METMDST1	NamPlt.swRev	FID	Firmware revision
Functional Constraint = MX[a] [b]			
METMDST1	DmdAnseq.instCVal.mag.f	INeg.Dmd	Negative-sequence current demand
METMDST1	DmdA.phsA.instCVal.mag.f	IA.Dmd	Phase A current demand
METMDST1	DmdA.phsB.instCVal.mag.f	IB.Dmd	Phase B current demand
METMDST1	DmdA.phsC.instCVal.mag.f	IC.Dmd	Phase C current demand
METMDST1	DmdA.res.instCVal.mag.f	IGnd.Dmd	Residual current demand
METMDST1	PkDmdAnseq.instCVal.mag.f	INeg.PkDmd	Negative-sequence current peak demand
METMDST1	PkDmdA.phsA.instCVal.mag.f	IA.PkDmd	Phase A current peak demand
METMDST1	PkDmdA.phsB.instCVal.mag.f	IB.PkDmd	Phase B current peak demand
METMDST1	PkDmdA.phsC.instCVal.mag.f	IC.PkDmd	Phase C current peak demand
METMDST1	PkDmdA.res.instCVal.mag.f	IGnd.PkDmd	Residual current peak demand
METMMXU1	A.phsA.instCVal.ang.f	IA.120ms_MagPri	Current, A-phase, angle
METMMXU1	A.phsA.instCVal.mag.f	IA.120ms_Ang	Current, A-phase, magnitude
METMMXU1	A.phsB.instCVal.ang.f	IB.120ms_MagPri	Current, B-phase, angle
METMMXU1	A.phsB.instCVal.mag.f	IB.120ms_Ang	Current, B-phase, magnitude
METMMXU1	A.phsC.instCVal.ang.f	IC.120ms_MagPri	Current, C-phase, angle
METMMXU1	A.phsC.instCVal.mag.f	IC.120ms_Ang	Current, C-phase, magnitude
METMMXU1	A.res.instCVal.ang.f	IGnd.120ms_MagPri	Current, calculated-residual, angle
METMMXU1	A.res.instCVal.mag.f	IGnd.120ms_Ang	Current, calculated-residual, magnitude
METMMXU1	A.neut.instCVal.ang.f	IN.120ms_MagPri	Neutral current, angle
METMMXU1	A.neut.instCVal.mag.f	IN.120ms_Ang	Neutral current, magnitude
METMMXU1	Hz.instMag.f	Freq.120ms_Mag	Frequency
METMMXU1	PhV.phsA.instCVal.ang.f	VA.120ms_MagPri	Voltage, A-phase-to-neutral, angle
METMMXU1	PhV.phsA.instCVal.mag.f	VA.120ms_Ang	Voltage, A-phase-to-neutral, magnitude
METMMXU1	PhV.phsB.instCVal.ang.f	VB.120ms_MagPri	Voltage, B-phase-to-neutral, angle
METMMXU1	PhV.phsB.instCVal.mag.f	VB.120ms_Ang	Voltage, B-phase-to-neutral, magnitude
METMMXU1	PhV.phsC.instCVal.ang.f	VC.120ms_MagPri	Voltage, C-phase-to-neutral, angle
METMMXU1	PhV.phsC.instCVal.mag.f	VC.120ms_Ang	Voltage, C-phase-to-neutral, magnitude
METMMXU1	PhV.res.instCVal.ang.f	VGnd.120ms_MagPri	Zero-sequence voltage, angle
METMMXU1	PhV.res.instCVal.mag.f	VGnd.120ms_Ang	Zero-sequence voltage, magnitude
METMMXU1	PPV.phsAB.instCVal.ang.f	VAB.120ms_MagPri	Voltage, A-to-B-phase, angle
METMMXU1	PPV.phsAB.instCVal.mag.f	VAB.120ms_Ang	Voltage, A-to-B-phase, magnitude
METMMXU1	PPV.phsBC.instCVal.ang.f	VBC.120ms_MagPri	Voltage, B-to-C-phase, angle
METMMXU1	PPV.phsBC.instCVal.mag.f	VBC.120ms_Ang	Voltage, B-to-C-phase, magnitude
METMMXU1	PPV.phsCA.instCVal.ang.f	VCA.120ms_MagPri	Voltage, C-to-A-phase, angle
METMMXU1	PPV.phsCA.instCVal.mag.f	VCA.120ms_Ang	Voltage, C-to-A-phase, magnitude
METMMXU1	TotPF.instMag.f	PF.120ms_Mag	Power factor, 3-phase, magnitude
METMMXU1	TotVA.instMag.f	S.120ms_Mag	Apparent power, 3-phase, magnitude
METMMXU1	TotVAr.instMag.f	Q.120ms_Mag	Reactive power, 3-phase, magnitude

Table F.31 Logical Device: MET (Metering) (Sheet 3 of 4)

Logical Node	Attribute	Data Source	Comment
METMMXU1	TotW.instMag.f	P.120ms_Mag	Real power, 3-phase, magnitude
METMSQI1	SeqA.c1.instCVal.ang.f	IPos.120ms_MagPri	Positive-sequence current, angle
METMSQI1	SeqA.c1.instCVal.mag.f	IPos.120ms_Ang	Positive-sequence current, magnitude
METMSQI1	SeqA.c2.instCVal.ang.f	INeg.120ms_Ang	Negative-sequence current, angle
METMSQI1	SeqA.c2.instCVal.mag.f	INeg.120ms_MagPri	Negative-sequence current, magnitude
METMSQI1	SeqA.c3.instCVal.ang.f	IGnd.120ms_Ang	Current, calculated-residual, angle
METMSQI1	SeqA.c3.instCVal.mag.f	IGnd.120ms_MagPri	Current, calculated-residual, magnitude
METMSQI1	SeqV.c1.instCVal.ang.f	VPos.120ms_MagPri	Positive-sequence voltage, angle
METMSQI1	SeqV.c1.instCVal.mag.f	VPos.120ms_Ang	Positive-sequence voltage, magnitude
METMSQI1	SeqV.c2.instCVal.ang.f	VNeg.120ms_Ang	Negative-sequence voltage, angle
METMSQI1	SeqV.c2.instCVal.mag.f	VNeg.120ms_MagPri	Negative-sequence voltage, magnitude
METMSQI1	SeqV.c3.instCVal.ang.f	VGnd.120ms_Ang	Zero-sequence voltage, angle
METMSQI1	SeqV.c3.instCVal.mag.f	VGnd.120ms_MagPri	Zero-sequence voltage, magnitude
METMSTA1	AvAmps.instMag.f	IAvg.120ms_MagPri	Current, average current, magnitude
METMSTA1	AvVolts.instMag.f	VAvg.120ms_MagPri	Average voltage, magnitude
METMSTA1	MaxA.phsA.instCVal.mag.f	IA.MaxMagPri	Current, A-phase, maximum magnitude
METMSTA1	MaxA.phsB.instCVal.mag.f	IB.MaxMagPri	Current, B-phase, maximum magnitude
METMSTA1	MaxA.phsC.instCVal.mag.f	IC.MaxMagPri	Current, C-phase, maximum magnitude
METMSTA1	MaxA.res.instCVal.mag.f	IGnd.MaxMagPri	Current, residual, maximum magnitude
METMSTA1	MaxA.neut.instCVal.mag.f	IN.MaxMagPri	Current, neutral, maximum magnitude
METMSTA1	MaxP2PV.phsAB.instCVal.mag.f	VAB.MaxMagPri	Voltage, A-to-B-phase, maximum magnitude
METMSTA1	MaxP2PV.phsBC.instCVal.mag.f	VBC.MaxMagPri	Voltage, B-to-C-phase, maximum magnitude
METMSTA1	MaxP2PV.phsCA.instCVal.mag.f	VCA.MaxMagPri	Voltage, C-to-A-phase, maximum magnitude
METMSTA1	MaxPhV.phsA.instCVal.mag.f	VA.MaxMagPri	Voltage, A-phase-to-neutral, maximum magnitude
METMSTA1	MaxPhV.phsB.instCVal.mag.f	VB.MaxMagPri	Voltage, B-phase-to-neutral, maximum magnitude
METMSTA1	MaxPhV.phsC.instCVal.mag.f	VC.MaxMagPri	Voltage, C-phase-to-neutral, maximum magnitude
METMSTA1	MaxFreq.instMag.f	Freq.MaxMag	Maximum frequency
METMSTA1	MaxVA.instMag.f	S.MaxMag	Apparent power, 3-phase, maximum magnitude
METMSTA1	MaxW.instMag.f	P.MaxMag	Real power, 3-phase, maximum magnitude
METMSTA1	MaxVAr.instMag.f	Q.MaxMag	Reactive power, 3-phase, maximum magnitude
METMSTA1	MinA.phsA.instCVal.mag.f	IA.MinMagPri	Current, A-phase, minimum magnitude
METMSTA1	MinA.phsB.instCVal.mag.f	IB.MinMagPri	Current, B-phase, minimum magnitude
METMSTA1	MinA.phsC.instCVal.mag.f	IC.MinMagPri	Current, C-phase, minimum magnitude
METMSTA1	MinA.res.instCVal.mag.f	IGnd.MinMagPri	Current, residual, minimum magnitude
METMSTA1	MinA.neut.instCVal.mag.f	IN.MinMagPri	Current, neutral, minimum magnitude
METMSTA1	MinP2PV.phsAB.instCVal.mag.f	VAB.MinMagPri	Voltage, A-to-B-phase, minimum magnitude
METMSTA1	MinP2PV.phsBC.instCVal.mag.f	VBC.MinMagPri	Voltage, B-to-C-phase, minimum magnitude
METMSTA1	MinP2PV.phsCA.instCVal.mag.f	VCA.MinMagPri	Voltage, C-to-A-phase, minimum magnitude
METMSTA1	MinPhV.phsA.instCVal.mag.f	VA.MinMagPri	Voltage, A-phase-to-neutral, minimum magnitude
METMSTA1	MinPhV.phsB.instCVal.mag.f	VB.MinMagPri	Voltage, B-phase-to-neutral, minimum magnitude
METMSTA1	MinPhV.phsC.instCVal.mag.f	VC.MinMagPri	Voltage, C-phase-to-neutral, minimum magnitude

Table F.31 Logical Device: MET (Metering) (Sheet 4 of 4)

Logical Node	Attribute	Data Source	Comment
METMSTA1	MinFreq.instMag.F	Freq.MinMag	Minimum frequency
METMSTA1	MinVA.instMag.f	S.MinMag	Apparent power, 3-phase, minimum magnitude
METMSTA1	MinVAr.instMag.f	Q.MinMag	Reactive power, 3-phase, minimum magnitude
METMSTA1	MinW.instMag.f	P.MinMag	Real power, 3-phase, minimum magnitude
RMSMMXU2	A.phsA.instCVal.mag.f	IA.RMS_120ms_Pri	RMS current, A-phase, magnitude
RMSMMXU2	A.phsB.instCVal.mag.f	IB.RMS_120ms_Pri	RMS current, B-phase, magnitude
RMSMMXU2	A.phsC.instCVal.mag.f	IC.RMS_120ms_Pri	RMS current, C-phase, magnitude
RMSMMXU2	A.neut.instCVal.mag.f	IN.RMS_120ms_Pri	RMS current, neutral, magnitude
RMSMMXU2	PhV.phsA.instCVal.mag.f	VA.RMS_120ms_Pri	RMS voltage, A-phase, magnitude
RMSMMXU2	PhV.phsB.instCVal.mag.f	VB.RMS_120ms_Pri	RMS voltage, B-phase, magnitude
RMSMMXU2	PhV.phsC.instCVal.mag.f	VC.RMS_120ms_Pri	RMS voltage, C-phase, magnitude
RMSMMXU2	PPV.phsAB.instCVal.mag.f	VAB.RMS_120ms_Pri	RMS voltage, AB-phase-to-phase, magnitude
RMSMMXU2	PPV.phsBC.instCVal.mag.f	VBC.RMS_120ms_Pri	RMS voltage, BC-phase-to-phase, magnitude
RMSMMXU2	PPV.phsCA.instCVal.mag.f	VCA.RMS_120ms_Pri	RMS voltage, CA-phase-to-phase, magnitude
METMHAI1	ThdA.phsA.instCVal.mag.f	IA.THD_120ms_Pct	THD, Phase Current IA
METMHAI1	ThdA.phsB.instCVal.mag.f	IB.THD_120ms_Pct	THD, Phase Current IB
METMHAI1	ThdA.phsC.instCVal.mag.f	IC.THD_120ms_Pct	THD, Phase Current IC
METMHAI1	ThdPhV.phsA.instCVal.mag.f	VA.THD_120ms_Pct	THD, Phase Current VA
METMHAI1	ThdPhV.phsB.instCVal.mag.f	VB.THD_120ms_Pct	THD, Phase Current VB
METMHAI1	ThdPhV.phsC.instCVal.mag.f	VC.THD_120ms_Pct	THD, Phase Current VC
METMHAI1	ThdPPV.phsAB.instCVal.mag.f	VAB.THD_120ms_Pct	THD, Phase Current VAB
METMHAI1	ThdPPV.phsBC.instCVal.mag.f	VBC.THD_120ms_Pct	THD, Phase Current VBC
METMHAI1	ThdPPV.phsCA.instCVal.mag.f	VCA.THD_120ms_Pct	THD, Phase Current VCA
Functional Constraint = ST			
METMDST1	DmdVArh.actVal	MVARh.Del	3-phase reactive energy OUT
METMDST1	DmdWh.actVal	MWh.Del	3-phase real energy OUT
METMDST1	SupVArh.actVal	MVARh.Rec	3-phase reactive energy IN
METMDST1	SupWh.actVal	MWh.Rec	3-phase real energy IN
METMDST1	TotVAh.actVal	MVAh.Mag	3-phase apparent energy
Functional Constraint = SP			
LLN0	GrRef.setSrcRef	IdName	Functional name

[a] MX values contain instantaneous attributes (instMag and instCVal), which are updated whenever the source updates and other attributes which are only updated when the source goes outside the data source's deadband (mag and cVal). Only the instantaneous values are shown in the table.

[b] Data validity depends on the relay model and installed card options. Refer to *Section 1: Introduction and Specifications* for different relay models and available card options. Refer to *Section 5: Metering and Monitoring* for the model dependent metering quantities.

Table F.32 shows the LN associated with control elements defined as Logical Device CON.

Table F.32 Logical Device: CON (Remote Control)

Logical Node	Status	Control	Relay Word Bit	Comment
RBGGIO1	SPCSO01.stVal–SPCSO08.stVal	SPCSO01.Oper.ctlVal–SPCSO08.Oper.ctlVal	RB_001.Sta–RB_008.Sta	Set/Clear Remote Bits RB01–RB08
RBGGIO2	SPCSO09.stVal–SPCSO16.stVal	SPCSO09.Oper.ctlVal–SPCSO16.Oper.ctlVal	RB_009.Sta–RB_016.Sta	Set/Clear Remote Bits RB09–RB16
PRBGGIO1	SPCSO01.stVal–SPCSO08.stVal	SPCSO01.Oper.ctlVal–SPCSO08.Oper.ctlVal	RB_001.Sta–RB_008.Sta	Pulse Remote Bits RB01–RB08
PRBGGIO2	SPCSO09.stVal–SPCSO16.stVal	SPCSO09.Oper.ctlVal–SPCSO16.Oper.ctlVal	RB_009.Sta–RB_016.Sta	Pulse Remote Bits RB09–RB16

Table F.33 shows the LN associated with annunciation elements defined as Logical Device ANN.

Table F.33 Logical Device: ANN (Annunciation) (Sheet 1 of 4)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = DC			
ANNLPHD1	PhyNam.model	Dev.PartNum	Part number
ANNLPHD1	PhyNam.serNum	Dev.SerNum	Serial number
LLN0	NamPlt.swRev	FID	Firmware revision
Functional Constraint = MX[a]			
ArcGGIO1	AnIn01.instMag.f–AnIn04.instMag.f	Light_01.1ms_Mag–Light_04.1ms_Mag[b]	Arc-flash sensor light (LSENS1–LSENS4)
PMVGGIO1	AnIn01.instMag.f–AnIn16.instMag.f	PMV_001.Val–PMV_016.Val[c]	Math Variables (PMV_001.Val–PMV_016.Val)
PFDLdLgGGIO1	AnIn01.instMag.f	PF.120ms_LdLg	3-phase power factor lead/lag indicator (1: LEAD, 0:LAG)
RAGGIO1	Ra001.instMag.f–Ra032.instMag.f	RA_001.Val–RA_032.Val	Remote Analogs (RA_001.Val–RA_032.Val)
PCGGIO1	AnIn01.instMag.f–AnIn16.instMag.f	PCN_001.CV–PCN_016.CV[d]	SELOGIC Protection Counters (PCN_001.CV–PCN_016.CV)
FGRX1GGIO1	AnIn01.instMag.f–AnIn08.instMag.f	FG_P2_01.RxAna01–FG_P2_01.RxAna08[e]	Fixed GOOSE Subscription 1 analogs
FGRX2GGIO1	AnIn01.instMag.f–AnIn08.instMag.f	FG_P2_02.RxAna01–FG_P2_02.RxAna08[e]	Fixed GOOSE Subscription 2 analogs
FGRX3GGIO1	AnIn01.instMag.f–AnIn08.instMag.f	FG_P2_03.RxAna01–FG_P2_03.RxAna08[e]	Fixed GOOSE Subscription 3 analogs
FGRX4GGIO1	AnIn01.instMag.f–AnIn08.instMag.f	FG_P2_04.RxAna01–FG_P2_04.RxAna08[e]	Fixed GOOSE Subscription 4 analogs
Functional Constraint = ST			
BinIn	Ind01.stVal–Ind10.stVal	IN_01.Sta–IN_10.Sta[f]	Digital Inputs (IN_01.Sta–IN_04.Sta)—Standard (IN_05.Sta–IN_10.Sta)—Optional
PLTGGIO1	Ind01.stVal–Ind16.stVal	PLT_001.Sta–PLT_016.Sta[g]	Latch Bits (PLT_001.Sta–PLT_016.Sta)
MBGGIO1	Ind01.stVal	MB_A.RxOk	Channel A, received data OK

Table F.33 Logical Device: ANN (Annunciation) (Sheet 2 of 4)

Logical Node	Attribute	Data Source	Comment
MBGGIO1	Ind02.stVal	MB_A.RxBad	Channel A, outage duration over threshold
MBGGIO1	Ind03.stVal	MB_A.ChBad	Channel A, channel unavailability over threshold
MBGGIO1	Ind04.stVal	MB_A.LoopOk	Channel A, looped back OK
MBGGIO1	Ind05.stVal–Ind08.stVal	0	Reserved for future use
EthGGIO1	Ind01.stVal	Port_02.LinkOk	Asserted when a valid link is detected on Port 2
EthGGIO1	Ind02.stVal	Port_02.LinkForcOv	Force network link switchover
EthGGIO1	Ind03.stVal	Port_02.LinkAOk	Asserted when a valid link is detected on Port 2A
EthGGIO1	Ind04.stVal	Port_02.LinkBOk	Asserted when a valid link is detected on Port 2B
EthGGIO1	Ind05.stVal	Port_02.LinkFail	Asserted when a valid link is not detected on the active port(s)
EthGGIO1	Ind06.stVal	Port_02.LinkAAct	Asserted when Port 2A is active
EthGGIO1	Ind07.stVal	Port_02.LinkBAct	Asserted when Port 2B is active
EthGGIO1	Ind08.stVal	0	Reserved for future use
DiagGGIO1	Ind01.stVal	Diag.MathErr	SELogic math error bit
DiagGGIO1	Ind02.stVal	Diag.Hw_Alm	Indication of a diagnostic failure or warning that warrants an ALARM
DiagGGIO1	Ind03.stVal	Diag.Secu_Alm	Indication of software or user activity that warrants an ALARM
DiagGGIO1	Ind04.stVal	0	Reserved for future use
MISCGGIO1	Ind01.stVal	Warning.Sta	Asserted when any element in the warning list is asserted
MISCGGIO1	Ind02.stVal	Event.Trg	Event report trigger SELOGIC control equation
MISCGGIO1	Ind03stVal–Ind04.stVal	0	Reserved for future use
TmGGIO1	Ind01.stVal	Time.IRIG_Ok	IRIG-B time sync input data is valid
TmGGIO1	Ind02.stVal	Time.SyncOk	Time synchronization OK
TmGGIO1	Ind03.stVal	Time.SNTP_PriSrvr	Asserted when relay time is based on SNTP, using primary server
TmGGIO1	Ind04.stVal	Time.SNTP_BackupSrvr	Asserted when relay time is based on SNTP, using backup server
TmGGIO1	Ind05.stVal	Time.UTCSign	Offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted; otherwise, add
TmGGIO1	Ind06.stVal	Time.UTCOff1	Offset hours from UTC time, binary, add 1 if asserted
TmGGIO1	Ind07.stVal	Time.UTCOff2	Offset hours from UTC time, binary, add 2 if asserted
TmGGIO1	Ind08.stVal	Time.UTCOff4	Offset hours from UTC time, binary, add 4 if asserted
TmGGIO1	Ind09.stVal	Time.UTCOff8	Offset hours from UTC time, binary, add 8 if asserted
TmGGIO1	Ind10.stVal	Time.UTCOffHalf	Offset half-hour from UTC time, binary, add 0.5 if asserted
TmGGIO1	Ind11.stVal	Time.DST	Daylight-saving time active
TmGGIO1	Ind12.stVal	Time.Qual8	Time quality bit, add 8 when asserted
TmGGIO1	Ind13.stVal	Time.Qual4	Time quality bit, add 4 when asserted

Table F.33 Logical Device: ANN (Annunciation) (Sheet 3 of 4)

Logical Node	Attribute	Data Source	Comment
TmGGIO1	Ind14.stVal	Time.Qual2	Time quality bit, add 2 when asserted
TmGGIO1	Ind15.stVal	Time.Qual1	Time quality bit, add 1 when asserted
TmGGIO1	Ind16.stVal	0	Reserved for future use
BinOutGGIO1	Ind01.stVal– Ind05.stVal	OUT_01.Sta– OUT_05.Sta	Digital Outputs (OUT_01.Sta–OUT_05.Sta)
PROGGIO1	Ind01.stVal	FreqTrk.Ok	Relay tracking system frequency
PROGGIO1	Ind02.stVal	Close_01.Sta	Breaker close output
PROGGIO1	Ind03.stVal	Close_01.Fail	Close fail status
PROGGIO1	Ind04.stVal	0	Reserved for future use
DmdGGIO1	Ind01.stVal	Meter.Dmd_IP_PU	Phase current demand pickup
DmdGGIO1	Ind02.stVal	Meter.Dmd_INeg_PU	Negative-sequence current demand pickup
DmdGGIO1	Ind03.stVal	Meter.Dmd_IGnd_PU	Zero-sequence current demand pickup
DmdGGIO1	Ind04.stVal	0	Reserved for future use
RCGGIO1	Ind01.stVal	79.Rst	Reclosing relay in reset state
RCGGIO1	Ind02.stVal	79.Cyc	Reclosing relay in reclose cycle state
RCGGIO1	Ind03.stVal	79.LO	Reclosing relay in lockout State
RCGGIO1	Ind04.stVal– Ind08.stVal	79.Shot0–79.Shot4	Reclosing relay shot counter = 0–4
RCGGIO1	Ind09.stVal	79.ClsSupvFail	Reclose supervision failure (asserts for 1/4 cycle)
RCGGIO1	Ind10.stVal	79.OpnTmSta	Open interval timer is timing
RCGGIO1	Ind11.stVal	79.RstTmSta	Reset timer is timing
RCGGIO1	Ind12.stVal– Ind16.stVal	0	Reserved for future use
MBRxGGIO1	Ind01.stVal– Ind08.stVal	MB_A.Rx01– MB_A.Rx08	Receive MIRRORED BITS (Channel A Receive MIRRORED BITS 01–08)
PCTInGGIO1	Ind01.stVal– Ind16.stVal	PCT_001.In– PCT_016.In[h]	SELOGIC Variables (PCT_001.In–PCT_016.In)
PCTGGIO1	Ind01.stVal– Ind16.stVal	PCT_001.Sta– PCT_016.Sta[g]	SELOGIC Variable Timers (PCT_001.Sta–PCT_016.Sta)
TLEDGGIO1	Ind01.stVal	EnaLED.Sta	ENABLED LED
TLEDGGIO1	Ind02.stVal	TripLED.Sta	TRIP LED
TLEDGGIO1	Ind03.stVal– Ind10.stVal	TLED_01.Sta– TLED_08.Sta	Target LEDs 1–8
MBTxGGIO1	Ind01.stVal– Ind08.stVal	MB_A.Tx01– MB_A.Tx08	Transmit MIRRORED BITS (Channel A Transmit MIRRORED BITS 01–08)
TripGGIO1	Ind01.stVal	Meter.Fault	Fault condition SELOGIC control equation
TripGGIO1	Ind02.stVal	Trip_01.RemSta	Remote trip issued
TripGGIO1	Ind03.stVal	Trip_01.LocSta	Local trip issued
TripGGIO1	Ind04.stVal	Trip_01.Init	Trip SELOGIC equation
TripGGIO1	Ind05.stVal	Trip_01.Unlt	Unlatch trip SELOGIC equation
TripGGIO1	Ind06.stVal– Ind08.stVal	0	Reserved for future use
VBGGIO1	Ind01.stVal– Ind32.stVal	VB_001.Sta– VB_032.Sta	Virtual Bits (VB_001.Sta-VB_032.Sta)

Table F.33 Logical Device: ANN (Annunciation) (Sheet 4 of 4)

Logical Node	Attribute	Data Source	Comment
ArcGGIO1	Ind01.stVal	AFD.Alm	Arc-flash system integrity alarm
ArcGGIO1	Ind02.stVal–Ind05.stVal	AFD.Sen01_AmbLight–AFD.Sen04_AmbLight	Arc-Flash Light Input 1–4 excessive ambient light pickup
FGRX1GGIO1	Ind01.stVal–Ind08.stVal	FG_P2_01.RxBin01–FG_P2_01.RxBin08[e]	Fixed GOOSE Subscription 1 digitals
FGRX2GGIO1	Ind01.stVal–Ind08.stVal	FG_P2_02.RxBin01–FG_P2_02.RxBin08[e]	Fixed GOOSE Subscription 2 digitals
FGRX3GGIO1	Ind01.stVal–Ind08.stVal	FG_P2_03.RxBin01–FG_P2_03.RxBin08[e]	Fixed GOOSE Subscription 3 digitals
FGRX4GGIO1	Ind01.stVal–Ind08.stVal	FG_P2_04.RxBin01–FG_P2_04.RxBin08[e]	Fixed GOOSE Subscription 4 digitals
Functional Constraint = SP			
LLN0	GrRef.setSrcRef	IdName	Functional name

[a] MX values contain instantaneous attributes (instMag) and (instCVal), which are updated whenever the source updates and other attributes which are only updated when the source goes outside the data source's deadband (mag and cVal). Only the instantaneous values are shown in the table.
[b] Active data depends on the optional arc-flash card installed.
[c] Active data depends on the PMV.Ena setting.
[d] Active data depends on the PCN.Ena setting.
[e] Active data depends on the number of Fixed GOOSE subscriptions.
[f] Active data depends on the optional I/O card installed in the slot.
[g] Active data depends on the PLT.Ena setting.
[h] Active data depends on the PCT.Ena setting.

Table F.34 Logical Device: CFG (Configuration) (Sheet 1 of 6)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
DevIDLPHD1	Sim.Oper.ctlVal	61850.Sim	IEC 61850 logical node for physical device simulation
GOLCCH2	RsStat.Oper.ctlVal	GORST[a]	Reset statistics for GOOSE traffic
IPLCCH1	RsStat.Oper.ctlVal	IPRST[a]	Reset statistics for general IP traffic (excluding GOOSE traffic)
LLN0	Mod.Oper.ctlVal[b]	61850.Mod[c]	IEC 61850 mode/behavior control
LGOS*n*[d]	RsStat.Oper.ctlVal	GRST*n*[e]	Reset GOOSE statistics for Message *n*
Functional Constraint = DC			
DevIDLPHD1	PhyNam.model	Dev.PartNum	Part number
DevIDLPHD1	PhyNam.serNum	Dev.SerNum	Serial number
LLN0	NamPlt.swRev	FID	Firmware revision
Functional Constraint = ST			
DevIDLPHD1	Sim.stVal	61850.Sim	IEC 61850 logical node for physical device simulation
DevIDLPHD1	PhyHealth.stVal	61850.Qual?3:1[f]	Relay enabled
GOLCCH2	ChLiv.stVal	GOCH[a]	Status of primary GOOSE channel
GOLCCH2	RedChLiv.stVal	GORCH[a]	Status of redundant GOOSE channel; always reported as false
GOLCCH2	RxCnt.actVal	GORX[a]	Number of frames received over the primary GOOSE channel
GOLCCH2	RedRxCnt.actVal	GORRX[a]	Number of frames received over the redundant GOOSE channel; always reported as 0

Table F.34 Logical Device: CFG (Configuration) (Sheet 2 of 6)

Logical Node	Attribute	Data Source	Comment
GOLCCH2	TxCnt.actVal	GOTX[a]	Number of frames transmitted on both primary and redundant GOOSE channels
GOLCCH2	FerCh.stVal	GOFER[a]	Frame error rate on the primary GOOSE channel
GOLCCH2	RedFerCh.stVal	GORFER[a]	Frame error rate on the redundant GOOSE channel; always reported as 0.
GOLCCH2	RsStat.stVal	GORST[a]	Status of statistics reset for GOOSE traffic
IPLCCH1	ChLiv.stVal	IPCH[a]	Status of primary IP channel
IPLCCH1	RedChLiv.stVal	IPRCH[a]	Status of redundant IP channel; always reported as false
IPLCCH1	RxCnt.actVal	IPRX[a]	Number of frames received over the primary IP channel
IPLCCH1	RedRxCnt.actVal	IPRRX[a]	Number of frames received over the redundant IP channel; always reported as 0
IPLCCH1	TxCnt.actVal	IPTX[a]	Number of frames transmitted on both primary and redundant IP channels
IPLCCH1	FerCh.stVal	IPFER[a]	Frame error rate on the primary IP channel
IPLCCH1	RedFerCh.stVal	IPRFER[a]	Frame error rate on the redundant IP channel; always reported as 0
IPLCCH1	RsStat.stVal	IPRST[a]	Status of statistics reset for general IP traffic (excludes GOOSE traffic)
LLN0	Mod.stVal	61850.Mod[c]	IEC 61850 mode/behavior status
LLN0	Health.stVal	61850.Qual?3:1[f]	Relay enabled
LGOS*n*[d]	NdsCom.stVal	GNCM*n*[e]	Subscription needs commissioning for GOOSE Message *n*; true if ConfRevNum does not match RxConfRevNum
LGOS*n*[d]	St.stVal	GST*n*[e]	Status of the subscription (True = active, False = not active) for GOOSE Message *n*
LGOS*n*[d]	SimSt.stVal	GSIM*n*[e]	Status showing that simulation messages are received and accepted for GOOSE Message *n*
LGOS*n*[d]	LastStNum.stVal	GLST*n*[e]	Last state number received (StNum) for GOOSE Message *n*
LGOS*n*[d]	LastSqNum.stVal	GLSQ*n*[e]	Last sequence number received (SqNum) for GOOSE Message *n*
LGOS*n*[d]	LastTal.stVal	GTAL*n*[e]	Last time-allowed-to-live received (TTL) for GOOSE Message *n*
LGOS*n*[d]	ConfRevNum.stVal	[g]	Expected configuration revision number for GOOSE Message *n*
LGOS*n*[d]	RxConfRevNum.stVal	GCNF*n*[e]	Received configuration revision number for GOOSE Message *n*
LGOS*n*[d]	ErrSt.stVal[h]	GERR*n*[e]	Error status of the subscription for GOOSE Message *n*
LGOS*n*[d]	OosCnt.stVal	GOOS*n*[e]	Number of out-of-sequence (OOS) errors for GOOSE Message *n*
LGOS*n*[d]	TalCnt.stVal	GTLC*n*[e]	Number of time-allowed-to-live violations for GOOSE Message *n*
LGOS*n*[d]	DecErrCnt.stVal	GDER*n*[e]	Number of messages that failed decoding for GOOSE Message *n*
LGOS*n*[d]	BufOvflCnt.stVal	GBFO*n*[e]	Number of messages lost because of buffer overflow for GOOSE Message *n*

Table F.34 Logical Device: CFG (Configuration) (Sheet 3 of 6)

Logical Node	Attribute	Data Source	Comment
LGOS*n*[d]	MsgLosCnt.stVal	GMSL*n*[e]	Number of messages lost due to OOS errors (estimated) for GOOSE Message *n*
LGOS*n*[d]	MaxMsgLos.stVal	GMXM*n*[e]	Maximum number of sequential messages lost because of OOS error (estimated) for GOOSE Message *n*
LGOS*n*[d]	InvQualCnt.stVal	GIDQ*n*[e]	Number of mapped data with invalid quality for GOOSE Message *n*
LGOS*n*[d]	RsStat.stVal	GRST*n*[e]	Status of statistics reset for GOOSE messages
LTIM	TmDT.stVal	TMDT[a]	Indicates daylight-saving time is currently in effect at the IED location
LTMS	TmAcc.stVal	TSACC[a]	Number of significant bits in the FractionOfSecond (an attribute of TimeStamp) 18: 4 ms accuracy (2^{-18}) 10: 1 ms accuracy (2^{-10}) 7: 10 ms accuracy (2^{-7}) 31: Unknown accuracy
LTMS	TmSrc.stVal	TSSRC[a]	Time-source identity If TmSrcTyp is SNTP, TmSrc indicates the IP address of the SNTP server For all other values of TmSrcTyp, TmSrc is set to "NA"
LTMS	SelTmSrcTyp.stVal	TSTYPE[a]	Type of the clock source as defined by Relay Word bits Time.SNTP_PriSrvr, Time.SNTP_BackupSrvr, Time.SyncOk, and Time.IRIG_Ok 1: Unknown 2: SNTP 3: PTP (Future) 4: IRIG-B
LTMS	SelTmSyn.stVal	TSSYN[a]	Traceability of the reference time to which the IED is synchronized 3: GlobalAreaClock—TmSrcTyp is PTP with grandmaster clock class of 6 (Future), TmSrcTyp is IRIG-B with IRIGC = C37.118, or TmSrcTyp is SNTP 2: LocalAreaClock—TmSrcTyp is PTP with grandmaster clock other than 6 (Future), or TmSrcTyp is IRIG-B with IRIGC ?C37.118 1: InternalClock—TmSrcTyp is unknown
LTMS	SelTmSynLkd.stVal	TSSYNLK[a]	Status of clock synchronization: 1: Locked 2: Unlocked for 0–10 seconds 3 Unlocked for 10–100 seconds 4: Unlocked for 100–1000 seconds 5: Unlocked for more than 1000 seconds
Functional Constraint = MX			
LGOS*n*[d]	TotDwnTm.instMag.f	GDWT*n*[e]	Total downtime in seconds for GOOSE Message *n*
LGOS*n*[d]	MaxDwnTm.instMag.f	GMXD*n*[e]	Maximum continuous downtime in seconds for GOOSE Message *n*
LTMS	SelTmTosPer.instMag.f	TSPER[a]	Duration, in milliseconds, between two consecutive top-of-second points on the synchronized time; TmTosPer is set to 0 for time sources other than high-accuracy PTP (future) or IRIG-B

Table F.34 Logical Device: CFG (Configuration) (Sheet 4 of 6)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = SP			
GOLCCH2	NetMod.setVal	Port_02.OpMod	Port 2 network operating mode setting (1: Fixed, 2: Failover, 3: Switched)
IPLCCH1	NetMod.setVal	Port_02.OpMod	Port 2 network operating mode setting (1: Fixed, 2: Failover, 3: Switched)
LGOS*n*[d]	GoCBRef.setSrcRef	[g]	Configured GOOSE control block reference for GOOSE Message *n*
LGOS*n*[d]	DatSet.setSrcRef	[g]	Configured data set reference for GOOSE Message *n*
LGOS*n*[d]	GoID.setVal	[g]	Configured ID for GOOSE Message *n*
LGOS*n*[d]	Addr.setVal	[g]	Configured multicast MAC address for GOOSE Message *n*
LGOS*n*[d]	VlanID.setVal	[g]	Configured VLAN ID for GOOSE Message *n*
LGOS*n*[d]	VlanPri.setVal	[g]	Configured VLAN priority for GOOSE Message *n*
LGOS*n*[d]	AppID.setVal	[g]	Configured APPID for GOOSE Message *n*
LTIM	TmOfsTmm.setVal	TMOFFS[a]	Offset of local time from UTC in minutes
LTIM	TmUseDT.setVal	TMUSEDT[a]	Set to True if daylight-saving time is enabled
LTIM	TmChgDT.setTm	TMCHGDT[a]	Local time of next change to daylight-saving time
LTIM	TmChgST.setTm	TMCHGST[a]	Local time of next change to standard time
Functional Constraint = SR			
LTRK1	SpcTrk.objRef	[i]	ACSI reference to the SPC object targeted in the request
LTRK1	SpcTrk.serviceType	[i, j]	Type of service requested or executed
LTRK1	SpcTrk.errorCode	[i, k]	ACSI service error status
LTRK1	SpcTrk.ctlVal	[i]	Control value in the request
LTRK1	SpcTrk.ctlNum	[i]	Control number in the request
LTRK1	SpcTrk.origin.orCat	[i]	Originator category value in the request
LTRK1	SpcTrk.origin.orIdent	[i]	Originator identity value in the request
LTRK1	SpcTrk.T	[i]	Time-stamp value in the request
LTRK1	SpcTrk.Test	[i]	Test value in the request
LTRK1	SpcTrk.Check	[i]	Check condition value in the request
LTRK1	SpcTrk.respAddCause	[i]	AddCause value returned in the response
LTRK1	DpcTrk.objRef	[i]	ACSI reference to the DPC object targeted in the request
LTRK1	DpcTrk.serviceType	[i, j]	Type of service requested or executed
LTRK1	DpcTrk.errorCode	[i, k]	ACSI service error status
LTRK1	DpcTrk.ctlVal	[i]	Control value in the request
LTRK1	DpcTrk.ctlNum	[i]	Control number in the request
LTRK1	DpcTrk.origin.orCat	[i]	Originator category value in the request
LTRK1	DpcTrk.origin.orIdent	[i]	Originator identity value in the request
LTRK1	DpcTrk.T	[i]	Time-stamp value in the request
LTRK1	DpcTrk.Test	[i]	Test value in the request
LTRK1	DpcTrk.Check	[i]	Check condition value in the request

Table F.34 Logical Device: CFG (Configuration) (Sheet 5 of 6)

Logical Node	Attribute	Data Source	Comment
LTRK1	DpcTrk.respAddCause	i	AddCause value returned in the response
LTRK1	EncTrk.objRef	i	ACSI reference to the ENC object targeted in the request
LTRK1	EncTrk.serviceType	i, j	Type of service requested or executed
LTRK1	EncTrk.errorCode	i, k	ACSI service error status
LTRK1	EncTrk.ctlVal	i	Control value in the request
LTRK1	EncTrk.ctlNum	i	Control number in the request
LTRK1	EncTrk.origin.orCat	i	Originator category value in the request
LTRK1	EncTrk.origin.orIdent	i	Originator identity value in the request
LTRK1	EncTrk.T	i	Time-stamp value in the request
LTRK1	EncTrk.Test	i	Test value in the request
LTRK1	EncTrk.Check	i	Check condition value in the request
LTRK1	EncTrk.respAddCause	i	AddCause value returned in the response
LTRK1	BrcbTrk.objRef	i	ACSI reference of the BRCB object targeted in the request
LTRK1	BrcbTrk.serviceType	i, j	Type of service requested or executed
LTRK1	BrcbTrk.errorCode	i, k	ACSI service error status
LTRK1	BrcbTrk.rptID	i	RptID attribute value in the request or target BRCB object
LTRK1	BrcbTrk.rptEna	i	RptEna attribute value in the request or target BRCB object
LTRK1	BrcbTrk.datSet	i	DatSet attribute value in the target BRCB object
LTRK1	BrcbTrk.confRev	i	ConfRev attribute value in the target BRCB object
LTRK1	BrcbTrk.optFlds	i	OptFlds attribute value in the request or target BRCB object
LTRK1	BrcbTrk.bufTm	i	BufTm attribute value in the request or target BRCB object
LTRK1	BrcbTrk.sqNum	i	SqNum attribute value in the target BRCB object
LTRK1	BrcbTrk.trgOps	i	TrgOps attribute value in the request or target BRCB object
LTRK1	BrcbTrk.intgPd	i	IntgPd attribute value in the request or target BRCB object
LTRK1	BrcbTrk.gi	i	GI attribute value in the request or target BRCB object
LTRK1	BrcbTrk.purgeBuf	i	PurgeBuf attribute value in the request or target BRCB object
LTRK1	BrcbTrk.entryID	i	EntryID attribute value in the request or target BRCB object
LTRK1	BrcbTrk.timeOfEntry	i	TimeOfEntry attribute value in the request or target BRCB object
LTRK1	UrcbTrk.objRef	i	ACSI reference of the URCB object targeted in the request
LTRK1	UrcbTrk.serviceType	i, j	Type of service requested or executed
LTRK1	UrcbTrk.errorCode	i, k	ACSI service error status
LTRK1	UrcbTrk.rptID	i	RptID attribute value in the request or target URCB object

Table F.34 Logical Device: CFG (Configuration) (Sheet 6 of 6)

Logical Node	Attribute	Data Source	Comment
LTRK1	UrcbTrk.rptEna	[i]	RptEna attribute value in the request or target URCB object
LTRK1	UrcbTrk.resv	[i]	Resv attribute value in the request or target URCB object
LTRK1	UrcbTrk.datSet	[i]	DatSet attribute value in the target URCB object
LTRK1	UrcbTrk.confRev	[i]	ConfRev attribute value in the target URCB object
LTRK1	UrcbTrk.optFlds	[i]	OptFlds attrbute value in the request or target URCB object
LTRK1	UrcbTrk.bufTm	[i]	BufTm attribute value in the request or target URCB object
LTRK1	UrcbTrk.sqNum	[i]	SqNum attribute value in the target URCB object
LTRK1	UrcbTrk.trgOps	[i]	TrgOps attribute value in the request or target URCB object
LTRK1	UrcbTrk.intgPd	[i]	IntgPd attribute value in the request or target URCB object
LTRK1	UrcbTrk.gi	[i]	GI attribute value in the request or target URCB object

[a] Internal data source and not available to the user.
[b] MMS controls to Mod.Oper are only accepted if IEC 61850 Mode/Behavior is enabled on the relay. Refer to Mode/Behavior Control for more details.
[c] I60MOD is an internal data source derived from the I850MOD analog quantity and is not available to the user.
[d] n = 1–16, corresponding to the first 16 GOOSE message subscriptions.
[e] Internal data source not available to the user. See GOOSE for more information.
[f] If enabled, value = 1. If disabled, value = 3.
[g] Data source defined in the IEC 61850 Configured IED Description (CID) file.
[h] See Table 7.20 for a description of each enumeration.
[i] The value depends on the ACSI service type requested, the target object, and the error status.
[j] Refer to Table F.8 for the IEC 61850 service type enumeration.
[k] Refer to Table F.9 for the IEC 61850 ACSI service error.

SEL Nameplate Data

The CID file contains information that describes the physical device attributes according to IEC 61850 standards. The LN0 logical node of each logical device contains the Nameplate DOI (instantiated data object) with the data shown in *Table F.35*.

Table F.35 SEL Nameplate Data

Data Attribute	Value
vendor	"SEL"
swRev	Contents of FID string from **ID** command
configRev	Always 0
IdNs	IEC 61850-7-4:2007A

Protocol Implementation Conformance Statement

The following tables are as shown in the IEC 61850 standard, Part 8-1, Section 24. Note that because the standard explicitly dictates which services and functions must be implemented to achieve conformance, only the optional services and functions are listed.

Table F.36 PICS for A-Profile Support

Profile		Client	Server	Value/Comment
A1	Client/Server	N	Y	
A2	GOOSE/GSE management	Y	Y	Only GOOSE, not GSSE Management
A3	GSSE	N	N	
A4	Time Sync	N	N	

Table F.37 PICS for T-Profile Support

Profile		Client	Server	Value/Comment
T1	TCP/IP	N	Y	
T2	OSI	N	N	
T3	GOOSE/GSE	Y	Y	Only GOOSE, Not GSSE
T4	GSSE	N	N	
T5	Time Sync	Y	N	

Refer to the ACSI Conformance statements in the Reference Manual for information on the supported services.

MMS Conformance

The MMS stack provides the basis for many IEC 61850 Protocol services. *Table F.38* defines the service support requirement and restrictions of the MMS services in the SEL-800 series products supporting IEC 61850. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table F.38 MMS Service Supported Conformance (Sheet 1 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
status		YES
getNameList		YES
identify		YES
rename		
read		YES
write		YES
getVariableAccessAttributes		YES
defineNamedVariable		
defineScatteredAccess		
getScatteredAccessAttributes		
deleteVariableAccess		
defineNamedVariableList		
getNamedVariableListAttributes		YES
deleteNamedVariableList		
defineNamedType		
getNamedTypeAttributes		
deleteNamedType		
input		

Table F.38 MMS Service Supported Conformance (Sheet 2 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
output		
takeControl		
relinquishControl		
defineSemaphore		
deleteSemaphore		
reportPoolSemaphoreStatus		
reportSemaphoreStatus		
initiateDownloadSequence		
downloadSegment		
terminateDownloadSequence		
initiateUploadSequence		
uploadSegment		
terminateUploadSequence		
requestDomainDownload		
requestDomainUpload		
loadDomainContent		
storeDomainContent		
deleteDomain		
getDomainAttributes		YES
createProgramInvocation		
deleteProgramInvocation		
start		
stop		
resume		
reset		
kill		
getProgramInvocationAttributes		
obtainFile		YES
defineEventCondition		
deleteEventCondition		
getEventConditionAttributes		
reportEventConditionStatus		
alterEventConditionMonitoring		
triggerEvent		
defineEventAction		
deleteEventAction		
alterEventEnrollment		
reportEventEnrollmentStatus		
getEventEnrollmentAttributes		
acknowledgeEventNotification		
getAlarmSummary		

Table F.38 MMS Service Supported Conformance (Sheet 3 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
getAlarmEnrollmentSummary		
readJournal		
writeJournal		
initializeJournal		
reportJournalStatus		
createJournal		
deleteJournal		
fileOpen		YES
fileRead		YES
fileClose		YES
fileRename		
fileDelete		YES
fileDirectory		YES
unsolicitedStatus		
informationReport		YES
eventNotification		
attachToEventCondition		
attachToSemaphore		
conclude		YES
cancel		YES
getDataExchangeAttributes		
exchangeData		
defineAccessControlList		
getAccessControlListAttributes		
reportAccessControlledObjects		
deleteAccessControlList		
alterAccessControl		
ReconfigureProgramInvocation		

Table F.39 lists specific settings for the MMS parameter Conformance Building Block (CBB).

Table F.39 MMS Parameter CBB

MMS Parameter CBB	Client-CR Supported	Server-CR Supported
STR1		YES
STR2		YES
VNAM		YES
VADR		YES
VALT		YES
TPY		YES
VLIS		YES
CEI		

The following Variable Access conformance statements are listed in the order specified in the IEC 61850 standard, Part 8-1. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table F.40 AlternateAccessSelection Conformance Statement

AlternateAccessSelection	Client-CR Supported	Server-CR Supported
accessSelection		YES
component		YES
index		
indexRange		
allElements		
alternateAccess		YES
selectAccess		YES
component		YES
index		
indexRange		
allElements		

Table F.41 VariableAccessSpecification Conformance Statement

VariableAccessSpecification	Client-CR Supported	Server-CR Supported
listOfVariable		YES
variableSpecification		YES
alternateAccess		YES
variableListName		YES

Table F.42 VariableSpecification Conformance Statement

VariableSpecification	Client-CR Supported	Server-CR Supported
name		YES
address		
variableDescription		
scatteredAccessDescription		
invalidated		

Table F.43 Read Conformance Statement

Read	Client-CR Supported	Server-CR Supported
Request		
specificationWithResult		
variableAccessSpecification		
Response		
variableAccessSpecification		YES
listOfAccessResult		YES

Table F.44 GetVariableAccessAttributes Conformance Statement

GetVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
name		
address		
Response		
mmsDeletable		YES
address		
typeSpecification		YES

Table F.45 DefineNamedVariableList Conformance Statement

DefineVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
variableListName		
listOfVariable		
variableSpecification		
alternateAccess		
Response		

Table F.46 GetNamedVariableListAttributes Conformance Statement

GetNamedVariableListAttributes	Client-CR Supported	Server-CR Supported
Request		
ObjectName		
Response		
mmsDeletable		YES
listOfVariable		YES
variableSpecification		YES
alternateAccess		YES

Table F.47 DeleteNamedVariableList

DeleteNamedVariableList	Client-CR Supported	Server-CR Supported
Request		
Scope		
listOfVariableListName		
domainName		
Response		
numberMatched		
numberDeleted		
DeleteNamedVariableList-Error		

GOOSE Services Conformance Statement

Table F.48 GOOSE Conformance

	Subscriber	Publisher	Value/Comment
GOOSE Services	YES	YES	
SendGOOSEMessage		YES	
GetGoReference			
GetGOOSEElementNumber			
GetGoCBValues		YES	
SetGoCBValues			
GSENotSupported			
GOOSE Control Block (GoCB)		YES	

ACSI Conformance Statements

Table F.49 ACSI Basic Conformance Statement

		Client/Subscriber	Server/Publisher	SEL-851 Support
Client-Server Roles				
B11	Server side (of Two-Party Application Association)	-	cl[a]	YES
B12	Client side (of Two-Party Application Association)	cl[a]	-	
SCMS Supported				
B21	SCSM: IEC 61850-8-1 used			YES
B22	SCSM: IEC 61850-9-1 used			
B23	SCSM: IEC 61850-9-2 used			
B24	SCSM: other			
Generic Substation Event Model (GSE)				
B31	Publisher side	-	O[b]	YES
B32	Subscriber side	O[b]	-	YES
Transmission of Sampled Value Model (SVC)				
B41	Published side	-	O[b]	
B42	Subscriber side	O[b]	-	

[a] c1 shall be mandatory if support for LOGICAL-DEVICE model has been declared.
[b] O = Optional.

Table F.50 ACSI Models Conformance Statement (Sheet 1 of 3)

		Client/Subscriber	Server/Publisher	SEL-851 Support
If Server Side (B11) Supported				
M1	Logical device	c2[a]	c2[a]	YES
M2	Logical node	c3[b]	c3[b]	YES
M3	Data	c4[c]	c4[c]	YES
M4	Data set	c5[d]	c5[d]	YES
M5	Substation	O[e]	O[e]	
M6	Setting group control	O[e]	O[e]	

Table F.50 ACSI Models Conformance Statement (Sheet 2 of 3)

		Client/Subscriber	Server/Publisher	SEL-851 Support
M17	File Transfer	O[e]	O[e]	YES
M18	Application association	C3[b]	C3[b]	YES
M19	GOOSE Control Block	O[e]	O[e]	YES
M20	Sampled Value Control Block	O[e]	O[e]	NO
Reporting				
M7	Buffered report control	O[e]	O[e]	YES
M7-1	sequence-number			YES
M7-2	report-time-stamp			YES
M7-3	reason-for-inclusion			YES
M7-4	data-set-name			YES
M7-5	data-reference			YES
M7-6	buffer-overflow			YES
M7-7	entryID			YES
M7-8	BufTm			YES
M7-9	IntgPd			YES
M7-10	G1			YES
M7-11	conf-revision			YES
M8	Unbuffered report control	O[e]	O[e]	YES
M8-1	sequence-number			YES
M8-2	report-time-stamp			YES
M8-3	reason-for-inclusion			YES
M8-4	data-set-name			YES
M8-5	data-reference			YES
M8-6	BufTm			YES
M8-7	IntgPd			YES
M8-8	GI			YES
M8-9	conf-revision			YES
Logging				
M9	Log control	O[e]	O[e]	
M9-1	IntgPd	O[e]	O[e]	
M10	Log	O[e]	O[e]	
M11	Control	M[f]	M[f]	YES
If GSE (B31/32) Is Supported				
M12	GOOSE	O[e]	O[e]	YES
M12-1	entryID			YES
M12-2	DataReflnc			YES
M13	GSSE	O[e]	O[e]	

Table F.50 ACSI Models Conformance Statement (Sheet 3 of 3)

		Client/Subscriber	Server/Publisher	SEL-851 Support
If GSE (B41/42) Is Supported				
M14	Multicast SVC	O[e]	O[e]	
M15	Unicast SVC	O[e]	O[e]	
For All IEDs				
M16	Time	M[f]	M[f]	YES[g]

[a] c2 shall be "M" if support for LOGICAL-NODE model has been declared.
[b] c3 shall be "M" if support for DATA model has been declared.
[c] c4 shall be "M" if support for DATA-SET, Substitution, Report, Log Control, or Time model has been declared.
[d] c5 shall be "M" if support for Report, GSE, or SV models has been declared.
[e] O = Optional.
[f] M = Mandatory.
[g] Time source with required accuracy shall be available. Only Time Master are SNTP (Mode 4 response) time server. All other Client/Server devices are SNTP (Mode 3 request) clients.

Table F.51 ACSI Services Conformance Statement (Sheet 1 of 3)

Services		AA: TP/MC	Client/ Subscriber	Service/ Publisher	SEL-851 Support
Server (Clause 6)					
S1	ServerDirectory	TP		M[a]	YES
Application Association (Clause 7)					
S2	Associate		M[a]	M[a]	YES
S3	Abort		M[a]	M[a]	YES
S4	Release		M[a]	M[a]	YES
Logical Device (Clause 8)					
S5	LogicalDeviceDirectory	TP	M[a]	M[a]	YES
Logical Node (Clause 9)					
S6	LogicalNodeDirectory	TP	M[a]	M[a]	YES
S7	GetAllDataValues	TP	O[b]	M[a]	YES
Data (Clause 10)					
S8	GetDataValues	TP	M[a]	M[a]	YES
S9	SetDataValues	TP	O[b]	O[b]	
S10	GetDataDirectory	TP	O[b]	M[a]	YES
S11	GetDataDefinition	TP	O[b]	M[a]	YES
Data Set (Clause 11)					
S12	GetDataSetValues	TP	O[b]	M[a]	YES
S13	SetDataSetValues	TP	O[b]	O[b]	
S14	CreateDataSet	TP	O[b]	O[b]	
S15	DeleteDataSet	TP	O[b]	O[b]	
S16	GetDataSetDirectory	TP	O[b]	O[b]	YES
Substitution (Clause 12)					
S17	SetDataValues	TP	M[a]	M[a]	
Setting Group Control (Clause 13)					
S18	SelectActiveSG	TP	O[b]	O[b]	
S19	SelectEditSG	TP	O[b]	O[b]	
S20	SetSGvalues	TP	O[b]	O[b]	

Table F.51 ACSI Services Conformance Statement (Sheet 2 of 3)

Services		AA: TP/MC	Client/ Subscriber	Service/ Publisher	SEL-851 Support
S21	ConfirmEditSGVal	TP	O[b]	O[b]	
S22	GetSGValues	TP	O[b]	O[b]	
S23	GetSGCBValues	TP	O[b]	O[b]	
Buffered Report Control Block (BRCB)					
S24	Report	TP	c6[c]	c6[c]	YES
S24-1	data-change (dchg)				YES
S24-2	qchg-change (qchg)				YES
S24-3	data-update (dupd)				YES
S25	GetBRCBValues	TP	c6[c]	c6[c]	YES
S26	SetBRCBValues	TP	c6[c]	c6[c]	YES
Unbuffered Report Control Block (URCB)					
S27	Report	TP	c6[c]	c6[c]	YES
S27-1	data-change (dchg)				YES
S27-2	qchg-change (qchg)				YES
S27-3	data-update (dupd)				YES
S28	GetURCBValues	TP	c6[c]	c6[c]	YES
S29	SetURCBValues	TP	c6[c]	c6[c]	YES
Logging (Clause 14)					
Log Control Block					
S30	GetLCBValues	TP	M[a]	M[a]	
S31	SetLCBValues	TP	O[b]	M[a]	
LOG					
S32	QueryLogByTime	TP	c7[d]	M[a]	
S33	QueryLogByEntry	TP	c7[d]	M[a]	
S34	GetLogStatusValues	TP	M[a]	M[a]	
Generic Substation Event Model (GSE) (Clause 14.3.5.3.4)					
GOOSE-Control-Block					
S35	SendGOOSEMessage	MC	c8[e]	c8[e]	YES
S36	GetReference	TP	O[b]	c9[f]	
S37	GetGOOSEElementNumber	TP	O[b]	c9[f]	
S38	GetGoCBValues	TP	O[b]	O[b]	YES
S39	SetGoCBValues	TP	O[b]	O[b]	
GSSE-Control-Block					
S40	SendGSSEMessage	MC	c8[e]	c8[e]	
S41	GetReference	TP	O[b]	c9[f]	
S42	GetGSSEElementNumber	TP	O[b]	c9[f]	
S43	GetGsCBValues	TP	O[b]	O[b]	
S44	GetGsCBValues	TP	O[b]	O[b]	

Table F.51 ACSI Services Conformance Statement (Sheet 3 of 3)

Services		AA: TP/MC	Client/ Subscriber	Service/ Publisher	SEL-851 Support
Transmission of Sample Value Model (SVC) (Clause 16)					
Multicast SVC					
S45	SendMSVMessage	MC	c10[g]	c10[g]	
S46	GetMSVCBValues	TP	O[b]	O[b]	
S47	SetMSVCBValues	TP	O[b]	O[b]	
Unicast SVC					
S48	SendUSVMessage	MC	c10[g]	c10[g]	
S49	GetUSVCBValues	TP	O[b]	O[b]	
S50	SetUSVCBValues	TP	O[b]	O[b]	
Control (Clause 16.4.8)					
S51	Select		M[a]	O[b]	
S52	SelectWithValue	TP	Ma	O[b]	YES
S53	Cancel	TP	O[b]	M[a]	YES
S54	Operate	TP	M[a]	M[a]	YES
S55	Command-Termination	TP	M[a]	M[a]	YES
S56	TimeActivated-Operate	TP	O[b]	O[b]	
File Transfer (Clause 20)					
S57	GetFile	TP	O[b]	M[a]	YES
S58	SetFile	TP	O[b]	O[b]	YES
S59	DeleteFile	TP	O[b]	O[b]	YES
S60	GetFileAttributeValues	TP	O[b]	M[a]	YES
Time (Clause 5.5)					
T1	Time resolution of internal clock (nearest negative power of 2 in seconds)				20 (1 µs)
T2	Time accuracy of internal clock				7 (10 ms) for SNTP 18 (4 µs) for IRIG-B
	T1				YES (for IRIG-B)
	T2				YES (for IRIG-B)
	T3				YES (for IRIG-B)
	T4				YES (for IRIG-B)
T3	Supported Time Stamp resolution (nearest negative power of 2 in seconds)				7 (10 ms) for SNTP 18 (4 µs) for IRIG-B

[a] M = Mandatory.
[b] O = Optional.
[c] c6 shall declare support for at least one (BRCB or URCB).
[d] c7 shall declare support for at least one (QueryLogByTime or QueryLogAfter).
[e] c8 shall declare support for at least one (SendGOOSEMessage or SendGSSEMessage).
[f] c9 shall declare support if TP association is available.
[g] c10 shall declare support for at least one (SendMSVMessage or SendUSVMessage).

Potential Client and Automation Application Issues With Edition 2 Upgrades

The following are issues that IEC 61850 Edition 1 (Ed1)-based client or automation applications may experience with IEC 61850 Edition 2 (Ed2) ICD and firmware changes. However, such issues may be resolved by reconfiguring the client or automation application. None of these should prevent a client application from dynamically discovering the data in the IED as long as the application adheres to the specification of the standard. Note that upgrading to Ed2 firmware will not break existing Ed1 configurations (CID files) in the field, nor require loading an Ed2 version of the CID file.

Unexpected Error Messages

Some MMS and control errors have been changed in Ed2. Hence, the firmware now issues only the Ed2-compliant errors. Clients or automation applications that rely on the Ed1-compliant errors will not function correctly. You can resolve this by reconfiguring the client or automation application to accept Ed2-compliant errors.

Missing or Unknown Data Objects and Attributes

Ed2 has changed some data object and attribute names, as well as the data types of some attributes. Ed2 also prohibits the use of proprietary CDCs. See *Logical Nodes on page F.27* and the logical nodes tables in each product specific manual to determine the Ed2 names. This may cause the failure of clients or automation applications that rely on the Ed1 names. You can resolve this by reconfiguring the client or automation application to accept the Ed2 names.

Unable to Find Operate Time-Out

A proprietary method was used to specify the operate time-out of control objects in the CID files. A client or automation application that relies on this proprietary method will fail to find the operate time-out in the CID file. You can resolve this by reconfiguring the client or automation application to accept the Ed2 control object operate time-outs.

Unexpected Control Block Data Attribute Type

The string type data attributes in control blocks (RptID, DatSet, etc.) have been changed from a maximum length of 65 to 129 characters, i.e., VisString65 to VisString129. Some clients and automation applications might see this as an error when the type is reported in the MMS GetVariableAccessAttributes response. You can resolve this by reconfiguring the client or automation application.

Unexpected Reports

Ed2 requires report buffering to start when the device is turned on, unlike in the Ed1 implementation where report buffering started after the first report enable. If a client or automation application relies on the Ed1 behavior, it might fail or indicate an error if the IED sends buffered reports immediately after the first enable. You can resolve this by reconfiguring the client or automation application.

Failure to Reselect a Control Object Before the Timeout

In Ed1, if a client reselected a control object before the select-before-operate time-out expired, the reselection would succeed and cause the selected timeout to restart. According to Ed2, this reselection is supposed to fail. Ed1-based clients or automation applications that rely on successful reselection might operate incorrectly. You can resolve this by reconfiguring the client or automation application.

Test Control Commands Fail Immediately

In Ed1, if the test attribute was set in a control command structure, the relay would accept the command but perform no action on the target control object. With enhanced control models, the IED would eventually report an operate timeout error after the operate time-out expired. However, in Ed2, any such test commands will fail immediately with an error indicating that the command is blocked because the IED is not in the appropriate mode. Clients or automation applications that depend on the Ed1 behavior might fail. You can resolve this by reconfiguring the client or automation application.

No Reports

Ed2 specifies that no reports are to be generated for a deadbanded attribute if the deadband is set to 0. Previously in Ed1, a deadband of 0 would cause the relay to generate reports for any change in the instantaneous value. Ed1-based clients or automation applications might not operate correctly because of the lack of reports. You can resolve this by reconfiguring the client or automation application.

Appendix G

Mirrored Bits Communications

Overview

Mirrored Bits is a direct relay-to-relay communications protocol that allows IEDs to exchange information quickly, securely, and with minimal expense. Use Mirrored Bits for functions such as remote control and remote sensing.

The SEL-851 Feeder Protection Relay supports a single channel, Channel A, for Mirrored Bits communications. Use the port setting Port_01.Proto to assign the Mirrored Bits communications channel to the serial port; Port_01.Proto := MBA.

IMPORTANT: Be sure to configure the port before connecting to a Mirrored Bits device. If you connect an unconfigured port to a Mirrored Bits device, the device will appear to be locked up.

Mirrored Bits are either Transmit Mirrored Bits (TMB) or Received Mirrored Bits (RMB). Transmit Mirrored Bits include MB_A.Tx01–MB_A.Tx08 for Channel A. Received bits include MB_A.Rx01–MB_A.Rx08 for Channel A.

NOTE: Complete all of the port settings for a port that you use for Mirrored Bits communications before you connect an external Mirrored Bits communications device. If you connect a Mirrored Bits communications device to a port that is not set for Mirrored Bits communications operation, the port will be continuously busy.

Control the transmit Mirrored Bits in SELogic control equations. Use the received Mirrored Bits as arguments in SELogic control equations. The channel status bits are MB_A.RxOk, MB_A.RxBad, MB_A.ChBad, and MB_A.LoopOk. You can also use these channel status bits as arguments in SELogic control equations. Use the **COM** command (see *Section 7: Communications*) for additional channel status information.

Because of different applications, the SEL product range supports several variations of the Mirrored Bits communications protocol. When communicating with an SEL-400 series relay, be sure to set the transmission mode setting in the SEL-400 series relay to paced transmission (TXMODE := P).

Operation

Message Transmission

In the SEL-851, the Mirrored Bits transmission rate is a function of both the data rate and the power system cycle. At data rates slower than 9600, the SEL-851 transmits Mirrored Bits as fast as possible for the given rate. At rates of 9600 bps and faster, the SEL-851 self-paces, using a technique similar to the SEL-400 series pacing mode. There are no settings to enable or disable the self-pacing mode; the SEL-851 automatically enters the self-pacing mode at data rates of 9600, 19200, and 38400. *Table G.1* shows the transmission rates of the Mirrored Bits messages at different data rates.

Table G.1 Number of MIRRORED BITS Messages for Different Data Rates

Data Rate	Transmission Rate of MIRRORED BITS Packets
2400	15 ms
4800	7.5 ms
9600	4 ms
19200	4 ms
38400	4 ms

NOTE: Exercise caution when applying a MIRRORED BITS channel to relays that protect systems which may not be synchronized, because the automatic pacing modes operate under the assumption that both relays are protecting systems of similar frequency. To maintain MIRRORED BITS channel dependability for this application, it is best to use a data rate of either 2400 or 4800.

Transmitting at longer intervals for data rates faster than 9600 bps avoids overflowing relays that receive MIRRORED BITS at a slower rate.

Message Reception Overview

During synchronized MIRRORED BITS communications with the communications channel in normal state, the relay decodes and checks each received message. If the message is valid, the relay sends each received logic bit to the corresponding pickup and dropout security counters, that in turn set or clear the MB_A.Rx0*n* (where *n* = 1–8) relay element bits.

Message Decoding and Integrity Checks

Set the Port_01.MB_RxId of the local SEL-851 to match the Port_01.MB_TxId of the remote SEL-851. The SEL-851 provides an indication of the status of the MIRRORED BITS communications channel with Relay Word bit MB_A.RxOk (receive OK). During normal operation, the relay sets MB_A.RxOk. The relay clears the MB_A.RxOk bit when it detects any of the following conditions.

- The relay is disabled.
- MIRRORED BITS communications is not enabled.
- Parity, framing, or overrun errors.
- Receive message identification error.
- No message received in the time three messages have been sent when Port_01.Proto = MBA, or seven messages have been sent when Port_01.Proto = MB8A.
- Loopback is enabled.

The relay asserts MB_A.RxOk only after successful synchronization as described below, and after two consecutive messages pass all of the data checks previously described. After MB_A.RxOk is reasserted, received data can be delayed while passing through the security counters described in the following paragraph.

While MB_A.RxOk is deasserted, 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 MB_A.Rx0*n*, use the Port_01.MB_RxDfltSta 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 Xs (for MB_A.Rx01–MB_A.Rx08), where X represents the most recently received valid value. The positions of the 1s and 0s correspond to the respective positions of the MIRRORED BITS in the Relay Word bits (see *Appendix H: Relay Word Bits*). *Table G.2* is an extract of *Appendix H: Relay Word Bits*, showing the positions of the MIRRORED BITS.

Table G.2 Positions of the MIRRORED BITS

Bit/ Row	7	6	5	4	3	2	1	0
55	MB_A.Rx08	MB_A.Rx07	MB_A.Rx06	MB_A.Rx05	MB_A.Rx04	MB_A.Rx03	MB_A.Rx02	MB_A.Rx01

Table G.3 shows an example of the values of the MIRRORED BITS for a Port_01.MB_RxDfltSta setting of 10100111.

Table G.3 MIRRORED BITS Values for a Port_01.MB_RxDfltSta Setting of 10100111

Bit/ Row	7	6	5	4	3	2	1	0
55	1	0	1	0	0	1	1	1

Individual pickup and dropout security counters supervise the movement of each received data bit into the corresponding MB_A.Rx0*n* element. You can set each pickup/dropout security counter from 1 to 8. A setting of 1 causes a security counter to pass every occurrence, while a setting of 8 causes a counter to wait for eight consecutive occurrences in the received data before updating the data bits. The pickup and dropout security count settings are separate. Control the security count settings with the settings Port_01.MB_Rx*n*PU and Port_01.MB_Rx*n*DO.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that the counter uses units of counted received messages instead of time. Select a setting for the security counter in accordance with the transmission rate (see *Table G.1*). For example, when transmitting at 2400 bps, a security counter set to 2 counts delays a bit by about 30 ms. However, when operating at 9600 bps, a setting of 2 counts delays a bit by about 8.5 ms.

You must consider the impact of the security counter settings in the receiving relay to determine the channel timing performance, particularly when two relays of different processing rates are communicating via MIRRORED BITS, such as an SEL-321 and an SEL-851. The SEL-321 processes power system information each 1/8 power system cycle, but, when transmitting at 19200 bps, the SEL-851 processes MIRRORED BITS messages every 4.0 ms. Although the SEL-321 processes power system information each 1/8 power system cycle, the relay processes the MIRRORED BITS pickup/dropout security counters as MIRRORED BITS messages are received. Because the SEL-851 transmits messages every 4.0 ms (9600 bps and faster, see *Table G.1*), a counter set to two in the SEL-321 delays a received bit by another approximately 1/2 cycle. However, a security counter in the SEL-851 with a setting of 8.0 ms delays a received bit from the SEL-321 by 1/4 cycle, because the SEL-851 is receiving new MIRRORED BITS messages each 1/8 cycle from the SEL-321.

Channel Synchronization

When an SEL-851 detects a communications error, it deasserts MB_A.RxOk. If an SEL-851 detects two consecutive communications errors, it transmits an attention message, which includes the Port_01.MB_TxId setting. The relay transmits an attention message until it receives an attention message that includes a match to the Port_01.MB_TxId setting value. If the attention message is successful, the relay has properly synchronized and data transmission resumes. If the attention message is not successful, the relay repeats the attention message until it is successful.

In summary, when a relay detects an error, it transmits an attention message until it receives an attention message with its own Port_01.MB_TxId included. If three or four relays are connected in a ring topology, the attention message goes all the way around the loop until the originating relay receives it. The message then dies and data transmission resumes. This method of synchronization allows the relays to reliably determine which byte is the first byte of the message. It also forces unsynchronized UARTs to become resynchronized. On the down side, this method takes down the entire loop for a receive error at any relay in the loop. This decreases availability. It also makes one-way communications impossible.

Loopback Testing

Use the **LOOP** command to enable loopback testing. In the loopback mode, you loop the transmit port to the receive port of the same relay to verify transmission messages. While in loopback mode, MB_A.RxOk is deasserted, and another user accessible Relay Word bit, MB_A.LoopOk (Loop Back OK) asserts and deasserts based on the received data checks (see the *Section 7: Communications* for the ASCII commands).

Channel Monitoring

Based on the results of data checks (described previously), the relay collects information regarding the 255 most recent communications errors. Each record contains at least the following fields:

- DATE—Date when the dropout occurred
- TIME—Time when the dropout occurred
- RECOVERY_DATE—Date when the channel returned to service (if the channel is currently failed, it is displayed and included in the calculations, as if its recovery were to occur at the time the report was requested)
- RECOVERY_TIME—Time when the channel returned to service (if the channel is currently failed, it is displayed and included in the calculations, as if its recovery were to occur at the time the report was requested)
- DURATION—Time elapsed during dropout
- CAUSE—Reason for dropout (see *Message Decoding and Integrity Checks on page G.2*)

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 currently failed, it is displayed and included in the calculations, as if its recovery were to occur at the time the report was requested.

NOTE: Combine error conditions including MB_A.RxBad and MB_A.ChBad with other alarm conditions by using SELogic control equations. You can use these alarm conditions to program the relay to take appropriate action when it detects a communications channel failure.

When the duration of an outage on Channel A exceeds a user-definable threshold, the relay asserts the user-accessible Relay Word bit, MB_A.RxBad. When channel unavailability exceeds a user-definable threshold for Channel A, the relay asserts the user-accessible Relay Word bit, MB_A.ChBad. Use the **COMM** command to generate a long or summary report of the communications errors.

Use the Port_01.MB_RxBadPUDly setting to determine how long a channel error must last before the meter element MB_A.RxBad is asserted. MB_A.RxBad is deasserted when the channel error is corrected. Port_01.MB_RxBadPUDly is accurate to ±1 second.

Use the Port_01.MB_ChBadPUVal setting to determine the ratio of channel down time to the total channel time before the meter element MB_A.ChBad is asserted. The times used in the calculation are those that are available in the COM records. See *COMMUNICATIONS Command* in *Section 7: Communications* for more information.

Settings

Set Port_01.Proto = MBA or MB8A to enable the MIRRORED BITS protocol Channel A on this port. The standard MIRRORED BITS protocol MBA uses a 6-data bit format for data encoding. The MB8 protocol MB8A uses an 8-data bit format, which allows MIRRORED BITS to operate on communications channels requiring an 8-data bit format. *Table G.4* shows the MIRRORED BITS protocol port settings, ranges, and default settings for Port 1.

Table G.4 MIRRORED BITS Protocol Settings

Setting Prompt	Setting Description	Factory Default Setting
Port_01.MB_TxId	MIRRORED BITS Transmit Identifier (1–4)	2
Port_01.MB_RxId	MIRRORED BITS Receive Identifier (1–4)	1
Port_01.MB_RxBadPUDly	MIRRORED BITS Rx Bad Pickup Time (1–10000 seconds)	60
Port_01.MB_ChBadPUVal	MIRRORED BITS Channel Bad Pickup	1000
Port_01.MB_RxDfltSta	MIRRORED BITS Receive Default State	XXXXXXXX
Port_01.MB_Rx01PU	Receive MIRRORED BITS 01 Pickup Debounce Messages (1–8 messages)	1
Port_01.MB_Rx01DO	Receive MIRRORED BITS 01 Dropout Debounce Messages (1–8 messages)	1
Port_01.MB_Rx02PU	Receive MIRRORED BITS 02 Pickup Debounce Messages (1–8 messages)	1
Port_01.MB_Rx02DO	Receive MIRRORED BITS 02 Dropout Debounce Messages (1–8 messages)	1
Port_01.MB_Rx03PU	Receive MIRRORED BITS 03 Pickup Debounce Messages (1–8 messages)	1
Port_01.MB_Rx03DO	Receive MIRRORED BITS 03 Dropout Debounce Messages (1–8 messages)	1
Port_01.MB_Rx04PU	Receive MIRRORED BITS 04 Pickup Debounce Messages (1–8 messages)	1
Port_01.MB_Rx04DO	Receive MIRRORED BITS 04 Dropout Debounce Messages (1–8 messages)	1
Port_01.MB_Rx05PU	Receive MIRRORED BITS 05 Pickup Debounce Messages (1–8 messages)	1
Port_01.MB_Rx05DO	Receive MIRRORED BITS 05 Dropout Debounce Messages (1–8 messages)	1
Port_01.MB_Rx06PU	Receive MIRRORED BITS 06 Pickup Debounce Messages (1–8 messages)	1
Port_01.MB_Rx06DO	Receive MIRRORED BITS 06 Dropout Debounce Messages (1–8 messages)	1
Port_01.MB_Rx07PU	Receive MIRRORED BITS 07 Pickup Debounce Messages (1–8 messages)	1
Port_01.MB_Rx07DO	Receive MIRRORED BITS 07 Dropout Debounce Messages (1–8 messages)	1
Port_01.MB_Rx08PU	Receive MIRRORED BITS 08 Pickup Debounce Messages (1–8 messages)	1
Port_01.MB_Rx08DO	Receive MIRRORED BITS 08 Dropout Debounce Messages (1–8 messages)	1

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Appendix H

Relay Word Bits

The protection and control element results are represented by Relay Word bits in the SEL-851 Feeder Protection Relay. Each Relay Word bit has a label name and can be in either of the following states:

- 1 (logical 1)
- 0 (logical 0)

Logical 1 represents an element being picked up or otherwise asserted. Logical 0 represents an element being dropped out or otherwise deasserted.

Table H.1 shows the Relay Word bits and their corresponding descriptions. Any Relay Word bit (except Row 0) can be used in SELOGIC control equations and the Sequential Events Recorder (SER) trigger list settings (see *Section 9: Analyzing Events*).

Table H.1 Relay Word Bits[a] (Sheet 1 of 18)

Row	Bit	Name	Bit Description
HMI Target/Status Indication			
Row 0			
	7	EnaLED.Sta	Enable LED
	6	TripLED.Sta	Trip LED
	5	*	Reserved for future use
	4	*	Reserved for future use
	3	*	Reserved for future use
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use
Row 1			
	7	TLED_01.Sta	Target LED 1 status
	6	TLED_02.Sta	Target LED 2 status
	5	TLED_03.Sta	Target LED 3 status
	4	TLED_04.Sta	Target LED 4 status
	3	TLED_05.Sta	Target LED 5 status
	2	TLED_06.Sta	Target LED 6 status
	1	TLED_07.Sta	Target LED 7 status
	0	TLED_08.Sta	Target LED 8 status

Table H.1 Relay Word Bits[a] (Sheet 2 of 18)

Row	Bit	Name	Bit Description
Target LED Equations			
Row 2			
	7	TLED_01.Set	Target LED 01 SELOGIC control equation
	6	TLED_02.Set	Target LED 02 SELOGIC control equation
	5	TLED_03.Set	Target LED 03 SELOGIC control equation
	4	TLED_04.Set	Target LED 04 SELOGIC control equation
	3	TLED_05.Set	Target LED 05 SELOGIC control equation
	2	TLED_06.Set	Target LED 06 SELOGIC control equation
	1	TLED_07.Set	Target LED 07 SELOGIC control equation
	0	TLED_08.Set	Target LED 08 SELOGIC control equation
Definite-Time Overcurrent Elements			
Row 3			
	7	50P_01.PU	Maximum phase definite-time overcurrent element pickup, Level 01
	6	50P_01.TmOut	Maximum phase definite-time overcurrent element trip, Level 01
	5	50P_01.TorqCtl	Maximum phase definite-time overcurrent element, torque control, Level 01
	4	50P_02.PU	Maximum phase definite-time overcurrent element pickup, Level 02
	3	50P_02.TmOut	Maximum phase definite-time overcurrent element trip, Level 02
	2	50P_02.TorqCtl	Maximum phase definite-time overcurrent element, torque control, Level 02
	1	*	Reserved for future use
	0	*	Reserved for future use
Row 4			
	7	50P_03.PU	Maximum phase definite-time overcurrent element pickup, Level 03
	6	50P_03.TmOut	Maximum phase definite-time overcurrent element trip, Level 03
	5	50P_03.TorqCtl	Maximum phase definite-time overcurrent element, torque control, Level 03
	4	50P_04.PU	Maximum phase definite-time overcurrent element pickup, Level 04
	3	50P_04.TmOut	Maximum phase definite-time overcurrent element trip, Level 04
	2	50P_04.TorqCtl	Maximum phase definite-time overcurrent element, torque control, Level 04
	1	*	Reserved for future use
	0	*	Reserved for future use
Row 5			
	7	50P_05.PU	Maximum phase definite-time overcurrent element pickup, Level 05
	6	50P_05.TmOut	Maximum phase definite-time overcurrent element trip, Level 05
	5	50P_05.TorqCtl	Maximum phase definite-time overcurrent element, torque control, Level 05
	4	50P_06.PU	Maximum phase definite-time overcurrent element pickup, Level 06
	3	50P_06.TmOut	Maximum phase definite-time overcurrent element trip, Level 06
	2	50P_06.TorqCtl	Maximum phase definite-time overcurrent element, torque control, Level 06
	1	*	Reserved for future use
	0	50ABC_01.TorqCtl	Per-phase definite-time overcurrent element, torque control, Level 01

Table H.1 Relay Word Bits[a] (Sheet 3 of 18)

Row	Bit	Name	Bit Description
Row 6			
	7	50ABC_01.PU_A	Per-phase definite-time overcurrent element pickup, Phase A, Level 01
	6	50ABC_01.TmOut_A	Per-phase definite-time overcurrent element trip, Phase A, Level 01
	5	50ABC_01.PU_B	Per-phase definite-time overcurrent element pickup, Phase B, Level 01
	4	50ABC_01.TmOut_B	Per-phase definite-time overcurrent element trip, Phase B, Level 01
	3	50ABC_01.PU_C	Per-phase definite-time overcurrent element pickup, Phase C, Level 01
	2	50ABC_01.TmOut_C	Per-phase definite-time overcurrent element trip, Phase C, Level 01
	1	50ABC_01.PU	Per-phase definite-time overcurrent element pickup, Phase A, B, or C, Level 01
	0	50ABC_01.TmOut	Per-phase definite-time overcurrent element trip, Phase A, B, or C, Level 01
Row 7			
	7	50Gnd_01.PU	Residual ground definite-time overcurrent element pickup, Level 01
	6	50Gnd_01.TmOut	Residual ground definite-time overcurrent element trip, Level 01
	5	50Gnd_01.TorqCtl	Residual ground definite-time overcurrent element, torque control, Level 01
	4	50Gnd_02.PU	Residual ground definite-time overcurrent element pickup, Level 02
	3	50Gnd_02.TmOut	Residual ground definite-time overcurrent element trip, Level 02
	2	50Gnd_02.TorqCtl	Residual ground definite-time overcurrent element, torque control, Level 02
	1	*	Reserved for future use
	0	*	Reserved for future use
Row 8			
	7	50Neg_01.PU	Negative-sequence definite-time overcurrent element pickup, Level 01
	6	50Neg_01.TmOut	Negative-sequence definite-time overcurrent element trip, Level 01
	5	50Neg_01.TorqCtl	Negative-sequence definite-time overcurrent element, torque control, Level 01
	4	50Neg_02.PU	Negative-sequence definite-time overcurrent element pickup, Level 02
	3	50Neg_02.TmOut	Negative-sequence definite-time overcurrent element trip, Level 02
	2	50Neg_02.TorqCtl	Negative-sequence definite-time overcurrent element, torque control, Level 02
	1	*	Reserved for future use
	0	*	Reserved for future use
Row 9			
	7	50N_01.PU	Neutral definite-time overcurrent element pickup, Level 01
	6	50N_01.TmOut	Neutral definite-time overcurrent element trip, Level 01
	5	50N_01.TorqCtl	Neutral definite-time overcurrent element, torque control, Level 01
	4	50N_02.PU	Neutral definite-time overcurrent element pickup, Level 02
	3	50N_02.TmOut	Neutral definite-time overcurrent element trip, Level 02
	2	50N_02.TorqCtl	Neutral definite-time overcurrent element, torque control, Level 02
	1	*	Reserved for future use
	0	*	Reserved for future use

Table H.1 Relay Word Bits[a] (Sheet 4 of 18)

Row	Bit	Name	Bit Description
Row 10			
	7	50.TmOut	Logical OR of all the definite-time overcurrent elements tripped outputs
	6	PkDet.CTSatPU_A	CT saturation detected on Phase A
	5	PkDet.CTSatPU_B	CT saturation detected on Phase B
	4	PkDet.CTSatPU_C	CT saturation detected on Phase C
	3	*	Reserved for future use
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use
Inverse-Time Overcurrent Elements			
Row 11			
	7	51P_01.PU	Maximum phase time-overcurrent element pickup, Level 01
	6	51P_01.TmOut	Maximum phase time-overcurrent element trip, Level 01
	5	51P_01.Rst	Maximum phase time-overcurrent element reset, Level 01
	4	51P_01.TorqCtl	Maximum phase time-overcurrent element, torque control, Level 01
	3	51P_02.PU	Maximum phase time-overcurrent element pickup, Level 02
	2	51P_02.TmOut	Maximum phase time-overcurrent element trip, Level 02
	1	51P_02.Rst	Maximum phase time-overcurrent element reset, Level 02
	0	51P_02.TorqCtl	Maximum phase time-overcurrent element torque control, Level 02
Row 12			
	7	51Gnd_01.PU	Residual ground time-overcurrent element pickup, Level 01
	6	51Gnd_01.TmOut	Residual ground time-overcurrent element trip, Level 01
	5	51Gnd_01.Rst	Residual ground time-overcurrent element reset, Level 01
	4	51Gnd_01.TorqCtl	Residual ground time-overcurrent element, torque control, Level 01
	3	51Gnd_02.PU	Residual ground time-overcurrent element pickup, Level 02
	2	51Gnd_02.TmOut	Residual ground time-overcurrent element trip, Level 02
	1	51Gnd_02.Rst	Residual ground time-overcurrent element reset, Level 02
	0	51Gnd_02.TorqCtl	Residual ground time-overcurrent element torque control, Level 02
Row 13			
	7	51Neg_01.PU	Negative-sequence time-overcurrent element pickup, Level 01
	6	51Neg_01.TmOut	Negative-sequence time-overcurrent element trip, Level 01
	5	51Neg_01.Rst	Negative-sequence time-overcurrent element reset, Level 01
	4	51Neg_01.TorqCtl	Negative-sequence time-overcurrent element, torque control, Level 01
	3	51Neg_02.PU	Negative-sequence time-overcurrent element pickup, Level 02
	2	51Neg_02.TmOut	Negative-sequence time-overcurrent element trip, Level 02
	1	51Neg_02.Rst	Negative-sequence time-overcurrent element reset, Level 02
	0	51Neg_02.TorqCtl	Negative-sequence time-overcurrent element, torque control, Level 02

Table H.1 Relay Word Bits[a] (Sheet 5 of 18)

Row	Bit	Name	Bit Description
Row 14			
	7	51N_01.PU	Neutral time-overcurrent element pickup, Level 01
	6	51N_01.TmOut	Neutral time-overcurrent element trip, Level 01
	5	51N_01.Rst	Neutral time-overcurrent element reset, Level 01
	4	51N_01.TorqCtl	Neutral time-overcurrent element, torque control, Level 01
	3	51N_02.PU	Neutral time-overcurrent element pickup, Level 02
	2	51N_02.TmOut	Neutral time-overcurrent element trip, Level 02
	1	51N_02.Rst	Neutral time-overcurrent element reset, Level 02
	0	51N_02.TorqCtl	Neutral time-overcurrent element, torque control, Level 02
Harmonic Blocking			
Row 15			
	7	HBlk.H2_PUA	Per-phase 2nd-harmonic blocking logic pickup, Phase A
	6	HBlk.H2_TmOutA	Per-phase 2nd-harmonic blocking logic trip, Phase A
	5	HBlk.H2_PUB	Per-phase 2nd-harmonic blocking logic pickup, Phase B
	4	HBlk.H2_TmOutB	Per-phase 2nd-harmonic blocking logic trip, Phase B
	3	HBlk.H2_PUC	Per-phase 2nd-harmonic blocking logic pickup, Phase C
	2	HBlk.H2_TmOutC	Per-phase 2nd-harmonic blocking logic trip, Phase C
	1	HBlk.H2_TmOut	3-phase 2nd-harmonic blocking logic trip
	0	HBlk.H2_TorqCtl	2nd-harmonic blocking logic torque control
Under- and Overvoltage Elements			
Row 16			
	7	27PP_01.PU	Phase-phase definite-time undervoltage element pickup, Level 01
	6	27PP_01.TmOut	Phase-phase definite-time undervoltage element trip, Level 01
	5	27PP_01.TorqCtl	Phase-phase definite-time undervoltage element, torque control, Level 01
	4	27PP_02.PU	Phase-phase definite-time undervoltage element pickup, Level 02
	3	27PP_02.TmOut	Phase-phase definite-time undervoltage element trip, Level 02
	2	27PP_02.TorqCtl	Phase-phase definite-time undervoltage element, torque control, Level 02
	1	*	Reserved for future use
	0	*	Reserved for future use
Row 17			
	7	59PP_01.PU	Phase-phase definite-time overvoltage element pickup, Level 01
	6	59PP_01.TmOut	Phase-phase definite-time overvoltage element trip, Level 01
	5	59PP_01.TorqCtl	Phase-phase definite-time overvoltage element, torque control, Level 01
	4	59PP_02.PU	Phase-phase definite-time overvoltage element pickup, Level 02
	3	59PP_02.TmOut	Phase-phase definite-time overvoltage element trip, Level 02
	2	59PP_02.TorqCtl	Phase-phase definite-time overvoltage element, torque control, Level 02
	1	*	Reserved for future use
	0	*	Reserved for future use

Table H.1 Relay Word Bits[a] (Sheet 6 of 18)

Row	Bit	Name	Bit Description
Row 18			
	7	59Gnd_01.PU	Residual ground definite-time overvoltage element pickup, Level 01
	6	59Gnd_01.TmOut	Residual ground definite-time overvoltage element trip, Level 01
	5	59Gnd_01.TorqCtl	Residual ground definite-time overvoltage element, torque control, Level 01
	4	59Gnd_02.PU	Residual ground definite-time overvoltage element pickup, Level 02
	3	59Gnd_02.TmOut	Residual ground definite-time overvoltage element trip, Level 02
	2	59Gnd_02.TorqCtl	Residual ground definite-time overvoltage element, torque control, Level 02
	1	*	Reserved for future use
	0	*	Reserved for future use
Frequency Elements			
Row 19			
	7	81_01.PU	Frequency element pickup, Level 01
	6	81_01.TmOut	Frequency element trip, Level 01
	5	81_01.TorqCtl	Frequency element torque control, Level 01
	4	81_02.PU	Frequency element pickup, Level 02
	3	81_02.TmOut	Frequency element trip, Level 02
	2	81_02.TorqCtl	Frequency element torque control, Level 02
	1	*	Reserved for future use
	0	*	Reserved for future use
Row 20			
	7	FreqTrk.Ok	Relay tracking system frequency
	6	Freq.I_Mod	Frequency measurement based on current signal
	5	Freq.VI_Ok	Voltage or current signal above threshold to measure frequency
	4	*	Reserved for future use
	3	*	Reserved for future use
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use
Power Elements			
Row 21			
	7	32_01.PU	32 directional power element pickup, Level 01
	6	32_01.TmOut	32 directional power element timeout, Level 01
	5	32_01.TorqCtl	Power element, torque control, Level 01
	4	32_02.PU	32 directional power element pickup, Level 02
	3	32_02.TmOut	32 directional power element timeout, Level 02
	2	32_02.TorqCtl	Power element, torque control, Level 02
	1	*	Reserved for future use
	0	*	Reserved for future use

Table H.1 Relay Word Bits[a] (Sheet 7 of 18)

Row	Bit	Name	Bit Description
Loss of Potential			
Row 22			
	7	60LOP.PU	Loss of potential element pickup
	6	60LOP.IncPU	Incremental loss of potential pickup
	5	60LOP.Rst	Loss of potential reset
	4	60LOP.NegPU	Negative-sequence loss of potential pickup
	3	60LOP.Blk	Loss of potential block
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use
Power Factor			
Row 23			
	7	55_01.PU	Power factor element pickup, Level 01
	6	55_01.TmOut	Power factor element trip, Level 01
	5	55_01.TorqCtl	Power factor element, torque control, Level 01
	4	55_02.PU	Power factor element pickup, Level 02
	3	55_02.TmOut	Power factor element trip, Level 02
	2	55_02.TorqCtl	Power factor element, torque control, Level 02
	1	*	Reserved for future use
	0	*	Reserved for future use
Arc-Flash Detection Elements			
Row 24			
	7	AFD.50P_PU	Sample-based phase overcurrent element for arc-flash detection
	6	AFD.50N_PU	Sample-based residual overcurrent element for arc-flash detection
	5	AFD.Sen01_PU	Arc-Flash Light Input Element 01 pickup
	4	AFD.Sen02_PU	Arc-Flash Light Input Element 02 pickup
	3	AFD.Sen03_PU	Arc-Flash Light Input Element 03 pickup
	2	AFD.Sen04_PU	Arc-Flash Light Input Element 04 pickup
	1	*	Reserved for future use
	0	AFD.Alm	Arc-flash integrity alarm, logical OR of all arc-flash diagnostics and excessive light bits (AFD.Sen0*n*_DiagFail and AFD.Sen0*n*_AmbLight)
Row 25			
	7	AFD.Sen01_AmbLight	Arc-Flash Sensor Input 01 excessive ambient light pickup
	6	AFD.Sen02_AmbLight	Arc-Flash Sensor Input 02 excessive ambient light pickup
	5	AFD.Sen03_AmbLight	Arc-Flash Sensor Input 03 excessive ambient light pickup
	4	AFD.Sen04_AmbLight	Arc-Flash Sensor Input 04 excessive ambient light pickup
	3	AFD.Sen01_DiagFail	Arc-Flash Sensor Input 01 diagnostic failure
	2	AFD.Sen02_DiagFail	Arc-Flash Sensor Input 02 diagnostic failure
	1	AFD.Sen03_DiagFail	Arc-Flash Sensor Input 03 diagnostic failure
	0	AFD.Sen04_DiagFail	Arc-Flash Sensor Input 04 diagnostic failure

Table H.1 Relay Word Bits[a] (Sheet 8 of 18)

Row	Bit	Name	Bit Description
Breaker Failure			
Row 26			
	7	BF_01.Init	Breaker failure initiate SELOGIC control equation
	6	BF_01.Supv	Breaker failure supervision SELOGIC control equation
	5	BF_01.50P_PU	Breaker failure phase current detector asserted
	4	BF_01.TmOut	Breaker failure timed out
	3	BF_01.Retrip_TmOut	Breaker failure re-trip timed out
	2	BF_01.Trip_Init	Breaker failure trip initiate SELOGIC control equation
	1	BF_01.UnltTrip	Breaker failure unlatch trip SELOGIC control equation
	0	BF_01.Trip	Breaker failure trip logic output
Close Logic			
Row 27			
	7	Close_01.LocInit	Local close SELOGIC control equation
	6	Close_01.LocSta	Breaker close while in local mode
	5	Close_01.RemInit	Remote close SELOGIC control equation
	4	Close_01.RemSta	Breaker close while in remote mode
	3	Close_01.Unlt	Unlatch close SELOGIC control equation
	2	Close_01.ManSta	Manual close status
	1	Close_01.Sta	Breaker close output
	0	Close_01.Fail	Close fail status
Trip Logic			
Row 28			
	7	Trip_01.LocInit	Local trip SELOGIC equation
	6	Trip_01.LocSta	Local trip issued
	5	Trip_01.RemInit	Remote trip SELOGIC equation
	4	Trip_01.RemSta	Remote trip issued
	3	*	Reserved for future use
	2	Trip_01.Init	Trip SELOGIC equation
	1	Trip_01.InitX	Extended trip SELOGIC equation
	0	Trip_01.Unlt	Unlatch trip SELOGIC equation
Row 29			
	7	Trip_01.Sta	Trip issued
	6	Trip.TrgtRst	Trip/Target reset SELOGIC equation
	5	Trip.TrgtRstSta	Target reset issued
	4	*	Reserved for future use
	3	*	Reserved for future use
	2	Warning.Sta	Asserted when any element in the warning list is asserted
	1	Ctl.LocSta	Breaker control in local mode
	0	Bkr_01.52A_Sta	52A SELOGIC equation

Table H.1 Relay Word Bits[a] (Sheet 9 of 18)

Row	Bit	Name	Bit Description
Control Elements			
Row 30			
	7	HMI.CtlBlkSta	Breaker control blocked from the front panel
	6	Ctl.RemSel	Remote control select SELOGIC control equation
	5	HMI.RemSel	Remote control select from the front panel
	4	Ctl.RemSta	Breaker control in remote mode
	3	HMI.ClsCmd	Close command from the front panel
	2	Comm.ClsCmd	Close command issued over communication protocols
	1	HMI.TripCmd	Trip command from the front panel
	0	Comm.TripCmd	Trip command issued over communication protocols
Recloser Control			
Row 31			
	7	79.Cyc	Reclosing relay in reclose cycle state
	6	79.LO	Reclosing relay in lockout state
	5	79.Rst	Reclosing relay in reset state
	4	79.ClsSupvFail	Reclose supervision failed
	3	79.Shot0	Reclosing relay shot counter = 0
	2	79.Shot1	Reclosing relay shot counter = 1
	1	79.Shot2	Reclosing relay shot counter = 2
	0	79.Shot3	Reclosing relay shot counter = 3
Row 32			
	7	79.Shot4	Reclosing relay shot counter = 4
	6	79.OpnTmSta	Open interval timer is timing
	5	79.RstTmSta	Reset timer is timing
	4	*	Reserved for future use
	3	*	Reserved for future use
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use
Inputs and Outputs			
Row 33			
	7	IN_08.Sta	Contact Input 08 status
	6	IN_07.Sta	Contact Input 07 status
	5	IN_06.Sta	Contact Input 06 status
	4	IN_05.Sta	Contact Input 05 status
	3	IN_04.Sta	Contact Input 04 status
	2	IN_03.Sta	Contact Input 03 status
	1	IN_02.Sta	Contact Input 02 status
	0	IN_01.Sta	Contact Input 01 status

Table H.1 Relay Word Bits[a] (Sheet 10 of 18)

Row	Bit	Name	Bit Description
Row 34			
	7	*	Reserved for future use
	6	*	Reserved for future use
	5	*	Reserved for future use
	4	*	Reserved for future use
	3	*	Reserved for future use
	2	*	Reserved for future use
	1	IN_10.Sta	Contact Input 10 status
	0	IN_09.Sta	Contact Input 09 status
Row 35			
	7	*	Reserved for future use
	6	*	Reserved for future use
	5	*	Reserved for future use
	4	OUT_05.Sta	Control equation for Contact Output 05
	3	OUT_04.Sta	Control equation for Contact Output 04
	2	OUT_03.Sta	Control equation for Contact Output 03
	1	OUT_02.Sta	Control equation for Contact Output 02
	0	OUT_01.Sta	Control equation for Contact Output 01
Demand Elements			
Row 36			
	7	Meter.Dmd_PU	Current demand pickup
	6	Meter.Dmd_IP_PU	Phase current demand pickup
	5	Meter.Dmd_IGnd_PU	Ground current demand pickup
	4	Meter.Dmd_INeg_PU	Negative-sequence current demand pickup
	3	Meter.Dmd_Rst	Reset demand data SELOGIC control equation
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use
Misc.			
Row 37			
	7	Event.Trg	Event report trigger SELOGIC control equation
	6	Meter.En_Rst	Reset energy data SELOGIC control equation
	5	Meter.MaxMin_Rst	Reset max/min data SELOGIC control equation
	4	Meter.Fault	Fault condition SELOGIC control equation
	3	*	Reserved for future use
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use

Table H.1 Relay Word Bits[a] (Sheet 11 of 18)

Row	Bit	Name	Bit Description
SELOGIC Control Equation Protection Latches			
Row 38			
	7	PLT_001.Sta	Latch Bit 001 status
	6	PLT_002.Sta	Latch Bit 002 status
	5	PLT_003.Sta	Latch Bit 003 status
	4	PLT_004.Sta	Latch Bit 004 status
	3	PLT_005.Sta	Latch Bit 005 status
	2	PLT_006.Sta	Latch Bit 006 status
	1	PLT_007.Sta	Latch Bit 007 status
	0	PLT_008.Sta	Latch Bit 008 status
Row 39			
	7	PLT_009.Sta	Latch Bit 009 status
	6	PLT_010.Sta	Latch Bit 010 status
	5	PLT_011.Sta	Latch Bit 011 status
	4	PLT_012.Sta	Latch Bit 012 status
	3	PLT_013.Sta	Latch Bit 013 status
	2	PLT_014.Sta	Latch Bit 014 status
	1	PLT_015.Sta	Latch Bit 015 status
	0	PLT_016.Sta	Latch Bit 016 status
SELOGIC Control Equation Protection Counters			
Row 40			
	7	PCN_001.QU	Protection Counter 001 asserted when counter = preset value
	6	PCN_002.QU	Protection Counter 002 asserted when counter = preset value
	5	PCN_003.QU	Protection Counter 003 asserted when counter = preset value
	4	PCN_004.QU	Protection Counter 004 asserted when counter = preset value
	3	PCN_005.QU	Protection Counter 005 asserted when counter = preset value
	2	PCN_006.QU	Protection Counter 006 asserted when counter = preset value
	1	PCN_007.QU	Protection Counter 007 asserted when counter = preset value
	0	PCN_008.QU	Protection Counter 008 asserted when counter = preset value
Row 41			
	7	PCN_009.QU	Protection Counter 009 asserted when counter = preset value
	6	PCN_010.QU	Protection Counter 010 asserted when counter = preset value
	5	PCN_011.QU	Protection Counter 011 asserted when counter = preset value
	4	PCN_012.QU	Protection Counter 012 asserted when counter = preset value
	3	PCN_013.QU	Protection Counter 013 asserted when counter = preset value
	2	PCN_014.QU	Protection Counter 014 asserted when counter = preset value
	1	PCN_015.QU	Protection Counter 015 asserted when counter = preset value
	0	PCN_016.QU	Protection Counter 016 asserted when counter = preset value

Table H.1 Relay Word Bits[a] (Sheet 12 of 18)

Row	Bit	Name	Bit Description
Row 42			
	7	PCN_001.QD	Protection Counter 001 asserted when counter = 0
	6	PCN_002.QD	Protection Counter 002 asserted when counter = 0
	5	PCN_003.QD	Protection Counter 003 asserted when counter = 0
	4	PCN_004.QD	Protection Counter 004 asserted when counter = 0
	3	PCN_005.QD	Protection Counter 005 asserted when counter = 0
	2	PCN_006.QD	Protection Counter 006 asserted when counter = 0
	1	PCN_007.QD	Protection Counter 007 asserted when counter = 0
	0	PCN_008.QD	Protection Counter 008 asserted when counter = 0
Row 43			
	7	PCN_009.QD	Protection Counter 009 asserted when counter = 0
	6	PCN_010.QD	Protection Counter 010 asserted when counter = 0
	5	PCN_011.QD	Protection Counter 011 asserted when counter = 0
	4	PCN_012.QD	Protection Counter 012 asserted when counter = 0
	3	PCN_013.QD	Protection Counter 013 asserted when counter = 0
	2	PCN_014.QD	Protection Counter 014 asserted when counter = 0
	1	PCN_015.QD	Protection Counter 015 asserted when counter = 0
	0	PCN_016.QD	Protection Counter 016 asserted when counter = 0
SELOGIC Control Equation Protection Conditioning Timer			
Row 44			
	7	PCT_001.In	Protection Conditioning Timer 001 input asserted
	6	PCT_002.In	Protection Conditioning Timer 002 input asserted
	5	PCT_003.In	Protection Conditioning Timer 003 input asserted
	4	PCT_004.In	Protection Conditioning Timer 004 input asserted
	3	PCT_005.In	Protection Conditioning Timer 005 input asserted
	2	PCT_006.In	Protection Conditioning Timer 006 input asserted
	1	PCT_007.In	Protection Conditioning Timer 007 input asserted
	0	PCT_008.In	Protection Conditioning Timer 008 input asserted
Row 45			
	7	PCT_009.In	Protection Conditioning Timer 009 input asserted
	6	PCT_010.In	Protection Conditioning Timer 010 input asserted
	5	PCT_011.In	Protection Conditioning Timer 011 input asserted
	4	PCT_012.In	Protection Conditioning Timer 012 input asserted
	3	PCT_013.In	Protection Conditioning Timer 013 input asserted
	2	PCT_014.In	Protection Conditioning Timer 014 input asserted
	1	PCT_015.In	Protection Conditioning Timer 015 input asserted
	0	PCT_016.In	Protection Conditioning Timer 016 input asserted

Table H.1 Relay Word Bits[a] (Sheet 13 of 18)

Row	Bit	Name	Bit Description
Row 46			
	7	PCT_001.Sta	Protection Conditioning Timer 001 output asserted
	6	PCT_002.Sta	Protection Conditioning Timer 002 output asserted
	5	PCT_003.Sta	Protection Conditioning Timer 003 output asserted
	4	PCT_004.Sta	Protection Conditioning Timer 004 output asserted
	3	PCT_005.Sta	Protection Conditioning Timer 005 output asserted
	2	PCT_006.Sta	Protection Conditioning Timer 006 output asserted
	1	PCT_007.Sta	Protection Conditioning Timer 007 output asserted
	0	PCT_008.Sta	Protection Conditioning Timer 008 output asserted
Row 47			
	7	PCT_009.Sta	Protection Conditioning Timer 009 output asserted
	6	PCT_010.Sta	Protection Conditioning Timer 010 output asserted
	5	PCT_011.Sta	Protection Conditioning Timer 011 output asserted
	4	PCT_012.Sta	Protection Conditioning Timer 012 output asserted
	3	PCT_013.Sta	Protection Conditioning Timer 013 output asserted
	2	PCT_014.Sta	Protection Conditioning Timer 014 output asserted
	1	PCT_015.Sta	Protection Conditioning Timer 015 output asserted
	0	PCT_016.Sta	Protection Conditioning Timer 016 output asserted
Remote and Virtual Bits			
Row 48			
	7	RB_001.Sta	Remote Bit 001 asserted
	6	RB_002.Sta	Remote Bit 002 asserted
	5	RB_003.Sta	Remote Bit 003 asserted
	4	RB_004.Sta	Remote Bit 004 asserted
	3	RB_005.Sta	Remote Bit 005 asserted
	2	RB_006.Sta	Remote Bit 006 asserted
	1	RB_007.Sta	Remote Bit 007 asserted
	0	RB_008.Sta	Remote Bit 008 asserted
Row 49			
	7	RB_009.Sta	Remote Bit 009 asserted
	6	RB_010.Sta	Remote Bit 010 asserted
	5	RB_011.Sta	Remote Bit 011 asserted
	4	RB_012.Sta	Remote Bit 012 asserted
	3	RB_013.Sta	Remote Bit 013 asserted
	2	RB_014.Sta	Remote Bit 014 asserted
	1	RB_015.Sta	Remote Bit 015 asserted
	0	RB_016.Sta	Remote Bit 016 asserted

Table H.1 Relay Word Bits[a] (Sheet 14 of 18)

Row	Bit	Name	Bit Description
Mirrored Bits			
Row 50			
	7	MB_A.Tx08	Channel A Transmit Mirrored Bit 08
	6	MB_A.Tx07	Channel A Transmit Mirrored Bit 07
	5	MB_A.Tx06	Channel A Transmit Mirrored Bit 06
	4	MB_A.Tx05	Channel A Transmit Mirrored Bit 05
	3	MB_A.Tx04	Channel A Transmit Mirrored Bit 04
	2	MB_A.Tx03	Channel A Transmit Mirrored Bit 03
	1	MB_A.Tx02	Channel A Transmit Mirrored Bit 02
	0	MB_A.Tx01	Channel A Transmit Mirrored Bit 01
Row 51			
	7	MB_A.Rx08	Channel A Receive Mirrored Bit 08
	6	MB_A.Rx07	Channel A Receive Mirrored Bit 07
	5	MB_A.Rx06	Channel A Receive Mirrored Bit 06
	4	MB_A.Rx05	Channel A Receive Mirrored Bit 05
	3	MB_A.Rx04	Channel A Receive Mirrored Bit 04
	2	MB_A.Rx03	Channel A Receive Mirrored Bit 03
	1	MB_A.Rx02	Channel A Receive Mirrored Bit 02
	0	MB_A.Rx01	Channel A Receive Mirrored Bit 01
Row 52			
	7	MB_A.LoopOk	Channel A receive data OK
	6	MB_A.RxOk	Channel A loop back OK
	5	MB_A.ChBad	Channel A unavailability over threshold
	4	MB_A.RxBad	Channel A outage duration over threshold
	3	*	Reserved for future use
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use
Diagnostic Bits			
Row 53			
	7	Diag.Hw_Alm	Indication of a diagnostic hardware alarm
	6	Diag.Hw_AlmLt	Indicates that diagnostic hardware alarm is latched
	5	Diag.Hw_AlmPul	Pulses for 5 seconds when a warning diagnostic condition occurs
	4	Diag.Hw_AlmPul60s	This bit pulses for 5 seconds every minute when a diagnostic hardware alarm has occurred. It stops pulsing within one second of the rising edge of Diag.Hw_Rst.
	3	Diag.Hw_Rst	Reset hardware alarm (Diag.Hw_AlmPul60s) SELOGIC control equation
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	Diag.MathErr	Asserted on SELOGIC math computation errors

Table H.1 Relay Word Bits[a] (Sheet 15 of 18)

Row	Bit	Name	Bit Description
Row 54			
	7	Diag.Secu_Alm	Indication of software or user activity that warrant a security ALARM
	6	Diag.Secu_AccLevAlm	Asserted while any user is logged in at Access Level 2 or higher
	5	Diag.Secu_PassBad	Pulses for 1 second when any user enters an invalid password
	4	Diag.Secu_AccLev2	Pulses for 1 second when any user increases their access level to 2 or higher
	3	*	Reserved for future use of GRPCHG
	2	Diag.Secu_SetChg	Pulses for 1 second whenever settings are changed
	1	Diag.Secu_PassChg	Pulses for 1 second whenever a password is changed
	0	Diag.Secu_PassLO	Pulses for 1 second whenever a user enters 3 successive bad passwords
Test			
Row 55			
	7	Test.ForcData	Command **TEST DB** (asserts when analog and digital values may be overridden)
	6	61850.Mod_Blk	SELOGIC control for IEC 61850 block mode
	5	61850.Mod_Test	SELOGIC control for IEC 61850 test mode
	4	61850.Sim	IEC 61850 logical node for physical device simulation
	3	61850.Qual	Quality reported over IEC 61850 MMS and GOOSE
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use
Ethernet Status			
Row 56			
	7	Port_02.LinkOk	Asserted when a valid link is detected on Port 2
	6	Port_02.LinkAOk	Asserted when a valid link is detected on Port 2A
	5	Port_02.LinkBOk	Asserted when a valid link is detected on Port 2B
	4	Port_02.LinkFail	Asserted when a valid link is not detected on the active port(s)
	3	Port_02.LinkAAct	Asserted when Port 2A is active
	2	Port_02.LinkBAct	Asserted when Port 2B is active
	1	Port_02.LinkForcOv	Force network link switchover
	0	*	Reserved for future use
Row 57			
	7	Port_02.Spd100M	Asserted when the speed on Port 2 is 100 Mbps
	6	Port_02.SpdA100M	Asserted when the speed on Port 2A is 100 Mbps
	5	Port_02.SpdB100M	Asserted when the speed on Port 2B is 100 Mbps
	4	Port_02.FullDup	Asserted when Port 2 is in full duplex mode
	3	Port_02.FullDupA	Asserted when Port 2A is in full duplex mode
	2	Port_02.FullDupB	Asserted when Port 2B is in full duplex mode
	1	Port_02.FailoverPU	Asserted when the failover timer is running
	0	*	Reserved for future use

Table H.1 Relay Word Bits[a] (Sheet 16 of 18)

Row	Bit	Name	Bit Description
Row 58			
	7	Time.SNTP_PriSrvr	Asserted when the relay time is based on SNTP, using primary server
	6	Time.SNTP_BackupSrvr	Asserted when the relay time is based on SNTP, using backup server
	5	Time.UTCSign	Offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted; otherwise, add
	4	Time.UTCOff1	Offset hours from UTC time, binary, add 1 if asserted
	3	Time.UTCOff2	Offset hours from UTC time, binary, add 2 if asserted
	2	Time.UTCOff4	Offset hours from UTC time, binary, add 4 if asserted
	1	Time.UTCOff8	Offset hours from UTC time, binary, add 8 if asserted
	0	Time.UTCOffHalf	Offset half-hour from UTC time, binary, add 0.5 if asserted
Row 59			
	7	Time.DST	Asserted during daylight-saving time
	6	Time.DST_Pend	Asserts up to a minute before daylight saving time change
	5	Time.LeapSecPol	Leap second polarity—add if deasserted, delete if asserted
	4	Time.LeapSecPend	Leap second pending—asserts up to a minute prior to leap second insertion
	3	Time.Qual8	Time quality bit, add 8 when asserted
	2	Time.Qual4	Time quality bit, add 4 when asserted
	1	Time.Qual2	Time quality bit, add 2 when asserted
	0	Time.Qual1	Time quality bit, add 1 when asserted
Time Synchronization Status			
Row 60			
	7	Time.SyncOk	Time synchronization OK
	6	Time.IRIG_Ok	Asserted when relay time is based on IRIG-B time source
	5	*	Reserved for future use
	4	*	Reserved for future use
	3	*	Reserved for future use
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use
Row 61–Row 63			
	7	*	Reserved for future use
	6	*	Reserved for future use
	5	*	Reserved for future use
	4	*	Reserved for future use
	3	*	Reserved for future use
	2	*	Reserved for future use
	1	*	Reserved for future use
	0	*	Reserved for future use

Table H.1 Relay Word Bits[a] (Sheet 17 of 18)

Row	Bit	Name	Bit Description
Row 64			
	7	VB_025.Sta	Virtual Bit 025 asserted
	6	VB_026.Sta	Virtual Bit 026 asserted
	5	VB_027.Sta	Virtual Bit 027 asserted
	4	VB_028.Sta	Virtual Bit 028 asserted
	3	VB_029.Sta	Virtual Bit 029 asserted
	2	VB_030.Sta	Virtual Bit 030 asserted
	1	VB_031.Sta	Virtual Bit 031 asserted
	0	VB_032.Sta	Virtual Bit 032 asserted
Row 65			
	7	VB_017.Sta	Virtual Bit 017 asserted
	6	VB_018.Sta	Virtual Bit 018 asserted
	5	VB_019.Sta	Virtual Bit 019 asserted
	4	VB_020.Sta	Virtual Bit 020 asserted
	3	VB_021.Sta	Virtual Bit 021 asserted
	2	VB_022.Sta	Virtual Bit 022 asserted
	1	VB_023.Sta	Virtual Bit 023 asserted
	0	VB_024.Sta	Virtual Bit 024 asserted
Row 66			
	7	VB_009.Sta	Virtual Bit 009 asserted
	6	VB_010.Sta	Virtual Bit 010 asserted
	5	VB_011.Sta	Virtual Bit 011 asserted
	4	VB_012.Sta	Virtual Bit 012 asserted
	3	VB_013.Sta	Virtual Bit 013 asserted
	2	VB_014.Sta	Virtual Bit 014 asserted
	1	VB_015.Sta	Virtual Bit 015 asserted
	0	VB_016.Sta	Virtual Bit 016 asserted
Row 67			
	7	VB_001.Sta	Virtual Bit 001 asserted
	6	VB_002.Sta	Virtual Bit 002 asserted
	5	VB_003.Sta	Virtual Bit 003 asserted
	4	VB_004.Sta	Virtual Bit 004 asserted
	3	VB_005.Sta	Virtual Bit 005 asserted
	2	VB_006.Sta	Virtual Bit 006 asserted
	1	VB_007.Sta	Virtual Bit 007 asserted
	0	VB_008.Sta	Virtual Bit 008 asserted

Table H.1 Relay Word Bits[a] (Sheet 18 of 18)

Row	Bit	Name	Bit Description
Fixed GOOSE			
Row 68			
	7	FG_P2_01.RxBin01	Fixed GOOSE Message1 Bit 01 asserted
	6	FG_P2_01.RxBin02	Fixed GOOSE Message1 Bit 02 asserted
	5	FG_P2_01.RxBin03	Fixed GOOSE Message1 Bit 03 asserted
	4	FG_P2_01.RxBin04	Fixed GOOSE Message1 Bit 04 asserted
	3	FG_P2_01.RxBin05	Fixed GOOSE Message1 Bit 05 asserted
	2	FG_P2_01.RxBin06	Fixed GOOSE Message1 Bit 06 asserted
	1	FG_P2_01.RxBin07	Fixed GOOSE Message1 Bit 07 asserted
	0	FG_P2_01.RxBin08	Fixed GOOSE Message1 Bit 08 asserted
Row 69			
	7	FG_P2_02.RxBin01	Fixed GOOSE Message2 Bit 01 asserted
	6	FG_P2_02.RxBin02	Fixed GOOSE Message2 Bit 02 asserted
	5	FG_P2_02.RxBin03	Fixed GOOSE Message2 Bit 03 asserted
	4	FG_P2_02.RxBin04	Fixed GOOSE Message2 Bit 04 asserted
	3	FG_P2_02.RxBin05	Fixed GOOSE Message2 Bit 05 asserted
	2	FG_P2_02.RxBin06	Fixed GOOSE Message2 Bit 06 asserted
	1	FG_P2_02.RxBin07	Fixed GOOSE Message2 Bit 07 asserted
	0	FG_P2_02.RxBin08	Fixed GOOSE Message2 Bit 08 asserted
Row 70			
	7	FG_P2_03.RxBin01	Fixed GOOSE Message3 Bit 01 asserted
	6	FG_P2_03.RxBin02	Fixed GOOSE Message3 Bit 02 asserted
	5	FG_P2_03.RxBin03	Fixed GOOSE Message3 Bit 03 asserted
	4	FG_P2_03.RxBin04	Fixed GOOSE Message3 Bit 04 asserted
	3	FG_P2_03.RxBin05	Fixed GOOSE Message3 Bit 05 asserted
	2	FG_P2_03.RxBin06	Fixed GOOSE Message3 Bit 06 asserted
	1	FG_P2_03.RxBin07	Fixed GOOSE Message3 Bit 07 asserted
	0	FG_P2_03.RxBin08	Fixed GOOSE Message3 Bit 08 asserted
Row 71			
	7	FG_P2_04.RxBin01	Fixed GOOSE Message4 Bit 01 asserted
	6	FG_P2_04.RxBin02	Fixed GOOSE Message4 Bit 02 asserted
	5	FG_P2_04.RxBin03	Fixed GOOSE Message4 Bit 03 asserted
	4	FG_P2_04.RxBin04	Fixed GOOSE Message4 Bit 04 asserted
	3	FG_P2_04.RxBin05	Fixed GOOSE Message4 Bit 05 asserted
	2	FG_P2_04.RxBin06	Fixed GOOSE Message4 Bit 06 asserted
	1	FG_P2_04.RxBin07	Fixed GOOSE Message4 Bit 07 asserted
	0	FG_P2_04.RxBin08	Fixed GOOSE Message4 Bit 08 asserted

[a] When the relay part number does not support an option, such as voltage, digital input, arc-flash, dual Ethernet, or IEC 61850, the related Relay Word bits for those options will display as "*" (an asterisk).

Appendix I

Analog Quantities

The SEL-851 Feeder Protection Relay contains several analog quantities that can be used for more than one function. The part number of the relay determines the actual analog quantities available. Typically, analog quantities are generated and used by a primary function, such as metering, and selected quantities are made available for one or more supplemental functions, for example, the signal profile. Analog quantity labels with 120 ms and 24 ms information reflect the corresponding update rate. Note that these quantities may not be suitable for fast-response control and protection applications.

Table I.1 lists the analog quantities for the following specific functions.

- Serial/Ethernet port (commands and reports)
- HMI (commands and reports)
- Display points (HMI)
- SELOGIC control equations (see *Section 4: Protection and Logic Functions*)
- Signal-profile recorder (see *Section 5: Metering and Monitoring*)
- DNP3 (see *Appendix D: DNP3 Communications*)
- Modbus (see *Appendix E: Modbus Communications*)
- SEL Fast Meter (see *Appendix C: SEL Communications Processors*)
- IEC 61850 (see *Appendix F: IEC 61850 Communications*)

Table I.1 Analog Quantities (Sheet 1 of 9)

Name	Description	Units	Comm Port	HMI	Display Points	SELOGIC	Signal Profile	DNP3	Modbus	Fast Meter	IEC 61850
Instantaneous (Fundamental) Metering											
IA.120ms_MagPri	Current, A-phase, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x	x	x
IA.120ms_Ang	Current, A-phase, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
IB.120ms_MagPri	Current, B-phase, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x	x	x
IB.120ms_Ang	Current, B-phase, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
IC.120ms_MagPri	Current, C-phase, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x	x	x
IC.120ms_Ang	Current, C-phase, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
IAvg.120ms_MagPri	Current, average current, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x		x

Table I.1 Analog Quantities (Sheet 2 of 9)

Name	Description	Units	Comm Port	HMI	Display Points	SELOGIC	Signal Profile	DNP3	Modbus	Fast Meter	IEC 61850
IGnd.120ms_MagPri	Current, calculated-residual, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x	x	x
IGnd.120ms_Ang	Current, calculated-residual, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
IN.120ms_MagPri	Current, neutral, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x	x	x
IN.120ms_Ang	Current, neutral, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
IPos.120ms_MagPri	Current, positive-sequence, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x		x
IPos.120ms_Ang	Current, positive-sequence, angle, 120 ms avg	degrees			x	x	x	x	x		x
INeg.120ms_MagPri	Current, negative-sequence current, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x		x
INeg.120ms_Ang	Current, negative-sequence current, angle, 120 ms avg	degrees			x	x	x	x	x		x
VA.120ms_MagPri	Voltage, A-phase-to-neutral, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x	x	x
VA.120ms_Ang	Voltage, A-phase-to-neutral, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
VB.120ms_MagPri	Voltage, B-phase-to-neutral, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x	x	x
VB.120ms_Ang	Voltage, B-phase-to-neutral, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
VC.120ms_MagPri	Voltage, C-phase-to-neutral, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x	x	x
VC.120ms_Ang	Voltage, C-phase-to-neutral, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
VAB.120ms_MagPri	Voltage, A-to-B-phase, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x	x	x
VAB.120ms_Ang	Voltage, A-to-B-phase, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
VBC.120ms_MagPri	Voltage, B-to-C-phase, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x	x	x
VBC.120ms_Ang	Voltage, B-to-C phase, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
VCA.120ms_MagPri	Voltage, C-to-A-phase, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x	x	x
VCA.120ms_Ang	Voltage, C-to-A-phase, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x
VAvg.120ms_MagPri	Average voltage, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x		x
VGnd.120ms_MagPri	3V0 zero-sequence voltage, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x	x	x
VGnd.120ms_Ang	3V0 zero-sequence voltage, angle, 120 ms avg	degrees	x	x	x	x	x	x	x		x

Table I.1 Analog Quantities (Sheet 3 of 9)

Name	Description	Units	Comm Port	HMI	Display Points	SELOGIC	Signal Profile	DNP3	Modbus	Fast Meter	IEC 61850
VPos.120ms_MagPri	Positive-sequence voltage, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x		x
VPos.120ms_Ang	Positive-sequence voltage, angle, 120 ms avg	degrees			x	x	x	x	x		x
VNeg.120ms_MagPri	Negative-sequence voltage, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x		x
VNeg.120ms_Ang	Negative-sequence voltage, angle, 120 ms avg	degrees			x	x	x	x	x		x
S.120ms_Mag	3-phase apparent power, 120 ms avg	kVA pri	x	x	x	x	x	x	x	x	x
P.120ms_Mag	3-phase real power, 120 ms avg	kW pri	x	x	x	x	x	x	x	x	x
Q.120ms_Mag	3-phase reactive power, 120 ms avg	kVAR pri	x	x	x	x	x	x	x	x	x
PF.120ms_Mag	3-phase power factor, 120 ms avg		x	x	x	x	x	x	x	x	x
Freq.120ms_Mag	Frequency, 120 ms avg	Hz	x	x	x	x	x	x	x	x	x
Freq.120ms_DFDTMag	Rate-of-change-of-frequency, 120 ms avg	Hz/s	x	x	x	x	x	x	x	x	x
IA.24ms_MagPri	Current, A-phase, magnitude, 24 ms avg	A pri				x					
IA.24ms_Ang	Current, A-phase, angle, 24 ms avg	degrees				x					
IB.24ms_MagPri	Current, B-phase, magnitude, 24 ms avg	A pri				x					
IB.24ms_Ang	Current, B-phase, angle, 24 ms avg	degrees				x					
IC.24ms_MagPri	Current, C-phase, magnitude, 24 ms avg	A pri				x					
IC.24ms_Ang	Current, C-phase, angle, 24 ms avg	degrees				x					
IAvg.24ms_MagPri	Current, average current, magnitude, 24 ms avg	A pri				x					
IGnd.24ms_MagPri	Current, calculated-residual, magnitude, 24 ms avg	A pri				x					
IGnd.24ms_Ang	Current, calculated-residual, angle, 24 ms avg	degrees				x					
IN.24ms_MagPri	Current, neutral, magnitude, 24 ms avg	A pri				x					
IN.24ms_Ang	Current, neutral, angle, 24 ms avg	degrees				x					
IPos.24ms_MagPri	Current, positive-sequence, magnitude, 24 ms avg	A pri				x					
IPos.24ms_Ang	Current, positive-sequence, angle, 24 ms avg	degrees				x					
INeg.24ms_MagPri	Current, negative-sequence current, magnitude, 24 ms avg	A pri				x					
INeg.24ms_Ang	Current, negative-sequence current, angle, 24 ms avg	degrees				x					
VA.24ms_MagPri	Voltage, A-phase-to-neutral, magnitude, 24 ms avg	V pri				x					

Table I.1 Analog Quantities (Sheet 4 of 9)

Name	Description	Units	Comm Port	HMI	Display Points	SELOGIC	Signal Profile	DNP3	Modbus	Fast Meter	IEC 61850
VA.24ms_Ang	Voltage, A-phase-to-neutral, angle, 24 ms avg	degrees				x					
VB.24ms_MagPri	Voltage, B-phase-to-neutral, magnitude, 24 ms avg	V pri				x					
VB.24ms_Ang	Voltage, B-phase-to-neutral, angle, 24 ms avg	degrees				x					
VC.24ms_MagPri	Voltage, C-phase-to-neutral, magnitude, 24 ms avg	V pri				x					
VC.24ms_Ang	Voltage, C-phase-to-neutral, angle, 24 ms avg	degrees				x					
VAB.24ms_MagPri	Voltage, A-to-B-phase, magnitude, 24 ms avg	V pri				x					
VAB.24ms_Ang	Voltage, A-to-B-phase, angle, 24 ms avg	degrees				x					
VBC.24ms_MagPri	Voltage, B-to-C-phase, magnitude, 24 ms avg	V pri				x					
VBC.24ms_Ang	Voltage, B-to-C phase, angle, 24 ms avg	degrees				x					
VCA.24ms_MagPri	Voltage, C-to-A-phase, magnitude, 24 ms avg	V pri				x					
VCA.24ms_Ang	Voltage, C-to-A-phase, angle, 24 ms avg	degrees				x					
VAvg.24ms_MagPri	Average voltage, magnitude, 24 ms avg	V pri				x					
VGnd.24ms_MagPri	3V0 zero-sequence voltage, magnitude, 24 ms avg	V pri				x					
VGnd.24ms_Ang	3V0 zero-sequence voltage, angle, 24 ms avg	degrees				x					
VPos.24ms_MagPri	Positive-sequence voltage, magnitude, 24 ms avg	V pri				x					
VPos.24ms_Ang	Positive-sequence voltage, angle, 24 ms avg	degrees				x					
VNeg.24ms_MagPri	Negative-sequence voltage, magnitude, 24 ms avg	V pri				x					
VNeg.24ms_Ang	Negative-sequence voltage, angle, 24 ms avg	degrees				x					
S.24ms_Mag	3-phase apparent power, 24 ms avg	kVA pri				x					
P.24ms_Mag	3-phase real power, 24 ms avg	kW pri				x					
Q.24ms_Mag	3-phase reactive power, 24 ms avg	kVAR pri				x					
PF.24ms_Mag	3-phase power factor, 24 ms avg					x					
Freq.24ms_Mag	Frequency, 24 ms avg	Hz				x					
Freq.24ms_DFDTMag	Rate-of-change-of-frequency, 24 ms avg	Hz/s				x					

Table I.1 Analog Quantities (Sheet 5 of 9)

Name	Description	Units	Comm Port	HMI	Display Points	SELOGIC	Signal Profile	DNP3	Modbus	Fast Meter	IEC 61850
RMS Metering											
IA.RMS_120ms_Pri	RMS current, A-phase, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x		x
IB.RMS_120ms_Pri	RMS current, B-phase, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x		x
IC.RMS_120ms_Pri	RMS current, C-phase, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x		x
IN.RMS_120ms_Pri	RMS current, neutral, magnitude, 120 ms avg	A pri	x	x	x	x	x	x	x		x
VA.RMS_120ms_Pri	RMS voltage, A-phase, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x		x
VB.RMS_120ms_Pri	RMS voltage, B-phase, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x		x
VC.RMS_120ms_Pri	RMS voltage, C-phase, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x		x
VAB.RMS_120ms_Pri	RMS voltage, AB-phase-to-phase, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x		x
VBC.RMS_120ms_Pri	RMS voltage, BC-phase-to-phase, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x		x
VCA.RMS_120ms_Pri	RMS voltage, CA-phase-to-phase, magnitude, 120 ms avg	V pri	x	x	x	x	x	x	x		x
Light Metering											
Light_01.1ms_Mag	Arc-Flash Sensor 1 light	%	x	x	x	x	x	x	x		x
Light_02.1ms_Mag	Arc-Flash Sensor 2 light	%	x	x	x	x	x	x	x		x
Light_03.1ms_Mag	Arc-Flash Sensor 3 light	%	x	x	x	x	x	x	x		x
Light_04.1ms_Mag	Arc-Flash Sensor 4 light	%	x	x	x	x	x	x	x		x
Harmonic Metering											
IA.THD_120ms_Pct	THD, Phase Current IA, 120 ms avg	%	x	x	x	x	x	x	x		x
IB.THD_120ms_Pct	THD, Phase Current IB, 120 ms avg	%	x	x	x	x	x	x	x		x
IC.THD_120ms_Pct	THD, Phase Current IC, 120 ms avg	%	x	x	x	x	x	x	x		x
VA.THD_120ms_Pct	THD, Phase Voltage VA, 120 ms avg	%	x	x	x	x	x	x	x		x
VB.THD_120ms_Pct	THD, Phase Voltage VB, 120 ms avg	%	x	x	x	x	x	x	x		x
VC.THD_120ms_Pct	THD, Phase Voltage VC, 120 ms avg	%	x	x	x	x	x	x	x		x
VAB.THD_120ms_Pct	THD, Phase-to-Phase Voltage VAB, 120 ms avg	%	x	x	x	x	x	x	x		x
VBC.THD_120ms_Pct	THD, Phase-to-Phase Voltage VBC, 120 ms avg	%	x	x	x	x	x	x	x		x
VCA.THD_120ms_Pct	THD, Phase-to-Phase Voltage VCA, 120 ms avg	%	x	x	x	x	x	x	x		x

Table I.1 Analog Quantities (Sheet 6 of 9)

Name	Description	Units	Comm Port	HMI	Display Points	SELOGIC	Signal Profile	DNP3	Modbus	Fast Meter	IEC 61850
Demand Metering											
IA.Dmd	A-phase current demand	A pri	x	x	x	x		x	x		x
IB.Dmd	B-phase current demand	A pri	x	x	x	x		x	x		x
IC.Dmd	C-phase current demand	A pri	x	x	x	x		x	x		x
IGnd.Dmd	Calculated-residual current demand	A pri	x	x	x	x		x	x		x
INeg.Dmd	Negative-sequence current demand	A pri	x	x	x	x		x	x		x
Peak Demand Metering											
Meter.PkDmd_LastRst_s	Demand last reset time seconds		x	x				x	x		x
Meter.PkDmd_LastRstMn	Demand last reset time minutes		x	x				x	x		x
Meter.PkDmd_LastRstHr	Demand last reset time hours		x	x				x	x		x
Meter.PkDmd_LastRstDay	Demand last reset date day		x	x				x	x		x
Meter.PkDmd_LastRstMo	Demand last reset date month		x	x				x	x		x
Meter.PkDmd_LastRstYr	Demand last reset date year		x	x				x	x		x
IA.PkDmd	A-phase current peak demand	A pri	x	x	x	x		x	x		x
IB.PkDmd	B-phase current peak demand	A pri	x	x	x	x		x	x		x
IC.PkDmd	C-phase current peak demand	A pri	x	x	x	x		x	x		x
IGnd.PkDmd	Calculated-residual current peak demand	A pri	x	x	x	x		x	x		x
INeg.PkDmd	Negative-sequence current peak demand	A pri	x	x	x	x		x	x		x
Energy Metering											
Meter.En_LastRst_s	Energy last reset time seconds		x	x				x	x		x
Meter.En_LastRstMn	Energy last reset time minutes		x	x				x	x		x
Meter.En_LastRstHr	Energy last reset time hours		x	x				x	x		x
Meter.En_LastRstDay	Energy last reset date day		x	x				x	x		x
Meter.En_LastRstMo	Energy last reset date month		x	x				x	x		x
Meter.En_LastRstYr	Energy last reset date year		x	x				x	x		x
MWh.Rec	Real energy, 3-phase received	MWh pri	x	x	x	x	x	x	x		x
MWh.Del	Real energy, 3-phase delivered	MWh pri	x	x	x	x	x	x	x		x
MVARh.Rec	Reactive energy, 3-phase received	MVARh pri	x	x	x	x	x	x	x		x
MVARh.Del	Reactive energy, 3-phase delivered	MVARh pri	x	x	x	x	x	x	x		x
MVAh.Mag	Apparent energy, 3-phase magnitude	MVAh pri	x	x	x	x	x	x	x		x
Maximum/Minimum Metering											
Meter.MaxMin_LastRst_s	Max/Min last reset time seconds		x	x				x	x		x
Meter.MaxMin_LastRstMn	Max/Min last reset time minutes		x	x				x	x		x
Meter.MaxMin_LastRstHr	Max/Min last reset time hours		x	x				x	x		x
Meter.MaxMin_LastRstDay	Max/Min last reset date day		x	x				x	x		x

Table I.1 Analog Quantities (Sheet 7 of 9)

Name	Description	Units	Comm Port	HMI	Display Points	SELOGIC	Signal Profile	DNP3	Modbus	Fast Meter	IEC 61850
Meter.MaxMin_LastRstMo	Max/Min last reset date month		x	x				x	x		x
Meter.MaxMin_LastRstYr	Max/Min last reset date year		x	x				x	x		x
IA.MaxMagPri	Current, A-phase, maximum magnitude	A pri	x	x	x	x	x	x	x		x
IB.MaxMagPri	Current, B-phase, maximum magnitude	A pri	x	x	x	x	x	x	x		x
IC.MaxMagPri	Current, C-phase, maximum magnitude	A pri	x	x	x	x	x	x	x		x
IN.MaxMagPri	Current, neutral, maximum magnitude	A pri	x	x	x	x	x	x	x		x
IGnd.MaxMagPri	Current, calculated-residual, maximum magnitude	A pri	x	x	x	x	x	x	x		x
IA.MinMagPri	Current, A-phase, minimum magnitude	A pri	x	x	x	x	x	x	x		x
IB.MinMagPri	Current, B-phase, minimum magnitude	A pri	x	x	x	x	x	x	x		x
IC.MinMagPri	Current, C-phase, minimum magnitude	A pri	x	x	x	x	x	x	x		x
IN.MinMagPri	Current, neutral, minimum magnitude	A pri	x	x	x	x	x	x	x		x
IGnd.MinMagPri	Current, calculated-residual, minimum magnitude	A pri	x	x	x	x	x	x	x		x
VAB.MaxMagPri	Voltage, A-to-B-phase, maximum magnitude	V pri	x	x	x	x	x	x	x		x
VBC.MaxMagPri	Voltage, B-to-C-phase, maximum magnitude	V pri	x	x	x	x	x	x	x		x
VCA.MaxMagPri	Voltage, C-to-A-phase, maximum magnitude	V pri	x	x	x	x	x	x	x		x
VA.MaxMagPri	Voltage, A-phase-to-neutral, maximum magnitude	V pri	x	x	x	x	x	x	x		x
VB.MaxMagPri	Voltage, B-phase-to-neutral, maximum magnitude	V pri	x	x	x	x	x	x	x		x
VC.MaxMagPri	Voltage, C-phase-to-neutral, maximum magnitude	V pri	x	x	x	x	x	x	x		x
VAB.MinMagPri	Voltage, A-to-B-phase, minimum magnitude	V pri	x	x	x	x	x	x	x		x
VBC.MinMagPri	Voltage, B-to-C-phase, minimum magnitude	V pri	x	x	x	x	x	x	x		x
VCA.MinMagPri	Voltage, C-to-A-phase, minimum magnitude	V pri	x	x	x	x	x	x	x		x
VA.MinMagPri	Voltage, A-phase-to-neutral, minimum magnitude	V pri	x	x	x	x	x	x	x		x
VB.MinMagPri	Voltage, B-phase-to-neutral, minimum magnitude	V pri	x	x	x	x	x	x	x		x
VC.MinMagPri	Voltage, C-phase-to-neutral, minimum magnitude	V pri	x	x	x	x	x	x	x		x

Table I.1 Analog Quantities (Sheet 8 of 9)

Name	Description	Units	Comm Port	HMI	Display Points	SELOGIC	Signal Profile	DNP3	Modbus	Fast Meter	IEC 61850
S.MaxMag	Apparent power, 3-phase, maximum magnitude	kVA pri	x	x	x	x	x	x	x		x
P.MaxMag	Real power, 3-phase, maximum magnitude	kW pri	x	x	x	x	x	x	x		x
Q.MaxMag	Reactive power, 3-phase, maximum magnitude	kVAR pri	x	x	x	x	x	x	x		x
S.MinMag	Apparent power, 3-phase, minimum magnitude	kVA pri	x	x	x	x	x	x	x		x
P.MinMag	Real power, 3-phase, minimum magnitude	kW pri	x	x	x	x	x	x	x		x
Q.MinMag	Reactive power, 3-phase, minimum magnitude	kVAR pri	x	x	x	x	x	x	x		x
Freq.MaxMag	Maximum frequency	Hz	x	x	x	x	x	x	x		x
Freq.MinMag	Minimum frequency	Hz	x	x	x	x	x	x	x		x
Date/Time											
Time.Date	Present date		x	x	x						
Time.Tm	Present time		x		x						
Time.Yr	Year number (0000–9999)					x					
Time.DayOfYr	Day of year number (1–366)					x					
Time.Wk	Week number (1–52)					x					
Time.DayOfWk	Day of week number (1–7)					x					
Time.MnMidNight	Minutes since midnight					x					
Device Identification											
Dev.ID	Relay identifier		x	x	x						x
Dev.Loc	Location identifier		x	x	x						x
Dev.Code	Unique device code							x	x		x
Part/Serial Numbers											
Dev.PartNum	Part number		x	x	x						x
Dev.SerNum	Serial number		x	x	x						x
Math Variables											
PMV_001.Val to PMV_016.Val	Math Variable 001 to Math Variable 016		x	x	x	x	x	x	x		x
SELogic Counters											
PCN_001.CV to PCN_016.CV	SELOGIC Counter 001 to SELOGIC Counter 016		x	x	x	x	x	x	x		x
Remote Analogs[a]											
RA_001.Val to RA_032.Val	Remote Analog 01 to Remote Analog 32		x	x	x	x	x	x	x	x	x

Table I.1 Analog Quantities (Sheet 9 of 9)

Name	Description	Units	Comm Port	HMI	Display Points	SELOGIC	Signal Profile	DNP3	Modbus	Fast Meter	IEC 61850
Fault Information											
Event.Id	Unique identification number of the latest event							x	x		x
Event.Sta	Event report present (shall be 1 when an event report is present and 0 otherwise)							x	x		x
Event.NumofEve	Number of event logs							x	x		x
Relay Information											
Dev.FwRev	Relay firmware revision								x		x
Dev.FwVer	Relay firmware point release version								x		x
Dev.SerNumLow	Relay serial number, lowest 4 digits							x	x		x
Dev.SerNumMid	Relay serial number, middle 4 digits							x	x		x
Dev.SerNumHi	Relay serial number, highest 4 digits							x	x		x
IEC 61850 Test Mode											
61850.Mod_Beh	IEC 61850 Test Mode status		x	x	x	x					x
Fixed GOOSE Analogs											
FG_P2_01.RxAna01 to FG_P2_01.RxAna08	Fixed GOOSE Receive Msg1 Analogs 01 to 08		x	x	x	x	x	x	x	x	x
FG_P2_02.RxAna01 to FG_P2_02.RxAna08	Fixed GOOSE Receive Msg2 Analogs 01 to 08		x	x	x	x	x	x	x	x	x
FG_P2_03.RxAna01 to FG_P2_03.RxAna08	Fixed GOOSE Receive Msg3 Analogs 01 to 08		x	x	x	x	x	x	x	x	x
FG_P2_04.RxAna01 to FG_P2_04.RxAna08	Fixed GOOSE Receive Msg4 Analogs 01 to 08		x	x	x	x	x	x	x	x	x

[a] FM refers to Fast Message support for remote analogs. Remote analogs can be written by issuing an unsolicited Fast Message Write command.

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Appendix J

Cybersecurity Features

The SEL-851 is designed and intended for use only within operational technology (OT) networks protected by layered defenses specific to OT environments. This device supports SCADA and industrial protocols including Telnet and ICCP. Strict network segmentation is required to ensure this traffic does not traverse corporate networks. OT devices should not be visible or directly accessible from public-facing networks. The SEL-851 provides a number of features to help meet cybersecurity design requirements.

Access Control

The SEL-851 has a number of mechanisms for managing electronic access. These include limiting access, providing user authentication, and monitoring electronic and physical access.

Physical Port Controls

Serial Port 1 is always enabled. It cannot be disabled. However, the setting Port_F.Ena can be used to enable or disable serial Port F. By default, Port F is enabled. Similarly, the setting Port_02.Ena can be used to enable or disable Ethernet Port 2. By default, Port 2 is enabled. Disabling unused ports is good security practice.

IP Ports

When using Ethernet, there are a number of IP ports available within the SEL-851. Many of these IP port numbers are configurable. All IP ports can be disabled. *Table J.1* describes each of these.

Table J.1 IP Port Numbers

IP Port Default	Port Selection Setting	Network Protocol	Default Port State	Port Enable Setting	Purpose
21	--	TCP	Disabled	Port_02.FTP_Ena	FTP protocol access for file transfer of settings and reports
23	Port_02.Telnet_Port	TCP	Enabled	Port_02.Telnet_Ena	Telnet access for general engineering terminal access
80	Port_02.HTTP_TCPPort	TCP	Enabled	Port_02.HTTP_SrvrEna/ Port_02.HTTPS_SrvrEna	Web server access to various relay information
443	Port_02.HTTPS_TCPPort	TCP	Disabled	Port_02.HTTPS_SrvrEna	Secure web server access to various relay information
102	--	TCP	Disabled	Port_02.61850_Ena	IEC 61850 MMS for SCADA functionality
123	Port_02.SNTP_PortNum	UDP	Disabled	Port_02.SNTP_Ena	SNTP time synchronization
502	Port_02.Modbus_TCPPort1/ Port_02.Modbus_TCPPort2	TCP	Disabled	Port_02.Modbus_Ena	Modbus for SCADA functionality
20000	Port_02.DNP_PortNum	TCP/UDP	Disabled	Port_02.DNP_Ena	DNP for SCADA functionality

Authentication and Authorization

The SEL-851 supports four levels of access, as described in the *Access Levels on page 7.18*. Refer to this section to learn how each level is accessed and how to change passwords. Changing the default passwords of each access level and using a unique password for each level are good security practices.

The Port_F.AccLev and Port_02.Telnet_AccLev settings limit the level of access in the SEL-851. This permits you to operate under the principle of "least privilege," restricting ports to the levels necessary for the functions performed on those ports.

The SEL-851 supports strong passwords with as many as 12 characters, using any printable character, allowing users to select complex passwords if they so choose. SEL recommends that passwords have a minimum of 8 characters and include at least one of each of the following: lowercase letter, uppercase letter, number, and special character.

Ethernet protocols Telnet and FTP require the proper passwords to gain access to level-protected functions. Ethernet protocol MMS requires a password to gain access if MMS authentication is enabled via the CID file. See *Section 7: Communications* for more information on access restrictions for the Ethernet protocols.

Monitoring and Logging

The SEL-851 provides Relay Word bits that are useful for monitoring relay access.

- Diag.Secu_PassLO—Pulses for approximately one second if a user enters three successive incorrect passwords in an SEL ASCII terminal session or web session.
- Diag.Secu_AccLevAlm—Asserted while any user is logged into Access Level 1 or higher.
- Diag.Secu_AccLev2—Pulses for approximately one second whenever a user gains access to Access Level 2 or higher.
- Diag.Secu_PassBad—Pulses for approximately one second when an incorrect password is entered when attempting to Access Level 1 or higher, or when an incorrect password is entered when attempting to change passwords.
- Port_02.LinkOk, Port_02.LinkAOk, Port_02.LinkBOk—Asserted while the link is active on the Ethernet port(s). Loss of link can be an indication that an Ethernet cable has been disconnected.
- Port_02.LinkFail—Asserted if link is lost on the active IP port (Ports 2, 2A, or 2B).

These bits can be mapped for SCADA monitoring via DNP3, IEC 61850, Modbus, or SEL Fast Message. They also may be added to the SER for later analysis or assigned to output contacts for alarm purposes.

The SEL-851 SER is a useful tool for capturing a variety of relay events. In addition to capturing state changes of user selected Relay Word bits, it captures all power-ups and settings changes. See *Sequential Events Recorder (SER) on page 9.13* for more information about SER.

Physical Access Security

Physical security of cybersecurity assets is a common concern. SEL-851 relays can be installed within a control enclosure that provides physical security. Other times, relays are installed in breakers or enclosures within the switchyard. The SEL-851 provides tools to help manage physical security, especially when the unit is installed in the switch yard.

You can monitor physical ingress by wiring a door sensor to one of the SEL-851 contact inputs. This input can then be mapped for SCADA monitoring or added to the SER log so that you can monitor when physical access to the relay occurs. It is also possible to wire an electronic latch to an SEL-851 contact output. You could then map this output for SCADA control.

Configuration Management

Many users are concerned about managing the configuration of their relays. The SEL-851 provides mechanisms to help users manage relay configuration.

All settings changes are logged to the SER log. Analysis of this log indicates if any unauthorized settings changes occurred.

The following Relay Word bits also indicate changes in relay configuration:

- Diag.Secu_SetChg—Pulses for approximately one second when settings are changed or saved
- Diag.Secu_PassChg—Pulses for approximately one second when a password changes

Malware Protection

The SEL-851 has inherent and continuous monitoring for malware. For a full description of this, see selinc.com/mitigating_malware/.

Firmware Hash Verification

This device supports digitally signed firmware upgrades. SEL uses the SHA-256 secure hash algorithm to compress and digitally sign firmware upgrade files. The signature ensures that the file has been provided by SEL and that its contents have not been altered. When the file is uploaded to the relay, the signature is verified using a public key stored on the relay. If the relay cannot verify the signature, it rejects the file. See *Appendix B: Firmware Upgrade Instructions* for more information on firmware upgrades.

Operating System/ Firmware

SEL-851 relays are embedded devices that do not allow additional software to be installed. SEL-851 relays include a self-test that continually checks running code against the known good baseline version of code in nonvolatile memory. This process is outlined in more detail in the document titled *The SEL Process for Mitigating Malware Risk to Embedded Devices* located at selinc.com/mitigating_malware/. SEL-851 relays run in an embedded environment for which there is no commercial anti-virus software available.

Software/Firmware Verification

SEL-851 relays have the ability to install firmware updates in the field. Authenticity and integrity of firmware updates can be verified by using the *Firmware Hash* page at selinc.com/products/firmware/.

Security Vulnerabilities

If SEL finds a security vulnerability with the SEL-851, it will be disclosed using our standard security notification process. For a full description of this process, see selinc.com/support/security-notifications/.

Settings Erasure

It is often necessary to erase the settings from the relay when it is removed from service. You can completely erase all the configuration settings from the SEL-851 using this procedure.

Step 1. Go to Access Level C (see *Access Levels on page 7.18*).

Step 2. Execute the **R_S** command.

Step 3. Allow the relay to restart.

NOTE: Do not erase settings when sending the relay to the factory for service. SEL needs to see how the relay was configured to properly diagnose any problems.

Once this procedure is complete, all internal instances of user settings and passwords are erased. Do not do this when sending the relay to the factory for service. SEL needs to see how the relay was configured to properly diagnose any problems.

Glossary

A Abbreviation for amps or amperes; units of electrical current magnitude.

Analog In this instruction manual, Analog is synonymous with Transducer.

ANSI Standard Device Numbers A list of standard numbers used to represent electrical protection and control relays. The standard device numbers used in this instruction manual include:

- 27 Undervoltage Element
- 32 Directional Power Element
- 50 Instantaneous Overcurrent Element
- 51 Inverse Time-Overcurrent
- 52 AC Circuit Breaker
- 55 Power Factor Element
- 59 Overvoltage Element
- 60 Loss of Potential Element
- 79 Reclosing Control Logic
- 81 Frequency Element

These numbers are frequently used within a suffix letter to further designate application. The suffix letters used in this instruction manual include:

- P Phase Element
- G Residual Ground Element
- Q Negative-Sequence (3I2) Element
- N Neutral/Ground Element

Apparent Power, S Complex power expressed in units of volt-amps (VA), kilovolt-amps (kVA), or megavolt-amps (MVA). Accounts for both real (P) and reactive (Q) power dissipated in a circuit: $S = P + jQ$.

Arc-Flash Detection The sensing of an arc-flash condition by detection of light and overcurrent by the relay.

Arc-Flash Hazard A dangerous condition associated with the release of energy caused by an electric arc.

Arc-Flash Protection (Relay) An action performed by the relay to minimize the arc-flash hazard.

ASCII Abbreviation for American Standard Code for Information Interchange. Defines a standard way to communicate text characters between two electronic devices. The SEL-851 Feeder Protection Relay uses ASCII text characters to communicate using the relay front- and rear-panel EIA-232 serial ports.

Assert To activate; to fulfill the logic or electrical requirements needed to operate a device. To apply a short-circuit or closed contact to an SEL-851 input. To set a logic condition to the true state (logical 1). To close a normally open output contact. To open a normally closed output contact.

Breaker Auxiliary Contact A spare electrical contact associated with a circuit breaker that opens or closes to indicate the breaker position. A Form A breaker auxiliary contact (ANSI Standard Device Number 52A) closes when the breaker is closed, opens when the breaker is open. A Form B breaker auxiliary contact (ANSI Standard Device Number 52B) opens when the breaker is closed and closes when the breaker is open.

Checksum A numeric identifier of the firmware in the relay. Calculated by the result of a mathematical sum of the relay code.

CID Abbreviation for Checksum Identifier. The checksum of the specific firmware installed in the relay.

COMTRADE Common format for Transient Data Exchange for power systems. COMTRADE is a file format for oscilloscope data standardized by IEEE (IEEE C37.111-2013).

CR_RAM Abbreviation for Critical RAM. Refers to the area of relay Random Access Memory (RAM) where the relay stores mission-critical data.

CRC-16 Abbreviation for Cyclical Redundancy Check-16. A mathematical algorithm applied to a block of digital information to produce a unique, identifying number. Used to ensure that the information was received without data corruption.

CT Abbreviation for current transformer.

Deassert To deactivate; to remove the logic or electrical requirements needed to operate a device. To remove a short-circuit or closed contact from an SEL-851 input. To clear a logic condition to the false state (logical 0). To open a normally open output contact. To close a normally closed output contact.

Delta A phase-to-phase connection of voltage transformers for electrical measuring purposes. Typically, two voltage transformers are used with one primary lead of the first transformer connected to A-phase and the other lead connected to B-phase. The second voltage transformer is connected to measure the voltage from B-phase to C-phase. When two transformers are used, this connection is frequently called “Open-Delta.”

Distributed Network Protocol (DNP) Manufacturer-developed, hardware-independent communications protocol.

Dropout Time The time measured from the removal of an input signal until the output signal deasserts. The time can be settable, as in the case of a logic variable timer, or can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element dropout time.

Energy Meter Displays real, reactive, and apparent energy.

Event History A quick look at recent relay activity that includes a standard report header; event number, date, time, and type; maximum fault phase current; and targets.

Event Report A text-based collection of data stored by the relay in response to a triggering condition, such as a fault or command. The data show relay measurements before and after the trigger, in addition to the states of protection elements, relay inputs, and relay outputs each processing interval. After an electrical system fault, use event reports to analyze relay and system performance.

Event Summary A shortened version of stored event reports. An event summary includes items such as event date and time, event type, fault voltages, currents, etc. The relay sends an event report summary (if auto messaging is enabled) to the relay serial port a few seconds after an event.

Fail-Safe An output contact that is energized during normal relay operation and de-energized when relay power is removed or if the relay fails.

Fast Meter, Fast Operate Binary serial port commands that the relay recognizes at the communications ports. These commands and the responses from the relay make relay data collection by a communications processor faster and more efficient than transfer of the same data through use of formatted ASCII text commands and responses.

FID Relay firmware identification string. Lists the relay model, firmware version and date code, and other information that uniquely identifies the firmware installed in a particular relay.

Firmware The nonvolatile program stored in the relay that defines relay operation.

Flash A type of nonvolatile relay memory used for storing large blocks of nonvolatile data, such as signal-profile records.

Fundamental Frequency The component of the measured electrical signal for which frequency is equal to the normal electrical system frequency, usually 50 or 60 Hz. Generally used to differentiate between the normal system frequency and any harmonic frequencies present.

Fundamental Meter Type of meter data presented by the SEL-851 that includes the present values measured at the relay ac inputs. The word “Fundamental” is used to indicate that the values are Fundamental Frequency values and do not include harmonics.

IA, IB, IC A-, B-, and C-phase currents measured with a Rogowski sensor.

IEC International Electrotechnical Commission.

IEC 61850 Standard protocol for real-time exchange of data between databases in multi-vendor devices.

IG Residual current, calculated from the sum of the phase currents. In normal, balanced operation, this current is very small or zero. When a ground fault occurs, this current can be large.

IN Neutral current measured with a Rogowski sensor by the relay IN input. The IN input is typically connected to the secondary winding of a window-CT for ground fault detection on resistance-grounded systems.

LCD Abbreviation for Liquid Crystal Display. Used as the HMI alphanumeric display.

LED Abbreviation for Light-Emitting Diode. Used as indicator lamps on the relay front panel.

Logical Node In IEC 61850, the smallest part of a function that exchanges data. A logical node (LN) is an object defined by its data and methods. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function.

Loss of Potential Loss of one or more phase voltage inputs to the relay.

MAC Address The Media Access Control (hardware) address of a device connected to a shared network medium, most often used with Ethernet networks.

MIRRORED BITS Protocol for direct relay-to-relay communications.

MMS Manufacturing Message Specification, a data exchange protocol used by IEC 61850

Max/Min Meter Displays maximum and minimum operating quantities such as currents, voltages, power, and frequency.

Neutral Overcurrent Element A protection element that causes the relay to trip when the neutral current magnitude (measured by the IN input) exceeds a user-settable value. Used to detect and trip in response to ground faults.

Nominal Frequency Normal electrical system frequency, usually 50 or 60 Hz.

Nonfail-Safe Refers to an output contact that is not energized during normal relay operation. When referred to a trip or stop output contact, the protected equipment remains in operation unprotected when relay power is removed or if the relay fails.

Nonvolatile Memory Relay memory that is able to correctly maintain data it is storing even when the relay is de-energized.

Overfrequency Element A protection element that causes the relay to trip when the measured electrical system frequency exceeds a settable frequency.

Phase Rotation The sequence of voltage or current phasors in a multi-phase electrical system. In an ABC phase rotation system, the B-phase voltage lags the A-phase voltage by 120 degrees, and the C-phase voltage lags B-phase voltage by 120 degrees. In an ACB phase rotation system, the C-phase voltage lags the A-phase voltage by 120 degrees, and the B-phase voltage lags the C-phase voltage by 120 degrees.

Pickup Time The time measured from the application of an input signal until the output signal asserts. The time can be settable, as in the case of a logic variable timer, or can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element pickup time.

Pinout The definition or assignment of each electrical connection at an interface. Typically refers to a cable, connector, or jumper.

Power, P Real part of the complex power (S) expressed in units of watts (W), kilowatts (kW), or megawatts (MW).

Power Factor The cosine of the angle by which phase current lags phase voltage in an ac electrical circuit. Power factor equals 1.0 for power flowing to a resistive load.

Power, Q Reactive part of the complex power (S) expressed in units of Vars (W), kilovars (kVar), or megavars (MVar).

RAM Abbreviation for Random Access Memory. Volatile memory where the relay stores intermediate calculation results, Relay Word bits, and other data that are updated every processing interval.

Relay Word The collection of relay element and logic results. Each element or result is represented by a unique identifier, known as a Relay Word bit.

Relay Word Bit A single relay element or logic result that the relay updates once each processing interval. A Relay Word bit can be equal to either logical 1 or logical 0. Logical 1 represents a true logic condition, picked up element, or asserted contact input or contact output. Logical 0 represents a false logic condition, dropped out element, or deasserted contact input or contact output. You can use Relay Word bits in SELOGIC control equations to control relay tripping, event triggering, and output contacts, as well as other functions.

Remote Bit A Relay Word bit for which state is controlled by serial port commands, including the **CONTROL** command, binary Fast Operate command, or Modbus command.

RMS Abbreviation for root-mean-square. Refers to the effective value of the sinusoidal current and voltage measured by the relay, accounting for the fundamental frequency and higher order harmonics in the signal.

Rogowski Coil An air-core coil around a current carrying conductor that generates a voltage proportional to the rate of change of current. An integrator is used to derive current from the output of the Rogowski coil.

ROM Abbreviation for Read-Only Memory. Nonvolatile memory where the relay firmware is stored.

Self-Test A function that verifies the correct operation of a critical device subsystem and indicates if an out-of-tolerance condition is detected. The SEL-851 is equipped with self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SEL Grid Configurator Software (SEL-5037) SEL Grid Configurator is a freely distributed software tool for engineers and technicians to quickly and confidently create, manage, and deploy settings for SEL power system devices.

SELOGIC Control Equation A relay setting that allows you to control a relay function (such as an output contact) by using a logical combination of relay element outputs and fixed logic outputs. Logical AND, OR, rising edge [/], and falling edge [\] operators, plus a single level of parentheses are available to use in each control equation setting.

Sequential Events Recorder A relay function that stores a record of the date and time of each assertion and deassertion of every Relay Word bit in a settable list. Provides a useful way to determine the order and timing of events following a relay operation.

SER Abbreviation for Sequential Events Recorder or the relay serial port command to request a report of the latest 1024 sequential events.

Terminal Emulation Software Personal computer (PC) software that can be used to send and receive ASCII text messages via the PC serial port.

Underfrequency Element A protection element that causes the relay to trip when the measured electrical system frequency is less than a settable frequency.

VA, VB, VC Measured A-, B-, and C-phase-to-neutral voltages.

VAB, VBC, VCA Measured or calculated phase-to-phase voltages.

3V0 Residual voltage calculated from the sum of the three phase-to-neutral voltages, if connected.

VT Abbreviation for voltage transformer. Also referred to as a potential transformer or PT.

Wye As used in this instruction manual, a phase-to-neutral connection of voltage transformers for electrical measuring purposes. Three voltage transformers are used with one primary lead of the first transformer connected to A-phase and the other lead connected to ground. The second and third voltage transformers are connected to measure the voltage from B-phase and C-phase-to-ground, respectively. This connection is frequently called “four-wire wye,” alluding to the three phase leads plus the neutral lead.

Z-Number That portion of the relay FID string that identifies the proper SEL Grid Configurator relay driver version when creating or editing relay settings files.

SEL-851 Command Summary

The table below lists the SEL-851 ASCII commands associated with particular activities. The commands are shown in uppercase letters, but they can also be entered using lowercase letters.

Serial Port Command	Command Description
Access Level 0 Commands	
ACC	Goes to Access Level 1.
EXI	Terminates a Telnet session.
ID	Relay identification code.
QUI	Goes to Access Level 0.
Access Level 1 Commands	
2AC	Goes to Access Level 2.
COM A	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.
COM C	Clears all of the communications records.
COM L	Appends a long report to the summary report of the last 255 records in the MIRRORED BITS communications buffer.
COM L A	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.
DAT	View the date.
DAT *dd/mm/yyyy*	Enters the date in DMY format.
DAT *mm/dd/yyyy*	Enters the date in MDY format if Time.DateFormat setting is MDY.
DAT *yyyy/mm/dd*	Enters the date in YMD format if Time.DateFormat setting is YMD.
ETH	Shows the Ethernet port status.
ETH C or **R**	Resets Ethernet statistics.
FIL DIR	Returns a list of files.
FIL READ *filename*	Transfers file *filename* from the relay to the PC.
FIL SHOW *filename*	Displays contents of the file *filename*.
GOO *k*	Displays transmit and receive GOOSE messaging information. Enter number *k* to scroll the GOOSE data *k* times on the screen.
HEL	Displays a short description of selected commands.
HIS *n*	Shows summary of *n* latest event reports, where *n* = 1 is the most recent entry. If *n* is not specified, all event report summaries are displayed.
HIS C or **R**	Clears or resets history buffer.
PCN *n*	Shows current state of device counters. *n* = repeat the report *n* times, with a 1/2 second delay between each report.
PRO	Displays signal-profile data.
PRO C	Clears signal-profile data.
MAC	Displays the MAC address of the Ethernet port.
MET	Displays instantaneous fundamental metering data.

Serial Port Command	Command Description
MET *k*	Displays instantaneous fundamental metering data *k* times, where *k* is between 1 and 32767.
MET D	Display demand and peak demand metering data.
MET D R	Resets demand and peak demand metering data.
MET E	Displays energy metering data.
MET E R	Resets energy metering data.
MET H	Displays current and voltage % THD (total harmonic distortion) metering data.
MET L	Displays arc-flash detector (AFD) light input (relay requires the AFD option).
MET MM	Displays max/min metering data.
MET MM R	Resets max/min metering data.
MET RA	Displays remote analogs data.
MET RMS	Displays rms metering data.
MET PMV	Displays SELOGIC math variable data.
PING *x.x.x.x t*	Determines if Ethernet port is functioning or configured properly. *x.x.x.x* is the IP address and *t* is the PING interval settable from 2 to 255 seconds. Default *t* is 1 second. Press Q to stop.
SER	Displays all Sequential Events Recorder (SER) data.
SER *d1*	Displays all **SER** records made on date *d1*.
SER *d1 d2*	Displays all **SER** records made from dates *d2* to *d1*, inclusive, starting with *d2*.
SER *n*	Displays the *n* most recent **SER** records starting with record *n*.
SER *n1 n2*	Displays **SER** records *n2* to *n1*, starting with *n2*.
SER C or **R**	Clears **SER** data.
SHO	Displays relay protection settings.
SHO DNP *m*	Displays the DNP data map settings for Map *m* (*m* = 1, 2, or 3).
SHO H	Displays HMI settings.
SHO L	Displays general logic settings.
SHO M	Displays Modbus user map settings.
SHO P *n*	Displays port settings, where *n* specifies PORT (1, 2, or F); *n* defaults to the active port if not listed.
SHO R	Displays report settings.
STA	Displays relay self-test status.
STA S	Displays SELOGIC usage status report.
SUM	Displays an event summary.
SUM R or **C**	Resets event summary buffer.
TAR	Displays default target row or the most recently viewed target row.
TAR *n*	Displays target row *n*.
TAR *n k*	Displays target row *n*. Repeat display of row *n* for repeat count *k*.
TAR *name*	Displays the target row with target name in the row.
TAR *name k*	Displays the target row with target name in the row. Repeat display of this row for repeat count *k*.
TAR R	Resets any latched targets and the most recently viewed target row.
TIM	View time.
TIM *hh:mm:ss*	Sets time by entering **TIM** followed by hours, minutes, and seconds, as shown (24-hour clock).
TRI	Triggers an event report data capture.

Serial Port Command	Command Description
Access Level 2 Commands	
AFD	Tests arc-flash detector channels.
CAL	Enters Access Level C. The relay prompts for the entry of the Access Level C password. Access Level C is reserved for SEL use only.
CLO	Closes the circuit breaker.
CON RB_*n*.Sta *k*	Selects a remote bit to set, clear, or pulse where *n* is a number from 01 to 16, representing RB_001.Sta through RB_016.Sta. *k* is S, C, or P for Set, Clear, or Pulse.
CON O OUT_*x*.Sta	Tests OUT_*x*.Sta with one second pulse duration.
FIL WRITE *filename*	Transfers settings file *filename* from the PC to the relay.
L_D	Loads new firmware.
LOO	Enables loopback mode on the MIRRORED BITS channel.
LOO A	Enables loopback mode on MIRRORED BITS Channel A for 5 minutes.
LOO R	Disables loopback mode on Channel A and returns the relay to normal operation.
LOO *x* DATA	Enables loopback mode for *x* minutes and allows the loopback data to modify the RMB values.
OPE	Opens the circuit breaker.
PAS 1	Changes Access Level 1 password to *xxxxxxxx*.
PAS 2	Changes Access Level 2 password to *xxxxxxxx*.
PUL OUT_*x*.Sta *t*	Pulse OUT_*x*.Sta for *t* (1 to 30, default is 1) seconds.
R_S	Restores the factory-default settings and passwords and reboots the system.
SET	Modifies relay protection settings.
SET *name*	For all **SET** commands, jumps ahead to a specific setting by entering the setting name, e.g., 50P_01.PUVal.
SET DNP *m*	Modifies the DNP data map settings for Map *m* (*m* = 1, 2, or 3).
SET H	Modifies HMI settings.
SET L	Modifies SELOGIC variable and timer settings.
SET M	Modifies Modbus user map settings.
SET P *n*	Modifies Port *n* settings (*n* = F, 1, or 2; if not specified, the default is the active port).
SET R	Modifies report settings.
SET…TERSE	For all **SET** commands, **TERSE** disables the automatic **SHO** command after the settings entry.
STA R or **C**	Clears self-test status and restarts the relay.
VEC D	Displays diagnostic vector report (useful to the factory in troubleshooting).
VEC E	Displays exception vector report (useful to the factory in troubleshooting).
Access Level CAL Commands	
PAS C	Changes Access Level C password.

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HIS *n*	Shows summary of *n* latest event reports, where *n* = 1 is the most recent entry. If *n* is not specified, all event report summaries are displayed.
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PCN *n*	Shows current state of device counters. *n* = repeat the report *n* times, with a 1/2 second delay between each report.
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SHO L	Displays general logic settings.
SHO M	Displays Modbus user map settings.
SHO P *n*	Displays port settings, where *n* specifies PORT (1, 2, or F); *n* defaults to the active port if not listed.
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TAR *name k*	Displays the target row with target name in the row. Repeat display of this row for repeat count *k*.
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TIM	View time.
TIM *hh:mm:ss*	Sets time by entering **TIM** followed by hours, minutes, and seconds, as shown (24-hour clock).
TRI	Triggers an event report data capture.

Serial Port Command	Command Description
Access Level 2 Commands	
AFD	Tests arc-flash detector channels.
CAL	Enters Access Level C. The relay prompts for the entry of the Access Level C password. Access Level C is reserved for SEL use only.
CLO	Closes the circuit breaker.
CON RB_*n*.Sta *k*	Selects a remote bit to set, clear, or pulse where *n* is a number from 01 to 16, representing RB_001.Sta through RB_016.Sta. *k* is S, C, or P for Set, Clear, or Pulse.
CON O OUT_*x*.Sta	Tests OUT_*x*.Sta with one second pulse duration.
FIL WRITE *filename*	Transfers settings file *filename* from the PC to the relay.
L_D	Loads new firmware.
LOO	Enables loopback mode on the MIRRORED BITS channel.
LOO A	Enables loopback mode on MIRRORED BITS Channel A for 5 minutes.
LOO R	Disables loopback mode on Channel A and returns the relay to normal operation.
LOO *x* DATA	Enables loopback mode for *x* minutes and allows the loopback data to modify the RMB values.
OPE	Opens the circuit breaker.
PAS 1	Changes Access Level 1 password to *xxxxxxxx*.
PAS 2	Changes Access Level 2 password to *xxxxxxxx*.
PUL OUT_*x*.Sta *t*	Pulse OUT_*x*.Sta for *t* (1 to 30, default is 1) seconds.
R_S	Restores the factory-default settings and passwords and reboots the system.
SET	Modifies relay protection settings.
SET *name*	For all **SET** commands, jumps ahead to a specific setting by entering the setting name, e.g., 50P_01.PUVal.
SET DNP *m*	Modifies the DNP data map settings for Map *m* (*m* = 1, 2, or 3).
SET H	Modifies HMI settings.
SET L	Modifies SELOGIC variable and timer settings.
SET M	Modifies Modbus user map settings.
SET P *n*	Modifies Port *n* settings (*n* = F, 1, or 2; if not specified, the default is the active port).
SET R	Modifies report settings.
SET…TERSE	For all **SET** commands, **TERSE** disables the automatic **SHO** command after the settings entry.
STA R or **C**	Clears self-test status and restarts the relay.
VEC D	Displays diagnostic vector report (useful to the factory in troubleshooting).
VEC E	Displays exception vector report (useful to the factory in troubleshooting).
Access Level CAL Commands	
PAS C	Changes Access Level C password.

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