SEL-651R

Recloser Control

Instruction Manual

20160715

SCHWEITZER ENGINEERING LABORATORIES, INC.

PM651R-01

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Preface

Manual Overview

The SEL-651R Recloser Control Instruction Manual describes common aspects of recloser control application and use. It includes the necessary information to install, set, test, and operate the relay and more detailed information about settings and commands.

An overview of each manual section and topics follows:

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

Section 1: Introduction and Specifications. Introduces SEL-651R features, options, and accessories. This section also summarizes relay functions and applications; lists relay specifications, type tests, and ratings.

Section 2: Installation. Discusses recloser compatibility and control mounting and grounding. It includes interface features (current and voltage inputs, tripping and closing outputs, recloser status inputs, and general purpose inputs and outputs for example); provides information about how to configure the front-panel pushbuttons and LEDs; details how to set relay board jumpers and make proper rear-panel connections (including wiring to CTs, PTs, and an IRIG-B receiver); and explains basic connections for the relay communications ports.

Section 3: PC Software. Explains how to use the ACSELERATOR QuickSet SEL-5030 Software Program.

Section 4: Protection Functions. Describes the function of various relay protection elements; describes how the relay processes these elements; gives detailed specifics on protection scheme logic.

Section 5: Trip and Target Logic. Describes the factory default tripping logic for single-phase (single-phase or three-phase tripping) and three-phase reclosers; includes switch onto fault logic and factory default target logic.

Section 6: Close and Reclose Logic. Describes the factory default close and reclose logic for single-phase and three-phase reclosers.

Section 7: SELOGIC Control Equation Programming. Describes SELOGIC® control equations and how to apply these equations; discusses SELOGIC control equation features such as operands, timers, latches, counters, and analog comparisons.

Section 8: Metering and Monitoring. Provides information on viewing fundamental and rms metering quantities for voltages and currents, as well as power and energy metering data. Describes how to use the recloser/circuit breaker monitor and the battery monitor.

Section 9: Settings. Provides a list of all SEL-651R settings and defaults. The organization of the settings is the same as for the settings organization in the relay and in the ACSELERATOR QuickSet software. Provides detailed information required to set the SEL-651R. It includes default settings and settings sheets.

Section 10: Communications. Explains the physical interfaces of the SEL-651R. Describes the various SEL software protocols and references appendices with detailed information on these protocols. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 11: Front-Panel Operations. Describes the LCD display messages and menu screens; shows how to use programmable front-panel targets; shows how to use programmable operator control pushbuttons, and programmable LEDs to provide local substation control.

Section 12: Analyzing Events. Explains how to obtain event summaries and history reports, obtain and interpret filtered and unfiltered event reports, obtain SER reports, and obtain SSI reports.

Section 13: Testing and Troubleshooting. Describes techniques for testing, troubleshooting, and maintaining the SEL-651R; includes the list of status notification messages and a troubleshooting chart.

Appendix A: Firmware and Manual Versions. Lists the current firmware versions and details differences between the current and previous versions.

Appendix B: SEL-651R Recloser Control Relay Firmware Upgrade Instructions. Describes the procedure to update the firmware stored in flash memory.

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

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

Appendix E: DNP3 Communications. Describes the DNP3 communications protocol and how to apply this protocol to substation integration and automation.

Appendix F: Relay Word Bits. Contains a summary of Relay Word bits.

Appendix G: Analog Quantities. Contains a summary of analog quantities.

Appendix H: Fast SER Protocol (SEL-651R-1 Only). Describes special binary Fast Sequential Events Recorder (SER) messages.

SEL-651R Recloser Control Command Summary. Briefly describes the serial port commands that are fully described in *Section 10: 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 There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.	**⚠ATTENTION** Une pile remplacée incorrectement pose des risques d'explosion. Remplacez seulement avec un Ray-O-Vac® no BR2335 ou un produit équivalent recommandé par le fabricant. Voir le guide d'utilisateur pour les instructions de sécurité. La pile utilisée dans cet appareil peut présenter un risque d'incendie ou de brûlure chimique si vous en faites mauvais usage. Ne pas recharger, démonter, chauffer à plus de 100°C ou incinérer. Éliminez les vieilles piles suivant les instructions du fabricant. Gardez la pile hors de la portée des enfants.

Other Safety Marks (Sheet 1 of 2)

⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠DANGER Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER If the recloser is energized while the control cable is disconnected from the recloser control, the CT secondaries in the control cable may generate dangerously high voltages. Do not come in contact with the pins or pin sockets in the control cable. Contact with high voltage can cause serious injury or death.	⚠DANGER Si le réenclencheur est sous tension tandis que le câble de commande est débranché de la commande du réenclencheur, le secondaire des transformateurs de courant (TC) dans le câble de commande peut présenter des tensions dangereusement élevées. Ne pas toucher les broches du câble de commande. Tout contact avec une tension élevée peut entraîner des blessures graves ou la mort.
⚠DANGER The removed cables for connections J201, J202, and J205 are still energized. Contact with such terminals can cause electrical shock that can result in injury or death.	⚠DANGER Les câbles retirés des raccordements J201, J202 et J205 sont encore sous tension. Le contact avec ces câbles peut causer des chocs électriques qui peuvent entraîner des blessures ou la mort.
⚠WARNING Do not transport the SEL-651R with the battery inside the enclosure.	⚠AVERTISSEMENT Ne pas transporter le SEL-651R avec la batterie à l'intérieur du coffret.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠AVERTISSEMENT Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.
⚠WARNING Setting 79CLSD = OFF can create an indefinite "standing close" condition. This is usually not desirable in practice.	⚠AVERTISSEMENT Le réglage 79CLSD=OFF peut créer une condition de commande de fermeture permanente. Cette pratique n'est normalement pas recommandée.
⚠WARNING Take proper precautions to prevent personal injury or equipment damage when lifting and mounting the SEL-651R. Make sure doors are latched closed. Secure lifting attachments to the lifting holes. Lift slowly. Do not transport the SEL-651R with the battery inside the enclosure.	⚠AVERTISSEMENT Prendre les précautions appropriées pour éviter les blessures au personnel et les dommages à l'équipement quand on soulève et qu'on monte le SEL-651R. S'assurer que les portes sont verrouillées. Fixer les attaches sur les trous prévus pour l'élévation. Soulever lentement. Ne pas transporter le SEL-651R avec la batterie dans le coffret.
⚠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.
⚠CAUTION Disconnect separable connector J202 from the back of the relay module before disconnecting the battery terminals and removing the battery. Connect J202 last when installing the battery. Do not leave the cable harness for J202 connected without the batteries also connected. The ring terminals on the battery wiring harness (that connect directly to the battery terminals) are energized and can short-circuit if they come in contact with the enclosure floor or each other, consequently damaging the internal power supply in the relay module.	⚠ATTENTION Débrancher le connecteur séparable J202 de l'arrière du relais avant de débrancher les bornes de la batterie et de la retirer. Raccorder J202 en dernier quand on installe la batterie. Ne pas laisser le harnais du câble de J202 raccordé sans que la batterie ne soit elle-même raccordée. Les raccords à oeillet sur le harnais de filage de la batterie (qui sont connectés directement sur les bornes de la batterie) sont sous tension et peuvent se court-circuiter s'ils entrent en contact ou touchent le fonds du boîtier avec comme conséquence des dommages à l'alimentation interne du relais.
⚠CAUTION Do not connect the SEL-651R to an energized recloser until all control settings have been properly programmed and verified. Failure to comply can result in control and recloser misoperation, equipment damage, and personal injury.	⚠ATTENTION Ne pas raccorder le SEL-651R à un réenclencheur sous-tension avant que tous les réglages de la commande n'aient été proprement programmés et vérifiés. Toute dérogation à cette directive peut entraîner une opération intempestive de la commande ou du réenclencheur, des dommages à l'équipement ou des blessures au personnel.

Other Safety Marks (Sheet 2 of 2)

⚠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 The battery temperature sensor board contains exposed components that are sensitive to Electrostatic Discharge (ESD). When working with this board, work surfaces and personnel must be properly grounded or equipment damage may result.	⚠ATTENTION Le capteur de température de la batterie contient des composants à découvert qui sont sensibles aux décharges électrostatiques. Lorsqu'on travaille sur cette carte, les surfaces de travail et le personnel doivent être adéquatement mis à la terre sans quoi des dommages à l'équipement pourraient survenir.
⚠CAUTION The recloser control must be mounted on the same pole as the recloser when low-energy analog (LEA) inputs are used. This practice reduces surges that may damage the recloser control. Shielded cables are recommended when using LEA inputs.	⚠ATTENTION La commande du réenclencheur doit être montée sur le même poteau que le réenclencheur quand des entrées analogiques de bas niveau sont utilisées. Cette pratique réduit les bruits impulsifs qui pourraient endommager les circuits de commande du réenclencheur. Des câbles blindés sont recommandés avec ce type d'entrées.

General Information

Typographic Conventions

There are four ways to communicate with the SEL-651R:

- Using a command line interface on a PC terminal emulation window.
- Using a command line interface through the virtual terminal interface of a DNP3 communications link.
- Using the front-panel menus and pushbuttons.
- Using ACSELERATOR QuickSet SEL-5030 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 software dialog boxes and menu selections. The > character indicates submenus.
{CLOSE}	Relay front-panel pushbuttons.
ENABLE	Relay front- or rear-panel labels.
MAIN > METER	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.

Technical Assistance

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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Pullman, WA 99163-5603 U.S.A.
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Section 1

Introduction and Specifications

The SEL-651R Recloser Control builds upon the success of the SEL-351R Recloser Control, with new features and wider applicability. Apply the SEL-651R in urban and rural distribution systems for increased system reliability. Connect the SEL-651R to existing traditional reclosers and newer single-phase trip/reclose-capable reclosers, as detailed in following information.

This section introduces the SEL-651R Recloser Control and provides information on the following topics:

- ➤ Features
- ➤ Models and options
- ➤ Applications
- ➤ Specifications

Features

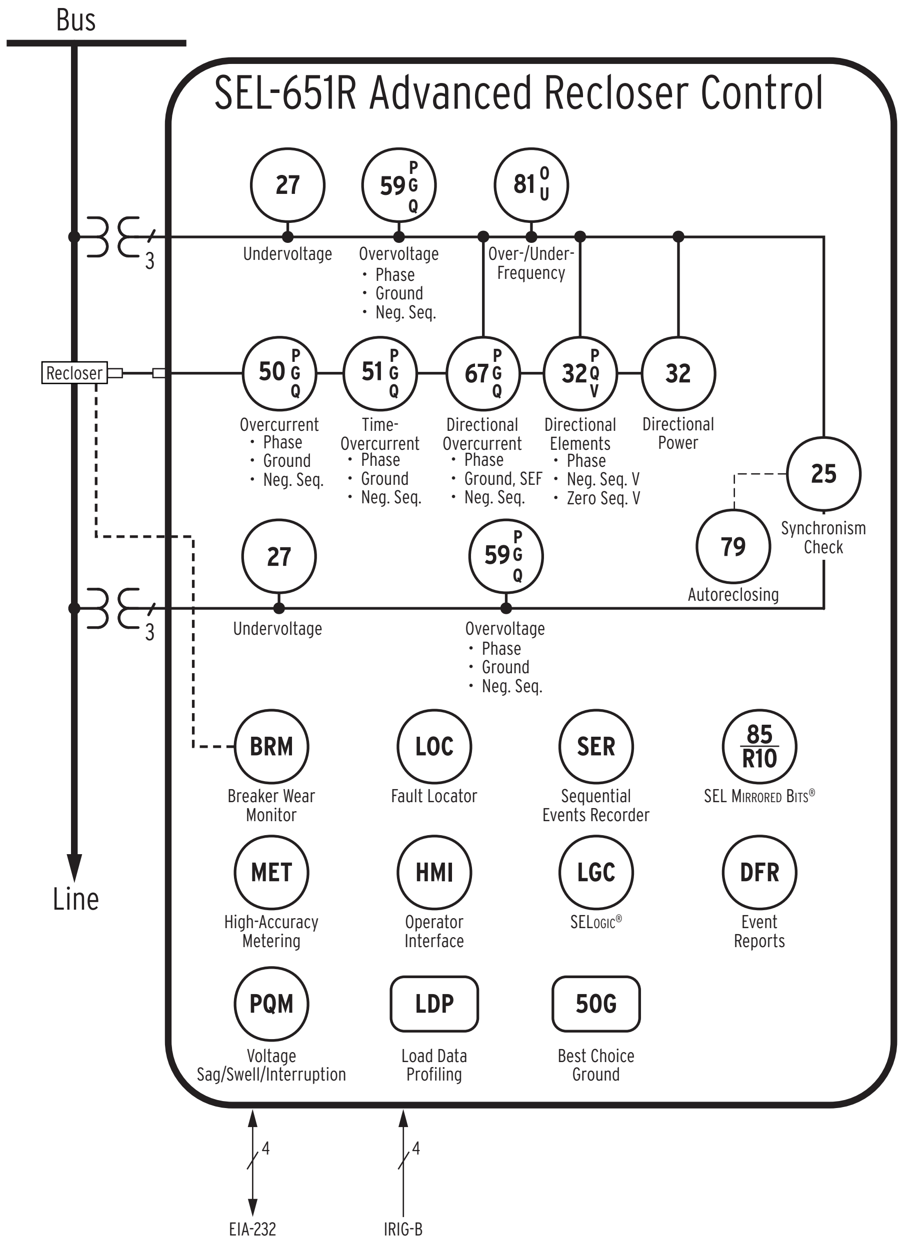


Figure 1.1 Functional Overview

The SEL-651R contains many protection, automation, and control features. *Figure 1.1* presents a simplified functional overview of the relay.

Automatic Network Reconfiguration

Augment system reliability by using automatic network reconfiguration to automatically isolate faulted line sections and restore service to the unaffected areas of the system. The SEL-651R includes six voltage inputs to monitor both source-side and load-side voltages, ensuring safe and secure automatic network reconfiguration automation. Automatic network reconfiguration automation is especially applicable in urban areas.

Single-Phase Tripping/Reclosing

Reduce system and customer impacts due to faults. With single-phase tripping, interrupt only faulted phases while maintaining service to unaffected customers. Select single-phase or three-phase lockout, depending on connected loads. Single-phase operation is especially applicable in rural areas (requires a single-phase capable recloser).

PC Software

In addition to communicating and setting the relay using an ASCII terminal, use the PC-based ACSELERATOR QuickSet® SEL-5030 Software to more easily configure the SEL-651R and analyze fault records with relay element response.

Harmonics Metering

Improve power quality by tracking system harmonic levels. The SEL-651R meters harmonics from the second to the fifteenth, as well as total harmonic distortion (THD). THD is also available for system control and protection decisions.

Additional metering capabilities include RMS values, phantom voltage generation from single-phase voltage, and energy values.

Directional Control

Trip securely for forward or reverse faults with phase and ground directional elements applied to overcurrent protection. The SEL Best Choice Ground Directional Element™ logic selects the best ground directional element for system conditions and eliminates settings.

Substantial Auxiliary Power Supply

Adequately power demanding 12 Vdc accessories with a built-in 40 W (continuous) auxiliary power supply.

Large Cabinet (Ordering Option)

Front and rear doors provide fast and easy access for front-panel operation or rear-panel connections. Large internal volume and 19" rack system allow plenty of room for accessory installation. The removable connector panel at bottom of enclosure accommodates custom hole sizes/fittings.

Extensive Recloser Compatibility (Ordering Option)

Connect traditional Cooper and G&W Viper®-S (14-pin), G&W Viper®-ST (32-pin), ABB OVR-3/VR-3S (15 and 27 kV models) (24-pin), Control-Powered Kyle® NOVA (19-pin), Joslyn TriMod™ 600R (27-pin), Kyle® NOVA-TS or NOVA-STS Triple-Single (26-pin), Tavrida OSM (32-pin), Siemens SDR Triple-Single (40-pin), or Siemens SDR Three-Phase (40-pin) reclosers to the SEL-651R. Select the desired control cable interface for the SEL-651R at ordering time. Learn the setting and operation of this one recloser control and retrofit numerous existing recloser installations and equip new recloser installations.

Low-Energy Analog (LEA) Voltage Inputs (Ordering Option)

Connect the low-level voltage outputs from less-costly power system voltage transducers to three-phase LEA voltage inputs on the SEL-651R.

DC Power Supply (Ordering Option)

Power station mounted SEL-651R recloser controls directly from the substation 125 Vdc supply.

Accessories (Ordering Option)

Order additional accessories for the SEL-651R, such as:

- 19" rack mount accessory shelf for radios, etc.
- Vandal sleeves to prevent cable connection tampering.
- Fuse blocks for voltage input and control power protection.
- AC transfer switch for alternate control power source switching—especially useful in automatic network reconfiguration operation.

Models and Options

See the latest SEL-651R Model Option Table at selinc.com, under SEL Literature, Ordering Information (Model Option Tables).

Recloser Compatibility

To determine the recloser interface of an SEL-651R, inspect the recloser control cable receptacle (see *Figure 2.41*). The part number (found on the serial number sticker inside the SEL-651R enclosure) can also be checked and compared to the SEL-651R Model Option Table.

Option Considerations

Consider the following options when ordering and configuring the SEL-651R Recloser Control.

- Control Cable Interface
  - Traditional Retrofit (14-pin)
  - G&W Viper-ST (32-pin, Single-Phase Trip Capable)
  - ABB OVR-3/VR-3S (15 and 27 kV models) (24-pin, Single-Phase Trip Capable)
  - Control-Powered Kyle NOVA (19-pin)
  - Joslyn TriMod 600R (27-pin, Single-Phase Trip Capable)
  - Kyle NOVA-TS or NOVA-STS Triple-Single (26-pin, Single-Phase Trip Capable)
  - Tavrida OSM (32-pin, rectangular receptacle)
  - Siemens SDR Triple-Single (40-pin, Single-Phase Trip Capable)
  - Siemens SDR Three-Phase (40-pin)
- Enclosure Type
  - Dual door (Side Mount)
  - Single door (Rear Mount)
- Enclosure Material
  - Painted steel
  - Type 304 stainless steel
- Door Latching
  - Single-point latch
  - Three-point latch

- Secondary Input Voltage Ratings
  - Two three-phase 300 Vac sets
  - One three-phase 8 Vac LEA set
    One three-phase 300 Vac set
  - One three-phase 8 Vac LEA set
    One three-phase "Lindsey SVMI LEA" set
  - One three-phase "Kyle/Cooper NOVA LEA" set
    One three-phase 300 Vac set
  - One three-phase "Kyle/Cooper NOVA LEA" set
    One three-phase "Lindsey SVMI LEA" set
  - One three-phase 300 Vac set
    One three-phase "Lindsey SVMI LEA" set
  - Two three-phase 8 Vac LEA sets
  - One three-phase 300 Vac set
    One three-phase "Siemens LEA" set
  - One three-phase "Lindsey SVMI LEA" set
    One three-phase "Siemens LEA" set
- Extra Inputs/Outputs
  - 7 optoisolated inputs (12 Vdc)
  - 8 output contacts
- Power Supply
  - 120 Vac (includes GFCI [Ground-Fault Circuit Interrupter] outlet)
  - 230 Vac
  - 125 Vdc (battery charger not included)
- Battery
  - 12 V, 16 Ahr
  - 12 V, 40 Ahr
- User Interface
  - Configurable labels
  - Tricolor LEDs
- Accessories

Contact the SEL factory or your local Technical Service Center for particular part number and ordering information (see *Factory Assistance on page 13.12*). You can also view the latest part number and ordering information on the SEL website at selinc.com.

Applications

As stated in preceding subsections, the SEL-651R can be applied to:

- Traditional Retrofit (14-pin)
- G&W Viper-ST (32-pin, Single-Phase Trip Capable)
- ABB OVR-3/VR-3S (15 and 27 kV models) (24-pin, Single-Phase Trip Capable)
- Control-Powered Kyle NOVA (19-pin)

- ➤ Joslyn TriMod 600R (27-pin, Single-Phase Trip Capable)
- ➤ Kyle NOVA-TS or NOVA-STS Triple-Single (26-pin, Single-Phase Trip Capable)
- ➤ Tavrida OSM (32-pin, rectangular receptacle)
- ➤ Siemens SDR Triple-Single (40-pin, Single-Phase Trip Capable)
- ➤ Siemens SDR Three-Phase (40-pin)

Note that G&W Viper-ST, ABB OVR-3/VR-3S (15 and 27 kV models), Joslyn TriMod 600R, Kyle NOVA-TS or NOVA-STS Triple-Single, and Siemens SDR Triple-Single reclosers include single-pole trip/reclose capability. They can also three-phase trip/reclose and combinations in between (e.g., single-phase trip/reclose and three-phase lockout).

Figure 1.2 shows principal connections to the SEL-651R, with full voltage connections on each side. Complete voltage connections are used in such applications as automatic network reconfiguration. *Figure 1.3* shows automatic network reconfiguration augmented by MIRRORED BITS® communications between SEL-651R Recloser Controls. Automatic network reconfiguration operation automatically isolates faulted line sections and restores service to the rest of the system.

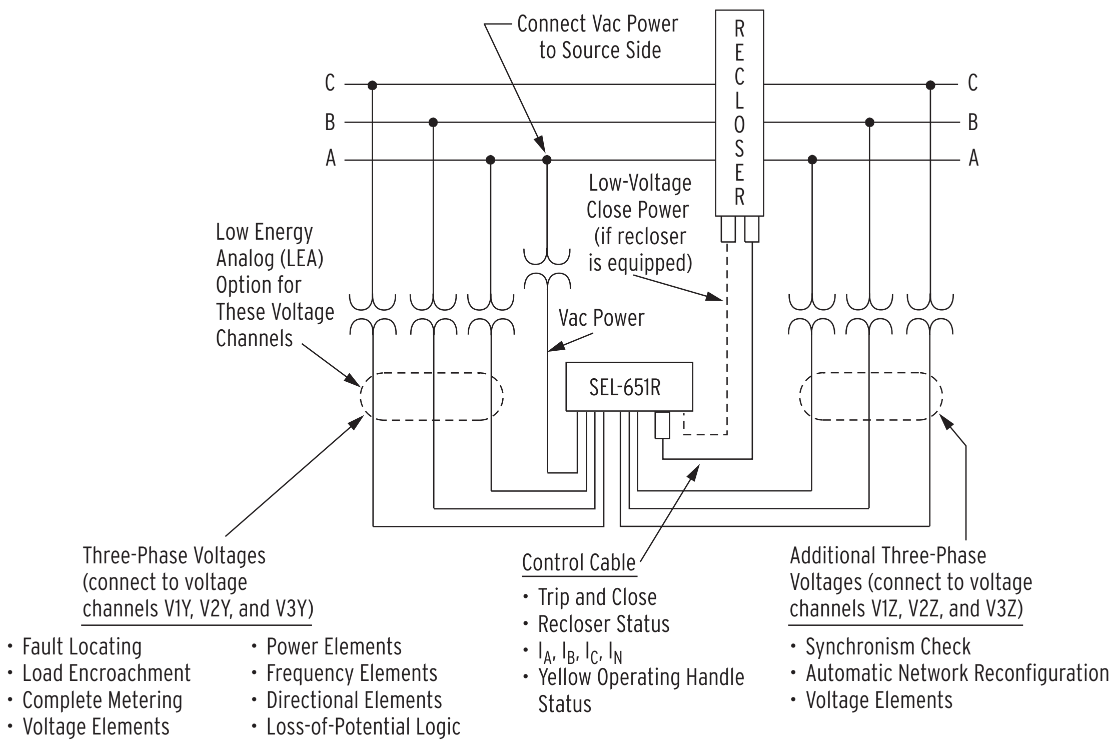


Figure 1.2 Connect Three-Phase Load and Source Voltages to SEL-651R

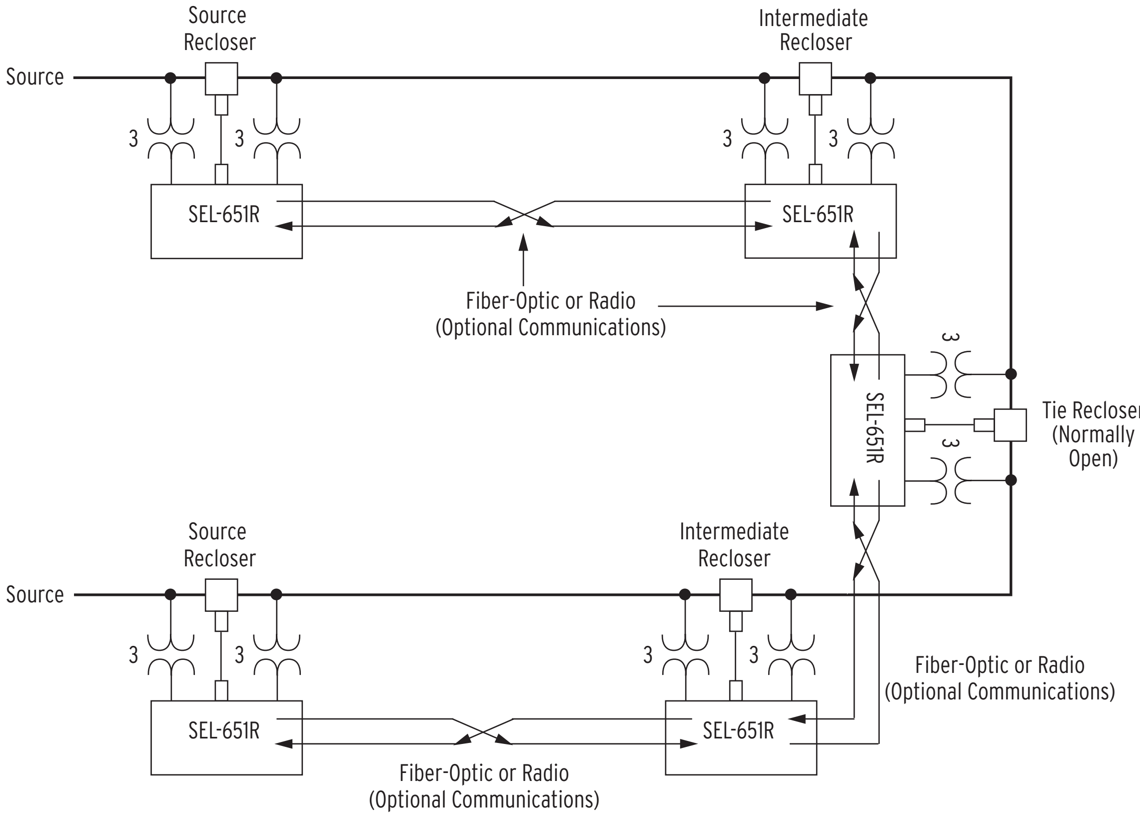


Figure 1.3 Implement Automatic Network Reconfiguration With SEL-651R Recloser Controls

Specifications

Important: Do not use the following specification information to order an SEL-651R. Refer to the actual ordering information sheets.

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

General

AC Current Inputs

Channels IA, IB, IC

1 A nominal:	3 A continuous, linear to 20 A symmetrical; 100 A for 1 s; 250 A for 1 cycle
	Burden: 0.13 VA @ 1 A, 1.31 VA @ 3 A

Channel IN

0.2 A nominal:	15 A continuous, linear to 5.5 A symmetrical; 500 A for 1 s; 1250 A for 1 cycle
	Burden: <0.5 VA @ 0.2 A

AC Voltage Inputs

300 V Maximum (PT):	300 $V_{L\text{-}N}$ continuous (connect any voltage up to 240 Vac, with allowance for surge): 600 Vac for 10 seconds.
Burden:	<0.03 VA @ 67 V <0.06 VA @ 120 V <0.80 VA @ 300 V
8 V LEA Maximum:	8 $V_{L\text{-}N}$ continuous (connect any voltage up to 6.5 Vac, with allowance for surge): 300 Vac for 10 seconds.
Burden:	Relay Input Z = 1 MΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	50 Vac
Kyle/Cooper NOVA LEA:	37 $V_{L\text{-}N}$ continuous (connect any voltage up to 29.6 Vac with allowance for surge): 250 Vac for 10 seconds.
Burden:	Relay Input Z = 165 kΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	53 Vac
Lindsey SVMI LEA:	200 $V_{L\text{-}N}$ continuous (connect any voltage up to 160 Vac with allowance for surge): 250 Vac for 10 seconds.
Burden:	Relay Input Z = 1 MΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	25 Vac
Siemens LEA:	8.49 $V_{L\text{-}N}$ continuous (connect any voltage up to 6.79 Vac with allowance for surge): 155 Vac for 10 seconds.
Burden:	Relay Input Z = 24.22 kΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	50 Vac

Frequency and Rotation

System Frequency:	60 or 50 Hz
Phase Rotation:	ABC or ACB
Frequency Tracking:	40–65 Hz

Note: V1Y or V1Z required for frequency tracking.

Power Supply

120 Vac Nominal	
Rated Range:	85–132 Vac
Frequency Range:	40–65 Hz
Maximum Burden:	250 VA average, 500 VA peak
Inrush:	< 100 A (I^2t < 24 A^2 – s)
230 Vac Nominal	
Rated Range:	170–265 Vac
Frequency Range:	40–65 Hz
Maximum Burden:	250 VA average, 500 VA peak
Inrush:	< 50 A (I^2t < 6 A^2 – s)
125 Vdc Nominal:	
Rated Range:	100–137.5 Vdc
Maximum Burden:	25 W continuous, 300 W for 1.5 seconds

12 V Accessory Power Supply

For Models With AC Power Supply

12 Vdc ±10%, 40 W continuous, 60 W for 6 s every 60 s

For Models With DC Power Supply

12 Vdc ±10%, 3 W (0.25 A) continuous

Note: Some models momentarily dip to 9 Vdc during trip/close operations.

Output Contacts (except Trip and Close)

Make:	30 A per *IEEE C37.90:1989*
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection:	270 Vac, 360 Vdc, 40 J
Pickup Time:	<5 ms
Update Rate:	1/8 cycle

Break Capacity (10000 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 = 40 ms

Cyclic Capacity (1 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 = 40 ms

Note: Per *IEC 60255-0-20: 1974*, using the simplified assessment method.

Trip and Close Outputs

Traditional Interface Rating

Coil Voltage:	24 ± 2.4 Vdc
Coil Current:	15.5 A [Close], 12.2 A [Trip]

G&W Viper-ST Rating

Coil Voltage:	155 +5, –3 Vdc
Coil Current:	12–17 A [Close], 4 A [Trip] (per phase)
Pulse Duration:	53–55 ms [Close], 28–30 ms [Trip]

ABB OVR-3/VR-3S (15 and 27 kV models) Rating

Coil Voltage:	48 +5, –3 Vdc
Pulse Duration:	85 ms [Close], 45 ms [Trip]

Control-Powered Kyle NOVA Rating

Coil Voltage:	48 +5, –3 Vdc

Joslyn TriMod 600R Rating

Coil Voltage:	155 +5, –3 Vdc
Pulse Duration:	35 ms [Close], 14 ms [Trip]

Kyle NOVA-TS or NOVA-STS Triple-Single Rating

Coil Voltage:	48 +5, –3 Vdc

Tavrida OSM Rating

Coil Voltage:	155 +5, –3 Vdc
Pulse Duration:	60 ms [Close], 15 ms [Trip]

Siemens SDR Triple-Single Rating

Coil Voltage:	155 +5, –3 Vdc
Pulse Duration:	65 ms [Close], 40 ms [Trip]

Siemens SDR Three-Phase Rating

Coil Voltage:	155 +5, –3 Vdc
Pulse Duration:	65 ms [Close], 40 ms [Trip]

Note: Supports an entire trip-close-trip-close-trip-close-trip-close-trip-lockout sequence every minute.

Optoisolated Inputs (Optional)

DC Pickup Range	9.6–14.4 Vdc

Note: Optoisolated inputs draw approximately 4–10 mA of current.

Status Inputs

DC Dropout Range:	0–4 Vdc
DC Pickup Range:	8–28 Vdc
Current Draw:	1–10 mA

For Kyle NOVA-TS or NOVA-STS Triple-Single Recloser applications, inputs IN204–IN206 are self-whetted (< 20 Vdc output; < 20 mA output).

Communications Ports

EIA-232:	1 Front, 3 Rear
Baud Rate:	300–57600 bps
DNP Response Time:	20 ms typical

Time-Code Input

Recloser control accepts demodulated IRIG-B time-code input at Port 1 and a BNC Connector, but not simultaneously. Recloser control time is synchronized to within ±0.5 ms of time-source input. Input impedance is 1.33 kΩ ±50 Ω.

Operating Temperature

Relay Module:	–40° to +85°C (–40° to +185°F)
Batteries:	–40° to +80°C (–40° to +176°F)
Entire SEL-651R unit:	–40° to +55°C (–40° to +131°F)

Note: LCD contrast impaired for temperatures below –20°C (–4°F). The entire SEL-651R unit is operationally tested to +70°C (+158°F). The 15°C (27°F) difference between the +55°C rating and +70°C is for direct sunlight temperature rise.

Weight

<114 kg (<250 lb)

Battery Specifications

Base Version Requirement:

Normal Capacity:	16 amp-hours @ 25°C
Run Time (Relay electronics operate plus one trip/close cycle):	≥9.6 hours @ 25°C ≥3.2 hours @ –40°C
Recharge Time (Deep discharge to fully charged):	≤ 9.6 hours @ 25°C
Estimated Life:	≥4 years @ 25°C ≥1 year @ +80°C

Extended Capacity Option Requirement:

Normal Capacity:	40 amp-hours @ 25°C
Run Time (Relay electronics operate plus one trip/close cycle):	≥24 hours @ 25°C ≥8 hours @ –40°C
Recharge Time (Deep discharge to fully charged):	≤ 24 hours @ 25°C
Estimated Life:	≥4 years @ 25°C ≥1 year @ +80°C

Processing Specifications

AC Voltage and Current Inputs

32 samples per power system cycle, 3 dB low-pass filter cut-off frequency of 960 Hz.

Digital Filtering

One cycle cosine after low-pass analog filtering.
Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental for protection.

Protection and Control Processing

Most Elements:	Four times per power system cycle.
Time-Overcurrent Elements:	Two times per power system cycle.

Relay Element Settings Ranges and Accuracies

Instantaneous/Definite-Time Overcurrent Elements (50)

Current Pickup Range (A secondary)

Phase and Neg.-Seq.:	0.05–20.00 A, 0.01 A steps
Ground:	0.005–20 A, 0.001 A steps
Neutral:	0.005–2.5 A

Steady-State Pickup Accuracy

Phase and Neg.-Seq.:	±0.01 A plus ±3% of setting
Ground:	±0.001 A plus ±3% of setting (IN < 4.7 A) ±0.010 A plus ±3% of setting (IN ≥ 4.7 A)
Neutral:	±0.001 A plus ±3% of setting
Transient Overreach:	±5% of pickup
Pickup/Dropout Time:	1.25 cycles
Time Delay Range:	0.00–16,000.00 cycles, 0.25–cycle steps
Time Delay Accuracy:	±0.25 cycle plus ±0.1% of setting

Time-Overcurrent Elements (51)

Current Pickup Range (A secondary)

Phase and Neg.-Seq.:	0.10–3.20 A, 0.01 A steps
Ground:	0.005–3.200 A, 0.001 A steps

Steady-State Pickup Accuracy

Phase and Neg.-Seq.:	±0.01 A plus ±3% of setting
Ground:	±0.001 A plus ±3% of setting (IN < 4.7 A) ±0.010 A plus ±3% of setting (IN ≥ 4.7 A)

Time Dials

U.S.:	0.5–15.0, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Recloser Curves:	0.10–2.00, 0.01 steps
Curve Timing Accuracy:	±1.50 cycles plus ±4% of setting, between 2 and 30 multiples of pickup

Undervoltage (27) and Overvoltage (59)

Pickup Ranges (V secondary)

300 V Maximum Inputs:	
Phase:	1.00–300.00 V, 0.01 V steps
Phase-to-Phase:	1.76–520.00 V, 0.02 V steps
Sequence:	2.00–300.00 V, 0.02 V steps
8 V LEA Maximum Inputs:	
Phase:	0.03–8.00 V[1]
Phase-to-Phase:	0.05–13.87 V[1]
Sequence:	0.05–8.00 V[1]
Kyle/Cooper NOVA LEA Inputs (37 Vac Max):	
Phase:	0.12–37.09 V[1]
Phase-to-Phase:	0.21–64.24 V[1]
Sequence:	0.25–37.09 V[1]
Lindsey SVMI LEA Inputs (200 Vac Max):	
Phase:	1.00–200.00 V
Phase-to-Phase:	1.76–346.00 V
Sequence:	2.00–200.00 V
Siemens LEA Inputs (8.49 Vac Max):	
Phase:	0.03–8.49 V[1]
Phase-to-Phase:	0.05–14.72 V[1]
Sequence:	0.05–8.00 V[1]

Steady-State Pickup Accuracy

300 V Maximum:	
Phase:	±0.5 V plus ±1% of setting
Phase-to-Phase:	±1 V plus ±2% of setting
Sequence:	±1.5 Vac plus ±3% of setting @ 12.5–300 Vac
8 V LEA Maximum:[1]	
Phase:	±10 mV plus ±1% of setting
Phase-to-Phase:	±20 mV plus ±2% of setting
Sequence:	±30 mVac plus ±3% of setting @ 0.33–8.00 Vac
Kyle/Cooper NOVA LEA:[1]	
Phase:	±60 mV plus ±1% of setting
Phase-to-Phase:	±120 mV plus ±2% of setting
Sequence:	±180 mVac plus ±3% of setting @ 1.55–37.09 Vac
Lindsey SVMI LEA:	
Phase:	±0.5 V plus ±1% of setting
Phase-to-Phase:	±1 V plus ±2% of setting
Sequence:	±1.5 Vac plus ±3% of setting @ 12.5–200 Vac
Siemens LEA:[1]	
Phase:	±10 mV plus ±1% of setting
Phase-to-Phase:	±20 mV plus ±2% of setting
Sequence:	±30 mVac plus ±3% of setting @ 0.33–8.49 Vac
Transient Overreach:	±5%
Pickup/Dropout Time:	<1.25 cycles

Note 1: See *Table 9.18* and accompanying text on how to set voltage elements when using these LEA inputs.

Synchronism-Check Elements (25)

Slip Frequency Pickup Range:	0.005–5.000 Hz, 0.001 Hz steps
Slip Frequency Pickup Accuracy:	±0.003 Hz
Phase Angle Range:	0–80°, 0.01° steps
Phase Angle Accuracy:	±4°

Under-/Overfrequency Elements (81)[1]

Frequency Range:	40.00–65.00 Hz, 0.01 Hz steps
Frequency Accuracy:	±0.01 Hz
Time Delay Range:	2.00–16,000.00 cycles, 0.25-cycle steps
Time Delay Accuracy:	±0.25 cycle plus ±0.1%
Undervoltage Frequency Element Block Range:	
300 V Inputs:	12.50–300.00 V
8 V LEA Inputs:	0.33–8.00 V

Power Elements[2]

Minimum Current:	0.01 A
Minimum Voltage:	40 V
Steady-State Pickup Accuracy:	0.58 W plus ±5% of setting at unity power factor

Pickup/Dropout Time:	<3.75 cycles
Time Delay Accuracy:	±0.25 cycle plus ±0.1% of setting

Load Encroachment[2]

Minimum Current:	0.1 A
Minimum Voltage:	12.5 Vac
Forward Load Impedance:	0.5–640 ohms secondary
Forward Positive Load Angle:	–90° to +90°
Forward Negative Load Angle:	–90° to +90°
Negative Load Impedance:	0.50–640 ohms secondary
Negative Positive Load Angle:	+90° to +270°
Negative Negative Load Angle:	+90° to +270°
Pickup Accuracy:	
Impedance:	±3%
Angle:	±2°

Note 2: Voltage, Power, and Impedance values listed for 300 Vbase (PT) inputs.

SELogic Control Equation Variable Timers

Pickup Ranges	
0.00–999,999.00 cycles:	0.25-cycle steps (programmable timers)
Pickup/Dropout Accuracy:	±0.25 cycle plus ±0.1% of setting

Metering Accuracies

Accuracies specified at 20°C and at nominal system frequency unless noted otherwise.

Instantaneous and Maximum/Minimum Metering

Voltages	
VAY, VBY, VCY, VAZ, VBZ, VCZ:	±0.2% (50–300 V), ±0.5°
VABY, VBCY, VCAY, VABZ, VBCZ, VCAZ:	±0.4% (50–300 V), ±1.0°
3V0Y, V1Y, V2Y, 3V0Z, V1Z, V2Z:	±0.6% (50–300 V), ±1.0°
Currents	
IA, IB, IC:	±0.5 mA plus ±0.1% of reading (0.1–2 A), ±0.5°
IN:	±0.08 mA plus ±0.1% of reading (0.005–4.5 A), ±1°
3I1, 3I0, 3I2:	±0.01 A plus ±3% of reading (0.1–2 A), ±1°
Power	
Apparent (MVA) MVAA, MVAB, MVAC, MVA3P:	±1.2% (V_{phase}[5] > 50 Vac, I_{phase} > 0.1 A)
Real (MW) MWA, MWB, MWC, MW3P	±0.7% @ PF = 1, ±1.0% @ PF > 0.87 (V_{phase}[5] > 50 Vac, I_{phase} > 0.1 A)
Reactive (MVAR) MVARA, MVARB, MVARC, MVAR3P:	±0.7% @ PF = 0, ±1.0% @ PF < 0.50 (V_{phase}[5] > 50 Vac, I_{phase} > 0.1 A)
Energy	
Megawatt Hours (In and Out): MWhA, MWhB, MWhC, MWh3P:	+1.2% @ PF=1, (V_{phase}[5] > 50 Vac, I_{phase} > 0.1 A)
Megavar Hours (In and Out): MVARhA, MVARhB, MVARhC, MVARh3P:	+1.2% @ PF=0, (V_{phase}[5] > 50 Vac, I_{phase} > 0.1 A)

Demand Metering

Currents	
IA, IB, IC:	±0.25% (0.1–2 A)
IN (Measured):	±0.25% (0.005–4.5 A)
3I2, 3I0 (IG):	±3% ±0.01 A, (0.1–20.0 A)

Harmonic Metering

±5%

RMS Metering

Voltages	
VAY, VBY, VCY, VAZ, VBZ, VCZ:	±1.2% V_{phase}[5] > 50 Vac
Currents	
IA, IB, IC:	±0.5 mA plus ±0.2% (0.1–2 A)
IN (Measured):	±0.08 mA plus ±0.2% (0.005–4.5 A)
Average Real Power (MW) MWA, MWB, MWC, MW3P:	±2.0% @ PF = 1 (V_{phase}[5] > 50 Vac, I_{phase} > 0.1 A)

Note 5: Voltage threshold for 8 V LEA inputs is 0.67 Vac. Voltage threshold for Kyle/Cooper NOVA LEA inputs is 1.7 Vac. Voltage threshold for Lindsey SVMI LEA inputs is 14 Vac.

Recloser Type Tests

ANSI/IEEE C37.60: 1981, performed with the following reclosers:

G&W Viper-ST	27 kV, 12.5 kA interrupting, 800 A continuous

ANSI/IEEE C37.60: 2003, performed with the following reclosers:

Cooper NOVA	27 kV, 12.5 kA interrupting, 630 A continuous
Kyle® Recloser type "WVE-27"	27 kV, 8 kA interrupting, 560 A continuous
ABB OVR-3	27 kV, 12.5 kA interrupting, 630 A continuous
Cooper NOVA-TS	15.5 kV, 8 kA interrupting, 400 A continuous
Cooper NOVA (control powered)	27 kV, 12.5 kA interrupting, 630 A continuous

Section 6.12

Cable Charging Current Interrupting test for automatic circuit reclosers and fault interrupters for AC systems, 5 A rms charging current interrupted, 20 close-open operations, randomly timed.

Section 6.13
Transformer Magnetizing Current Interruption test for automatic circuit reclosers and fault interrupters for AC systems, magnetizing current interrupted equal to 3.5% of the continuous current rating of the recloser, 20 close-open operations, randomly timed.

Section 6.14
Control Elements, SWC tests for automatic circuit reclosers and fault interrupters for AC systems, 1.0–1.5 MHz oscillatory test wave of crest voltage of 2.5–3.0 kV occurring in the first half-cycle, decaying to 50% in not less than 6 µs.

Section 6.2
Insulation (Dielectric) tests for automatic circuit reclosers and fault interrupters for AC systems, 1.2 • 50 µs voltage impulse (positive and negative) of crest voltage of 125 kV, applied to recloser with control connected.

Section 6.3
Interruptions.

Section 2

Installation

Design your installation using the mounting and connection information in this section. This section also includes information on configuring the SEL-651R Recloser Control front panel for your application.

Dual-Door Enclosure Hardware Overview

The control consists of four major pieces:

- ➤ Enclosure
- ➤ Power Module
- ➤ Relay Module
- ➤ Battery

These pieces are shown in *Figure 2.1* and are described briefly in the following text.

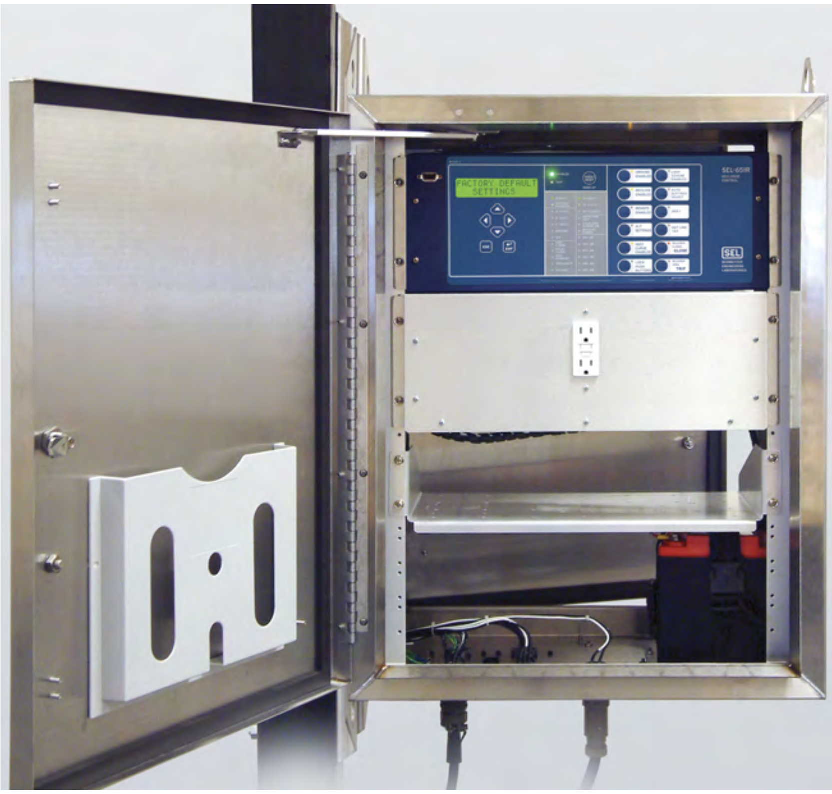


Figure 2.1 SEL-651R Front View With Enclosure Front Door Open (Dual-Door Enclosure)

Enclosure

NOTE: Serial number stickers are provided for the enclosure, power module, and relay module.

Select the painted cold-rolled steel enclosure for normal applications or the unpainted (type 304) stainless steel enclosure to prevent corrosion in harsh environments. Each enclosure is NEMA 3R rated and provides a 19-inch rack and ample space for mounting of the relay module, power supply module, and accessories (e.g., radio). It includes a front door for fast and easy access to the front-panel HMI and a rear door for easy access to wiring and fuses. SEL fiber-optic transceivers can mount on serial ports, with enough room for training the fiber-optic cable.

The front-door document holder is 22.9 cm (9 in) wide, by 3.0 cm (1.2 in) deep. It can carry items weighing up to 2 lb.

Near the upper corner of the enclosure (side near the pole), a small louvered vent is installed for the venting of battery gasses.

Optional three-point latches can be ordered for the doors.

Painted enclosures not ordered with three-point latches have a padlockable handle on the front door, and a quarter-turn padlockable latch on the rear door. Painted enclosures ordered with three-point latches and all stainless steel enclosures have padlockable handles on both the front and rear doors.

Table 2.1 Diameter of Door Handle Hole for Customer Lock

Enclosure/Door	Single-Point Latch Door Handle	Three-Point Latch Door Handle
Painted/front	1.0 cm (3/8 in)	1.0 cm (3/8 in)
Painted/rear	1.3 cm (1/2 in)	1.0 cm (3/8 in)
Stainless/front	1.3 cm (1/2 in)	1.3 cm (1/2 in)
Stainless/rear	1.3 cm (1/2 in)	1.3 cm (1/2 in)

NOTE: A lock with a 3/8″ diameter shackle would work in any scenario listed in Table 2.1.

The internal 19-inch rack system is designed according to the IEC 297 19-inch rack standard and accepts #10-32 screws.

Accessory Shelf

An optional accessory shelf can be installed in the 19-inch rack, below the power module. It has pre-drilled holes and installed PEM nuts for the installation of various radios, protocol converters, and other accessories (see the dimensions in *Figure 2.2*). The accessory shelf takes up 8.9 cm (3.5 vertical in) and can carry up to 6.8 kg (15 lb).

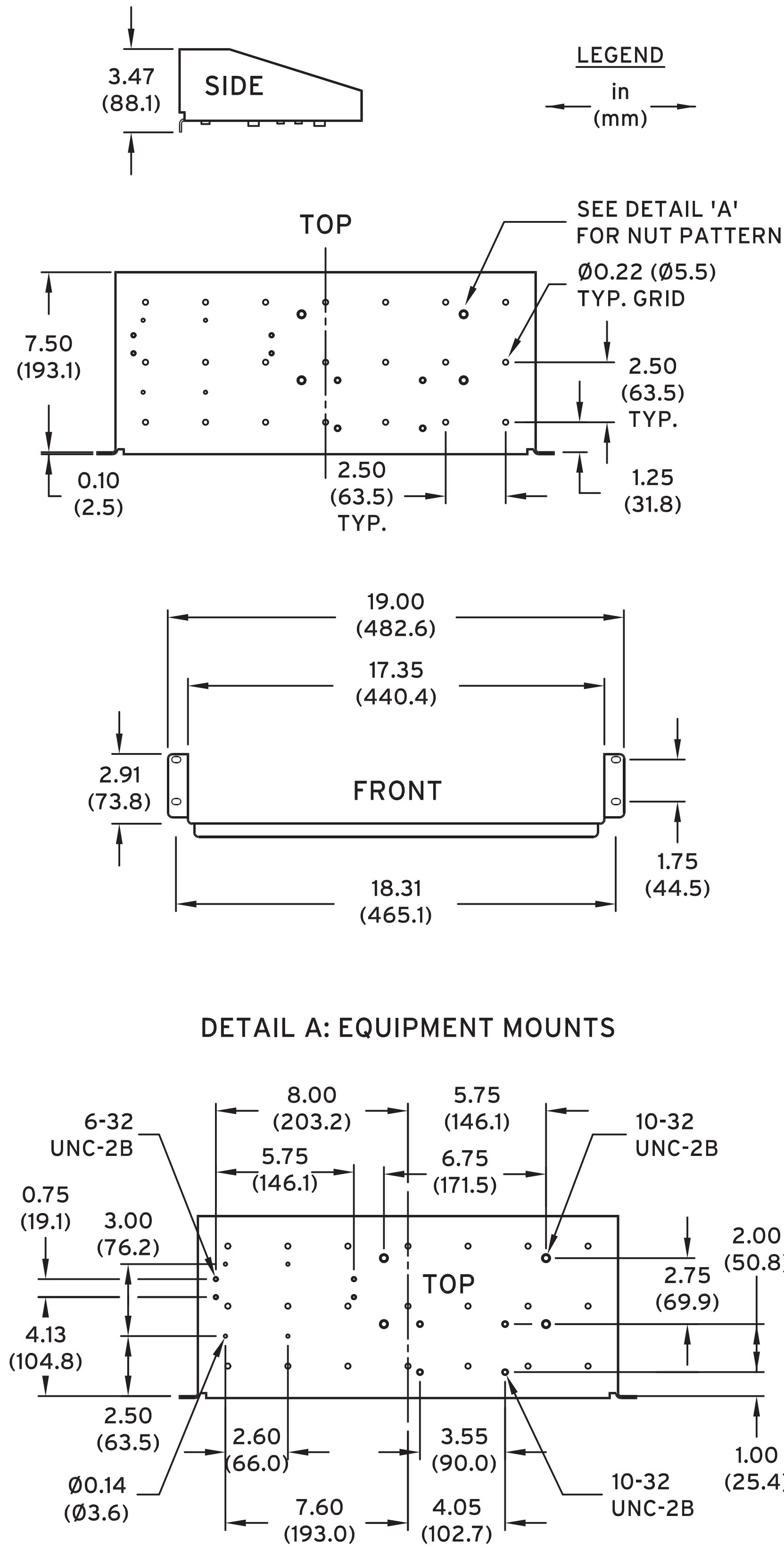


Figure 2.2 Accessory Shelf (Optional) (Dual-Door Enclosure)

Power Module

Figure 2.3 provides an overview of the major interconnections between the components within the SEL-651R enclosure.

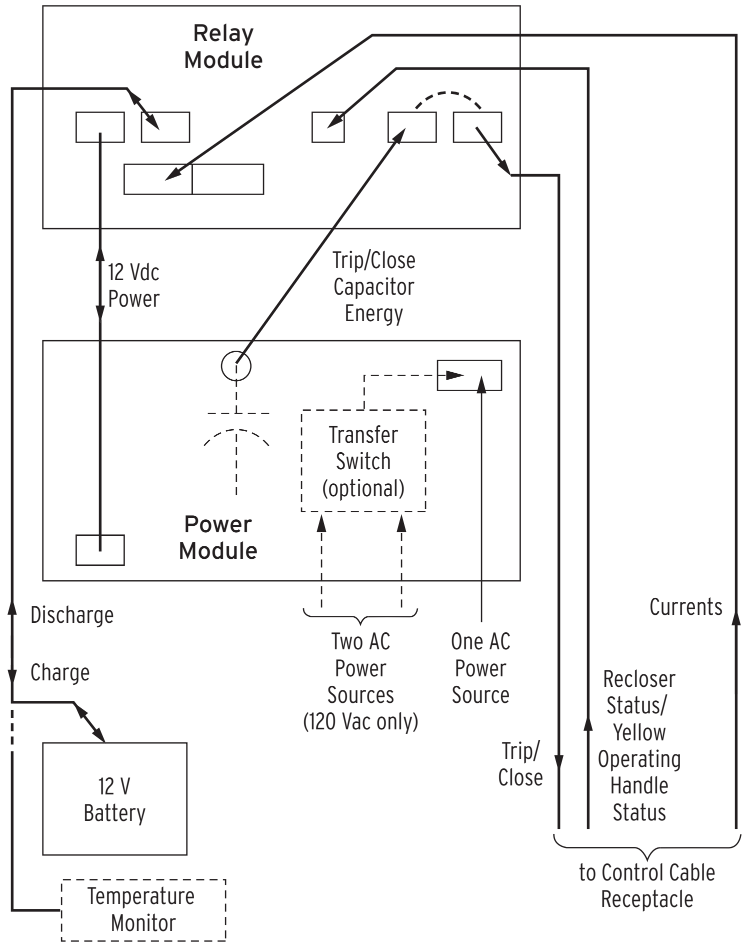


Figure 2.3 Major Interconnections Between SEL-651R Components—Rear View (Dual-Door Enclosure)

The power module is ordered with one input power option:

- 120 Vac (includes a GFCI [Ground Fault Circuit Interrupter] convenience outlet on front)
- 230 Vac (two-wire)
- or 125 Vdc

If two sources of 120 Vac power are brought to the power module, they must first be routed through a transfer switch on the power module. The output of the transfer switch is then connected to the power module inputs, as shown in *Figure 2.3*.

12 Vdc is output from the power module to power the relay module. The trip/close capacitor is charged inside the power module and this energy source is connected (via wire harness) to the trip and close output circuits in the relay module.

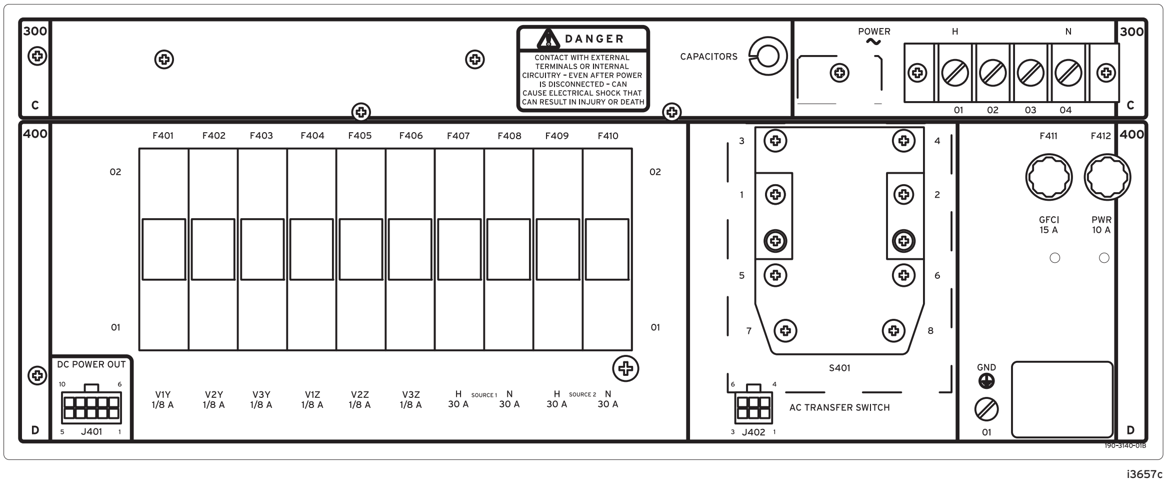


Figure 2.4 Rear View of SEL-651R Power Module (Dual-Door Enclosure)

Relay Module

Each SEL-651R relay module provides protection, control, and monitoring features. The relay module is powered from 12 Vdc from the power module, as shown in *Figure 2.3*. This 12 Vdc also powers the battery charger in the relay module and is available as auxiliary power, such as for powering a radio. Secondary currents and voltages from the power system and recloser status are input to the relay module.

Trip and close signals are output from the relay module, with the trip/close capacitor (connected from the power module) providing the energy to actuate the trip or close operation.

Slide-in configurable front-panel labels can be customized for unique applications.

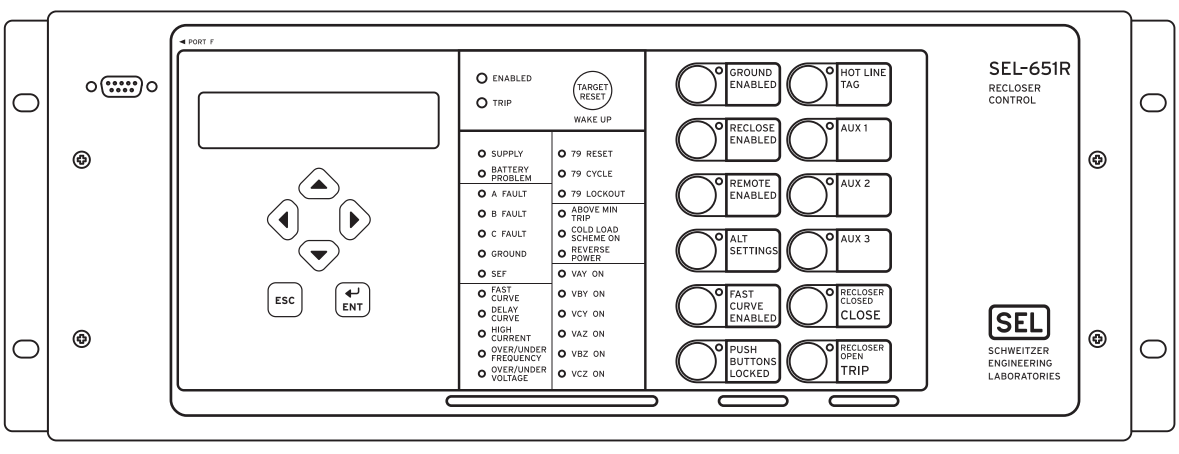


Figure 2.5 Front View of SEL-651R Relay Module (Dual-Door Enclosure)

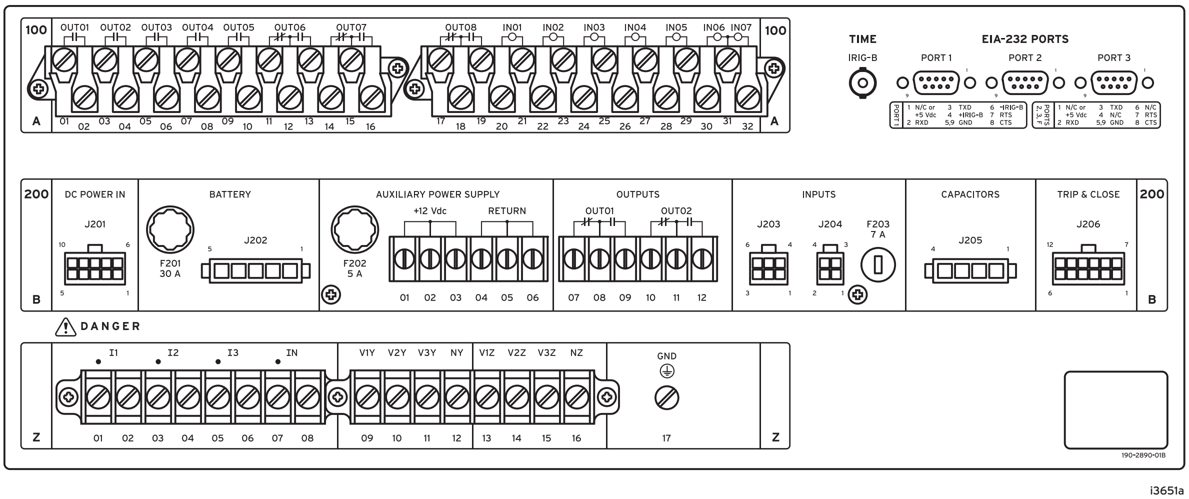


Figure 2.6 Rear View of SEL-651R Relay Module (Dual-Door Enclosure)

The internal wiring details of SEL-651R relay module connectors J202, J203, J204, and J206 are shown in the following figures.

- ➤ J202 (BATTERY) is shown in *Figure 2.27*
- ➤ J203 (INPUTS) is shown in *Figure 2.46*, *Figure 2.49*, *Figure 2.52*, *Figure 2.54*, *Figure 2.57*, *Figure 2.59*, *Figure 2.60*, *Figure 2.62*, *Figure 2.65*, and *Figure 2.66*
- ➤ J204 (INPUTS) is shown in *Figure 2.54*, *Figure 2.59*, *Figure 2.60*, and *Figure 2.69*
- ➤ J206 (TRIP & CLOSE) is shown in *Figure 2.46*, *Figure 2.48*, *Figure 2.51*, *Figure 2.54*, *Figure 2.56*, *Figure 2.59*, *Figure 2.62*, *Figure 2.65*, and *Figure 2.66*

The internal wiring details for connectors J201 (DC POWER IN) and J205 (CAPACITORS) are not shown. J201 and J205 should only be connected to the factory-supplied harnesses emanating from the SEL-651R power module (see *Figure 2.3* for an overview of such major interconnections).

Battery

Either a 16 or 40 A-hr extended temperature 12 V battery is shipped with the recloser control. The battery sits upon a slightly raised platform. This platform provides space underneath for the battery temperature monitor, as shown in *Figure 2.3*.

See *Battery Installation and Connection on page 2.28* and *Battery and Fuse Replacement on page 2.51* for more information on battery service and characteristics.

Single-Door Enclosure Hardware Overview

The control consists of four major pieces:

- ➤ Enclosure
- ➤ Power Module
- ➤ Relay Module
- ➤ Battery

These pieces are shown in *Figure 2.7* and are described briefly in the following text.

Figure 2.7 SEL-651R Front View With Enclosure Door Open (Single-Door Enclosure)

Enclosure

NOTE: Serial number stickers are provided for the enclosure, power module, and relay module.

Select the painted cold-rolled steel enclosure for normal applications or the unpainted (type 304) stainless steel enclosure to prevent corrosion in harsh environments. Each single-door enclosure is NEMA 3R rated and provides space for mounting of the relay module, power supply module, and accessories (e.g., radio). It includes a door for fast and easy access to the front-panel HMI and a swing-panel for easy access to wiring and fuses.

The front-door document holder is 22.9 cm (9 in) wide, by 3.0 cm (1.2 in) deep. It can carry items weighing up to 2 lb.

At the rear of the enclosure (near the mounting bracket), a small louvered vent is installed for the venting of battery gasses.

An optional three-point latch can be ordered for the door.

Table 2.2 Diameter of Door Handle Hole for Customer Lock[a]

Enclosure/Door	Single-Point Latch Door Handle	Three-Point Latch Door Handle
Painted	1.0 cm (3/8 in)	1.0 cm (3/8 in)
Stainless	1.3 cm (1/2 in)	1.3 cm (1/2 in)

[a] A lock with a 3/8″ diameter shackle would work in any scenario listed in Table 2.2.

Accessory Shelf

An optional accessory shelf can be installed in the enclosure, below the relay and power modules. It has pre-drilled holes and installed PEM nuts for the installation of various radios, protocol converters, and other accessories (see the dimensions in *Figure 2.8*).

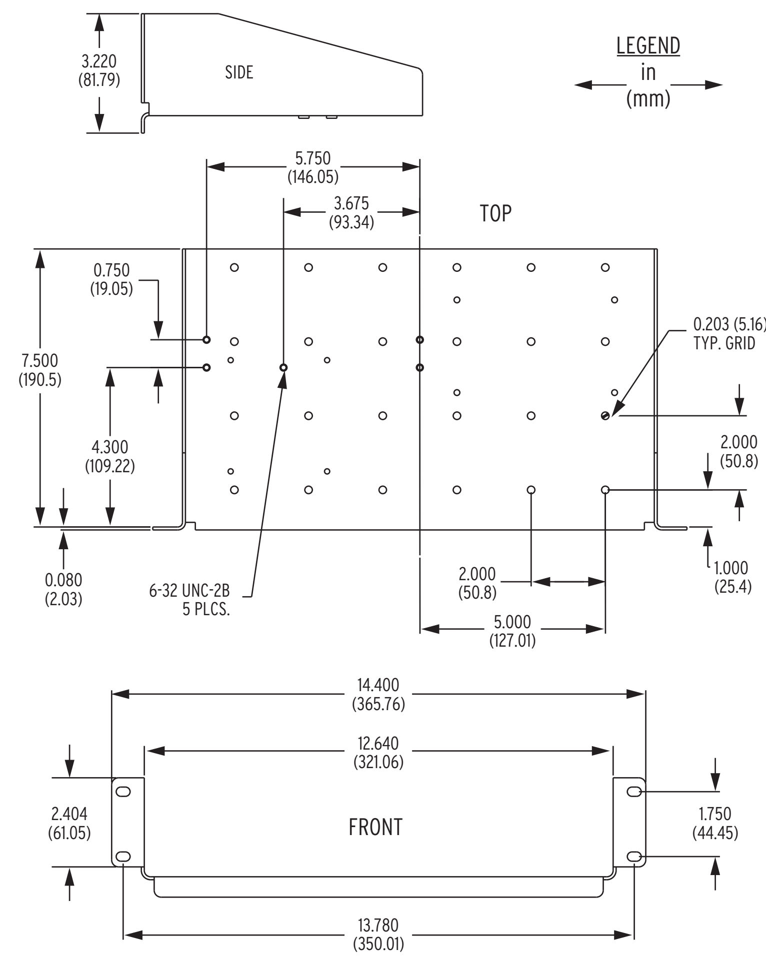


Figure 2.8 Accessory Shelf (Optional) (Single-Door Enclosure)

Power Module

Figure 2.9 provides an overview of the major interconnections among the components within the SEL-651R enclosure.

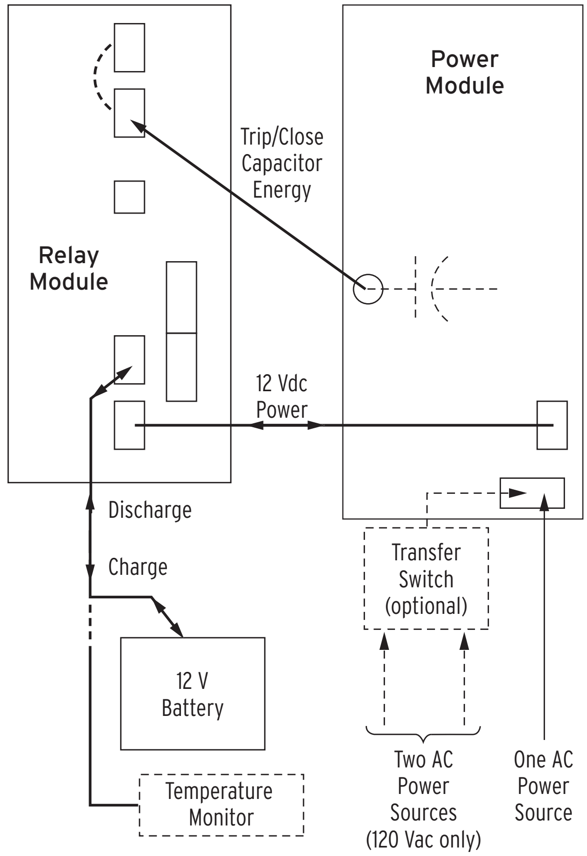


Figure 2.9 Major Interconnections Between SEL-651R Components—Front View (Single-Door Enclosure)

The power module is ordered with one input power option:

➤ 120 Vac (includes a GFCI [Ground Fault Circuit Interrupter] convenience outlet on front)

➤ 230 Vac (two-wire)

➤ or 125 Vdc

If two sources of 120 Vac power are brought to the power module, they must first be routed through a transfer switch. The output of the transfer switch is then connected to the power module inputs, as shown in *Figure 2.9*.

12 Vdc is output from the power module to power the relay module. The trip/close capacitor is charged inside the power module and this energy source is connected (via wire harness) to the trip and close output circuits in the relay module.

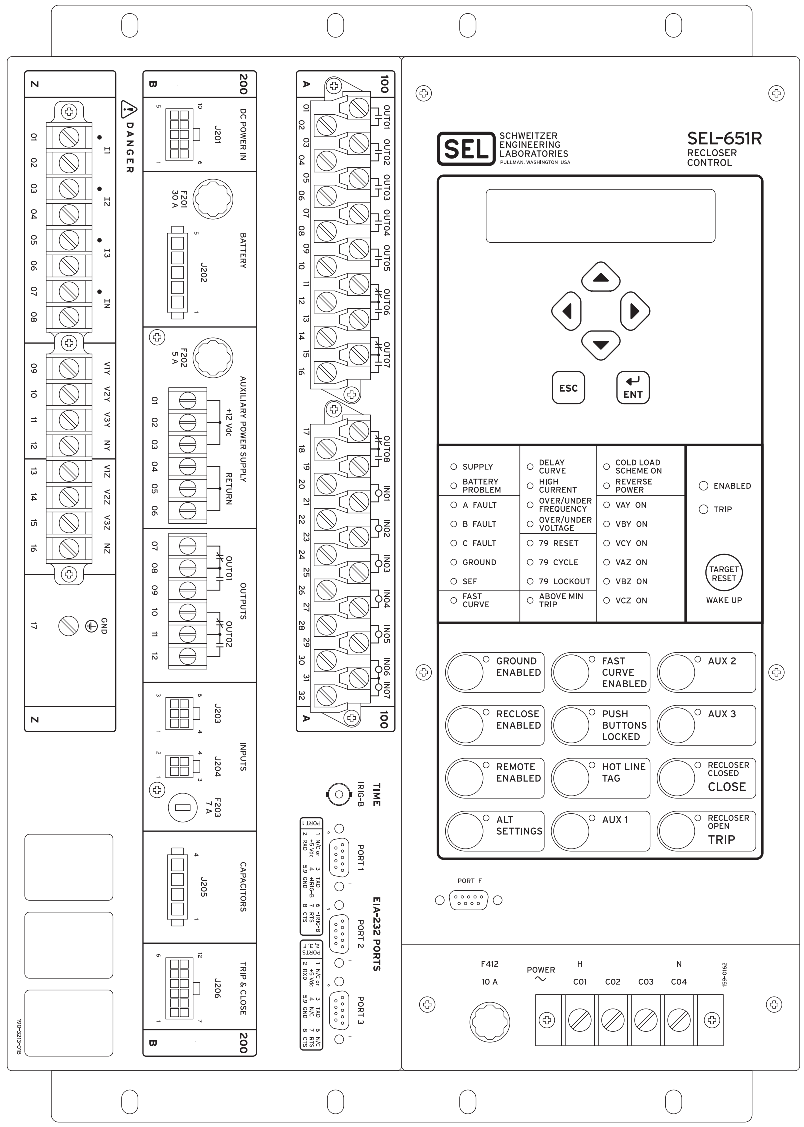


Figure 2.10 Front View of SEL-651R Modules (Single-Door Enclosure)

Relay Module

Each SEL-651R relay module provides protection, control, and monitoring features. The relay module is powered from 12 Vdc from the power module, as shown in *Figure 2.9*. This 12 Vdc also powers the battery charger in the relay module and is available as auxiliary power, such as for powering a radio. Secondary currents and voltages from the power system and recloser status are input to the relay module.

Trip and close signals are output from the relay module, with the trip/close capacitor (connected from the power module) providing the energy to actuate the trip or close operation.

Slide-in configurable front-panel labels can be customized for unique applications.

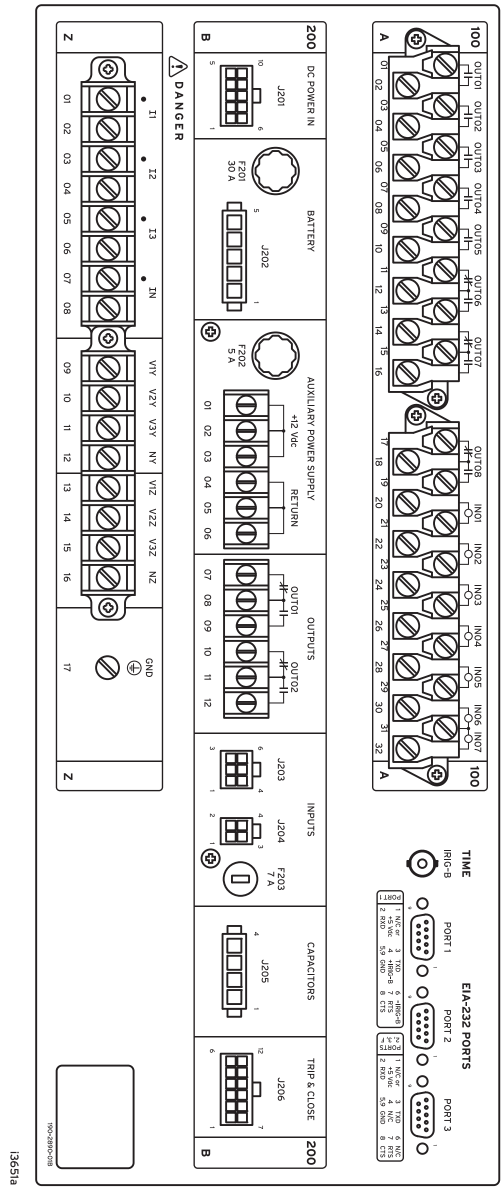


Figure 2.11 View of SEL-651R Relay Module (Single-Door Enclosure)

The internal wiring details of SEL-651R relay module connectors J202, J203, J204, and J206 are shown in the following figures.

- J202 (BATTERY) is shown in *Figure 2.27*
- J203 (INPUTS) is shown in *Figure 2.46*, *Figure 2.49*, *Figure 2.52*, *Figure 2.54*, *Figure 2.57*, *Figure 2.59*, *Figure 2.60*, *Figure 2.62*, *Figure 2.65*, and *Figure 2.66*
- J204 (INPUTS) is shown in *Figure 2.54*, *Figure 2.59*, *Figure 2.60*, and *Figure 2.69*
- J206 (TRIP & CLOSE) is shown in *Figure 2.46*, *Figure 2.48*, *Figure 2.51*, *Figure 2.54*, *Figure 2.56*, *Figure 2.59*, *Figure 2.62*, *Figure 2.65*, and *Figure 2.66*

The internal wiring details for connectors J201 (DC POWER IN) and J205 (CAPACITORS) are not shown. J201 and J205 should only be connected to the factory-supplied harnesses emanating from the SEL-651R power module (see *Figure 2.9* for an overview of such major interconnections).

Battery

Either a 16 or 40 A-hr extended temperature 12 V battery is shipped with the recloser control. The battery sits upon a slightly raised platform. This platform provides space underneath for the battery temperature monitor, as shown in *Figure 2.9*.

See *Battery Installation and Connection on page 2.28* and *Battery and Fuse Replacement on page 2.51* for more information on battery service and characteristics.

No Enclosure Options

SEL-651R recloser controls can be ordered from SEL without enclosures. This option might be used where the control will be installed in a substation environment or where a custom enclosure will be used. An SEL-651R ordered with no enclosure consists of four items:

- Relay Module
- Power Module
- Battery Temperature Sensor (with cables)
- Wiring Harnesses

⚠CAUTION
The battery temperature sensor board contains exposed components that are sensitive to Electrostatic Discharge (ESD). When working with this board, work surfaces and personnel must be properly grounded or equipment damage may result.

All hardware is as described in the previous sections. See *Installation Steps on page 2.13* and *Supplemental Connection Details on page 2.53* for details on wiring the recloser control.

Installation Steps

Dual-Door Control Mounting

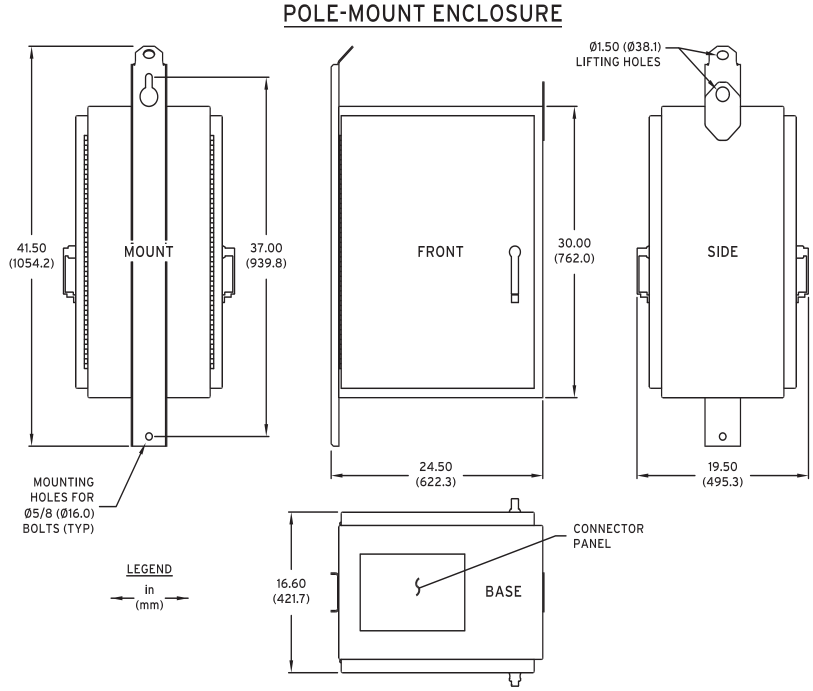


Figure 2.12 SEL-651R Enclosure Dimensions and Mounting Drill Plan (Dual-Door Enclosure)

⚠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.

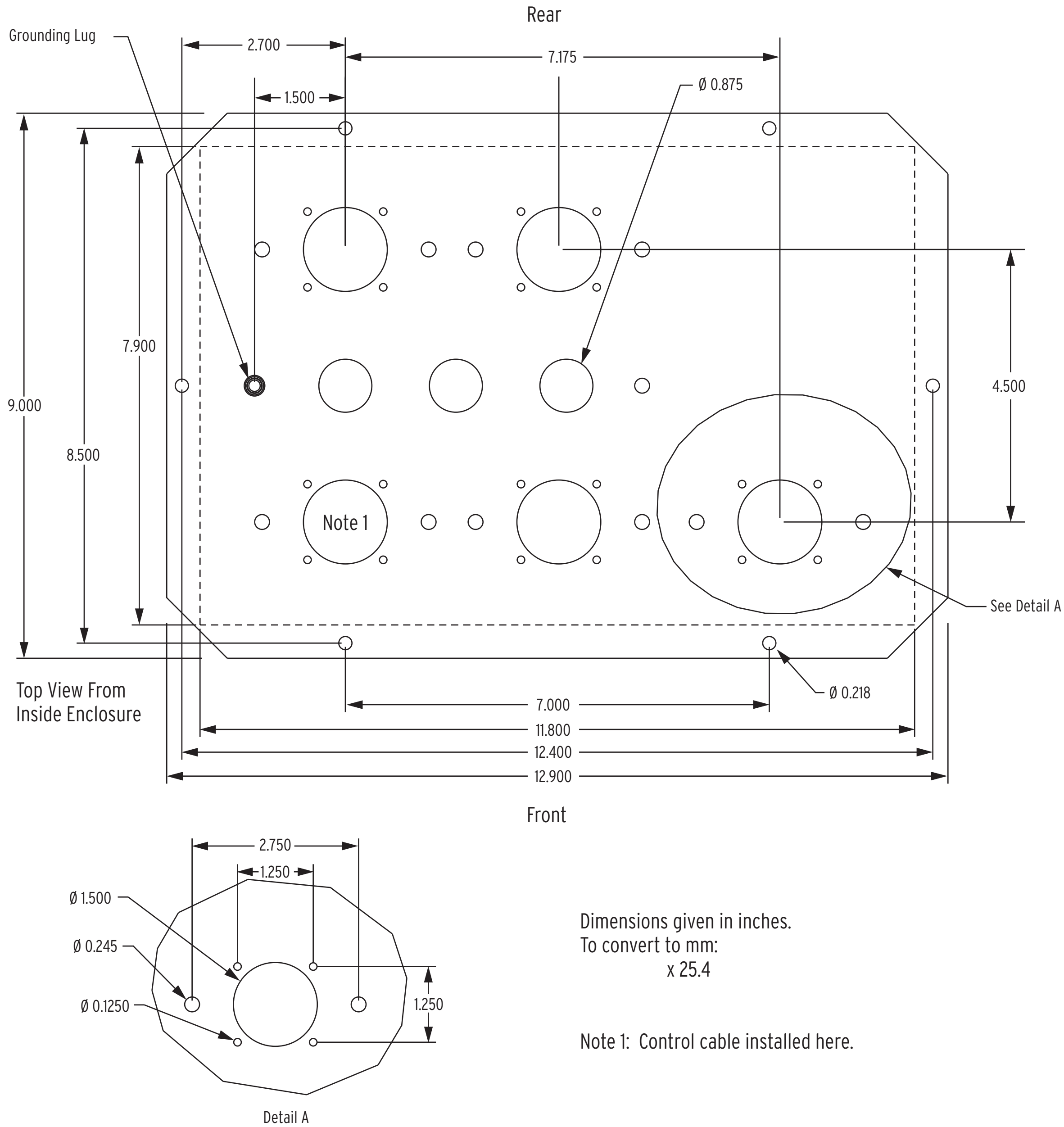


Figure 2.13 Connector Panel at Bottom of Enclosure for Traditional Retrofit and Control-Powered Kyle NOVA Reclosers (Dual-Door Enclosure)

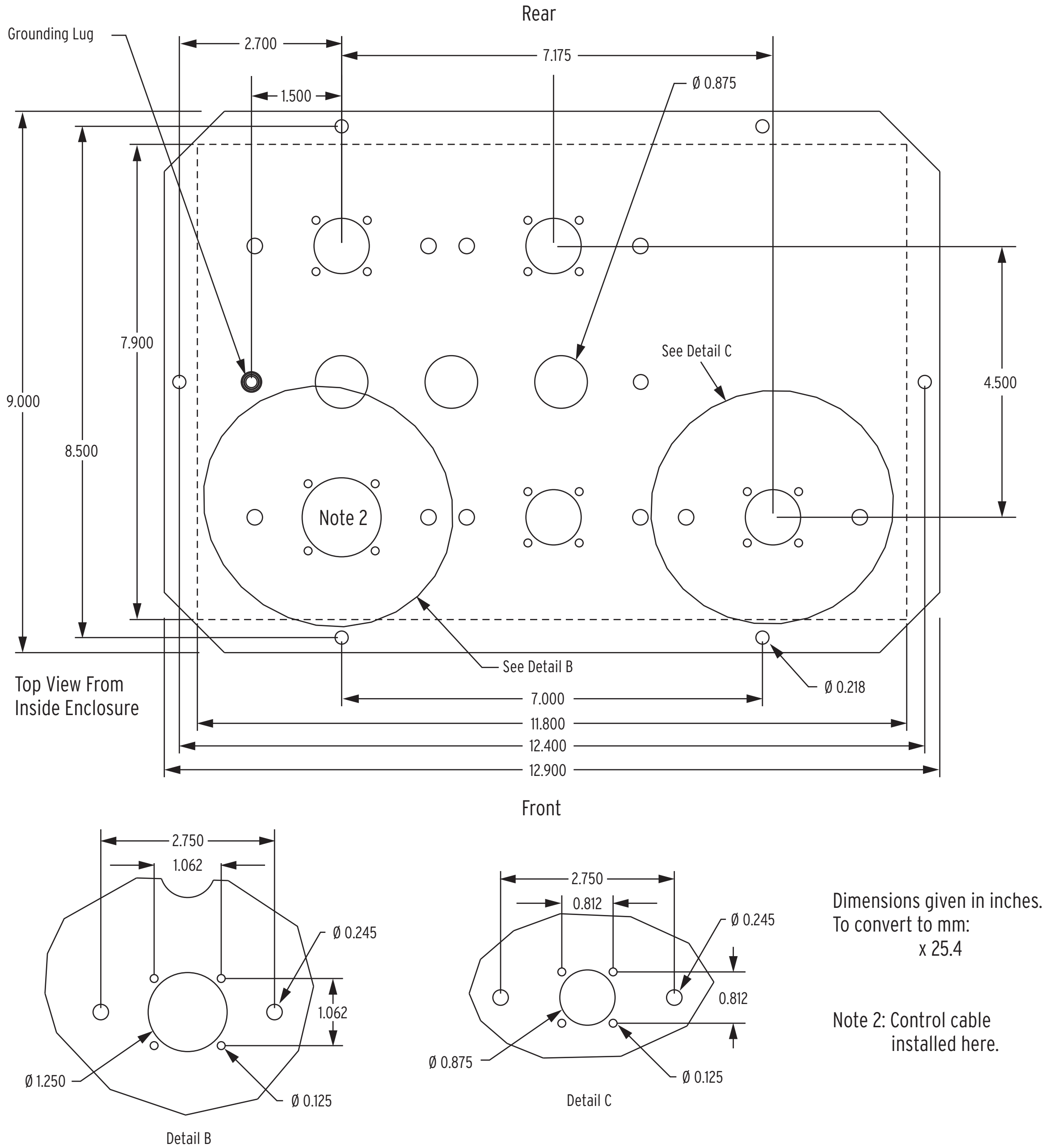


Figure 2.14 Connector Panel at Bottom of Enclosure for G&W Viper-ST Recloser (Dual-Door Enclosure)

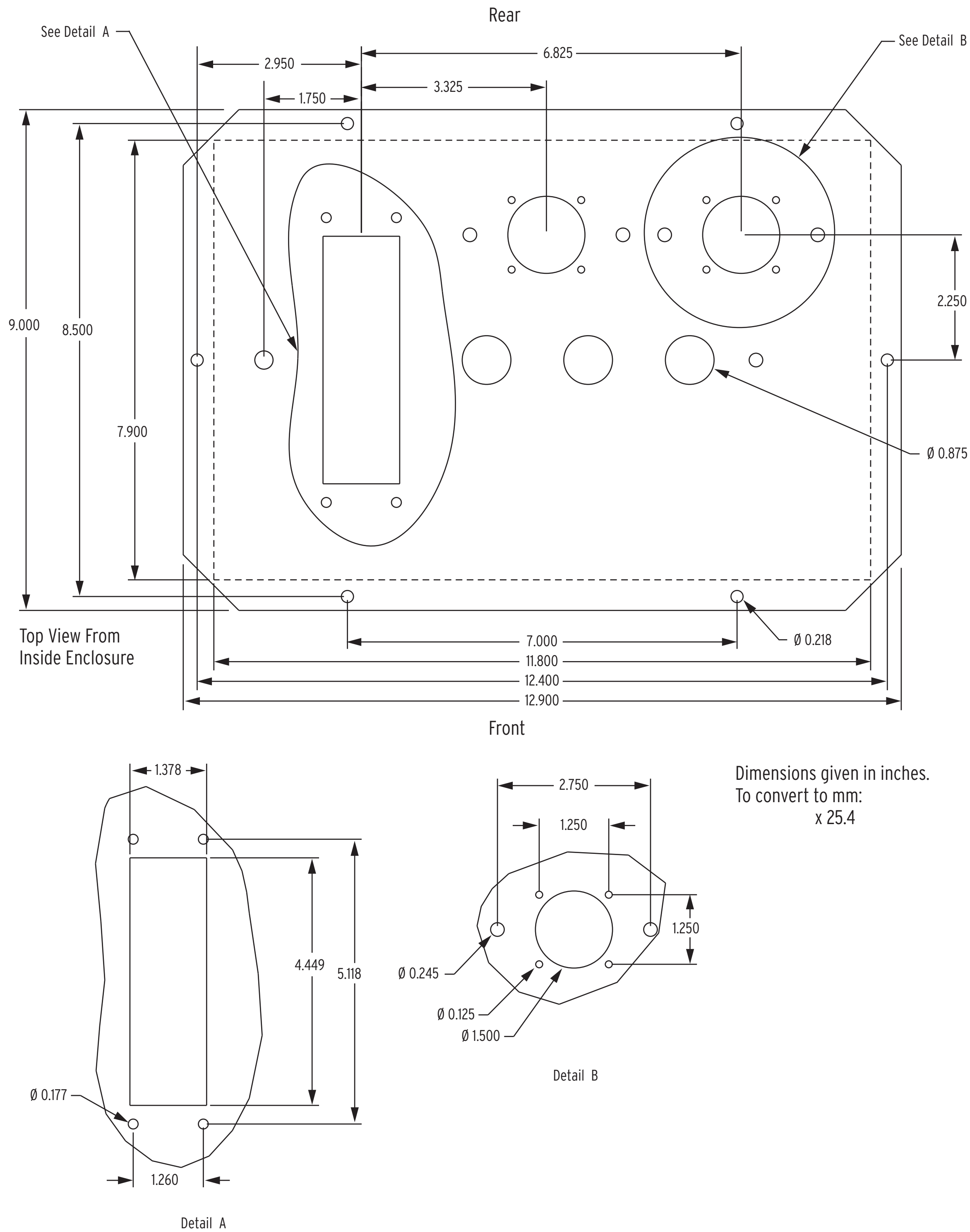


Figure 2.15 Connector Panel at Bottom of Enclosure for ABB OVR-3/VR-3S (15 and 27 kV models) Recloser (Dual-Door Enclosure)

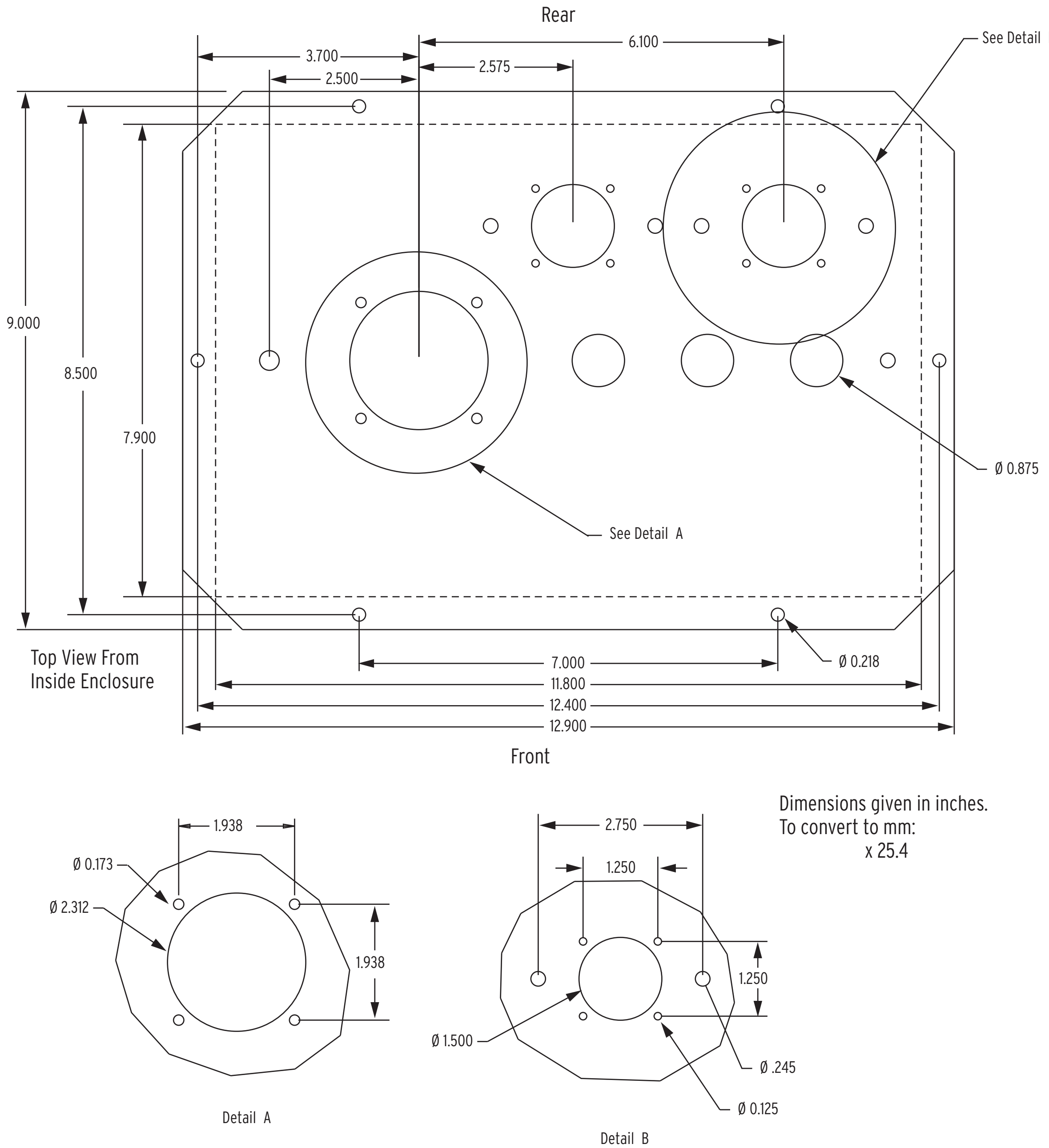


Figure 2.16 Connector Panel at Bottom of Enclosure for Joslyn TriMod 600R Recloser (Dual-Door Enclosure)

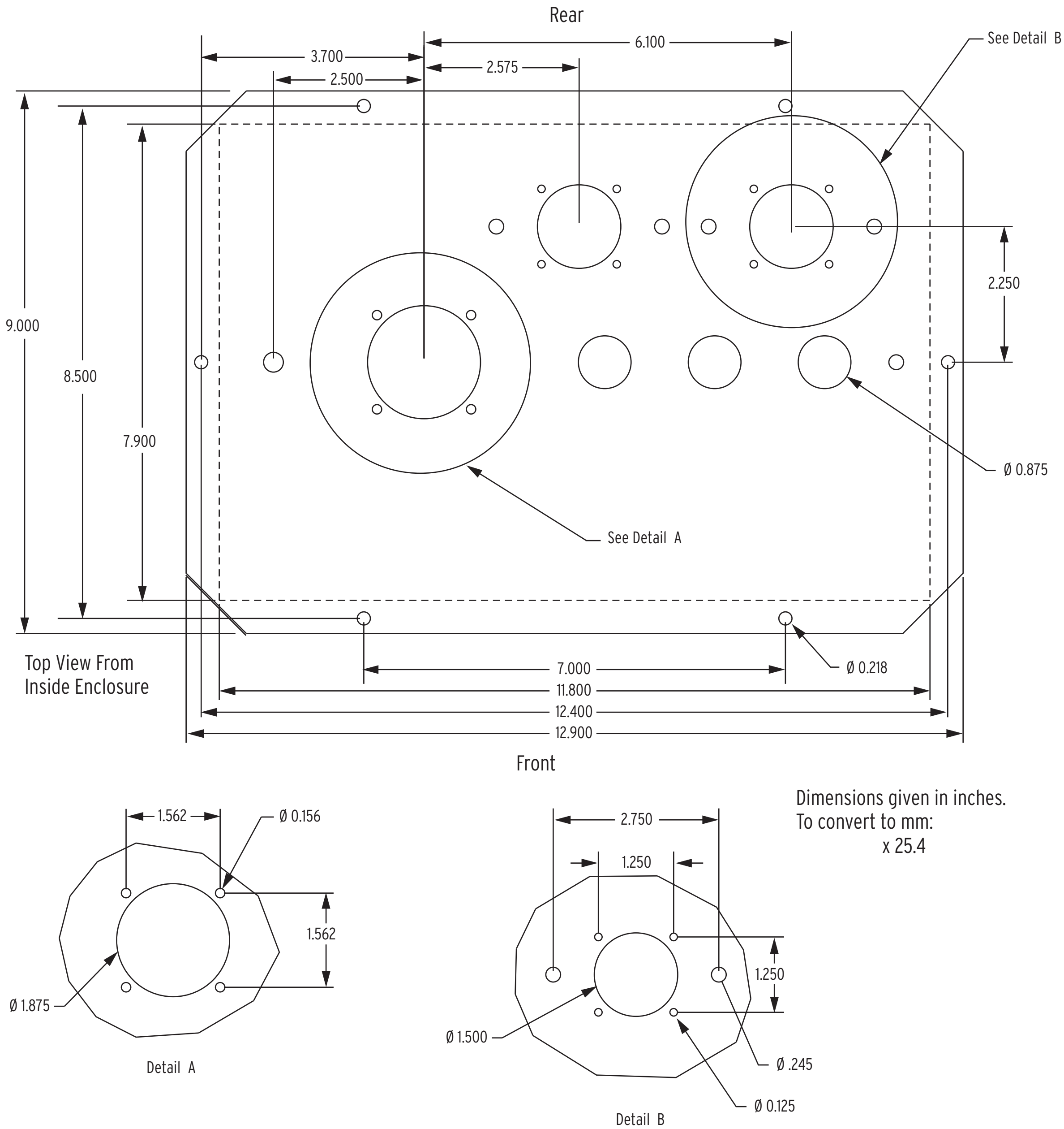


Figure 2.17 Connector Panel at Bottom of Enclosure for Kyle NOVA-TS or NOVA-STS Triple-Single Recloser (Dual-Door Enclosure)

⚠WARNING
Take proper precautions to prevent personal injury or equipment damage when lifting and mounting the SEL-651R. Make sure doors are latched closed. Secure lifting attachments to the lifting holes. Lift slowly. Do not transport the SEL-651R with the battery inside the enclosure.

The drill plan detailed in *Figure 2.12* (37 inches on center) is the same as the traditional drill plan for double-size Kyle® enclosures. If a retrofit of such an enclosure is taking place, no extra drilling of the pole or mounting structure is needed.

Mounting Bolts/Washers: SEL does not provide the 5/8-inch mounting bolt/washer assemblies required for mounting the SEL-651R. The mounting hole on the enclosure is 2 inches in diameter, so any washer used with the mounting bolt must be less than 2 inches in diameter.

⚠DANGER
If the recloser is energized while the control cable is disconnected from the recloser control, the CT secondaries in the control cable may generate dangerously high voltages. Do not come in contact with the pins or pin sockets in the control cable. Contact with high voltage can cause serious injury or death.

The SEL-651R has one 1.5 inch diameter lifting-hole on the mounting-bracket (angled out on top at 45 degrees) and one 1.5-inch diameter lifting-hole on the smaller centered bracket at the top of the other side of the enclosure.

Step 1. Secure lifting attachments to the lifting holes.

Step 2. Lift slowly.

Step 3. Slip the top mounting hole/keyway over the top mounting bolt/washer assembly.

Step 4. Rest the unit on the bolt, settled in the keyway slot.

Step 5. Secure the bottom mounting bracket with another mounting bolt/washer assembly.

Step 6. Secure both top and bottom mounting bolt/washer assemblies.

The unit weighs (fully-featured) 68 kg (≤150 lb.), without the battery. Battery weights are given in *Table 2.6*.

Single-Door Control Mounting

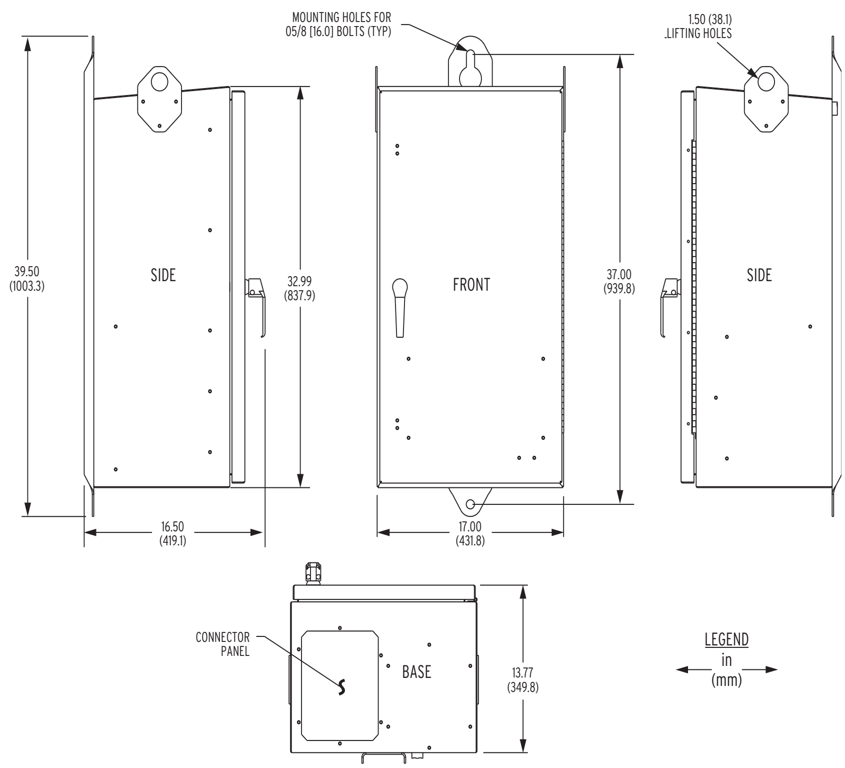


Figure 2.18 SEL-651R Enclosure Dimensions and Mounting Drill Plan (Single-Door Enclosure)

⚠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.

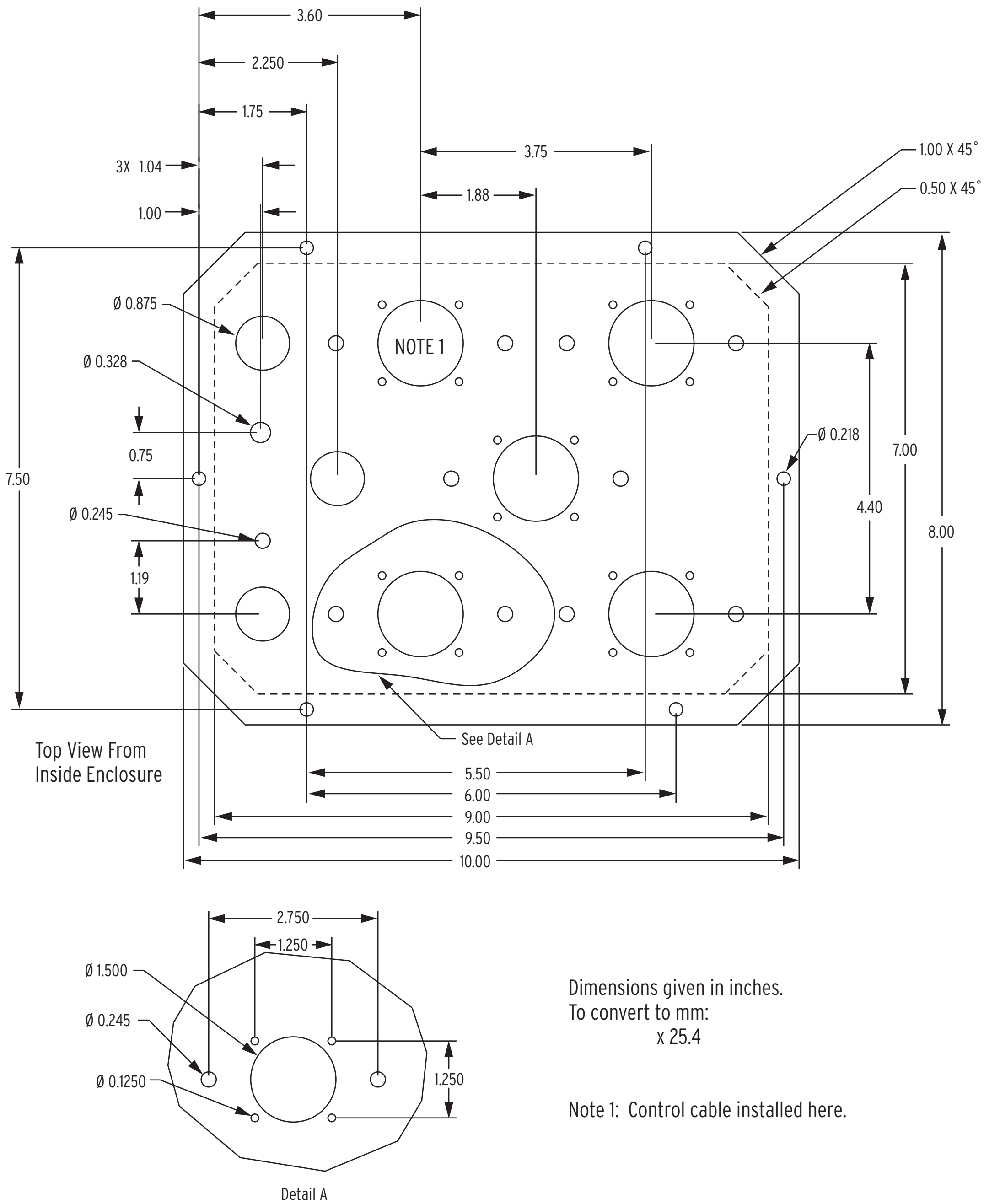


Figure 2.19 Connector Panel at Bottom of Enclosure for Traditional Retrofit and Control-Powered Kyle NOVA Recloser (Single-Door Enclosure)

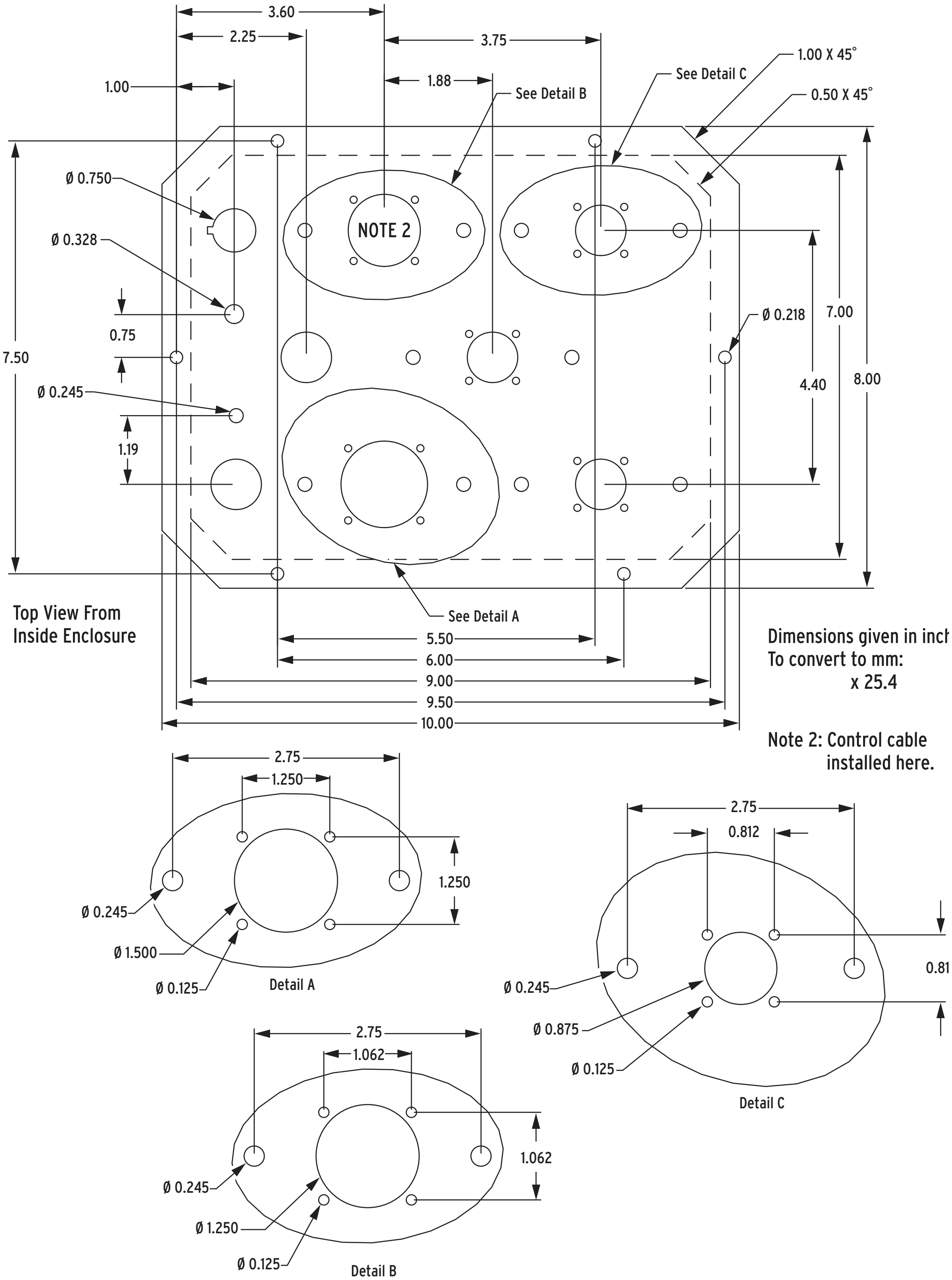


Figure 2.20 Connector Panel at Bottom of Enclosure for G&W Viper-ST Recloser (Single-Door Enclosure)

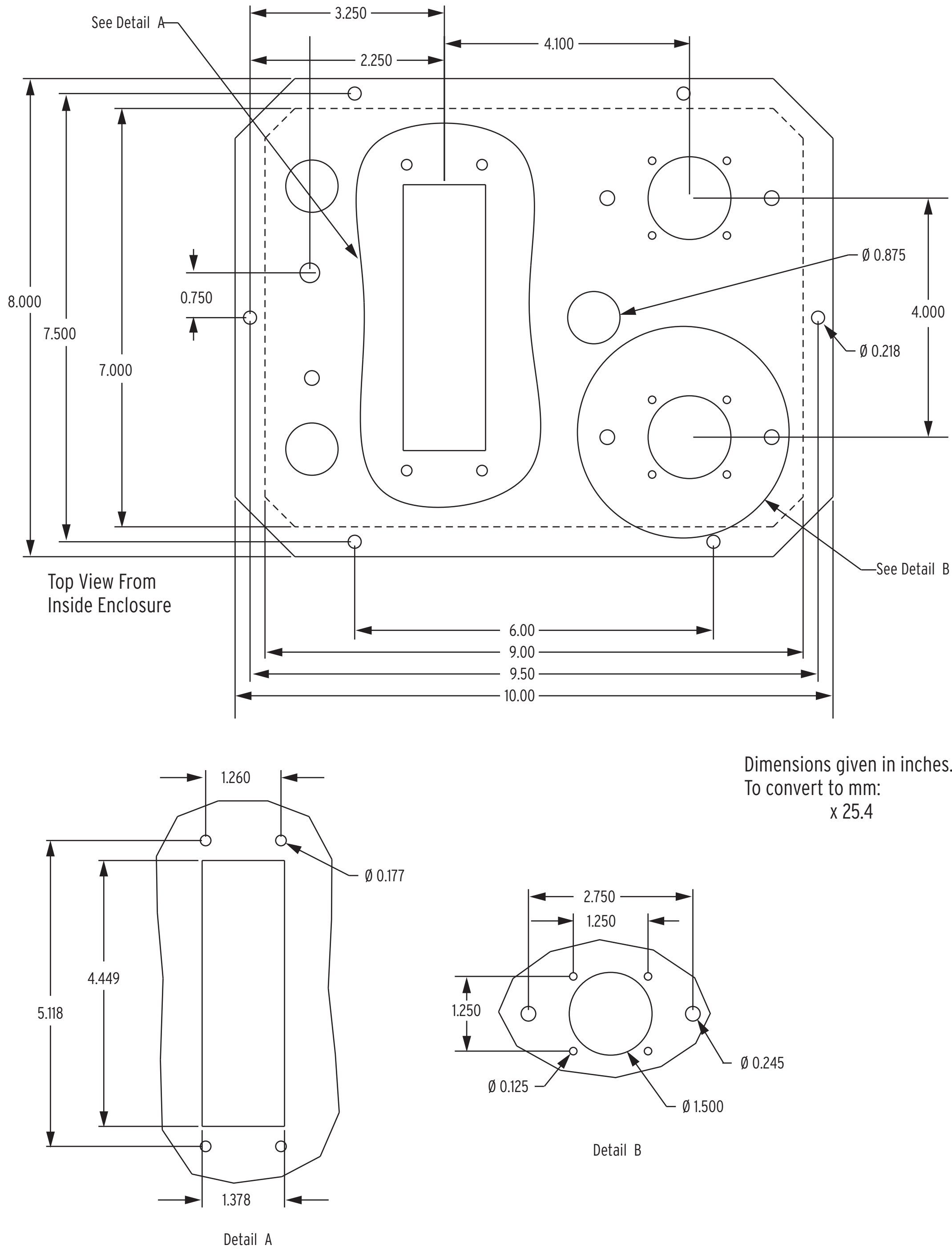


Figure 2.21 Connector Panel at Bottom of Enclosure for ABB OVR-3/VR-3S (15 and 27 kV models) Recloser (Single-Door Enclosure)

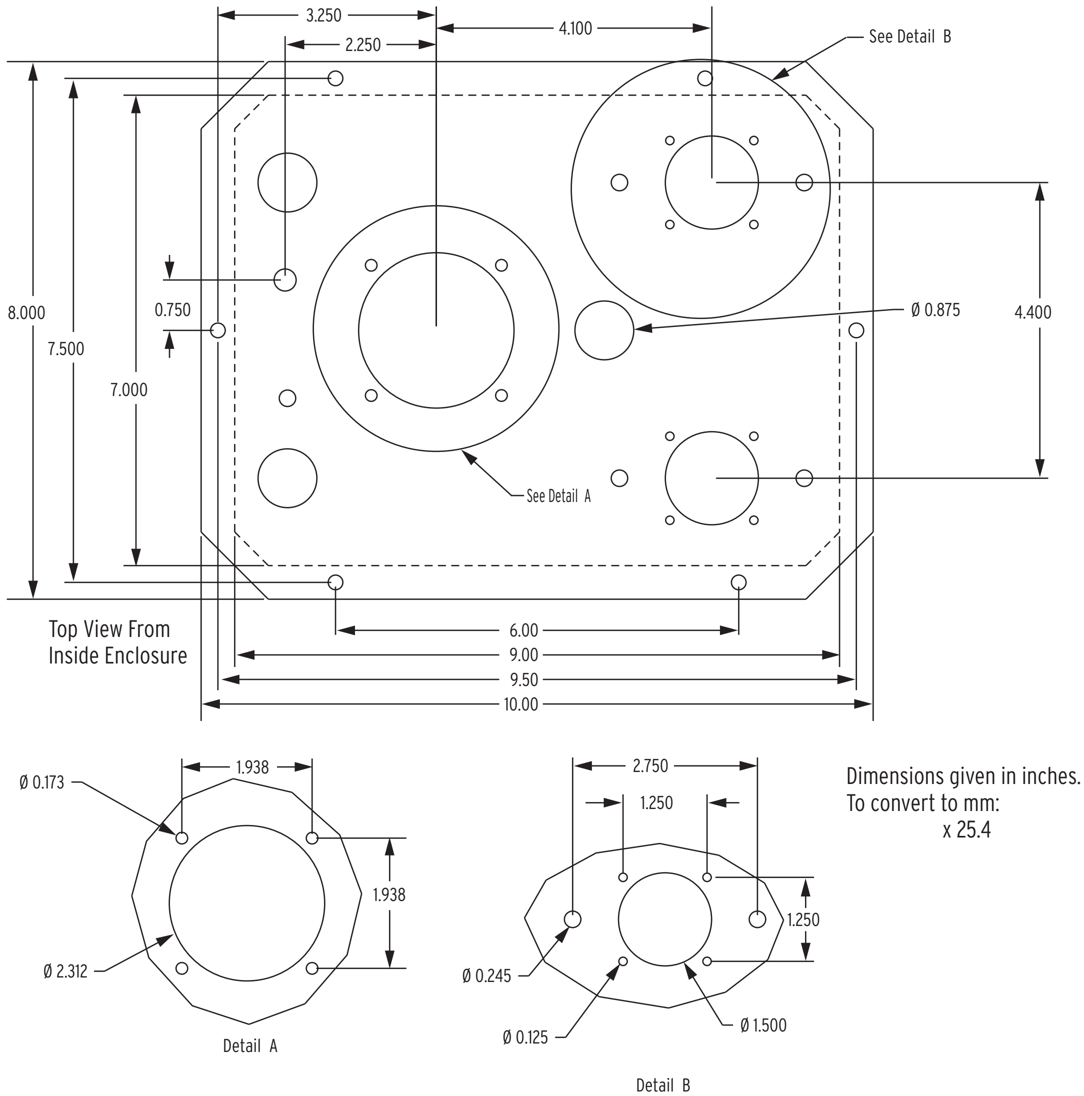


Figure 2.22 Connector Panel at Bottom of Enclosure for Joslyn TriMod 600R Recloser (Single-Door Enclosure)

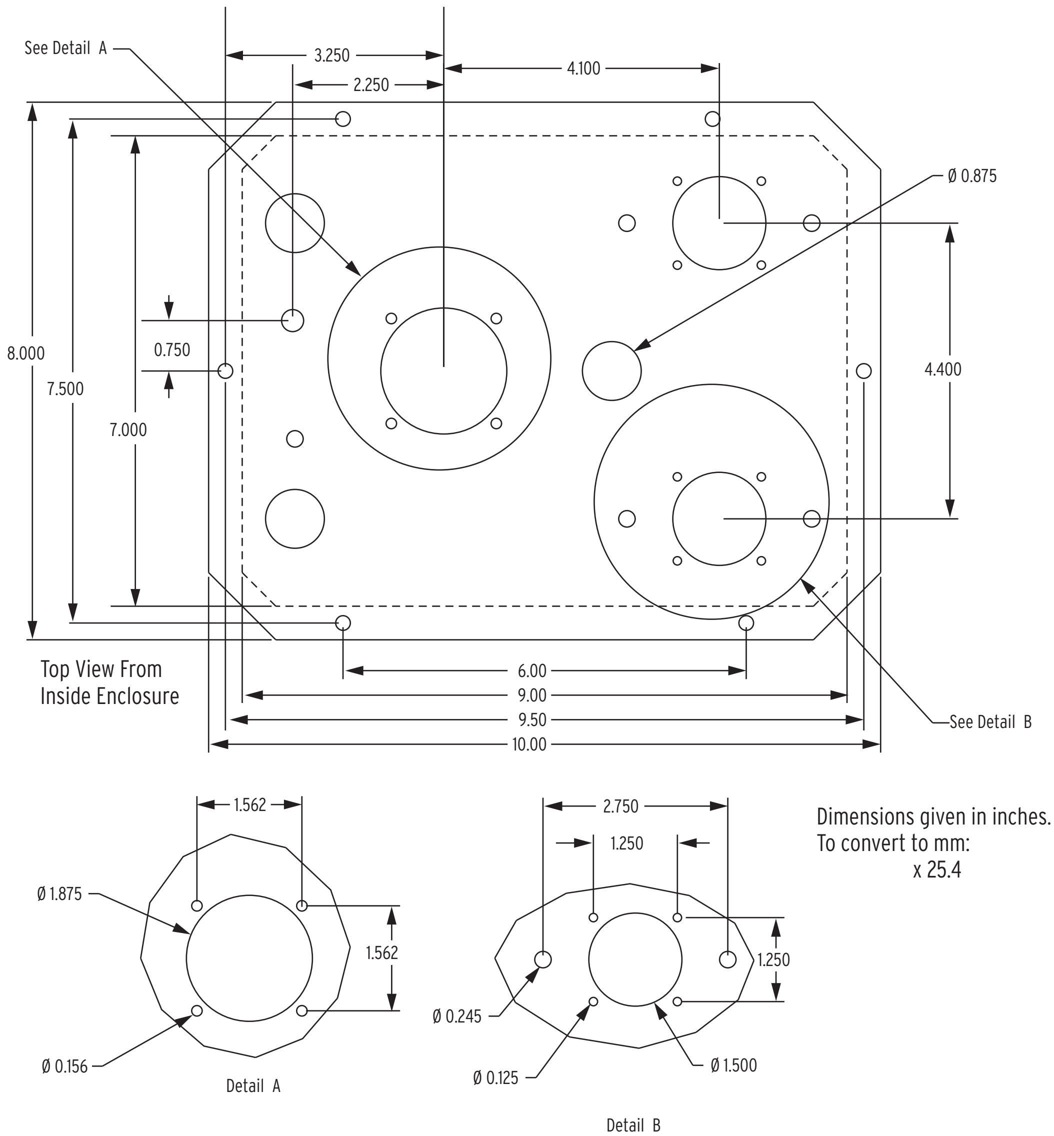


Figure 2.23 Connector Panel at Bottom of Enclosure for Kyle NOVA-TS or NOVA-STS Triple-Single Recloser (Single-Door Enclosure)

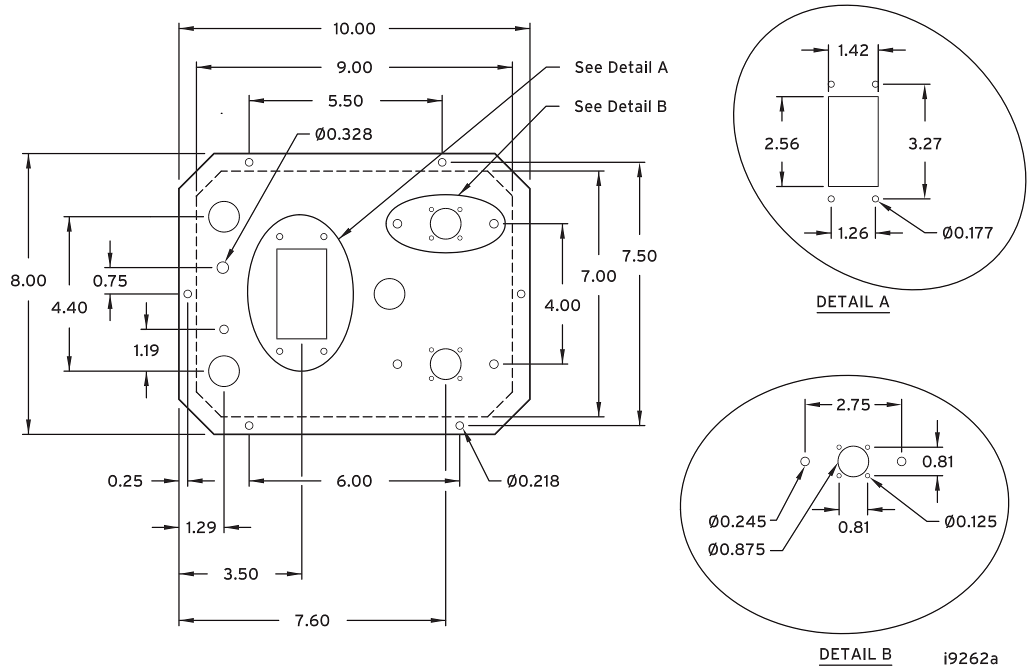


Figure 2.24 Connector Panel at Bottom of Enclosure for Tavrida OSM Recloser (Single-Door Enclosure)

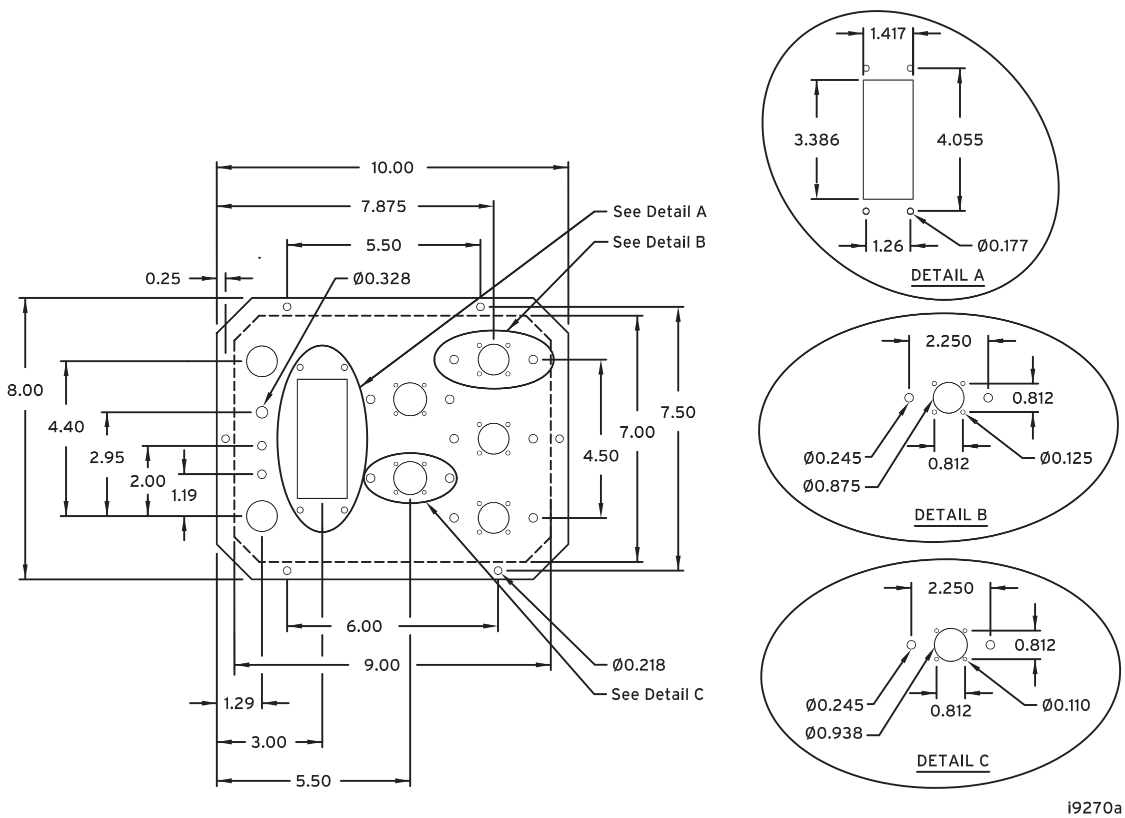


Figure 2.25 Connector Panel at Bottom of Enclosure for Siemens SDR Triple-Single and Siemens SDR Three-Phase reclosers (Single-Door Enclosure)

⚠WARNING
Take proper precautions to prevent personal injury or equipment damage when lifting and mounting the SEL-651R. Make sure doors are latched closed. Secure lifting attachments to the lifting holes. Lift slowly. Do not transport the SEL-651R with the battery inside the enclosure.

⚠DANGER
If the recloser is energized while the control cable is disconnected from the recloser control, the CT secondaries in the control cable may generate dangerously high voltages. Do not come in contact with the pins or pin sockets in the control cable. Contact with high voltage can cause serious injury or death.

The drill plan detailed in *Figure 2.18* (37 inches on center) is the same as the traditional drill plan for double-size Kyle® enclosures. If a retrofit of such an enclosure is taking place, no extra drilling of the pole or mounting structure is needed.

Mounting Bolts/Washers: SEL does not provide the 5/8-inch mounting bolt/washer assemblies required for mounting the SEL-651R. The mounting hole on the enclosure is 2 inches in diameter, so any washer used with the mounting bolt must be less than 2 inches in diameter.

The SEL-651R has one 1.5 inch diameter lifting-hole on each side of the enclosure.

Step 1. Secure lifting attachments to the lifting holes.

Step 2. Lift slowly.

Step 3. Slip the top mounting hole/keyway over the top mounting bolt/washer assembly.

Step 4. Rest the unit on the bolt, settled in the keyway slot.

Step 5. Secure the bottom mounting bracket with another mounting bottom bolt/washer assembly.

Step 6. Secure both top and bottom mounting bolt/washer assemblies.

The unit weighs (fully-featured) 68 kg (≤150 lb.), without the battery. Battery weights are given in *Table 2.6*.

Control Grounding

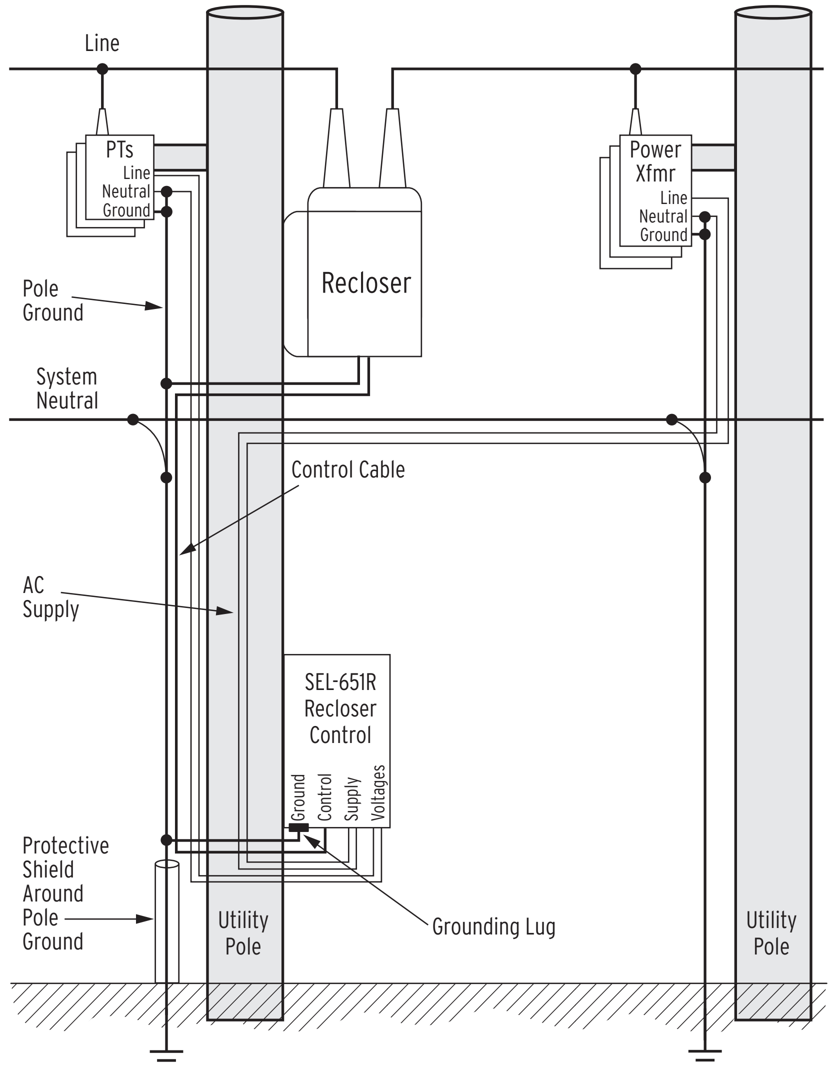


Figure 2.26 SEL-651R Recloser Control Customer Ground Connection to Required System Grounding

IMPORTANT: All devices interfacing to the SEL-651R Recloser Control must be connected to the same pole ground. Figure 2.26 shows a suggested method of making these connections.

IMPORTANT: All connections to the SEL-651R Recloser Control must be routed in close proximity to and parallel to their corresponding ground paths for adequate surge protection. The connections and their ground paths should be approximately equal in length. Use applicable IEEE and IEC grounding standards. Follow the proceeding recommendations to reduce high potentials from surges that can damage equipment.

Step 1. Connect the pole ground to the grounding lug on the bottom of the recloser control enclosure as shown in *Figure 2.26*.

The grounding lug accommodates No. 10 through No. 4 conductors (solid or stranded) (up to two No. 4). A protective shield around the pole ground is suggested to help prevent physical damage to the ground wire, such as preventing an open circuit.

Step 2. Ground all devices interfacing to the recloser control at the same pole ground.

Devices include: recloser, power transformer, potential transformers/voltage transducers, and SCADA. Even devices on adjacent poles with their own pole ground (e.g., power transformer) must still connect to the pole ground for the recloser control.

Step 3. Route the control cable in close proximity to and parallel with the recloser ground.

IMPORTANT: All external control wiring brought into the SEL-651R Recloser Control enclosure should be protected within shielded cables. Ground these cable shields inside the enclosure at the hex head bolt (#10-32, stainless steel) that protrudes through the floor of the enclosure.

ENCLOSURE OPENINGS
No openings into the SEL-651R enclosure should be left uncovered with the exception of the vented hole plugs provided by SEL. Any conduit or other wire entry must be properly sealed.

Step 4. Route ac supply voltage (power) and power system voltages in parallel with their transformer ground paths.

Step 5. Ground any shielding for control wiring connections to the optional optoisolated inputs IN101 through IN107 and output contacts OUT101 through OUT108.

Step 6. Make these ground connections to the hex head bolt, mentioned in *Step 1*, that protrudes through the floor of the enclosure.

Step 7. Bring all other points that require grounding (e.g., a radio) inside the SEL-651R enclosure to the hex head bolt and make the connections secure.

Note that the relay module and power module are both grounded at this protruding hex head bolt.

Step 8. When installing the recloser control and recloser, include the following according to the manufacturers' recommendations:

- ➢ Protection of the recloser and the power transformer with lightning arresters.
- ➢ Grounding of the recloser head and tank.
- ➢ Grounding of the power transformer tank.
- ➢ Grounding of the control cabinet.

Battery Installation and Connection

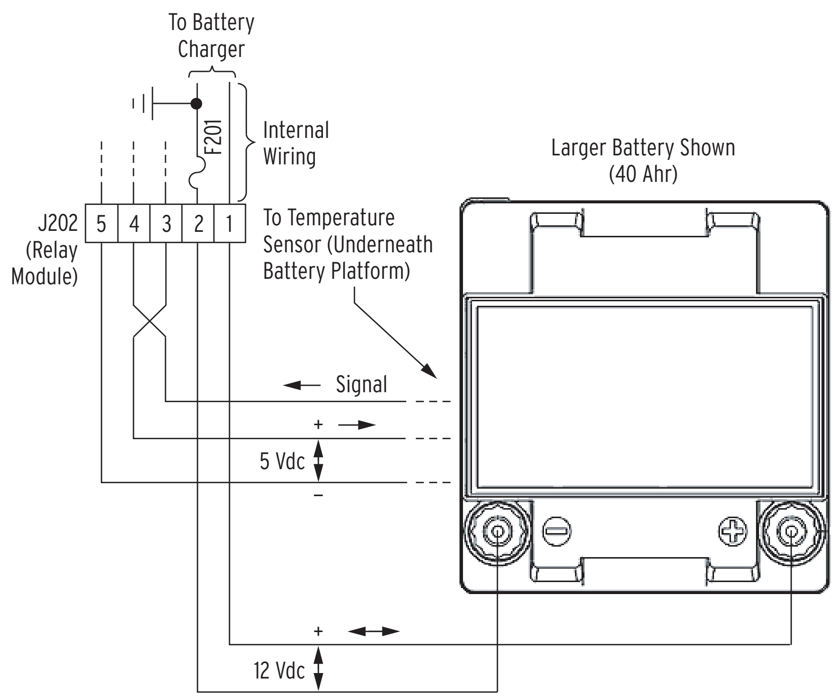


Figure 2.27 Battery Wiring Harness Connections (Shown Connected to Relay Module)

⚠CAUTION
Disconnect separable connector J202 from the back of the relay module before disconnecting the battery terminals and removing the battery. Connect J202 last when installing the battery. Do not leave the cable harness for J202 connected without the batteries also connected. The ring terminals on the battery wiring harness (that connect directly to the battery terminals) are energized and can short-circuit if they come in contact with the enclosure floor or each other, consequently damaging the internal power supply in the relay module.

Step 1. Follow any manufacturer installation recommendations and warnings for the battery.

Step 2. Remove separable connector J202 from the back of the relay module (see ⚠).

Note that the battery wiring harness has two terminals for connection to the battery, plus three wires that go underneath the raised battery platform to the battery temperature monitor.

Step 3. Unbuckle and move the two side-release buckle straps so that the raised battery platform is clear.

The straps should already be fitted underneath the slots provided on the raised platform, one strap oriented in one horizontal dimension and the other strap in the other horizontal dimension.

Step 4. Set the 12 V battery on the raised battery platform, with the terminals up and oriented toward the center of the enclosure.

Step 5. Fasten and secure the two side-release buckle straps over the battery, keeping the battery terminals clear.

Step 6. Connect the battery wiring harness to the battery terminals (separable connector J202 is still removed/disconnected from the back of the relay module).

The positive (+) battery terminal connects to the harness wire that terminates on pin position 1 on separable connector J202, as shown in *Figure 2.27*. The negative (–) battery terminal connects to the other available harness wire that terminates on pin position 2 on separable connector J202.

Step 7. Reconnect separable connector J202 to the back of the relay module.

Proceed to *Wake Up* to turn on the control using the {**WAKE UP**} pushbutton. The front panel will remain dark until you press the {**WAKE UP**} pushbutton.

⚠WARNING
Do not transport the SEL-651R with the battery inside the enclosure.

See *Battery and Fuse Replacement on page 2.51* for more battery information.

See *Battery System Monitor on page 8.34* for help on testing the battery.

Wake Up

With the battery installed, press the front-panel {**WAKE UP**} pushbutton to energize the SEL-651R.

- If the unit turns on, the **ENABLED** LED illuminates and the **BATTERY PROBLEM** LED remains extinguished.
- If the unit does not turn on, check the following items:
  - Battery condition.
  - Battery fuse (panel-mount fuse F201 on the rear panel of the relay module, next to separable connector J202). See *Figure 2.27* and *Table 2.7*.

Note that application of Vac power (120 or 230 Vac, depending on unit) always energizes the SEL-651R.

Power Connections

Order the power supply of the SEL-651R at one of the following nominal voltage levels:

- 120 Vac [includes a Ground Fault Circuit Interrupter (GFCI) convenience outlet on the front]
- 230 Vac
- 125 Vdc

The serial number label lists the power supply rating. *Figure 2.28*, *Figure 2.29*, and *Figure 2.30* show the simplest 120 Vac, 230 Vac, and 125 Vdc power connections, respectively. These connections are made in the upper-right corner of the rear panel of the power module. Note that fuse protection is provided for both of these scenarios. The fuse blocks have

NOTE: When 120 Vac (or 230 Vac, depending on ordered unit) power is correctly connected to the SEL-651R, the front-panel SUPPLY LED illuminates. If it is still extinguished, check fuse F412 (for the 120 Vac power supply) or both fuses F411 and F412 (for the 230 Vac power supply)—see Table 2.7. The SUPPLY LED illuminates if the relay module is powered-up/functional and the battery is not discharging. The SUPPLY LED may flicker at times when tripping or closing, because of the battery momentarily discharging.

The connected 120 Vac (or 230 Vac) power source is isolated from the power module chassis ground.

integral fuse pullers, for ease of safely removing/installing fuses. Pull these fuses to de-energize/isolate the modules, although battery power can still keep the modules on. Fuse values are given in *Table 2.7*.

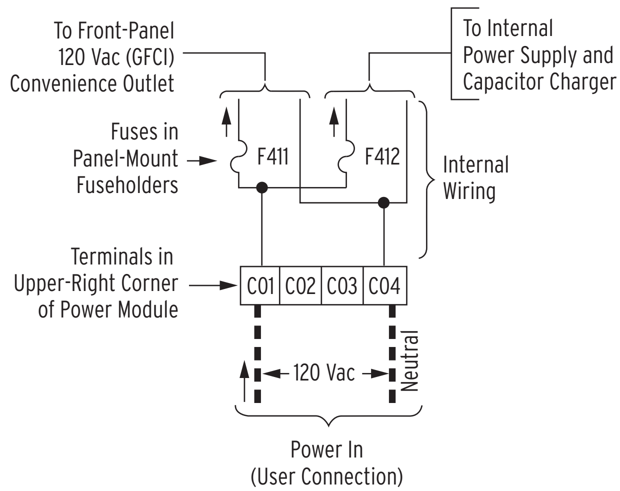


Figure 2.28 120 Vac Power Connection

For the 120 Vac connection, the screws on terminals C01 and C04 are #10-32 [use max. width 11.4 mm (0.45 in) ring terminals; tightening torque of 1.0 to 2.0 Nm (9 to 18 in-lb.)].

The 120 Vac power option has other possible connection options and accessories, detailed in *Figure 2.31* through *Figure 2.35*.

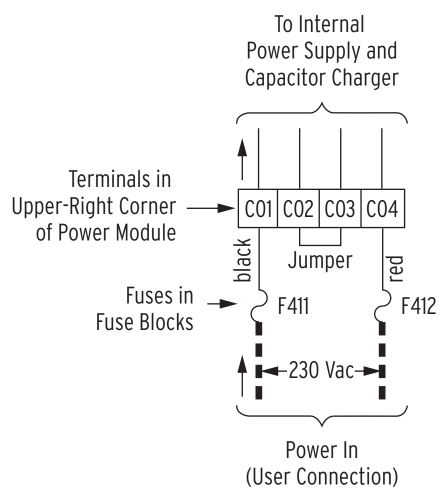


Figure 2.29 230 Vac Power Connection

For the two-wire 230 Vac connection, the screws on fuse blocks F411 and F412 are #10-32 [use max. width 11.4 mm (0.45 in) ring terminals; tightening torque of 1.0 to 2.0 Nm (9 to 18 in-lb.)].

The 230 Vac power option has only the connection in *Figure 2.29*. No front-panel GFCI convenience outlet is provided with the 230 Vac power option.

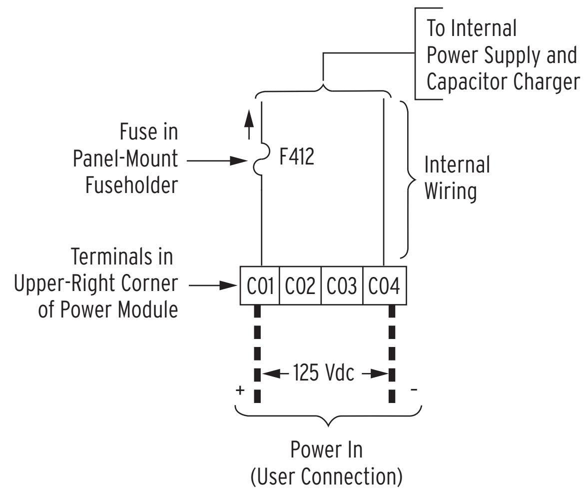


Figure 2.30 125 Vdc Power Connection

For the 125 Vdc connection, the screws on terminals C01 and C04 are #10-32 [use max. width 11.4 mm (0.45 in) ring terminals; tightening torque of 1.0 to 2.0 Nm (9 to 18 in-lb.)].

The 125 Vdc power option has only the connection in *Figure 2.30*. No front-panel GFCI convenience outlet is provided with the 125 Vdc power option.

Additional 120 Vac Power Connection Options and Accessories

Figure 2.31 through *Figure 2.35* show additions to the simple 120 Vac power connection in *Figure 2.28*. The Universal Fuseblock, AC Transfer Switch, 3-Pin Power Receptacle, and Low-Voltage Close accessories, discussed herein, can be installed on a 120 Vac powered unit.

Universal Fuseblock

The Universal Fuseblock in *Figure 2.31* appears to provide redundant fusing (fuse F407 in line with fuses F411 and fuse F412). But, with the addition of the low-voltage (120 Vac) close option for Traditional Retrofit reclosers (see *Figure 2.35*), the Universal Fuseblock provides protection for this effective 120 Vac exposure going out to the recloser. The Universal Fuseblock is mounted near the center of the rear panel of the power module. The fuse blocks have integral fuse pullers, for ease of safely removing or installing fuses. Fuse values are given in *Table 2.7*.

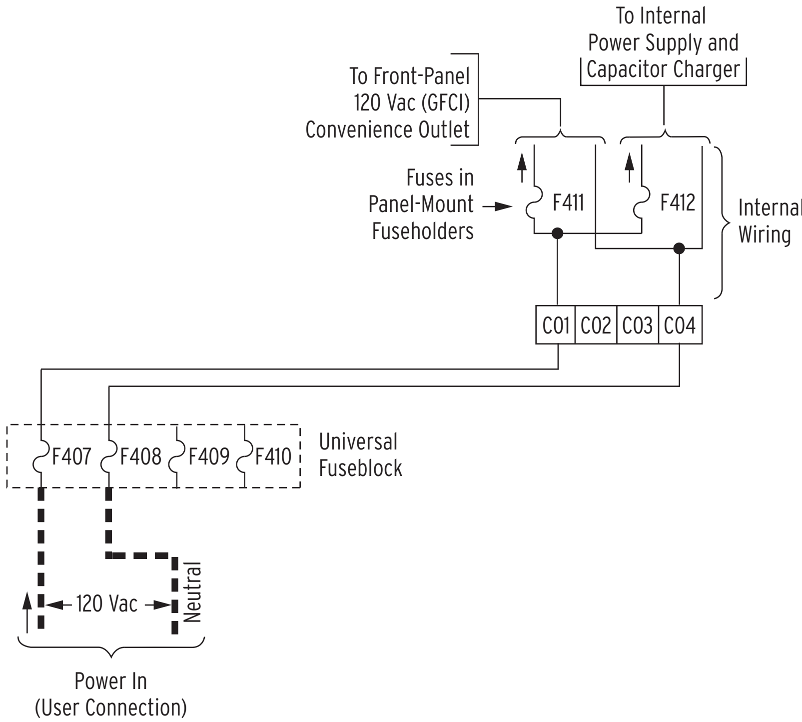


Figure 2.31 Universal Fuseblock Power Connection

For the Universal Fuseblock connection, the screws on fuse blocks F407 through F410 are #10-32. Use max. width 11.4 mm (0.45 in) ring terminals; tightening torque of 1.0 to 2.0 Nm (9 to 18 in-lb.).

AC Transfer Switch

The AC Transfer Switch in *Figure 2.32* is used in automatic network reconfigurations, to switch the SEL-651R to an alternate source of power if the primary source is unavailable. Two separate 120 Vac power sources are brought to the Transfer Switch. The Transfer Switch is a break-before-make switch, so the two 120 Vac power sources are never paralleled. More operation details on the Transfer Switch are found in *Figure 2.44* and accompanying text. The Transfer Switch is mounted on the right side of the rear panel of the power module.

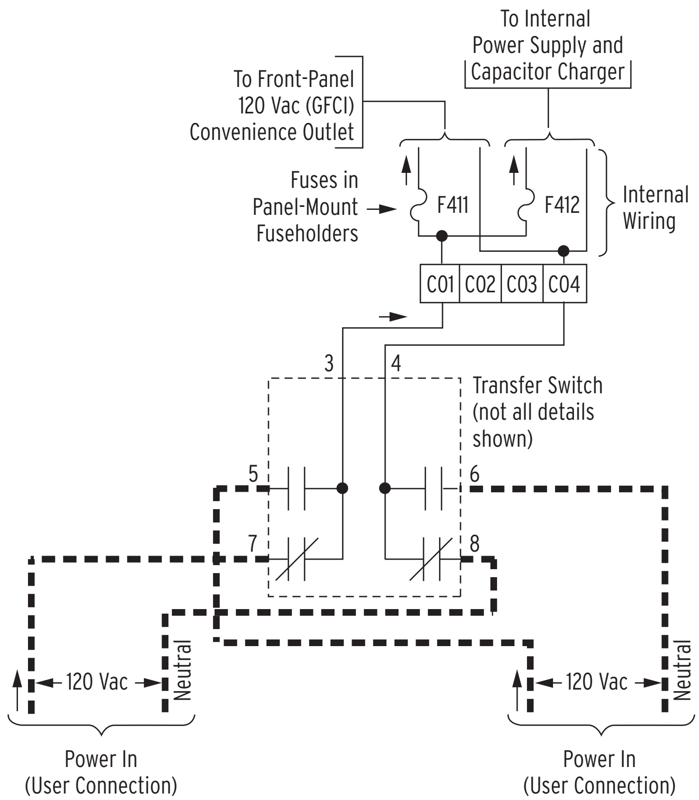


Figure 2.32 AC Transfer Switch Power Connections

For the Transfer Switch connection, the screws on the Transfer Switch terminals (numbered 1 through 8) are #10-32 [use max. width 11.4 mm (0.45 in) ring terminals; tightening torque of 1.0 to 2.0 Nm (9 to 18 in-lb.)].

Figure 2.33 shows the combination of the Universal Fuseblock and the Transfer Switch, with the Universal Fuseblock providing fuse protection for the Transfer Switch and every 120 Vac circuit beyond it.

120 Vac power sources for recloser controls are typically provided by dedicated distribution power transformers (e.g., 5 kVA), mounted on adjacent poles/structures (see *Figure 2.26*). *Figure 2.36* and *Figure 2.38* in the following subsection show other possible wiring to provide 120 Vac power.

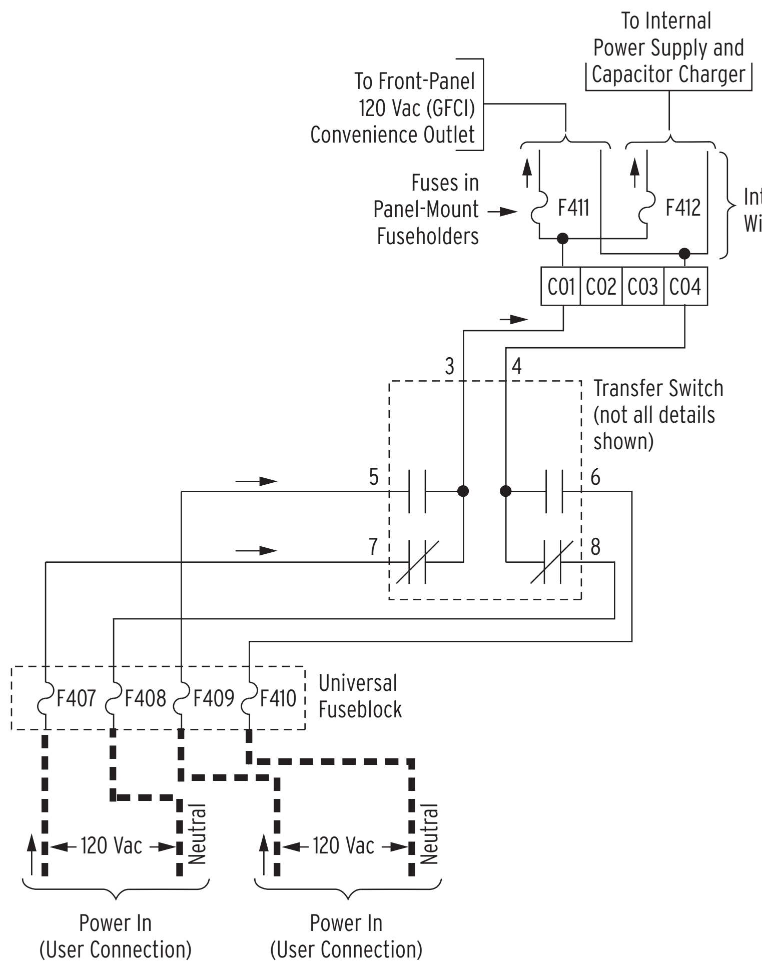


Figure 2.33 Universal Fuseblock/AC Transfer Switch Power Connections

3-Pin Power Receptacle (G&W Viper-ST Recloser Only)

To ease connection and removal of 120 Vac power, install the 3-pin power receptacle accessory (see *Figure 2.34*). A 3-pin power receptacle can be applied in *Figure 2.28* or *Figure 2.31*; and two 3-pin power receptacles can be applied in *Figure 2.32* or *Figure 2.33*, where 120 Vac, Power In (User Connection) is listed.

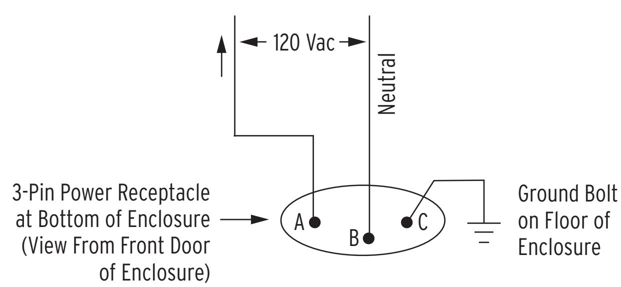


Figure 2.34 3-Pin Power Receptacle

This 3-pin power receptacle accessory is installed at the bottom of the enclosure (male pins to the outside), ready for receiving an outside cable (female sockets on cable). Such an outside cable then connects to a 120 Vac power source. Note in *Figure 2.34* that Pin C on the receptacle is connected to the hex head bolt (#10-32, stainless steel) that protrudes through the floor of the enclosure.

The key for the receptacle (to help in guiding outside cable connection) is oriented toward the rear door of the enclosure.

Low-Voltage Close Power (Traditional Retrofit Recloser Only)

Many Traditional Retrofit reclosers need 120 Vac power in order to close the main recloser contacts. Close operations for traditional reclosers are started with the 24 Vdc close circuit (see *Figure 2.46*), but the power required to close the main contacts and compress the tripping springs in the recloser is usually either 120 Vac, as discussed here, or primary voltage. This depends on recloser construction.

For convenience, such 120 Vac power can be brought out to the bottom of the enclosure from terminals C01 (120 Vac) and C04 (neutral) on the relay module (see *Figure 2.35*). This low-voltage close power accessory has a 2-socket receptacle at the bottom of the enclosure (female sockets to the outside), ready for receiving an outside 2-pin (male) cable connection. This outside cable (SEL cable C515) then takes the 120 Vac power out to the recloser.

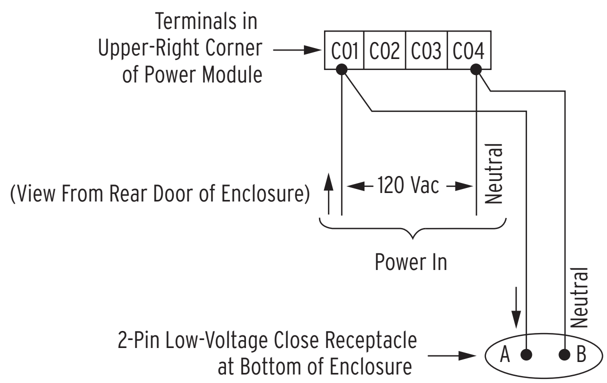


Figure 2.35 Low-Voltage Close Power Connections

The key for the receptacle (to help in guiding outside cable connection) is oriented toward the rear door of the enclosure.

Voltage Connections

In addition to traditional three-phase voltage connections, this subsection discusses:

- 8-pin receptacles for ease of connection and removal of power system secondary voltages
- Low-energy analog (LEA) voltage inputs connections
- Settings for designating phase connections
- Single-phase (line-neutral) and phase-to-phase voltage connections

Three-Phase Voltage Connections

Figure 2.36 shows two three-phase, Y-connected voltage circuits connected to the relay module voltage inputs (terminals Z09 through Z16; voltage inputs rated up to 300 Vac, line-neutral), via the Voltage Input Fuseblock. The Voltage Input Fuseblock can be installed as an accessory for a 120 Vac-powered unit. The fuse blocks have integral fuse pullers, for ease of safely removing or installing fuses. Pull these fuses to simulate loss-of-voltage. Fuse values are given in *Table 2.7*.

If desired, the three-phase voltage circuits can be connected directly to the relay module voltage inputs (terminals Z09 through Z16) in *Figure 2.36*, without going through the Voltage Input Fuseblock, although it is recommended that there be some kind of overcurrent protection on such voltage circuits. The three-phase voltage connections are used for automatic network reconfiguration, under-/overvoltage elements, synchronism-check elements, power elements, metering, and so forth.

If the three-phase, Y-connected voltage circuits brought into the Voltage Input Fuseblock are capable of providing 120 Vac line-neutral power for the 120 Vac-powered unit, then additional wiring can be installed, as shown traversing to the right in *Figure 2.36*. This single-phase power is wired from the source side of the Voltage Input Fuseblock and available for connection to the power input circuitry portrayed in preceding *Figure 2.28*, *Figure 2.31*, *Figure 2.32*, and *Figure 2.33*. The power connections portrayed in *Figure 2.36* arbitrarily show line-neutral connections to the middle phases (i.e., V2Y-NY and V2Z-NZ).

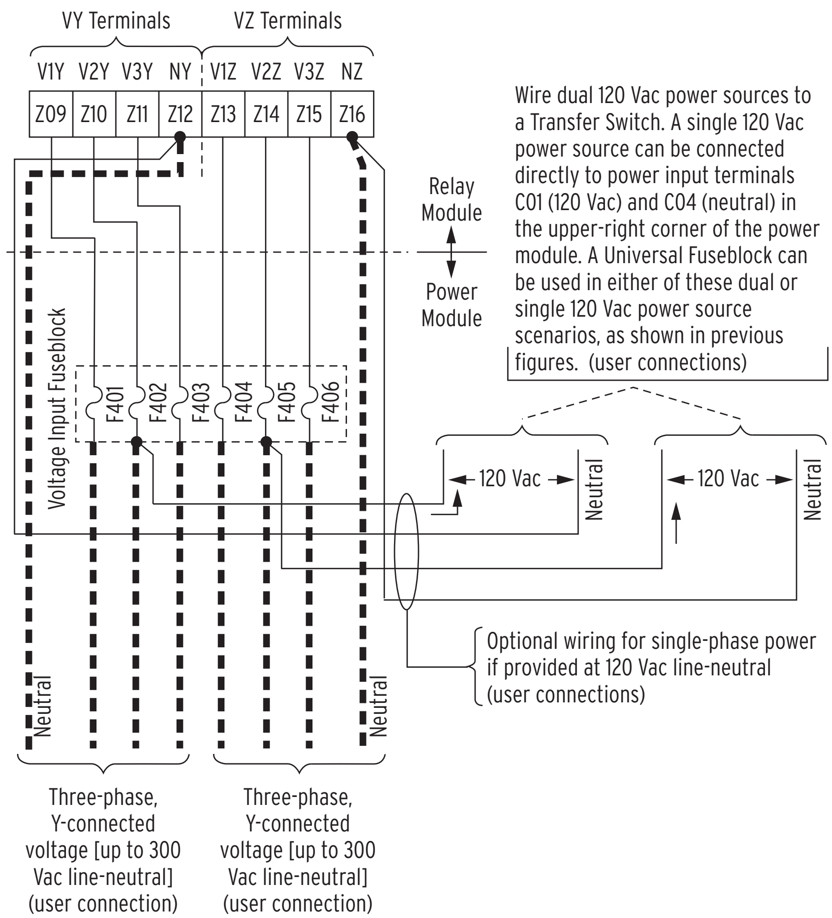


Figure 2.36 Three-Phase Voltage Connections

For voltage input connections, the screws on terminals Z09 through Z16 are #8-32. Use max. width 9.1 mm (0.36 in) ring terminals; tightening torque of 1.0 to 2.0 Nm (9 to 18 in-lb.).

For Voltage Input Fuseblock connections, the screws on fuse blocks F401 through F406 are #10-32. Use max. width 11.4 mm (0.45 in) ring terminals; tightening torque of 1.0 to 2.0 Nm (9 to 18 in-lb.).

8-Pin Receptacle for Voltage Connections

Note that the 8-pin receptacle accessories for Traditional Retrofit, Control-Powered Kyle NOVA, and Kyle NOVA-TS or NOVA-STS Triple-Single reclosers and G&W Viper-ST reclosers appear to connect the same way based on the labels, but they are different connectors (see *Figure 2.37*).

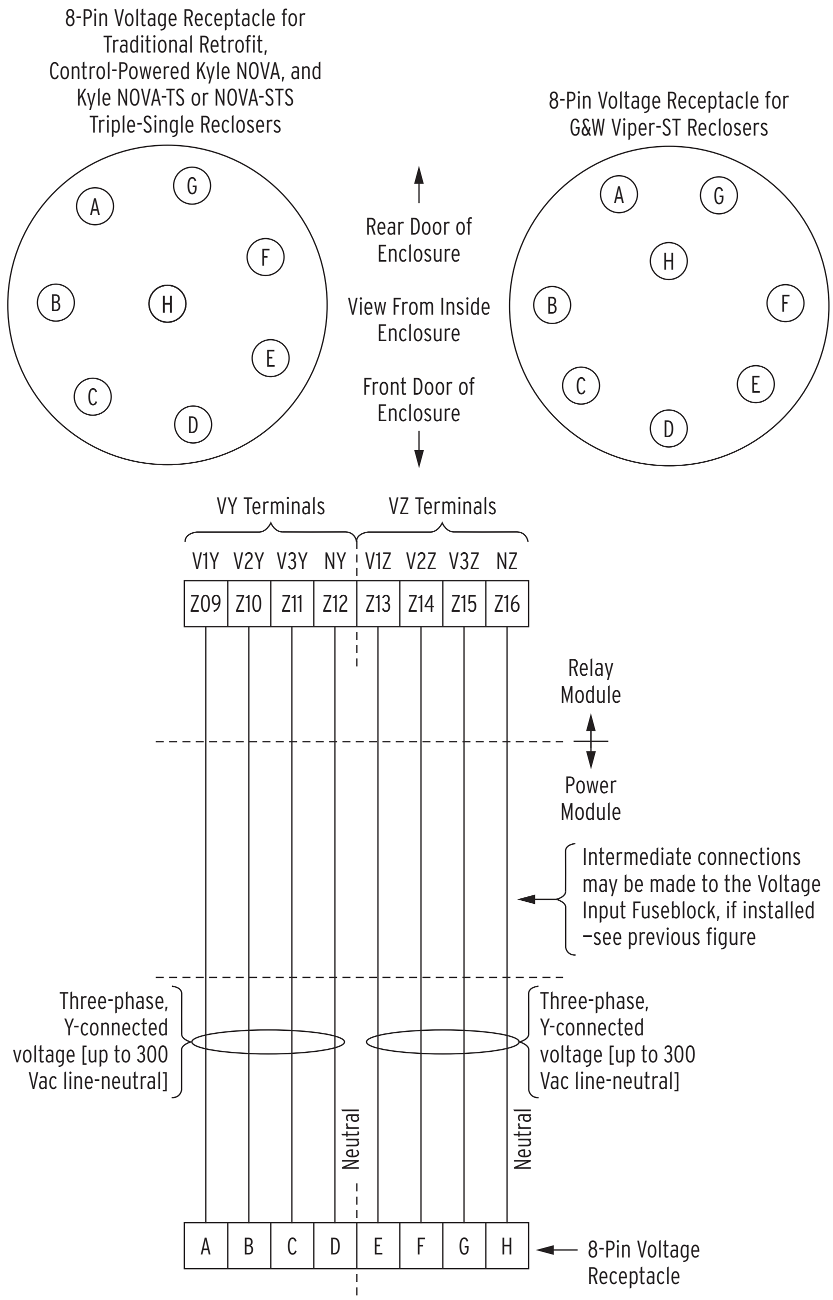


Figure 2.37 8-Pin Receptacles for Voltage Connections

For ease of connection and removal of power system secondary voltages, like those in *Figure 2.36*, install the 8-pin receptacle accessory for voltage inputs. *Figure 2.37* describes the 8-pin receptacle accessories. They are wired up directly to relay module voltage inputs Z09 through Z16 or to the intermediate Voltage Input Fuseblock, if installed, as shown in *Figure 2.36*.

This 8-pin receptacle at the bottom of the enclosure has male pins to the outside, ready for receiving an outside 8-socket (female) cable connection. Such an 8-socket cable then connects to the power system secondary voltages (e.g., three-phase, Y-connected voltages from both sides of the recloser).

The key for either receptacle (to help in guiding outside cable connection) is oriented toward the rear door of the enclosure.

LEA (Low Energy Analog) Voltage Inputs Connections

8 Vac LEA Inputs Voltage Connections

8 VAC LEA OPTIONS
There are more 8 VAC LEA input options than just that shown in Figure 2.38. See Figure 2.47 and Figure 2.61. See the SEL-651R Model Option Table.

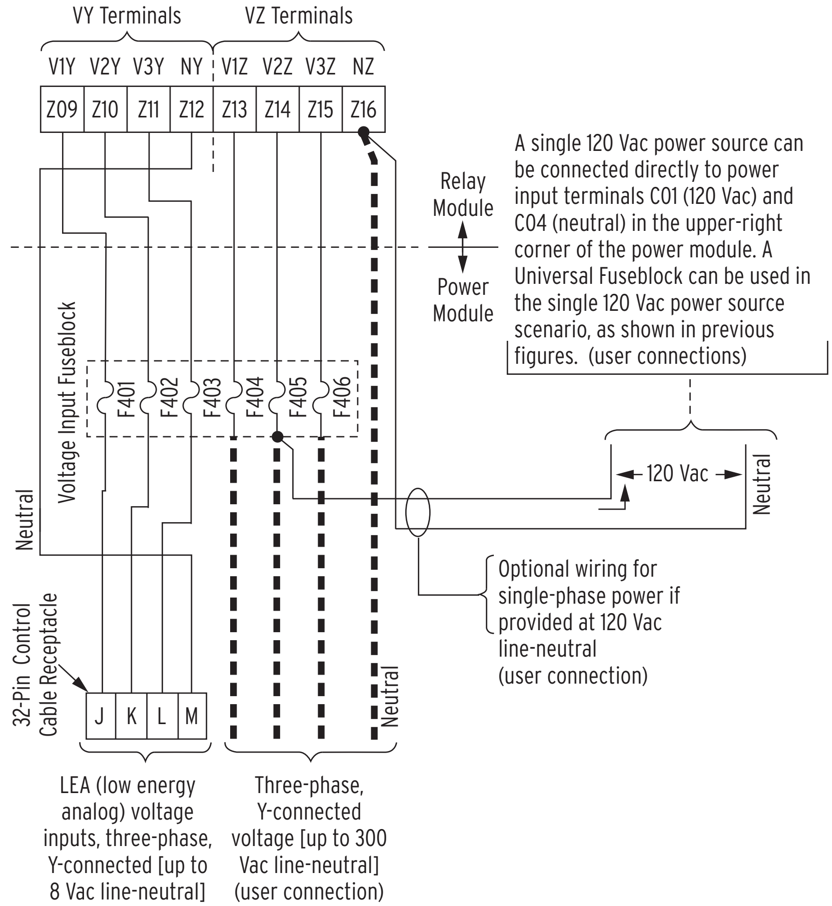


Figure 2.38 8 Vac LEA Voltage Connections for VY-Terminal Voltages (G&W Viper-ST Recloser Example)

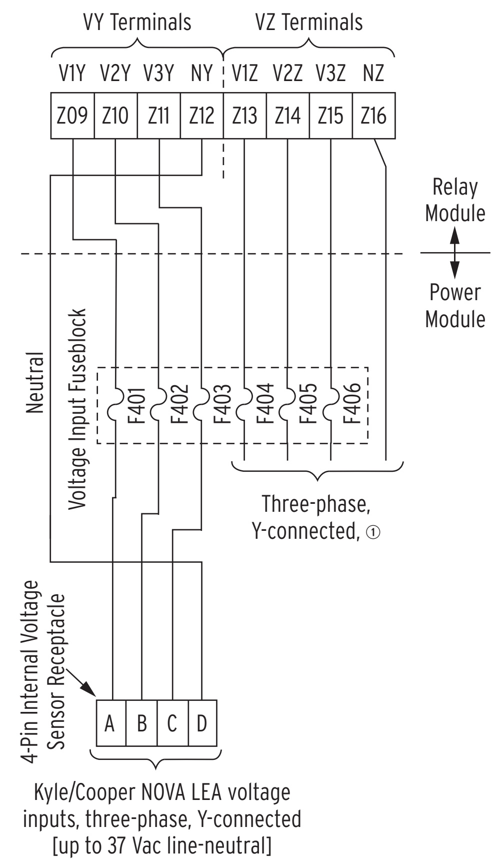
Figure 2.38 varies from *Figure 2.36* in that terminals Z09 through Z12 (VY terminals) are rated up to 8 Vac, line-neutral, instead of 300 Vac, line-neutral (VZ terminals Z13 through Z16 are rated up to 300 Vac, line-neutral (*Figure 2.38*) or 200 Vac, line-neutral (*Figure 2.40*)). This LEA ordering option for terminals Z09 through Z12 accommodates the output of the three-phase capacitive screen voltage devices from one side of the G&W Viper-ST recloser. Note the partial control cable shown at the bottom of *Figure 2.38*. These three-phase low-level voltage signals are brought from one side of the G&W Viper-ST recloser to the SEL-651R in the standard control cable. The serial number label lists the phase voltage input ratings for the VY and VZ terminals.

⚠CAUTION
The recloser control must be mounted on the same pole as the recloser when LEA inputs are used. This practice reduces surges that may damage the recloser control. Shielded cables are recommended when using LEA inputs.

These LEA voltage inputs can also be used with other low-level voltage signals, not exceeding 8 Vac. Such signals would be brought into the enclosure separately, such as through the 8-pin receptacle shown in *Figure 2.36*, not through any recloser control cable.

Kyle/Cooper NOVA LEA Inputs Voltage Connections

KYLE NOVA-TS OR NOVA-STS VOLTAGE CONNECTIONS
The Kyle NOVA-TS or NOVA-STS Triple-Single recloser can use the control cable to bring voltage sensor outputs to the SEL-651R (see Figure 2.58).



① Refer to Figure 2.38, or Figure 2.40, for VZ-terminal voltage connections.

Figure 2.39 Kyle/Cooper NOVA LEA Voltage Connections for VY-Terminal Voltages

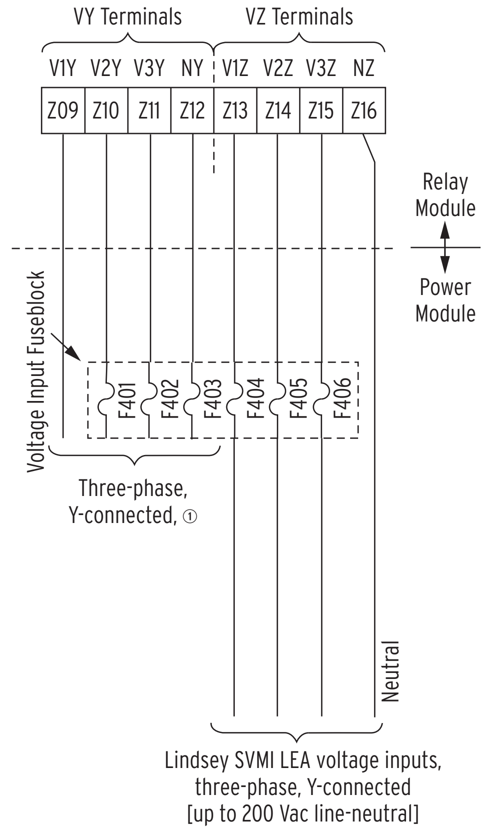
The Kyle/Cooper NOVA LEA inputs ordering option for terminals Z09 through Z12 accommodates the internal voltage sensing outputs of Kyle/Cooper NOVA reclosers.4

4-pin Internal Voltage sensor receptacle is shown at the bottom of *Figure 2.39*. These three-phase low-level voltage signals are brought from the NOVA recloser (equipped with Internal Voltage sensors) to the SEL-651R through a shielded 4-conductor cable provided by Kyle/Cooper. The serial number label lists the phase voltage input ratings for the VY and VZ terminals.

Refer to VZ-terminal voltage connections in *Figure 2.38*, if VZ-terminal voltage inputs are rated up to 300 Vac. Refer to VZ-terminal voltage connections in *Figure 2.40*, if VZ-terminal voltage inputs are Lindsey SVMI LEA inputs.

Lindsey SVMI LEA Inputs Voltage Connections

LINDSEY SVMI LEA OPTIONS
There are more Lindsey SVMI input options than just that shown in Figure 2.40. See the SEL-651R Model Option Table.



① Refer to Figure 2.36, Figure 2.38, or Figure 2.39, for VY-terminal voltage connections.

Figure 2.40 Lindsey SVMI LEA Voltage Connections for VZ-Terminal Voltages

Lindsey SVMI LEA inputs ordering option for terminals Z13 through Z16 accommodates Lindsey's Standard Voltage Monitoring Insulators (SVMI) with AC output voltage of 120 Vac and the Load impedance greater than 1 MΩ.

These three-phase low-level voltage signals are brought from Lindsey SVMI to the SEL-651R through a shielded 4-conductor cable. The serial number label lists the phase voltage input ratings for the VY and VZ terminals.

Refer to VY-terminal voltage connections in *Figure 2.36*, if VY-terminal voltage inputs are rated up to 300 Vac. Refer to VY-terminal voltage connections in *Figure 2.38*, if VY-terminal voltage inputs are 8 Vac LEA inputs. Refer to VY-terminal voltage connections in *Figure 2.39*, if VY-terminal voltage inputs are Kyle/Cooper NOVA LEA inputs.

Phase Designations for Voltage Connections

The voltage inscriptions for terminals Z09 through Z16 in *Figure 2.6*, *Figure 2.11*, *Figure 2.36*, *Figure 2.37*, and *Figure 2.38*:

V1Y, V2Y, V3Y, NY (VY terminal connections)

V1Z, V2Z, V3Z, NZ (VZ terminal connections)

have no permanent phase A, B, C designation. Phase designation is determined by global settings:

VYCONN for VY terminal connections

VZCONN for VZ terminal connections

See *Current and Voltage Connection Settings on page 9.28* for more information on these settings.

Single-Phase and Phase-to-Phase Voltage Connections

Any single-phase or phase-to-phase voltage connections are made between terminals V1Y-NY and V1Z-NZ for the VY and VZ sides, respectively. See *Current and Voltage Connection Settings on page 9.28* for information on how previously referenced global settings VYCONN and VZCONN also handle single-phase or phase-to-phase voltage connections.

Verify Settings/Set Date and Time

Note that this step presumes that the factory-set {ALTERNATE SETTINGS} operator control is operative.

Step 1. If the alternate settings are not going to be used, copy the main settings (Settings Group 1) to the alternate settings (Settings Group 2) with the **COPY** command (i.e., **COP 1 2**).

The settings in both settings groups will then be the same. If the {ALTERNATE SETTINGS} operator control pushbutton is accidentally pressed (switching the active settings group), the SEL-651R still operates on the same settings.

Step 2. Set the date and time with the **DATE** and **TIME** commands (**DAT** and **TIM**, respectively).

⚠CAUTION
Do not connect the SEL-651R to an energized recloser until all control settings have been properly programmed and verified. Failure to comply can result in control and recloser misoperation, equipment damage, and personal injury.

Disable Ground

Note that this step presumes that the factory-set {GROUND ENABLED} operator control is operative.

Disable ground overcurrent tripping with the {GROUND ENABLED} operator control on the SEL-651R (corresponding LED extinguishes). Set other operator controls as desired for normal operation or whatever your standard commissioning procedure dictates.

Connect the Control Cable

Note that the control cable carries the currents among other signals, between the recloser and the SEL-651R. The phase current inscriptions for terminals Z01 through Z06 in *Figure 2.6* and *Figure 2.11* (I1, I2, I3) have no permanent phase A, B, C designation. Phase designation is determined by global setting IPCONN. See *Current Connection Setting (IPCONN) on page 9.28* for more information on this setting.

⚠DANGER
If the recloser is energized while the control cable is disconnected from the recloser control, the CT secondaries in the control cable may generate dangerously high voltages. Do not come in contact with the pins or pin sockets in the control cable. Contact with high voltage can cause serious injury or death.

The SEL-651R can be ordered with only one control cable receptacle (for connection to the desired recloser). This interface cannot be changed in the field.

The following help identify the control cable receptacle at the bottom of the SEL-651R enclosure to which the control cable should be connected:

- ➤ The applicable figure of the connector panel at the bottom of the enclosure (see *Figure 2.13* through *Figure 2.25*)
- ➤ The pinout of the applicable control cable receptacle (see *Figure 2.41*)

CONTROL CABLES FROM SEL
The only control cable SEL can provide is Cable C510 for a Traditional Retrofit recloser (14-pin).

Presuming that the control cable is already connected to the recloser, connect the other end to the control cable receptacle at the bottom of the SEL-651R enclosure. Pay attention to possible keying of the cable end and receptacle for proper connection.

Figure 2.41 shows the pinouts for the available control cable receptacles (view from inside enclosure). The uses for the different pins are shown in the following figures:

- ➤ Traditional Retrofit control cable: *Figure 2.45* and *Figure 2.46*
- ➤ G&W Viper-ST control cable: *Figure 2.38*, *Figure 2.47*, *Figure 2.48*, and *Figure 2.49*
- ➤ ABB OVR-3/VR-3S (15 and 27 kV models) control cable: *Figure 2.50*, *Figure 2.51*, and *Figure 2.52*
- ➤ Control-Powered Kyle NOVA control cable: *Figure 2.53* and *Figure 2.54*
- ➤ Joslyn TriMod 600R control cable: *Figure 2.55*, *Figure 2.56*, and *Figure 2.57*
- ➤ Kyle NOVA-TS or NOVA-STS Triple-Single control cable: *Figure 2.58*, *Figure 2.59*, and *Figure 2.60*
- ➤ Tavrida OSM control cable: *Figure 2.61* and *Figure 2.62*
- ➤ Siemens SDR Triple-Single control cable: *Figure 2.63*, *Figure 2.65*, and *Figure 2.67*
- ➤ Siemens SDR Three-Phase control cable: *Figure 2.64*, *Figure 2.66*, and *Figure 2.68*

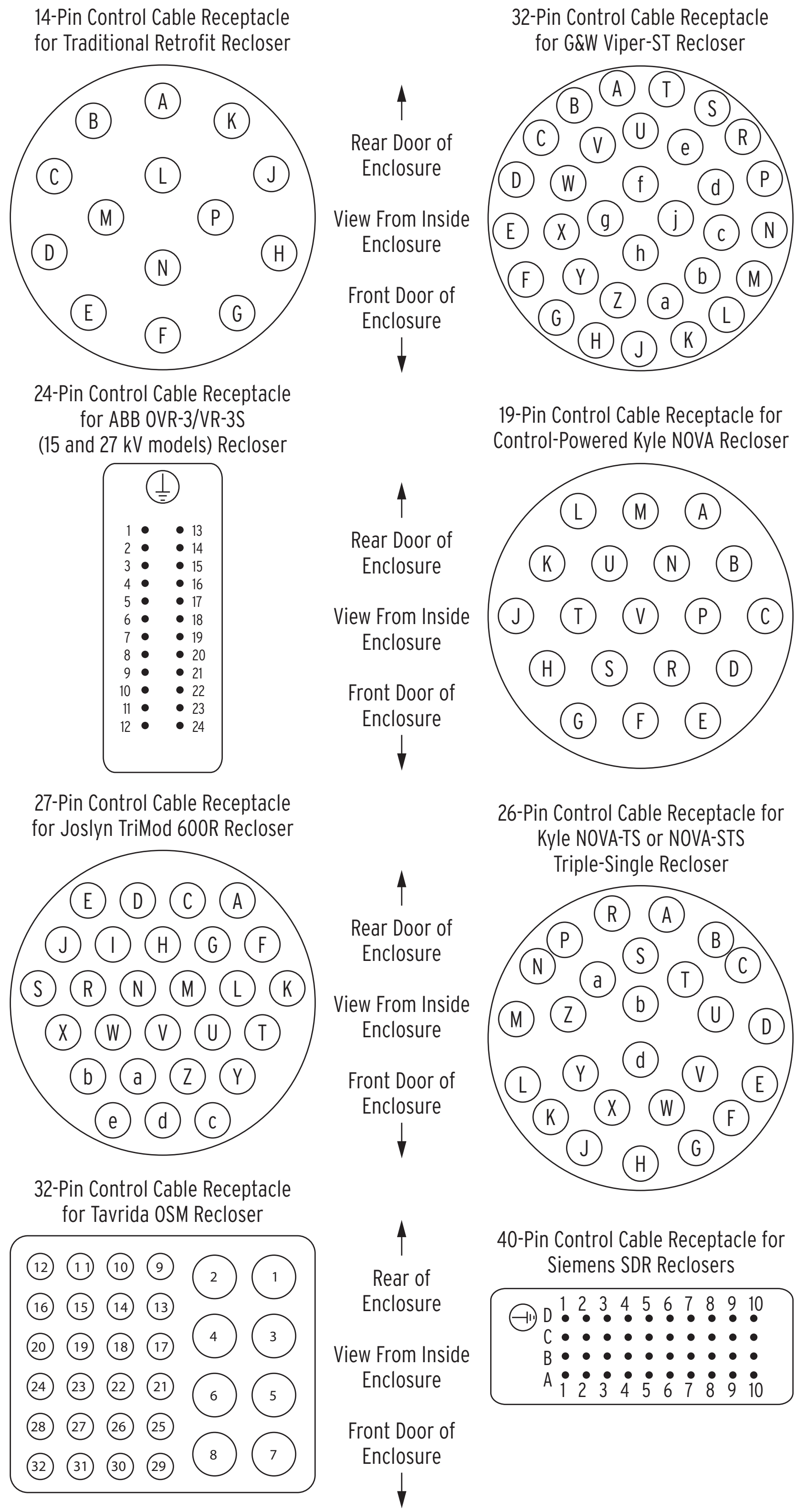


Figure 2.41 Control Cable Receptacle Pinouts

Metering Check

Step 1. Using the front-panel LCD and navigation buttons, go to the fundamental (instantaneous) metering screens.

Step 2. Scroll through the fundamental metering values (primary), checking current IA, IB, and IC magnitude and angle for expected phase rotation.

The ground (IG) and neutral (IN) current displays should show relatively low current magnitudes, when compared to IA, IB, and IC, if system loading is well-balanced. The negative-sequence (3I2) current display should show relatively low current magnitude, when compared to IA, IB, and IC, if system loading is well-balanced and phase rotation is correct.

Step 3. If system loading is well-balanced, but current display 3I2 shows an abnormally high current level (i.e., at a level near the phase current levels or above), suspect a wiring problem or setting problem (see settings listed below).

a. Solve this problem before enabling ground overcurrent tripping.

b. This may require taking the SEL-651R out of service.

Step 4. Do similar checks for the voltage connections with the instantaneous metering screens, comparing phase voltages VAY, VBY, VCY (VY-side) and VAY, VBY, VCY (VZ-side) with corresponding negative-sequence voltage values (V2Y and V2Z). If system voltage (VY-side or VZ-side) is well-balanced, but the corresponding negative-sequence voltage (V2Y or V2Z) shows an abnormally high voltage level, such as a level near the phase voltage levels, suspect a wiring problem or setting problem (see settings listed below).

Check current and voltage-connection global settings IPCONN, VYCONN, and VZCONN in case of problems (see *Table 9.8* and *Table 9.9*).

Step 5. Check the phase rotation setting, too (global setting PHROT). *Figure 2.45*, *Figure 2.47*, *Figure 2.50*, *Figure 2.53*, *Figure 2.55*, and *Figure 2.58* show current connections. *Figure 2.36*, *Figure 2.37*, *Figure 2.38*, *Figure 2.39*, and *Figure 2.40* show voltage connections.

Enable Ground

Again, note that this step presumes that the factory-set **{GROUND ENABLED}** operator control is operative.

If desired for normal operation, enable ground overcurrent tripping with the **{GROUND ENABLED}** operator control on the SEL-651R (corresponding LED illuminates), or whatever your standard commissioning procedure dictates.

This is the last of the basic installation steps. Information on extra connections and supporting material follow.

Extra Connections

Connect extra I/O, IRIG-B time code, EIA-232 serial ports, and auxiliary 12 Vdc power as needed in the application.

Extra Inputs/Outputs

Optoisolated inputs IN101–IN107 and output contacts OUT101–OUT108 are an ordering option and available for connection at the top of the relay module rear panel, row 100. Output contacts OUT201 and OUT202 are standard and available for connection in the middle of the relay module rear panel, row 200. In *Figure 2.6* and *Figure 2.11* notice that the output contact types are:

- Form A (normally open): OUT101–OUT105
- Form C (normally closed/normally open): OUT106–OUT108, OUT201, OUT202

Notice that the Form C output contacts share a common terminal and that optoisolated inputs IN106 and IN107 also share a common terminal. Ratings for the optoisolated inputs and output contacts are found in *Specifications on page 1.8*. The serial number label lists the optoisolated input voltage rating (listed under label: **CONTACT INPUTS**).

For optoisolated inputs IN101–IN107 and output contacts OUT101–OUT108 connections, the screws on terminals A01 through A32 are #8-32. Use max. width 9.1 mm (0.36 in) ring terminals; tightening torque of 1.0 to 2.0 Nm (9 to 18 in-lb.).

The screw terminal connectors for optoisolated inputs IN101–IN107 and output contacts OUT101–OUT108 can be removed by unscrewing the screws at each end of the connector block.

Step 1. Remove the connector by pulling the connector block straight out.

Note that the receptacle on the relay circuit board is keyed; you can insert each screw terminal connector in only one location on the rear panel.

Step 2. To replace the screw terminal connector proceed with the following steps:

a. Confirm that you have the correct connector.
b. Push the connector firmly onto the circuit board receptacle.
c. Reattach the two screws at each end of the block.

This feature allows the terminal wiring to remain undisturbed.

Additionally, you can rotate these screw terminal connectors so that the connector wire dress position is the reverse of the factory-installed position, for example, wires entering the relay panel from below instead of from above. To rotate these connectors, you must change the screw terminal connector keying. Inserts in the circuit board receptacles key the receptacles for only one screw terminal connector in one orientation. Each screw terminal connector has a missing web into which the key fits (see *Figure 2.42*). If you want to reverse the connector orientation, you must rearrange the receptacle keys to match the screw terminal connector block. Use long-nosed pliers to move the keys. *Figure 2.42* shows the factory default key positions.

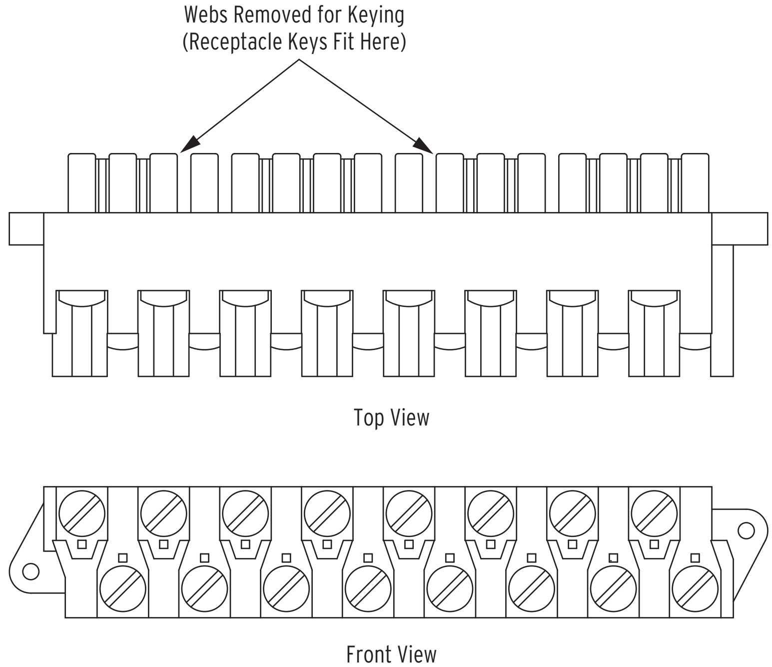


Figure 2.42 Screw Terminal Connector Keying

Standard Outputs

For output contacts OUT201–OUT202 connections, the screws on terminals B07 through B12 are #6-32. Use max. width 7.9 mm (0.31 in) ring terminals; tightening torque of 0.9 to 1.3 Nm (8 to 12 in-lb.).

Alarm Output

From the factory, OUT201 is configured as an alarm. OUT202 is wired into the Transfer Switch scheme, when installed at the factory (see *Figure 2.44*).

IRIG-B Time-Code Input

The SEL-651R accepts a demodulated IRIG-B time signal to synchronize the recloser control internal clock with some external source. The demodulated IRIG-B time signal can come via an SEL Communications Processor. The IRIG-B time signal can be input to the BNC input or Port 1 but **not both**.

A demodulated IRIG-B time code can be input into Serial Port 1 by connecting Serial Port 1 of the SEL-651R to an SEL Communications Processor using Cable C273A.

Serial Ports

All EIA-232 ports accept 9-pin D-subminiature male connectors. Port 1 includes the IRIG-B time-code signal input.

The pin definitions for all the ports are given on the relay rear panel and detailed in *Table 10.1* through *Table 10.3*.

Refer to *Section 10: Communications* for detailed cable diagrams for selected cables (cable diagrams follow *Table 10.3*).

+12 Vdc Auxiliary Power Supply

A +12 Vdc auxiliary power supply rated for 40 W continuous and surges to 60 W is a standard feature. Use this supply to power radios, small RTUs, or other accessories installed in the cabinet. Three +12 Vdc and three return terminal screws are for convenience. Fuse F202 protects this +12 Vdc supply (fuse F202 is in-line with the “+12 Vdc” rail; see *Table 2.7*).

For +12 Vdc and Return connections, the screws on terminals B01 through B06 are #6-32. Use max. width 7.9 mm (0.31 in) ring terminals; tightening torque of 0.9 to 1.3 Nm (8 to 12 in-lb.).

Relay Module Main Board Jumpers and Clock Battery

The main board (top circuit board) in the SEL-651R relay module has features that very infrequently (if at all) need to be set or changed. These features are:

➤ Password and breaker control jumpers

➤ Serial port voltage jumpers

➤ Clock battery

Access the password and breaker control jumpers by just removing the front panel. Access the serial port jumpers and the clock battery by removing the front panel and then sliding out the main board. The procedures for doing so follow later in this subsection.

Password and Breaker Control Jumpers

The password and breaker control jumpers are jumpers JMP5-A and JMP5-B, respectively, found at the front of the main board (see *Figure 2.43*). In this figure, notice that these jumpers are left-to-right lettered:

D C B A

Their individual positions, for a standard relay shipment, and function are described in *Table 2.3* and *Table 2.4*.

Table 2.3 Password and Breaker Jumper Positions for Standard Relay Shipments

Password Jumper/Position (for standard relay shipments)	Breaker Jumper/Position (for standard relay shipments)	Reference Figure
JMP5-A = OFF	JMP5-B = ON	*Figure 2.43*

Table 2.4 Password and Breaker Jumper Operation

Jumper Type	Jumper Position	Function
Password	ON (in place over both pins)	Disable password protection[a] for serial ports and front panel
	OFF[b] (removed/**not** in place over both pins)	Enable password protection[a] for serial ports and front panel
Breaker	ON (in place over both pins)	Enable serial port commands **OPEN**[c], **CLOSE**[c], and **PULSE**[d]
	OFF[b] (removed/**not** in place over both pins)	Disable serial port commands **OPEN**[c], **CLOSE**[c], and **PULSE**[d]

[a] View or set the passwords with the **PASSWORD** command (see Section 10: Communications).
[b] The OFF position can have the jumper placed over one pin only (to retain the jumper and prevent its loss).
[c] Also controls Fast Operate Breaker Control Open/Close Commands (see Appendix C: SEL Communications Processors).
[d] The **OPEN**, **CLOSE**, and **PULSE** serial port commands are used primarily to assert output contacts for circuit breaker control or testing purposes. The outputs of the **OPEN** and **CLOSE** commands are in the factory trip and close logic (see Factory Default Trip Logic Settings and Figure 6.4, respectively).

In *Figure 2.43*, note there are two additional jumper positions, JMP5-C and JMP5-D. These two jumpers are not used and the positions (ON or OFF) of these jumpers are of no consequence.

If passwords are forgotten, put jumper JMP5-A temporarily in place (ON) to gain access to the relay and retrieve the password settings, via the **PASSWORD** command.

Rear-Panel Serial Port Voltage Jumpers

The jumpers listed in *Table 2.5* connect or disconnect +5 Vdc to Pin 1 on the corresponding EIA-232 serial ports. The +5 Vdc is rated at 0.5 A maximum for each port. See *Table 10.2* for all EIA-232 serial port pin functions.

The +5 Vdc is **not** connected to Pin 1 on the corresponding EIA-232 serial ports when the jumpers are OFF (removed/**not** in place over both pins). Put the jumpers ON (in place over both pins) so that the +5 Vdc is connected to Pin 1 on the corresponding EIA-232 serial ports, if needed. This Pin 1 power source is useful for powering some types of external modems.

Table 2.5 Rear-Panel Serial Port Voltage Jumper Positions for Standard Relay Shipments

EIA-232 Serial Port 1	EIA-232 Serial Port 2	EIA-232 Serial Port 3
JMP10 = OFF	JMP9 = OFF	JMP1 = ON

Condition of Acceptability for North American Product Safety Compliance

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

Clock Battery

Refer to *Figure 2.43* for clock battery location (front of main board). A lithium battery powers the relay clock (date and time) if the external power source (AC power or 12 V battery) is lost or removed. The clock battery is a 3 V lithium coin cell. At room temperature (25ºC), the clock battery will nominally operate for 10 years at rated load.

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

If the relay does not maintain the date and time after power loss, replace the clock battery. Follow the main board removal instructions that follow.

Accessing and Removing the Relay Module Main Board in the Dual-Door Enclosure

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

⚠DANGER
The removed cables for connections **J201**, **J202**, and **J205** are still energized. Contact with such terminals can cause electrical shock that can result in injury or death.

⚠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.

⚠CAUTION
There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.

Refer to *Figure 2.43*.

Step 1. Following your company's standard procedure, remove the SEL-651R Recloser Control from service.

Step 2. Make sure the unit remains grounded.

Step 3. Remove any cables connected to serial ports on the front and rear panels.

Step 4. Remove the IRIG-B cable, too.

Step 5. De-energize the relay module by disconnecting the following cables from the rear panel in the following order (see *Figure 2.6* and *Figure 2.11*).

  a. **J205 CAPACITORS**

  b. **J202 BATTERY**

  c. **J201 DC POWER IN**

Step 6. Loosen the four front-panel screws (they remain attached to the front panel).

Step 7. Remove the relay module front panel (see *Figure 2.5*), disconnecting the large ribbon cable connected to it by operating the cable ejector latches on the front-panel circuit board.

Step 8. Place the front panel in an ESD (Electrostatic Discharge)-safe place to prevent ESD damage.

At this point, you can access the password and breaker control jumpers (JMP5-A and JMP5-B, respectively) and the clock battery (see *Figure 2.43*), if need be.

Step 9. If changing the password or breaker control jumpers, carefully remove and insert them in the desired configuration (ON or OFF).

Step 10. If changing the clock battery, carefully remove the old battery, perhaps using a small tool to lever the battery up some so that it can be extracted from the clip that holds it down.

Step 11. With the positive side (+) of the new battery face up, insert it in at an angle to get under the clip and then slide it into position.

Step 12. Later, set the relay date and time via serial communications port or front panel.

Step 13. If changing any of the rear-panel serial port voltage jumpers, continue with the following steps, otherwise skip to *Step 14* to reassemble the unit.

a. Note that the large ribbon cable that was disconnected from the front panel is also connected to the interface circuit board, below the main board.

b. Disconnect this cable from the interface board by operating the cable ejector latches on the interface circuit board.

This large ribbon cable remains connected to the main board, via connector J13 (see *Figure 2.43*).

c. Remove the analog ribbon cable from the main board, via connector J18 (see *Figure 2.43*).

d. Grasp the drawout assembly of the main board and pull the assembly from the relay chassis.

e. Locate the rear-panel serial port voltage jumpers (see *Figure 2.43*) to be changed and carefully remove and insert them in the desired configuration (ON or OFF).

f. When finished, slide the drawout assembly back into the relay chassis, being careful to first align the assembly into the tray guides.

Step 14. Reconnect the ribbon cables removed in *Step 7* and *Step 13*.

Step 15. Replace the relay front-panel cover.

Step 16. Reenergize the relay module by reconnecting the following cables in the following order:

a. J201 DC POWER IN

b. J202 BATTERY

c. J205 CAPACITORS

Step 17. Replace any external cables previously connected to serial ports and IRIG-B port.

Step 18. Following your company’s standard procedure put the SEL-651R Recloser Control back in service.

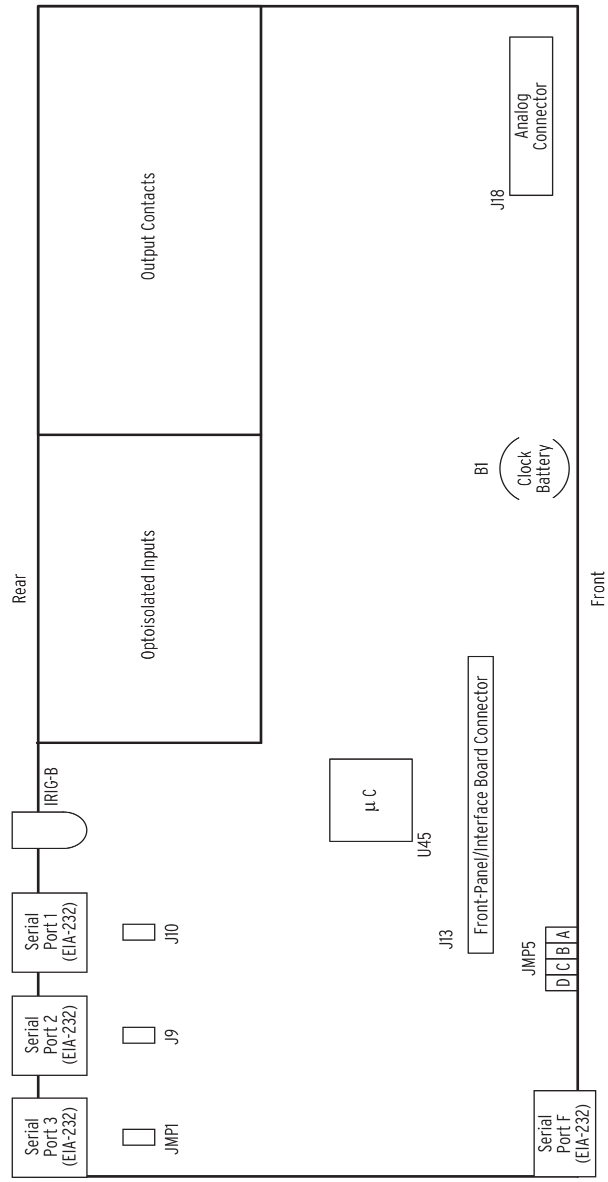


Figure 2.43 Jumper, Connector, and Major Component Locations on the Main Board

Battery and Fuse Replacement

The SEL-651R is shipped with either a 16 or 40 A-h extended temperature battery. Either of these battery types may be used as a replacement for the installed battery. The part numbers and characteristics are listed in the *Table 2.6*. Full specifications are shown in *Battery Specifications on page 1.9*. Connections are shown in *Figure 2.27*.

Table 2.6 Replacement Batteries for the SEL-651R

Function	Option 1	Option 2
Part Number	Hawker Genesis XE 16	Hawker Genesis XE 40
Capacity	16 A-h	40 A-h
Battery Life	≥ 4 years @ +25°C ≥ 1 year @ +80°C	≥ 4 years @ +25°C ≥ 1 year @ +80°C
Weight	6.4 kg (≤14.1 lb)	16.1 kg (≤35.4 lb)

See *Figure 2.6* and *Figure 2.11* for fuse positions F201–F203 on the rear panel of the relay module. See *Figure 2.4* for fuse positions F401–F412 on the rear panel of the power module. The last fuses listed in *Table 2.7* (for a 230 Vac unit) are not shown in *Figure 2.4*, but the fuse blocks for these 230 V unit fuses are mounted in the same general area as the F411 and F412 panel-mounted fuseholders in *Figure 2.4*.

Table 2.7 Replacement Fuses for the SEL-651R

Fuse Name/Figure Reference	Ampere Rating	Dimensions	Manufacturer	Catalog Numbers	Purpose
F201/relay module (*Figure 2.27*)	30 A	6.35 x 31.75 mm (0.25 x 1.25 in)	Littelfuse	314 030	Protect battery or battery charger circuitry from inadvertent short.
F202/relay module (AC power supply models only)	5 A	6.35 x 31.75 mm (0.25 x 1.25 in)	Littelfuse	314 005	Protect 12 Vdc aux power supply.
F202/relay module (125 Vdc power supply only)	0.5 A	6.35 x 31.75 mm (0.25 x 1.25 in)	Littelfuse	314.500	Protect 12 Vdc aux power supply on models with 125 Vdc power supply.
F203/relay module (Traditional Retrofit, Control-Powered Kyle NOVA, and Kyle NOVA-TS or NOVA-STS Triple-Single reclosers only; *Figure 2.46*, *Figure 2.54*, and *Figure 2.59*)	7 A	6.35 x 31.75 mm (0.25 x 1.25 in)	Littelfuse	313 007	Protect from inadvertent +24 Vdc short when connecting control cable.
F401–F406/power module (*Figure 2.36* and *Figure 2.38*)	1/8 A	10.3 x 38.1 mm (0.41 x 1.5 in)	Littelfuse	KLK 1/8	Installed in Voltage Input Fuseblock accessory. Protect both three-phase voltage inputs on the relay module.
F407–F410/power module (*Figure 2.31* and *Figure 2.33*)	30 A	10.3 x 38.1 mm (0.41 x 1.5 in)	Littelfuse	FLQ 30	Installed in Universal Fuseblock accessory. Protect transfer switch and other 120 Vac power accessories on the power module.
F411/power module (120 Vac power supply only; *Figure 2.28*)	15 A	6.35 x 31.75 mm (0.25 x 1.25 in)	Littelfuse	314 015	Protect 120 Vac (GFCI) convenience outlet for overload or line-to-line short circuits (15 Amp load limit).
F412/power module (120 Vac power supply only; *Figure 2.28*)	10 A	6.35 x 31.75 mm (0.25 x 1.25 in)	Littelfuse	314 010	Protect 120 Vac power module from overvoltage or internal short.
F411 and F412/power module (230 Vac power supply only; *Figure 2.29*)	8 A	10.3 x 38.1 mm (0.41 x 1.5 in)	Littelfuse	FLQ 8	Protect 230 Vac power module from overvoltage or internal short.

Supplemental Connection Details

AC Transfer Switch

Figure 2.44 provides the extra Transfer Switch connection and operational details, as compared to *Figure 2.32*. The Transfer Switch routes power either through terminals 5/6 or terminals 7/8. This routing is controlled by the dc coil shown in *Figure 2.44* (the dc coil is internal to the Transfer Switch and connected via terminals 1 and 2):

➤ DC coil energized: Form A contacts corresponding to terminals 5/6 **close** and Form B contacts corresponding to terminals 7/8 **open** (power is routed through terminals 5/6)

➤ DC coil de-energized: Form A contacts corresponding to terminals 5/6 **open** and Form B contacts corresponding to terminals 7/8 **close** (power is routed through terminals 7/8)

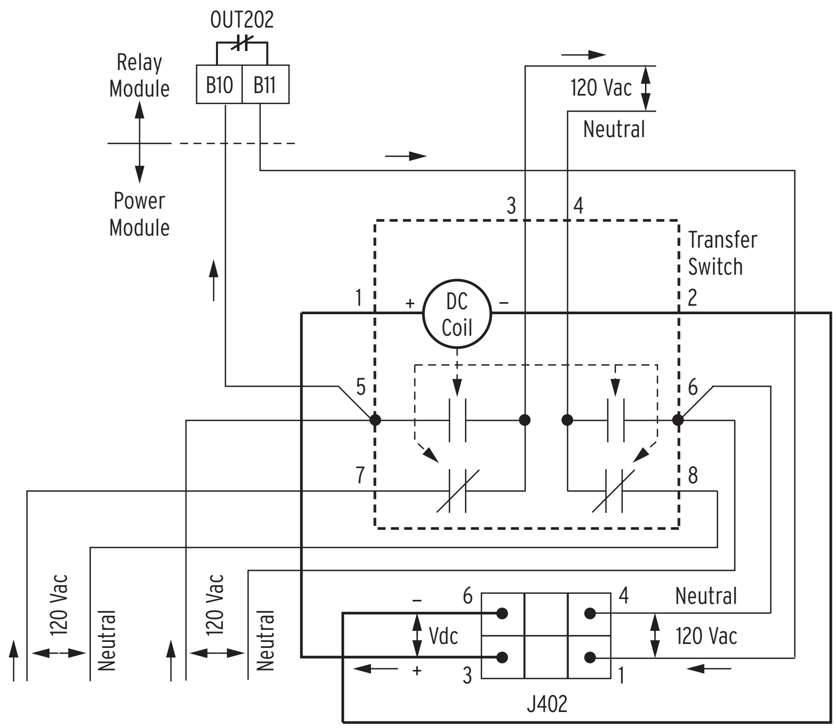


Figure 2.44 AC Transfer Switch AC/DC Voltage Connections

The energization or de-energization of the dc coil is dependent on the presence or absence, respectively, of the preferred 120 Vac power source. The preferred source is the 120 Vac power connected to terminals 5/6 of the Transfer Switch.

An ac to dc voltage conversion is needed to convert the preferred 120 Vac power source signal to a dc voltage to energize the dc coil. The electronics behind connector J402 do this conversion. In *Figure 2.44*, note the 120 Vac input into connector J402 comes from terminals 5/6 (preferred source) on the Transfer Switch. The Vdc output from connector J402 is then connected across the dc coil, via Transfer Switch terminals 1/2. The effective voltage operation range (120 Vac base) of the dc coil of the transfer switch is

Pick Up Voltage: 104 ± 4 Vac

Drop Out Voltage: 96 ± 4 Vac

Minimum Hysteresis: 4 Vac (helps eliminate Transfer Switch chattering)

Note that the preferred 120 Vac power source signal is supervised by Form-B output contact OUT202. If no special SELOGIC setting is made for output contact OUT202, then output contact OUT202 just remains shut and has no effect on the operation of the Transfer Switch: the Transfer Switch just operates, depending on the presence or absence of the preferred 120 Vac power source connected up to terminals 5/6 of the Transfer Switch. If a special SELOGIC setting is made for output contact OUT202, then output contact OUT202 can open per the SELOGIC setting and cause the Transfer Switch to switch from the preferred 120 Vac power source (terminals 5/6) to the alternate 120 Vac power source (terminals 7/8), for reasons other than the loss of the preferred source. See *Output Contacts on page 7.32* for more information on output contact OUT202.

Traditional Retrofit Reclosers

Figure 2.45 shows the SEL-651R factory wiring for current connections for Traditional Retrofit reclosers. Notice that the current transformers in the recloser are wired such that the residual path (through Pin K) is on the polarity side of the current transformer secondaries. This is nonstandard as far as traditional circuit breakers are concerned, but is easily accommodated by the wiring on the Z01 through Z08 terminals of the relay module of the SEL-651R.

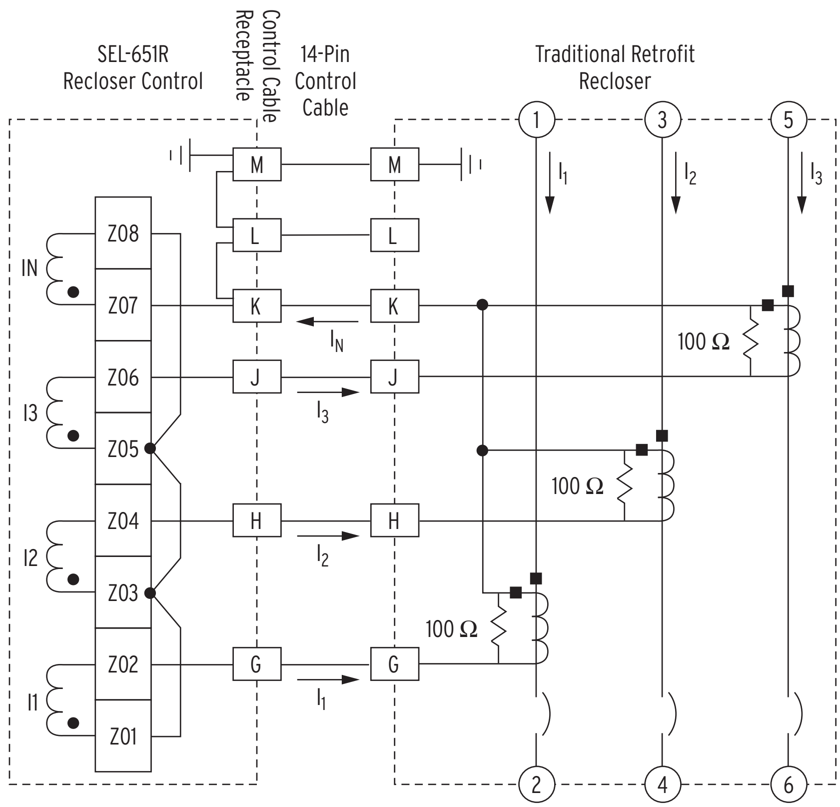


Figure 2.45 Current Connections and Polarity from Traditional Retrofit Recloser Primary to SEL-651R Recloser Control Current Inputs

INTERNAL BATTERY-CHARGING TRANSFORMER

Some Cooper reclosers have an internal battery-charging transformer (current transformer). This charging transformer is not used by the SEL-651R: its 12 Vdc battery is charged from a user-supplied Vac power source. If one of these reclosers is connected to the SEL-651R, this charging transformer is electrically shorted at the control cable receptacle (Pins K and L are shorted together and grounded—see Figure 2.45).

Notice also that the phase current terminals are labeled I1, I2, I3 (not IA, IB, IC). A-B-C designations are given to the current channels with global setting IPCONN. Current transformer polarity can effectively be changed with the global CTPOL setting, which is helpful for designating forward or reverse power flow, and so forth.

Figure 2.46 shows the SEL-651R factory wiring for trip/close/recloser status for traditional reclosers; 24 Vdc power goes out Pin A to the recloser and then returns through the trip circuit and close circuit paths.

RELAY WORD BIT TCCAP
Relay Word bit TCCAP indicates that the 24 Vdc voltage in Figure 2.46 is present for recloser operations (TCCAP = logical 1). The 24 Vdc voltage comes into the relay module via connector J205 (CAPACITORS), from the trip/close capacitors in the power module (see Figure 2.3, Figure 2.6, Figure 2.9, and Figure 2.11). If there is a problem with this connection or otherwise in the power module, then Relay Word bit TCCAP = logical 0. Relay Word bit TCCAP is used in factory-default close logic settings (see Figure 6.4 and Figure 6.5) and reclose supervision settings (see Table 6.8). Relay Word bit TCCAP does not detect an operation of fuse F203 in Figure 2.46.

The trip circuit path (top to bottom) is described below:

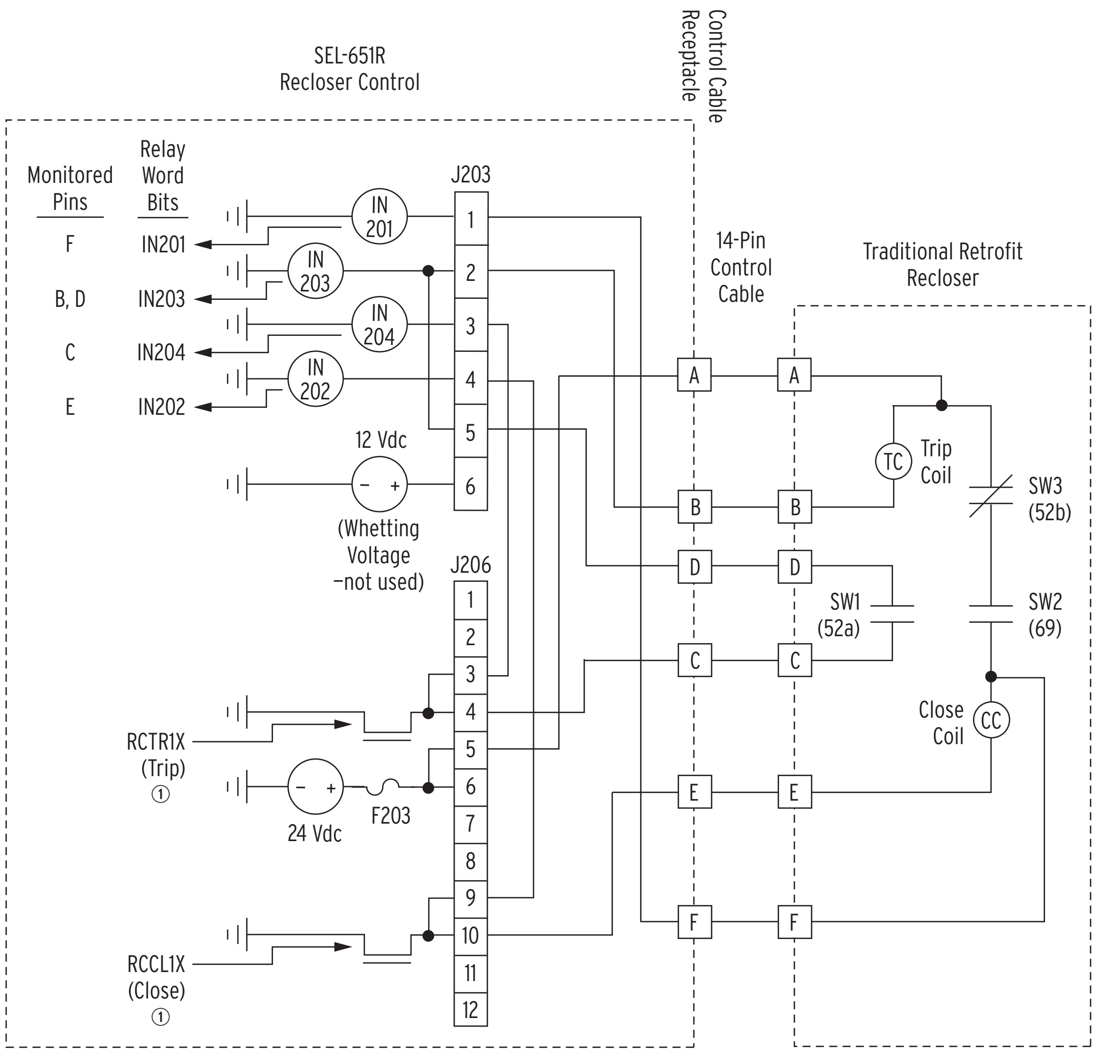
> Trip coil—SW1 (52a)—trip FET (controlled by Relay Word bit RCTR1X; see *Figure 7.25*)

Pins B, D are monitored by input IN203 and Pin C is monitored by input IN204. The 52a recloser status is derived from these inputs.

The close circuit path (top to bottom) is described below:

> SW3 (52b)—SW2 (69)—close coil—close FET (controlled by Relay Word bit RCCL1X; see *Figure 7.25*)

Pin E is monitored by input IN202 and Pin F is monitored by input IN201. Contact SW2 (69) opens and stays open when the external yellow operating handle on the recloser is pulled to the lock-open position. With contact SW2 open, there is no way to close the recloser until the yellow operating lever is reset again. Contact SW2 is then closed.



① See Figure 7.25

Figure 2.46 Trip/Close and Recloser Status Circuit Connections Between Traditional Retrofit Recloser and SEL-651R Recloser Control

Motor-Operated Traditional Retrofit Reclosers

With factory settings, the SEL-651R Recloser Control (ordered for a Traditional Retrofit recloser) works with motor-operated reclosers, such as Cooper MVE, CVE, CXE, CZE, VSA, VSO reclosers, too. Figure 2 in SEL Application Guide AG99-10, *Change Logic in SEL-351R Recloser Control for Motor-Operated Reclosers*, shows the internal differences for such reclosers, especially 52a at the top of trip circuit and diode bypassing SW1(52a). The SEL-651R factory settings important for working with these motor-operated reclosers are group settings:

TDURD := **40 cycles** (longer trip duration)

ULTR3P := **1** (set directly to logical 1; not dependent on NOT 52A3P to unlatch trip)

The **RECLOSER OPEN** LED is set:

PB12_LED := **NOT(52A3P)**

For a regular Traditional Retrofit recloser, as shown in *Figure 2.46*, as opposed to a motor-operated recloser (see *Figure 2* in the aforementioned SEL Application Guide AG99-10) this setting can be changed to:

PB12_LED := **NOT(52A3P) AND IN203**

Input IN203 monitors Pins B/D, as shown in *Figure 2.46*. With this setting change, the **RECLOSER OPEN** LED will extinguish when the control cable is removed from the SEL-651R Recloser Control, rather than staying illuminated.

If the recloser is *not* a motor-operated recloser, setting TDURD can be changed, if desired. See *Minimum Trip Duration Timer on page 5.5*, for more detail.

G&W Viper-ST Reclosers

Figure 2.47 shows the SEL-651R factory wiring for current connections for G&W Viper-ST reclosers. The current transformers in the recloser are wired like a circuit breaker in that the residual path through control cable Pins 14/D is on the nonpolarity side of the current transformer secondaries. This contrasts with the Traditional Retrofit recloser in *Figure 2.45*. Either wiring is easily accommodated by the wiring on the Z01 through Z08 terminals of the SEL-651R relay module.

CAPACITIVE VOLTAGE SENSORS

To make use of the standard capacitive voltage sensors at the bottom of Figure 2.47, the SEL-651R needs to be ordered with 8 Vac LEA voltage inputs for the three-phase VY voltage inputs. If both the standard and optional capacitive voltage sensors are to be used, then the SEL-651R needs to be ordered with 8 Vac LEA voltage inputs for both the three-phase VY and VZ voltage inputs.

Other voltage input options are available, though not using the control cable shown in Figure 2.47 (see SEL-651R Model Option Table).

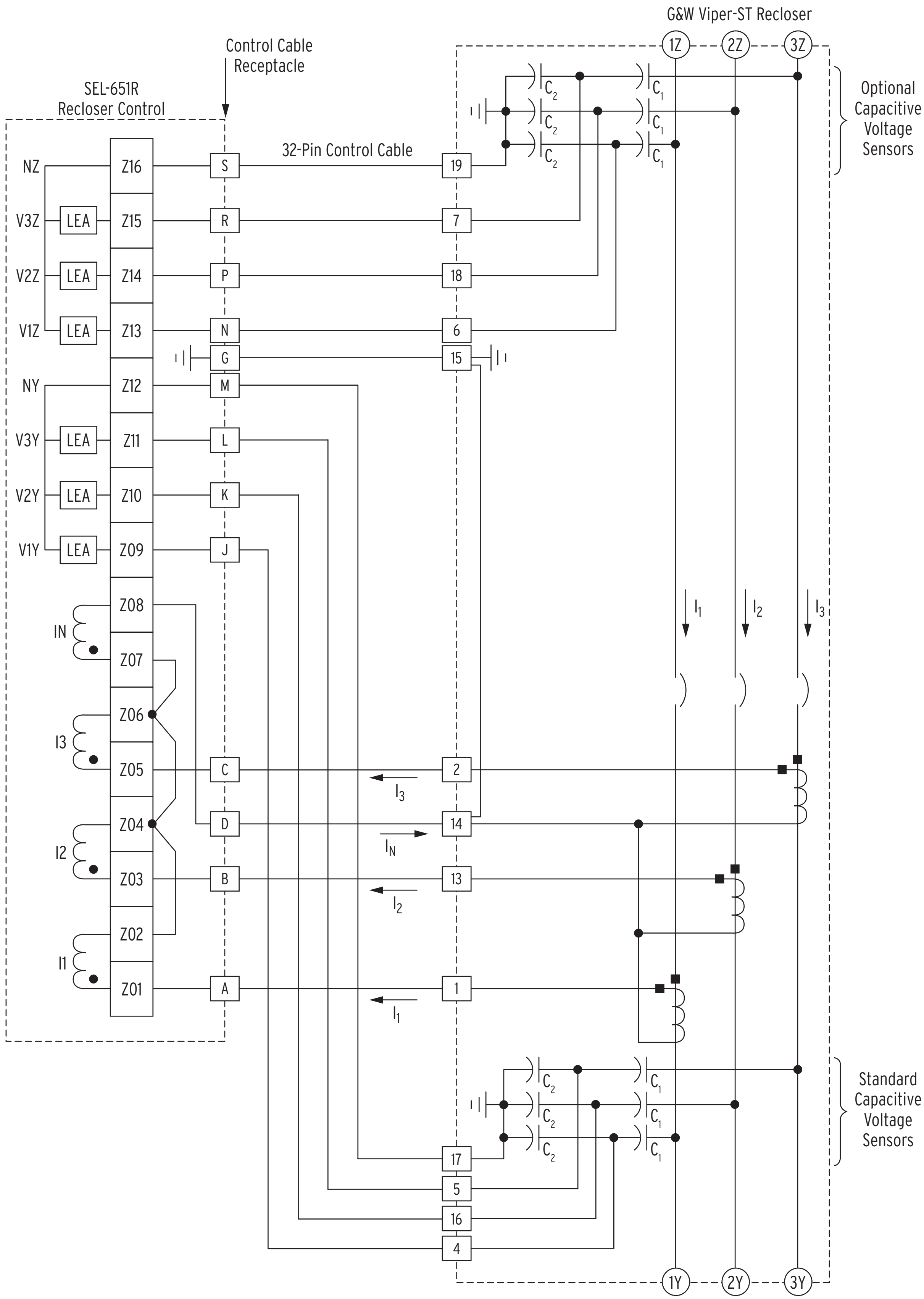


Figure 2.47 Current Connections and Polarity from G&W Viper-ST Recloser Primary to SEL-651R Recloser Control Current Inputs (Voltage Connections Also Shown)

Notice also that the phase current terminals are labeled I1, I2, I3 (not IA, IB, IC). A-B-C designations are given to the current channels with global setting IPCONN. Current transformer polarity can effectively be changed with the global CTPOL setting, which is helpful for designating forward or reverse power flow and similar things.

Figure 2.48 shows the SEL-651R factory wiring for trip/close for G&W Viper-ST reclosers. Each pole of the recloser has its own trip/close coil, trip for current flow in one direction, close for current flow in the other direction. This facilitates single-phase tripping/reclosing, although the SEL-651R factory settings have the recloser operating in a three-phase trip/close mode.

Note that the trip and close FETs in the SEL-651R are stacked one atop another, between 155 Vdc power and ground, with a tap in the middle. For a given FET stack, both FETs can never be on at the same time or else there would be a direct short between the 155 Vdc power and ground. Interlocking logic prevents both FETs from being on at the same time.

Trace the trip path for Coil 1 in *Figure 2.48*:

> Relay Word Bit RCTR1X (Trip 1; see *Figure 7.26*) turns on the bottom FET (ground) connected to terminal J206-3 and the top FET (155 Vdc) connected to terminal J206-9. This wiring goes through control cable Pins Y/10 and Z/22 to Coil 1. The 155 Vdc across Coil 1 (bottom to top) causes the current to flow in the indicated direction (Trip 1).

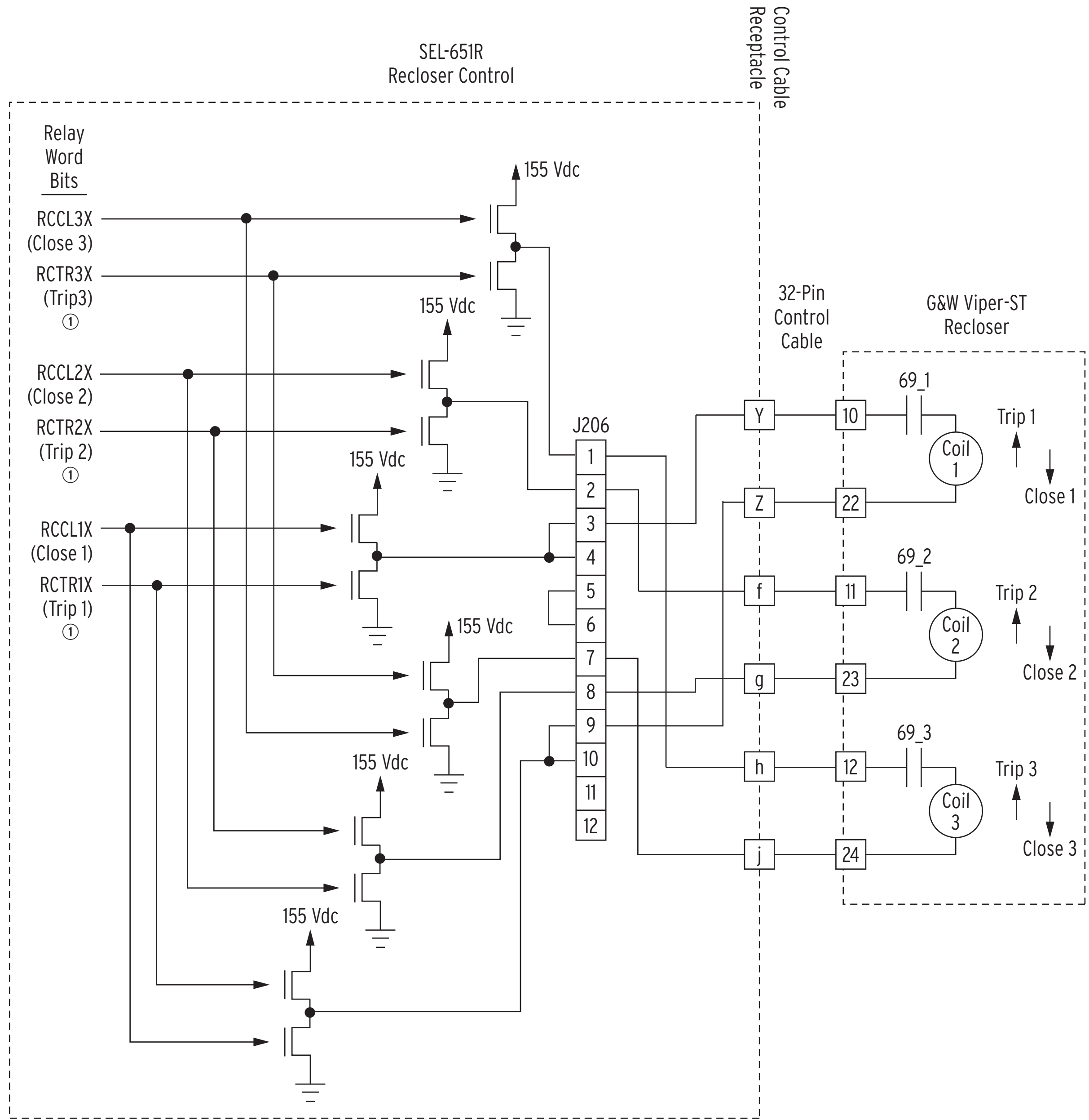
RELAY WORD BIT TCCAP

Relay Word bit TCCAP indicates that the 155 Vdc voltage in Figure 2.48 is present for recloser operations (TCCAP = logical 1). The 155 Vdc voltage comes into the relay module via connector J205 (CAPACITORS), from the trip/close capacitors in the power module (see Figure 2.3, Figure 2.6, Figure 2.9, and Figure 2.11). If there is a problem with this connection or otherwise in the power module, then Relay Word bit TCCAP = logical 0. Relay Word bit TCCAP is used in factory-default close logic settings (see Figure 6.4 and Figure 6.5) and reclose supervision settings (see Table 6.8).

Trace the close path for Coil 1 in *Figure 2.48*:

> Relay Word Bit RCCL1X (Close 1; see *Figure 7.26*) turns on the top FET (155 Vdc) connected to terminal J206-3 and the bottom FET (ground) connected to terminal J206-9. This wiring goes through control cable Pins Y/10 and Z/22 to Coil 1. The 155 Vdc across Coil 1 (top to bottom) causes the current to flow in the indicated direction (Close 1).

Tripping and closing for Coil 2 and Coil 3 operate similarly. The 69 contacts in the trip/close circuits open and stay open when the respective external yellow operating handles on individual poles of the recloser are pulled to the lock-open position. With contact 69 open for a particular pole, there is no way to close that particular recloser pole until the yellow operating handle is reset again. Contact 69 is then closed.



① See Figure 7.26

Figure 2.48 Trip/Close Circuit Connections Between G&W Viper-ST Recloser and SEL-651R Recloser Control

Figure 2.49 shows inputs IN201–IN203 monitoring individual 52a recloser pole status. Input IN204 monitors the combined status of yellow operating handles for the individual recloser poles. The 69 contact closes for corresponding yellow operating handle going to the lock-open position). Input IN204 is used in *Figure 5.2* logic.

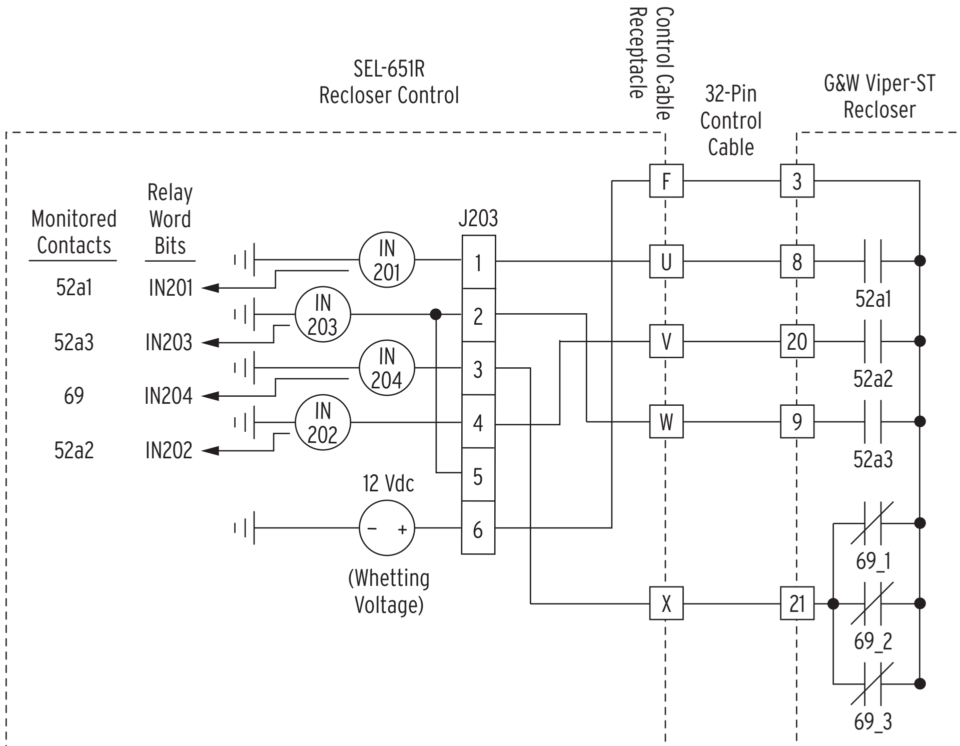


Figure 2.49 Recloser Pole Status and Yellow Operating Handle Circuit Connections Between G&W Viper-ST Recloser and SEL-651R Recloser Control

ABB OVR-3/VR-3S (15 and 27 kV models) Reclosers

Figure 2.50 shows the SEL-651R factory wiring for current connections for ABB OVR-3/VR-3S (15 and 27 kV models) reclosers. The current transformers in the recloser are wired like a circuit breaker in that the residual path through control cable Pin 12 is on the non-polarity side of the current transformer secondaries. This contrasts with the Traditional Retrofit recloser in *Figure 2.45*. Either wiring is easily accommodated by the wiring on the Z01 through Z08 terminals of the SEL-651R relay module.

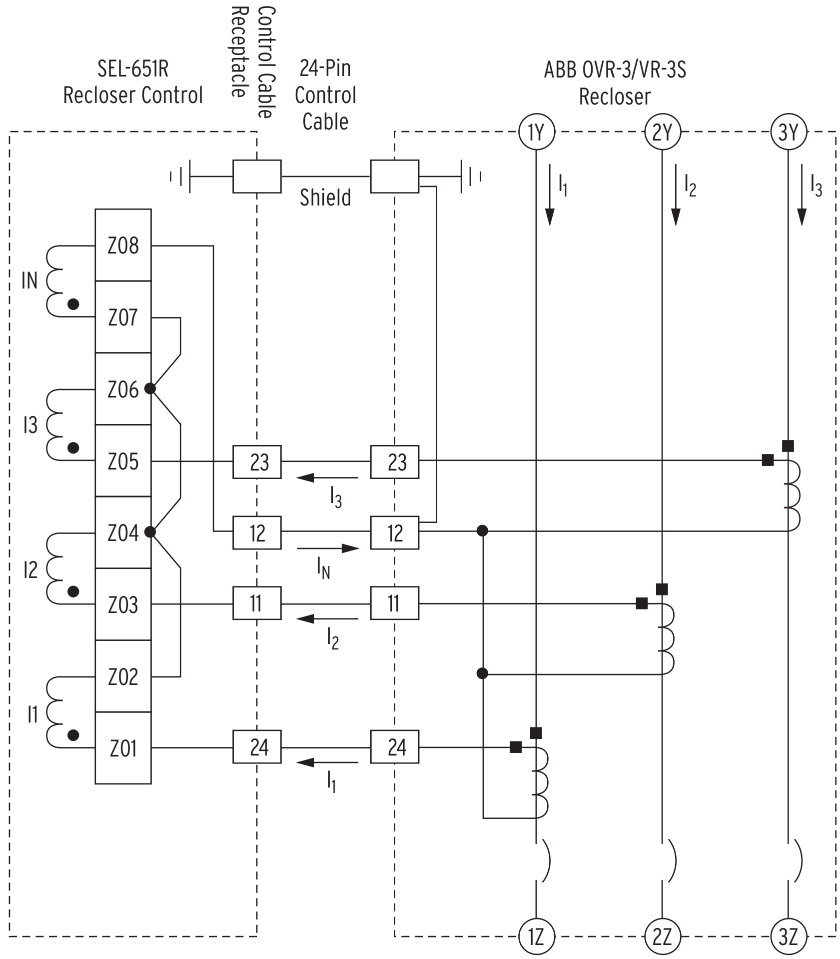


Figure 2.50 Current Connections and Polarity from ABB OVR-3/VR-3S (15 and 27 kV models) Recloser Primary to SEL-651R Recloser Control Current Inputs

Notice also that the phase current terminals are labeled I1, I2, I3 (not IA, IB, IC). A-B-C designations are given to the current channels with global setting IPCONN. Current transformer polarity can effectively be changed with the global CTPOL setting, which is helpful for designating forward or reverse power flow and similar things.

Figure 2.51 shows the SEL-651R factory wiring for trip/close for ABB OVR-3/VR-3S (15 and 27 kV models) reclosers. Each pole of the recloser has its own trip/close coil, trip for current flow in one direction, close for current flow in the other direction. This facilitates single-phase tripping/reclosing, although the SEL-651R factory settings have the recloser operating in a three-phase trip/close mode.

Note that the trip and close FETs in the SEL-651R are stacked one atop another, between 53 Vdc power and ground, with a tap in the middle. For a given FET stack, both FETs can never be on at the same time or else there would be a direct short between the 53 Vdc power and ground. Interlocking logic prevents both FETs from being on at the same time.

RELAY WORD BIT TCCAP
Relay Word bit TCCAP indicates that the 53 Vdc voltage in Figure 2.51 is present for recloser operations (TCCAP = logical 1). The 53 Vdc voltage comes into the relay module via connector J205 (CAPACITORS), from the trip/close capacitors in the power module (see Figure 2.3, Figure 2.6, Figure 2.9, and Figure 2.11). If there is a problem with this connection or otherwise in the power module, then Relay Word bit TCCAP = logical 0. Relay Word bit TCCAP is used in factory-default close logic settings (see Figure 6.4 and Figure 6.5) and reclose supervision settings (see Table 6.8).

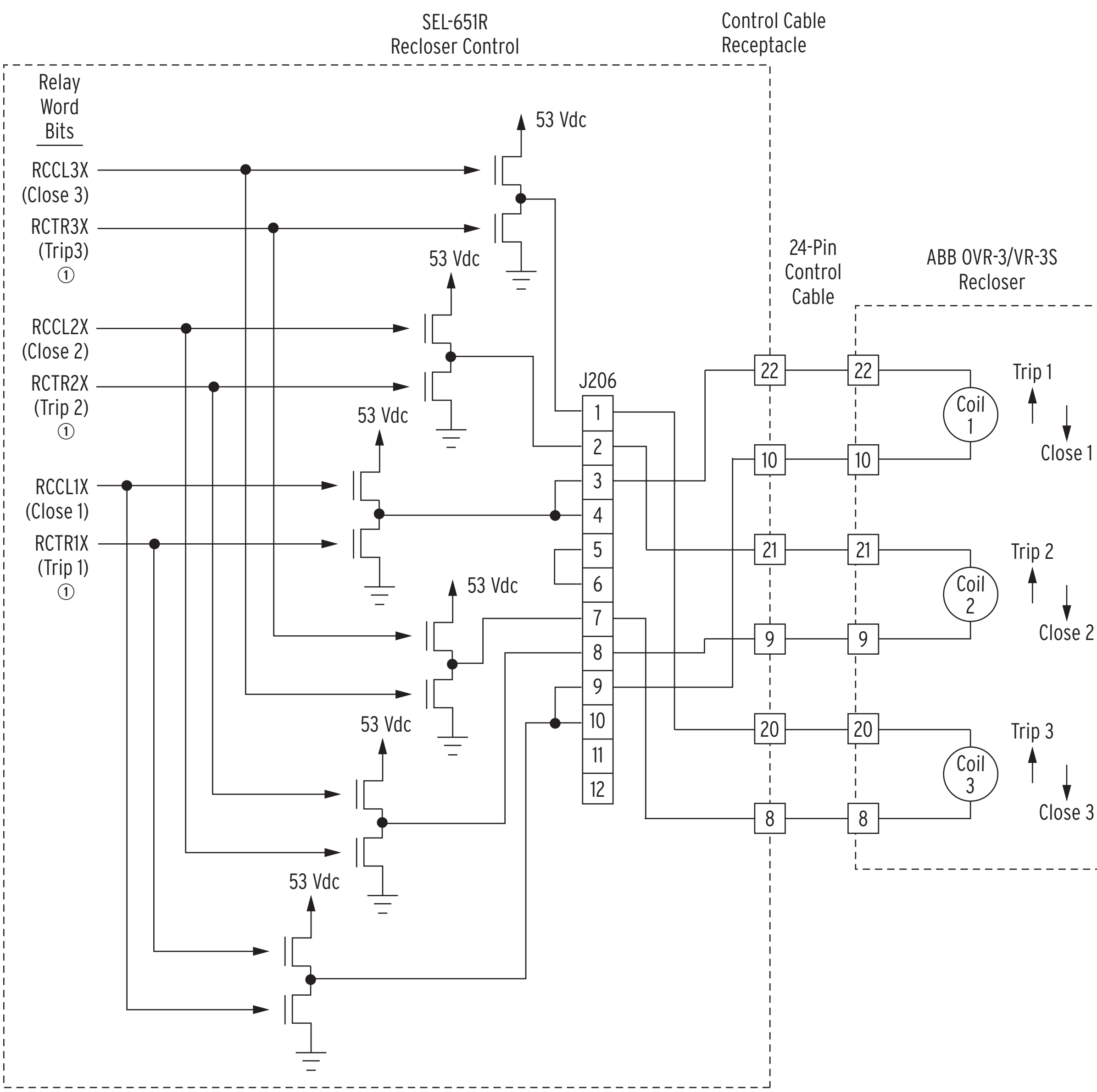
Trace the trip path for Coil 1 in *Figure 2.51*:

> Relay Word Bit RCTR1X (Trip 1; see *Figure 7.26*) turns on the bottom FET (ground) connected to terminal J206-3 and the top FET (53 Vdc) connected to terminal J206-9. This wiring goes through control cable Pins 22 and 10 to Coil 1. The 53 Vdc across Coil 1 (bottom to top) causes the current to flow in the indicated direction (Trip 1).

Trace the close path for Coil 1 in *Figure 2.51*:

> Relay Word Bit RCCL1X (Close 1; see *Figure 7.26*) turns on the top FET (53 Vdc) connected to terminal J206-3 and the bottom FET (ground) connected to terminal J206-9. This wiring goes through control cable Pins 22 and 10 to Coil 1. The 53 Vdc across Coil 1 (top to bottom) causes the current to flow in the indicated direction (Close 1).

Tripping and closing for Coil 2 and Coil 3 operate similarly.



① See Figure 7.26

Figure 2.51 Trip/Close Circuit Connections Between ABB OVR-3/VR-3S (15 and 27 kV models) Recloser and SEL-651R Recloser Control

Figure 2.52 shows inputs IN201–IN203 monitoring individual 52b recloser pole status.

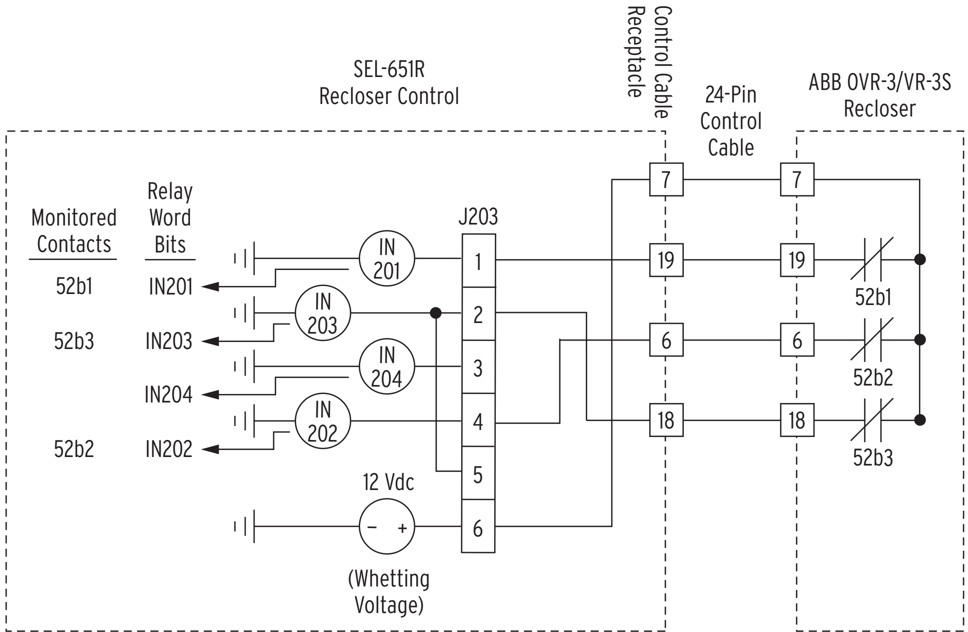


Figure 2.52 Recloser Pole Status Connections Between ABB OVR-3/VR-3S (15 and 27 kV models) Recloser and SEL-651R Recloser Control

Control-Powered Kyle NOVA Reclosers

Figure 2.53 shows the SEL-651R factory wiring for current connections for Control-Powered Kyle NOVA reclosers. Notice that the current transformers in the recloser are wired such that the residual path (through Pin K) is on the polarity side of the current transformer secondaries. This is nonstandard as far as traditional circuit breakers are concerned, but is easily accommodated by the wiring on the Z01 through Z08 terminals of the relay module of the SEL-651R.

Notice also that the phase current terminals are labeled I1, I2, I3 (not IA, IB, IC). A-B-C designations are given to the current channels with global setting IPCONN. Current transformer polarity can effectively be changed with the global CTPOL setting, which is helpful for designating forward or reverse power flow, and so forth.

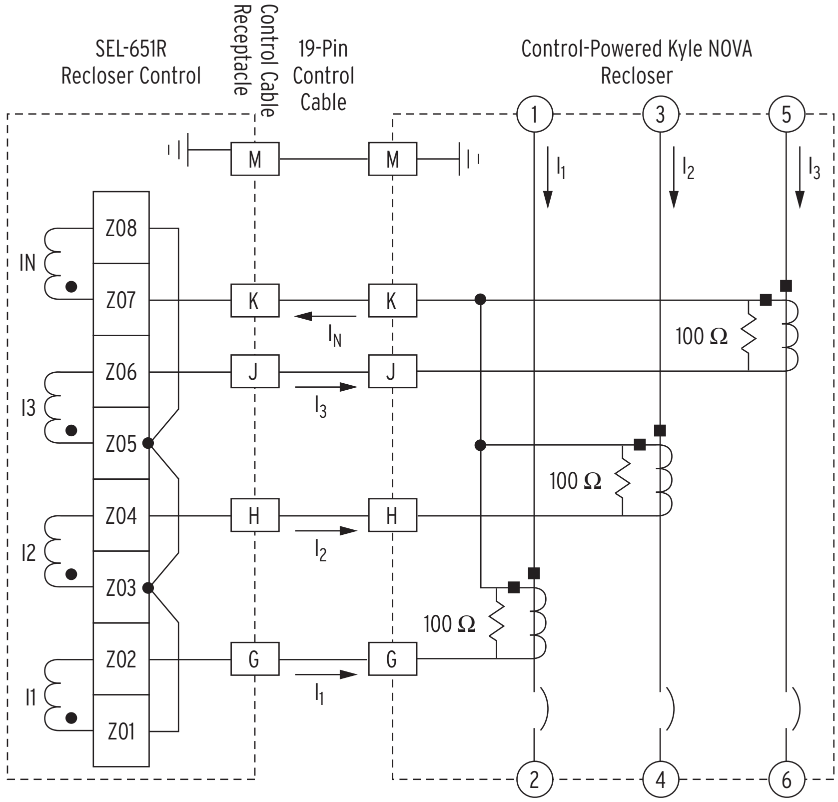


Figure 2.53 Current Connections and Polarity from Control-Powered Kyle NOVA Recloser Primary to SEL-651R Recloser Control Current Inputs

RELAY WORD BIT TCCAP

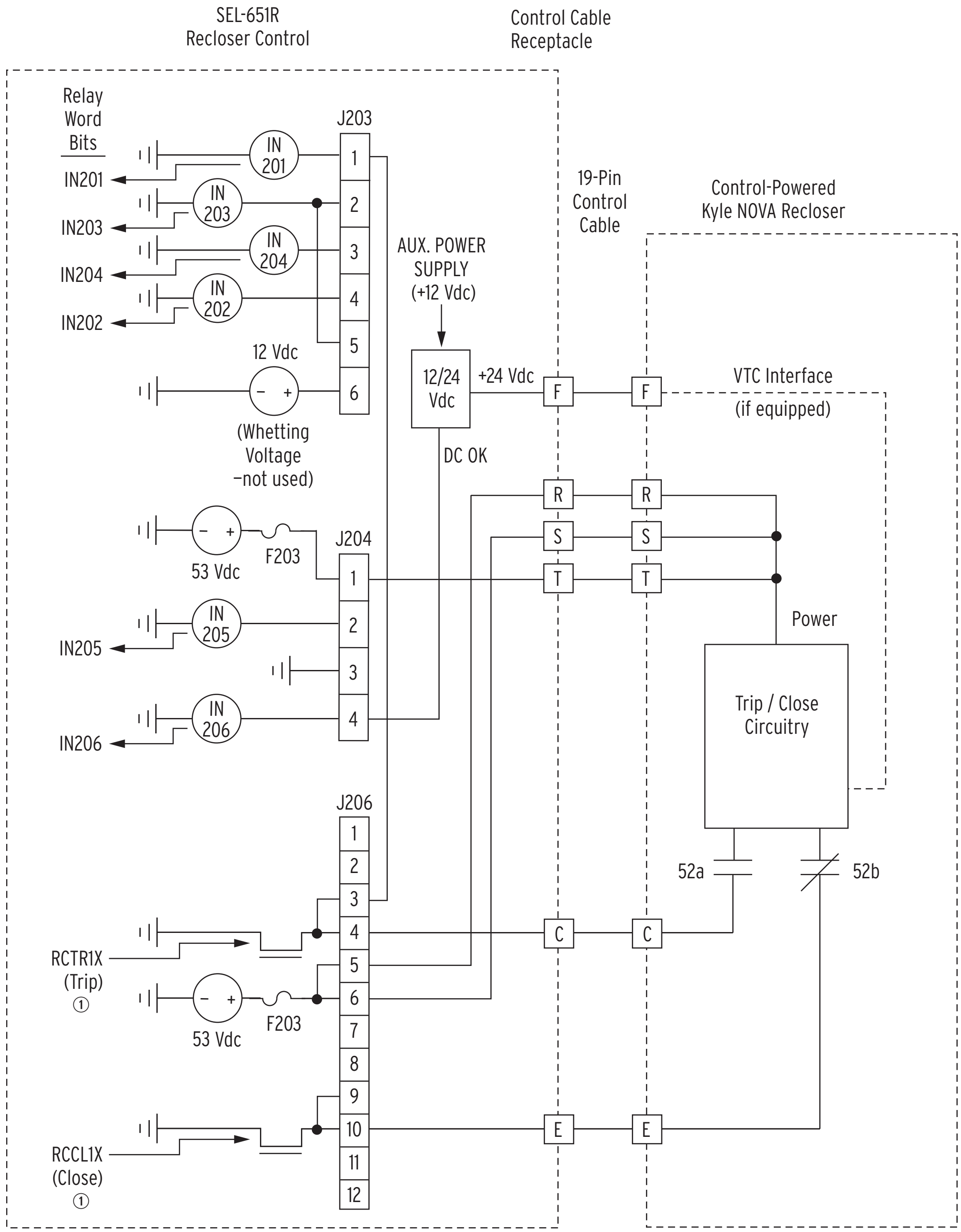
Relay Word bit TCCAP indicates that the 53 Vdc voltage in Figure 2.54 is present for recloser operations (TCCAP = logical 1). The 53 Vdc voltage comes into the relay module via connector J205 (CAPACITORS), from the trip/close capacitors in the power module (see Figure 2.3, Figure 2.6, Figure 2.9, and Figure 2.11). If there is a problem with this connection or otherwise in the power module, then Relay Word bit TCCAP = logical 0. Relay Word bit TCCAP is used in factory-default close logic settings (see Figure 6.4 and Figure 6.5) and reclose supervision settings (see Table 6.8). Relay Word bit TCCAP does not detect an operation of fuse F203 in Figure 2.54.

Figure 2.54 shows the SEL-651R factory wiring for trip/close/recloser status for Control-Powered Kyle NOVA; 53 Vdc power goes out Pins R, S, T to the recloser and then returns through the trip circuit and close circuit paths.

Pin C is monitored by input IN201. The 52a recloser status is derived from this input.

If the Control-Powered Kyle NOVA recloser is not VTC-equipped, then the signals to Pin F and IN206 can be ignored—they will not affect normal recloser operation. VTC-equipped reclosers cannot trip/close without the 24 Vdc signal to Pin F.

IN206 monitors the 12/24 Vdc converter. If the 12/24 Vdc converter is operating correctly, then IN206 is asserted. Use IN206 as an alarm, routing it to an LED, front-panel display point, or an output contact (e.g., make the following settings: ESV := 2, SV02PU := 600 cycles, SV02DO := 600, SV02 := NOT [IN206], and OUT202 := SV02T. OUT202 asserts, providing an alarm, if the 12/24 Vdc converter fails).



① See Figure 7.25.

Figure 2.54 Trip/Close and Recloser Status Circuit Connections Between Control-Powered Kyle NOVA Recloser and SEL-651R Recloser Control

Joslyn TriMod 600R Reclosers

Figure 2.55 shows the SEL-651R factory wiring for current connections for Joslyn TriMod 600R reclosers. The current transformers in the recloser are wired like a circuit breaker in that the residual path through control cable pins is on the non-polarity side of the current transformer secondaries. This contrasts with the Traditional Retrofit recloser in *Figure 2.45*. Either wiring is easily accommodated by the wiring on the Z01 through Z08 terminals of the SEL-651R relay module.

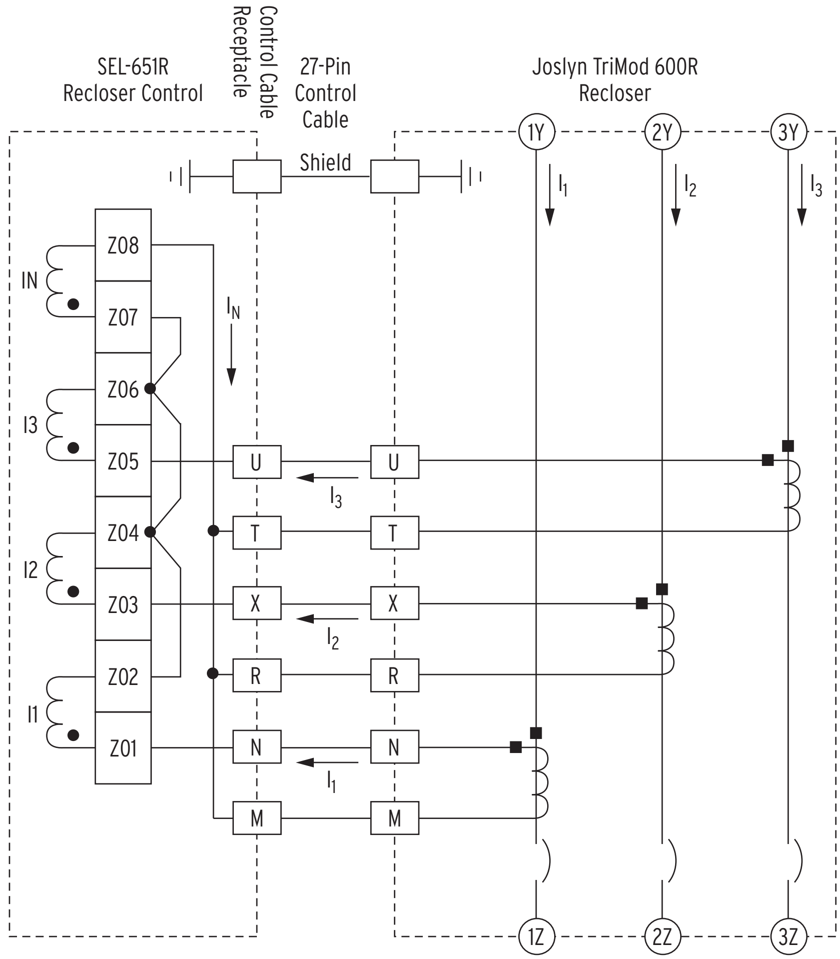


Figure 2.55 Current Connections and Polarity from Joslyn TriMod 600R Recloser Primary to SEL-651R Recloser Control Current Inputs

Notice also that the phase current terminals are labeled I1, I2, I3 (not IA, IB, IC). A-B-C designations are given to the current channels with global setting IPCONN. Current transformer polarity can effectively be changed with the global CTPOL setting, which is helpful for designating forward or reverse power flow and similar things.

Figure 2.56 shows the SEL-651R factory wiring for trip/close for Joslyn TriMod 600R reclosers. Each pole of the recloser has its own trip and close coils. This facilitates single-phase tripping/reclosing, although the SEL-651R factory settings have the recloser operating in a three-phase trip/close mode.

RELAY WORD BIT TCCAP
Relay Word bit TCCAP indicates that the 155 Vdc voltage in Figure 2.56 is present for recloser operations (TCCAP = logical 1). The 155 Vdc voltage comes into the relay module via connector J205 (CAPACITORS), from the trip/close capacitors in the power module (see Figure 2.3, Figure 2.6, Figure 2.9, and Figure 2.11). If there is a problem with this connection or otherwise in the power module, then Relay Word bit TCCAP = logical 0. Relay Word bit TCCAP is used in factory-default close logic settings (see Figure 6.4 and Figure 6.5) and reclose supervision settings (see Table 6.8).

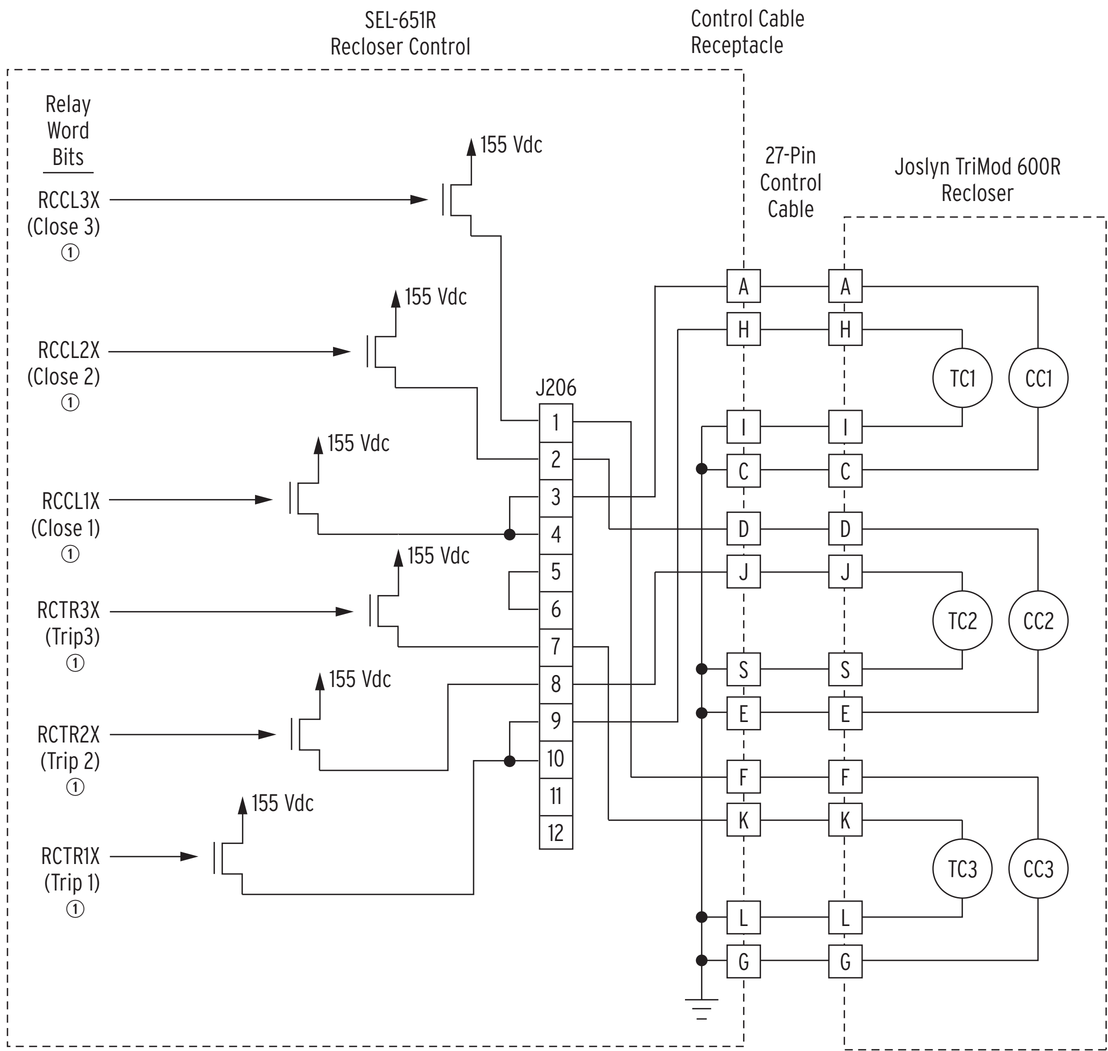
Trace the trip path for Coil 1 in *Figure 2.56*:

> Relay Word Bit RCTR1X (Trip 1; see *Figure 7.26*) turns on the FET (155 Vdc) connected to terminal J206-9. This wiring goes through control cable Pins H and I to Trip Coil 1. The 155 Vdc across Trip Coil 1 causes the current to flow through the coil.

Trace the close path for Coil 1 in *Figure 2.56*:

> Relay Word Bit RCCL1X (Close 1; see *Figure 7.26*) turns on the FET (155 Vdc) connected to terminal J206-3. This wiring goes through control cable Pins A and C to Coil 1. The 155 Vdc across Close Coil 1 causes the current to flow through the coil.

Tripping and closing for phases 2 and 3 operate similarly.



① See Figure 7.26

Figure 2.56 Trip/Close Circuit Connections Between Joslyn TriMod 600R Recloser and SEL-651R Recloser Control

Figure 2.57 shows inputs IN201–IN203 monitoring individual 52a recloser pole status. Input IN204 monitors the status of the yellow operating handle. The yellow operating handle mechanically trips all three phases and the 69 contact opens for the yellow operating handle going to the lock-open position.

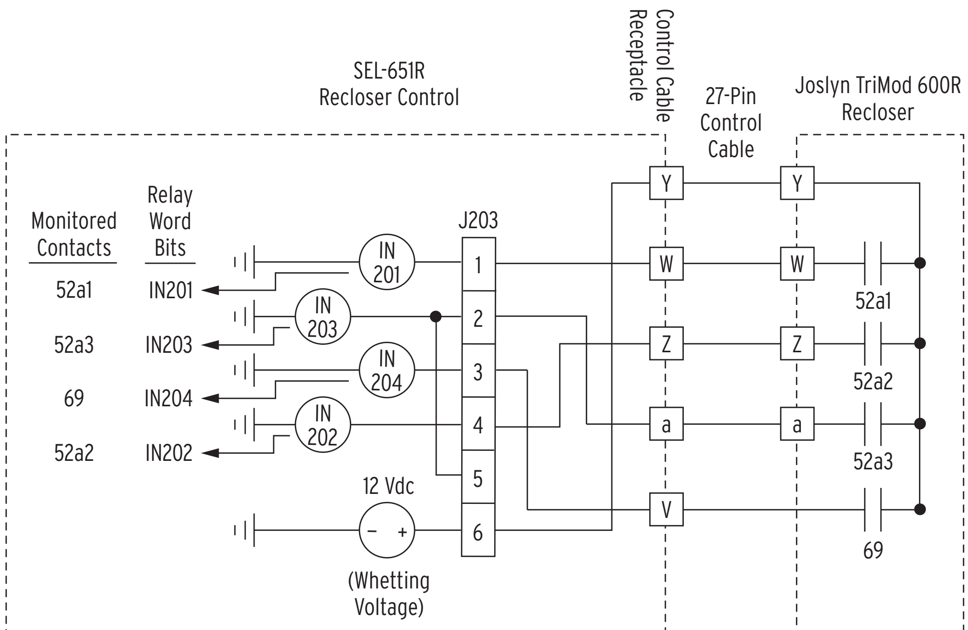


Figure 2.57 Recloser Pole Status Circuit Connections Between Joslyn TriMod 600R Recloser and SEL-651R Recloser Control

Kyle NOVA-TS or NOVA-STS Triple-Single Reclosers

RESISTIVE VOLTAGE SENSORS

To make use of the optional resistive voltage sensors in Figure 2.58, the SEL-651R needs to be ordered with Kyle NOVA LEA voltage inputs for the three-phase VY voltage inputs. See Table 9.11 for voltage phase angle correction settings for such voltage inputs.

Other voltage input options are available, though not using the control cable shown in Figure 2.58 (see SEL-651R Model Option Table).

Figure 2.58 shows the SEL-651R factory wiring for current connections for Kyle NOVA-TS or NOVA-STS Triple-Single reclosers. Notice that the current transformers in the recloser are wired such that the residual path (through Pin Y) is on the polarity side of the current transformer secondaries. This is nonstandard as far as traditional circuit breakers are concerned, but is easily accommodated by the wiring on the Z01 through Z08 terminals of the relay module of the SEL-651R.

Notice also that the phase current terminals are labeled I1, I2, I3 (not IA, IB, IC). A-B-C designations are given to the current channels with global setting IPCONN. Current transformer polarity can effectively be changed with the global CTPOL setting, which is helpful for designating forward or reverse power flow and similar things.

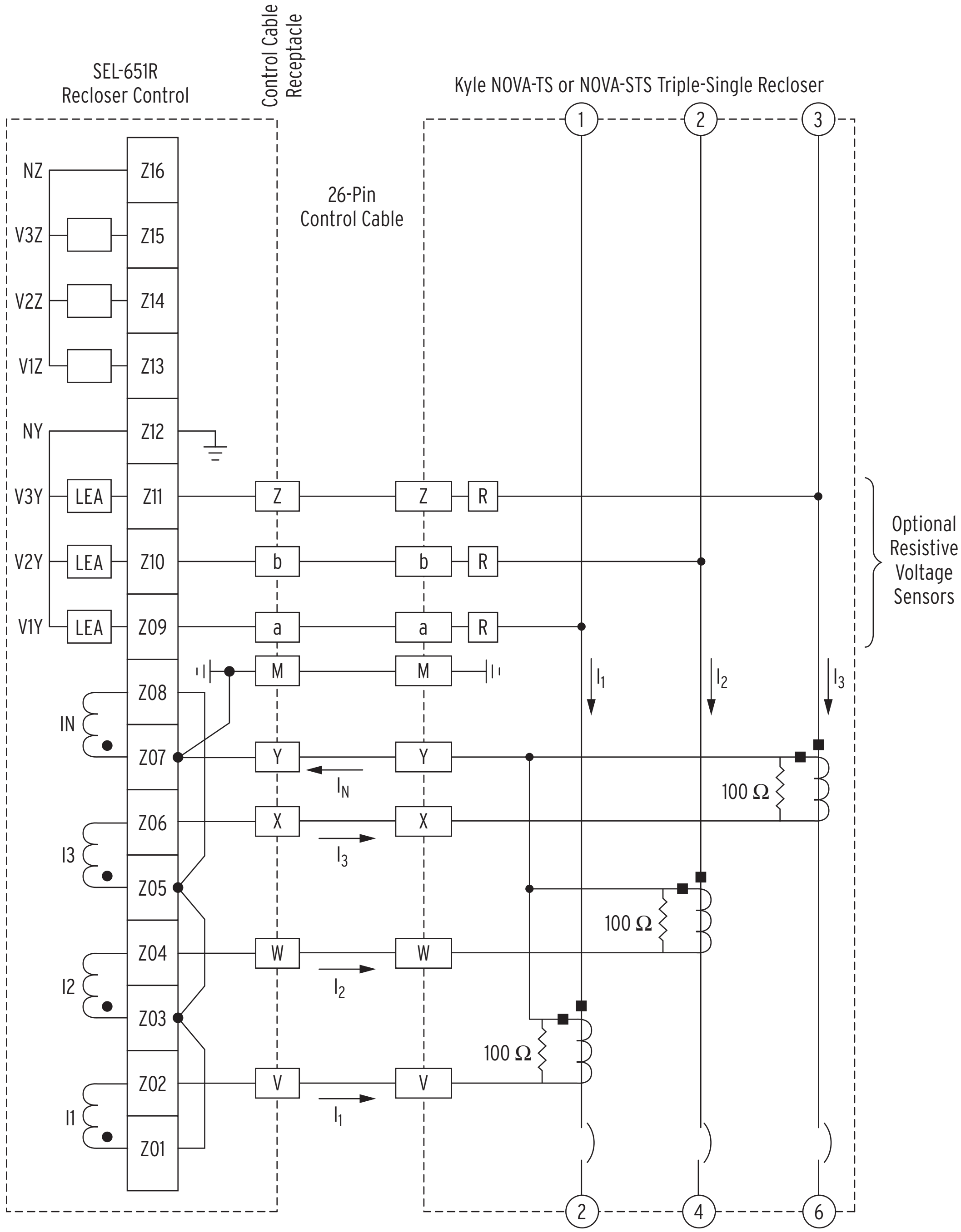


Figure 2.58 Current Connections and Polarity from Kyle NOVA-TS or NOVA-STS Triple-Single Recloser Primary to SEL-651R Recloser Control Current Inputs (Voltage Connections Also Shown)

Figure 2.59 shows the SEL-651R factory wiring for trip/close for Kyle NOVA-TS or NOVA-STS Triple-Single reclosers. Each pole of the recloser has its own trip/close coils. This facilitates single-phase tripping/reclosing, although the SEL-651R factory settings have the recloser operating in a three-phase trip/close mode.

Trace the trip path for Trip Coil 1 in *Figure 2.59*:

> Relay Word Bit RCTR1X (Trip 1; see *Figure 7.26*) turns on the FET (ground) connected to terminal J206-3. This wiring goes through control cable Pin E and on to contact 52a_1 and Trip Circuitry 1.

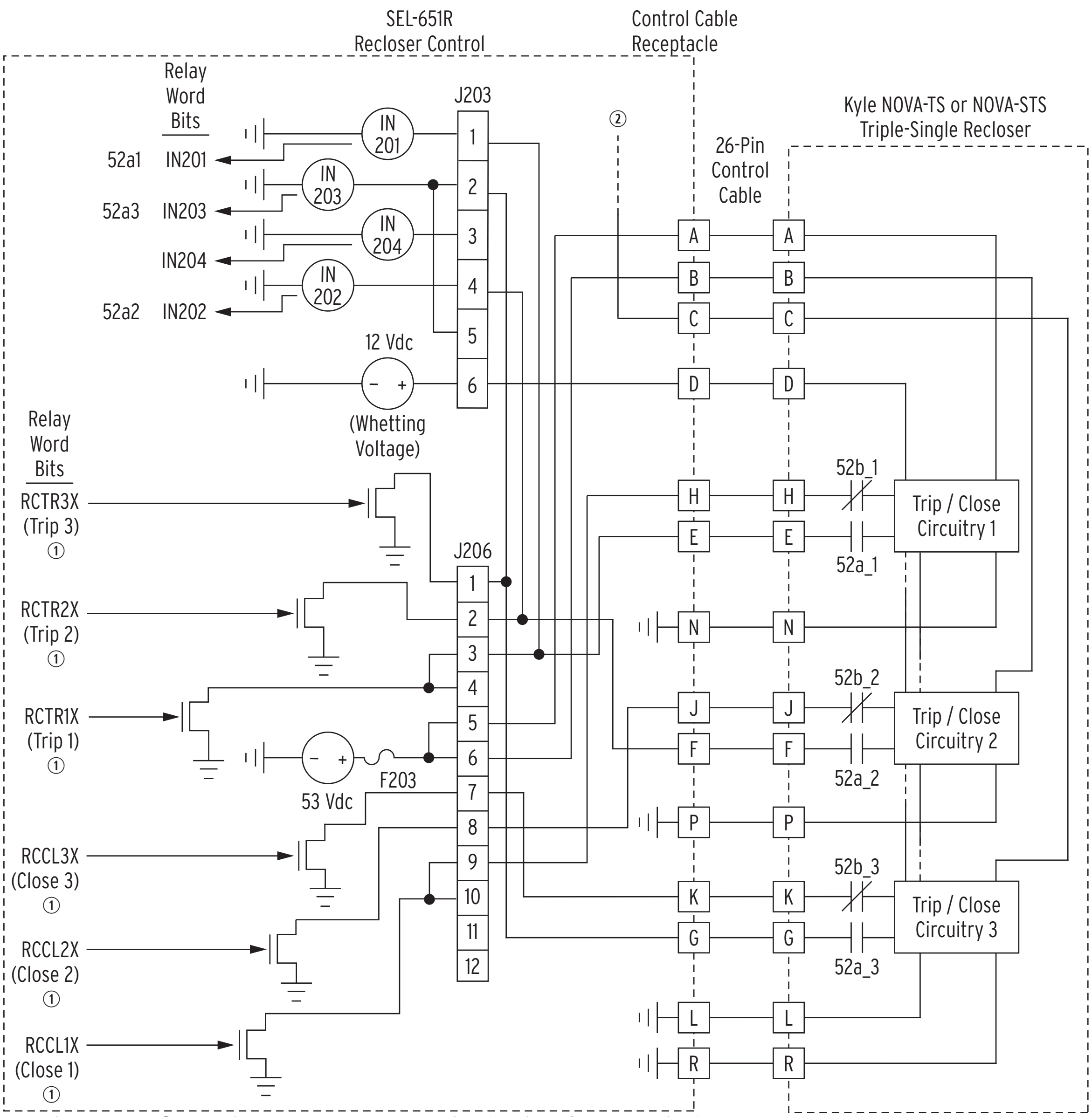
RELAY WORD BIT TCCAP
Relay Word bit TCCAP indicates that the 53 Vdc voltage in Figure 2.59 is present for recloser operations (TCCAP = logical 1). The 53 Vdc voltage comes into the relay module via connector J205 (CAPACITORS), from the trip/close capacitors in the power module (see Figure 2.3, Figure 2.6, Figure 2.9, and Figure 2.11). If there is a problem with this connection or otherwise in the power module, then Relay Word bit TCCAP = logical 0. Relay Word bit TCCAP is used in factory-default close logic settings (see Figure 6.4 and Figure 6.5) and reclose supervision settings (see Table 6.8). Relay Word bit TCCAP does not detect an operation of fuse F203 in Figure 2.59.

Trace the close path for Close Coil 1 in *Figure 2.59*:

> Relay Word Bit RCCL1X (Close 1; see *Figure 7.26*) turns on the FET (ground) connected to terminal J206-9. This wiring goes through control cable Pin H and on to contact 52b_1 and Close Circuitry 1.

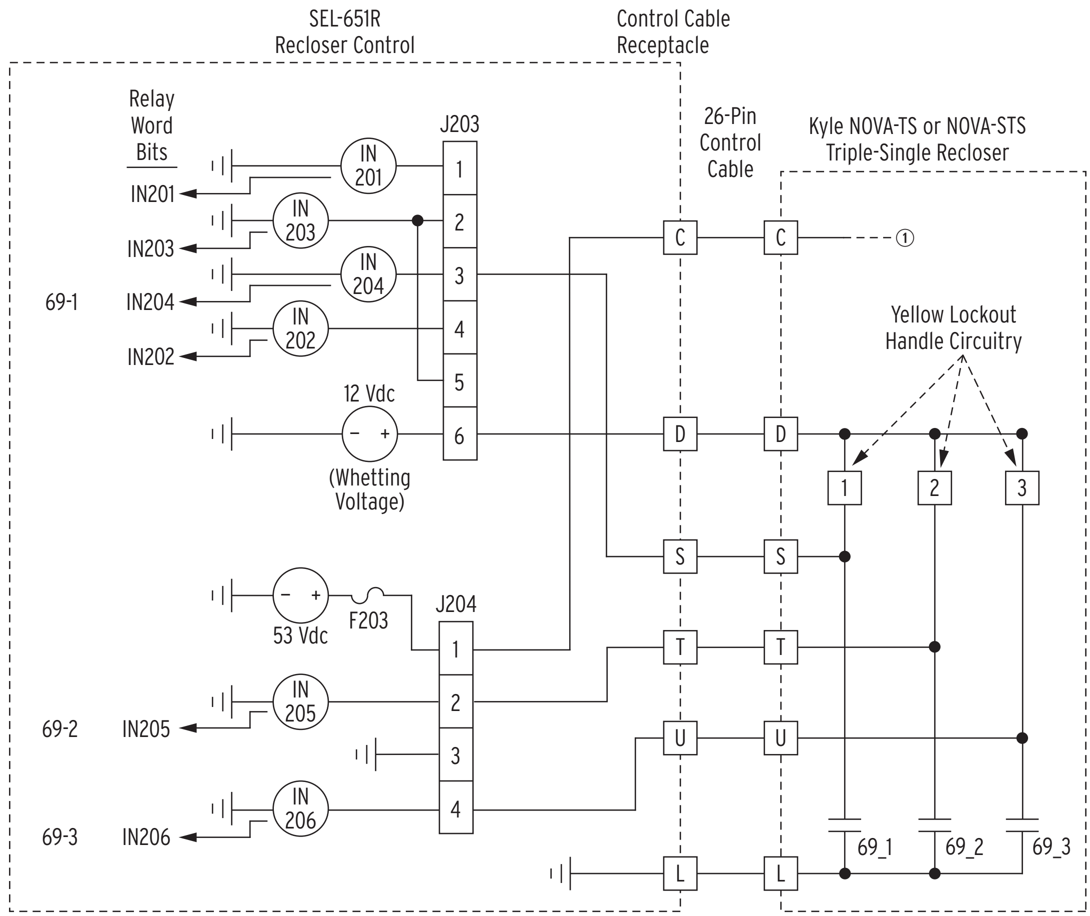
Tripping and closing for phases 2 and 3 operate similarly.

See *Figure 2.60*. The operation of any individual yellow lockout handle on the Kyle NOVA-TS or NOVA-STS Triple-Single recloser results in the opening/lockout of that phase (if not already open) and the opening of the corresponding "69" contact (69_1, 69_2, or 69_3) and the subsequent assertion of the corresponding input (IN204, IN205, or IN206) in the SEL-651R. Inputs IN204, IN205, and IN206 are effectively used in default SELOGIC control equation trip setting TR3X to trip the other two phases when the yellow lockout handle of one phase is operated.



① See Figure 7.25; ② See Figure 2.60 and connection to Pin C from Terminal J204-1

Figure 2.59 Trip/Close and Recloser Pole Status Circuit Connections Between Kyle NOVA-TS or NOVA-STS Triple-Single Recloser and SEL-651R Recloser Control



① See Figure 2.59 for the continuation of the Pin C circuit in the recloser

Figure 2.60 Yellow Lockout Handle Circuit Connections Between Kyle NOVA-TS or NOVA-STS Triple-Single Recloser and SEL-651R Recloser Control

Tavrida OSM Reclosers

Figure 2.61 shows the SEL-651R factory wiring for current and voltage connections for Tavrida OSM reclosers. The current transformers in the recloser are wired like a circuit breaker in that the residual path through control cable Pin 14 is on the nonpolarity side of the current transformer secondaries. This contrasts with the Traditional Retrofit recloser in *Figure 2.44*. Either wiring is easily accommodated by the wiring on the Z01 through Z08 terminals of the SEL-651R relay module.

Notice also that the phase current terminals are labeled I1, I2, I3 (not IA, IB, IC) in *Figure 2.61*. A-B-C designations are given to the current channels with global setting IPCONN. Current transformer polarity can effectively be changed with the global CTPOL setting, which is helpful for designating forward or reverse power flow and similar things.

The Tavrida OSM recloser has built-in capacitive voltage sensors (signified with capacitance C_1 in *Figure 2.61*) that are connected to the 8 Vac LEA voltage inputs of the SEL-651R via capacitance C_2 (capacitances C_1 and C_2 making an effective voltage divider). See *Factory Default Settings on page 9.56* for the required potential transformer ratio settings PTRY (for VY-terminal voltage inputs) and PTRZ (for VZ-terminal voltage inputs) that allow the SEL-651R to meter correctly with the capacitive voltage sensors of the Tavrida OSM reclosers.

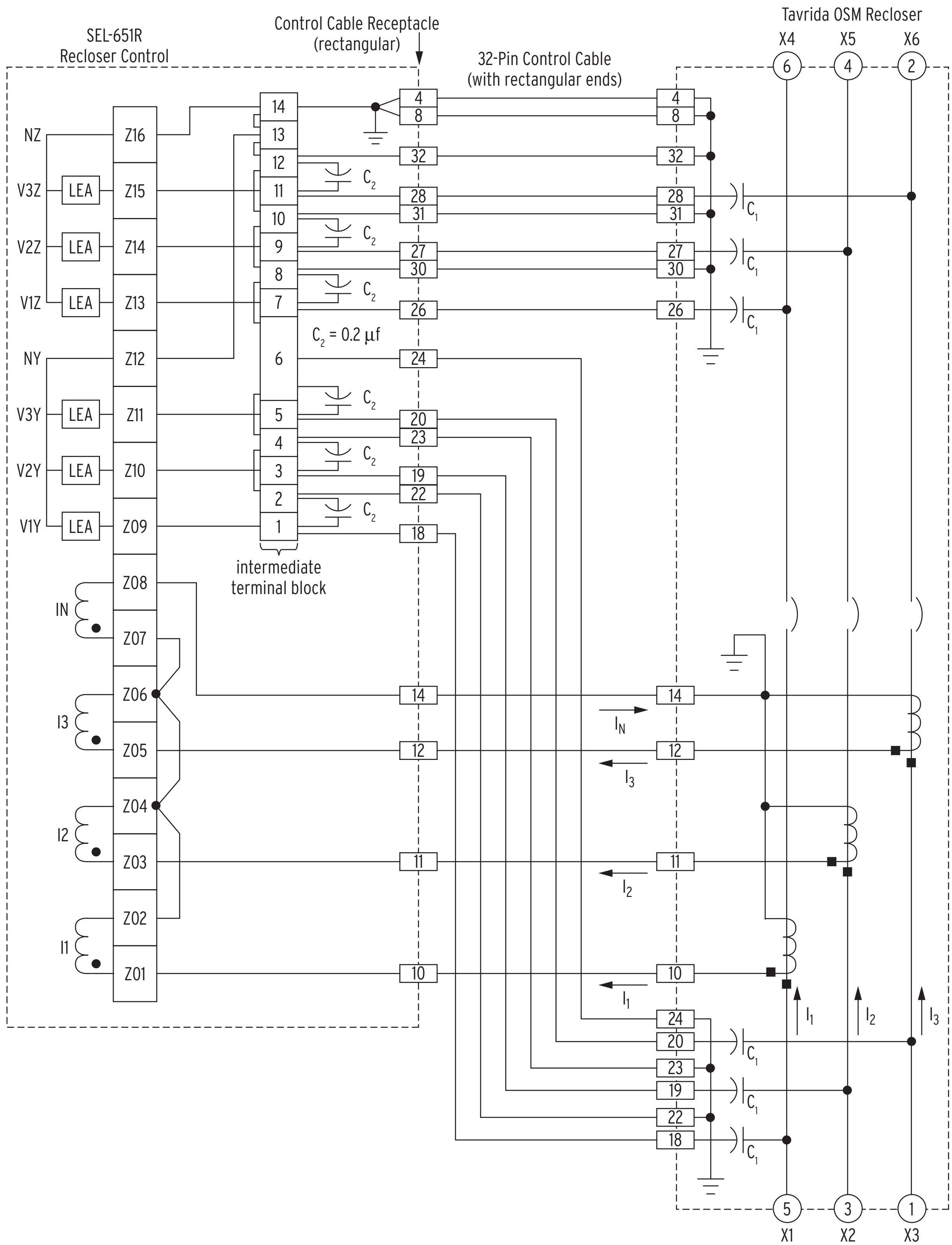
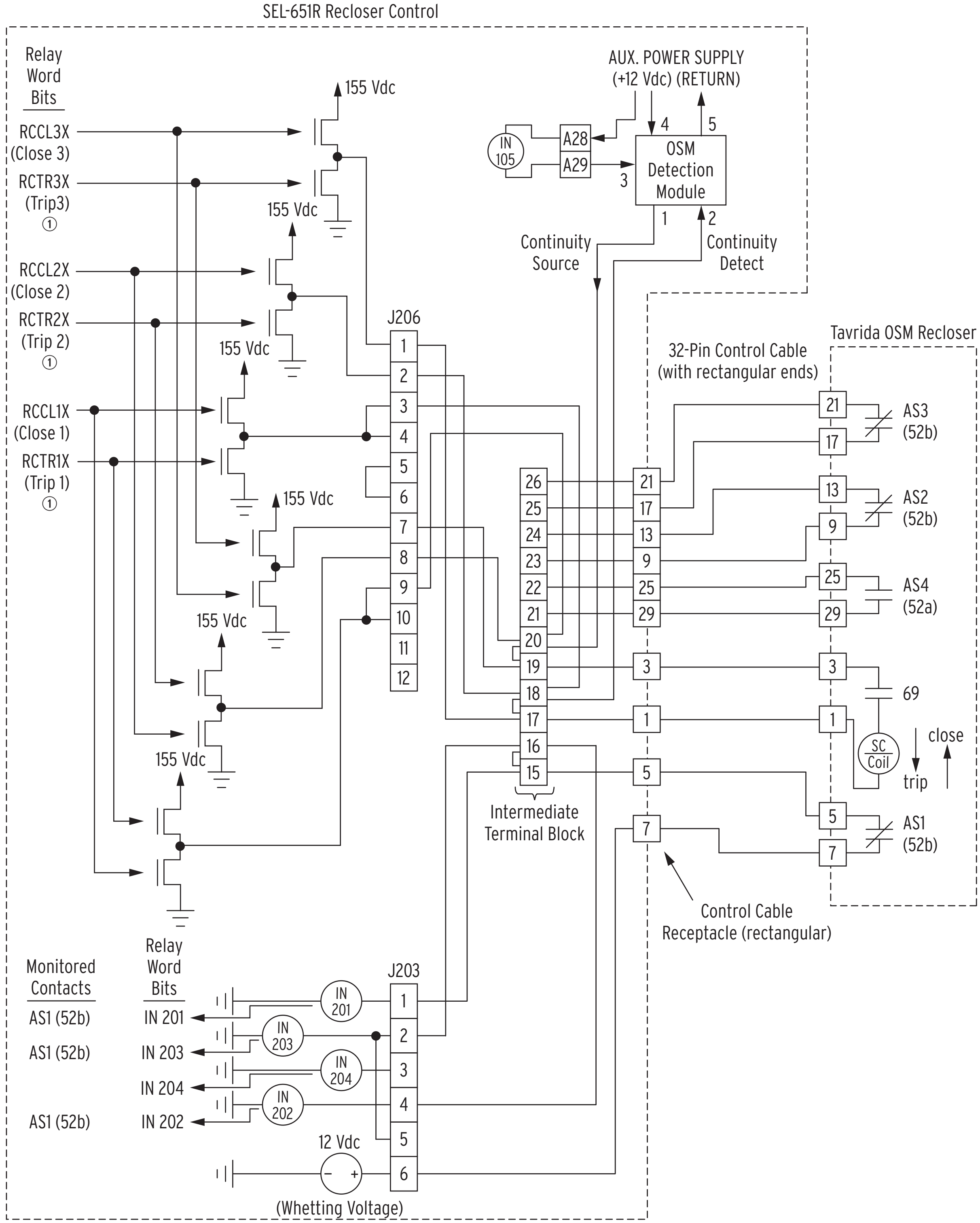


Figure 2.61 Current Connections and Polarity From Tavrida OSM Recloser Primary to SEL-651R Recloser Control Current Inputs (Voltage Connections Also Shown)



① See Figure 7.26

Figure 2.62 Trip/Close and Recloser Status Circuit Connections Between Tavrida OSM Recloser and SEL-651R Recloser Control

RELAY WORD BIT TCCAP

Relay Word bit TCCAP indicates that the 155 Vdc voltage in Figure 2.62 is present for recloser operations (TCCAP = logical 1). The 155 Vdc voltage comes into the relay module via connector J205 (CAPACITORS), from the trip/close capacitors in the power module (see Figure 2.3, Figure 2.6, Figure 2.9, and Figure 2.11). If there is a problem with this connection or otherwise in the power module, then Relay Word bit TCCAP = logical 0. Relay Word bit TCCAP is used in factory-default close logic settings (see Figure 6.4 and Figure 6.5) and reclose supervision settings (see Table 6.8).

The parallel connections shown between terminals 2, 4, 6, 8, 10, 12, 13, and 14 on the left-hand side of the intermediate terminal block in *Figure 2.61* are realized with hidden busing inside the intermediate terminal block itself. Terminal 14 of the intermediate terminal block is then taken to cabinet ground.

The Tavrida OSM recloser operates as a three-phase trip/three-phase close device—it does not have single-phase tripping/closing capability. There is only one trip/close coil (referenced as SC/coil in *Figure 2.62*) for the Tavrida OSM recloser: trip for current flow in one direction, close for current flow in the other direction.

In *Figure 2.62*, note that the trip and close FETs in the SEL-651R are stacked on top of one another, between 155 Vdc power and ground, with a tap in the middle. For a given FET stack, both FETs can never be on at the same time or else there would be a direct short between the 155 Vdc power and ground. Interlocking logic prevents both FETs from being on at the same time.

Also, note that there are redundant trip/close circuits connected to SC/coil:

- ➤ Three FET stacks (top trip FET/bottom close FET) paralleled to terminals 19 and 20 of the intermediate terminal block in *Figure 2.62*
- ➤ Three FET stacks (top close FET/bottom trip FET) paralleled to terminals 17 and 18 of the intermediate terminal block in *Figure 2.62*

Trace one of the trip paths in *Figure 2.62*:

Relay Word Bit RCTR1X (Trip 1; see *Figure 7.26*) turns on the bottom trip FET (ground) connected to terminal J206-3 (then terminal 18 of the intermediate terminal block) and the top trip FET (155 Vdc) connected to terminal J206-9 (then terminal 20 of the intermediate terminal block). This wiring continues through control cable Pin 3 and Pin 1 to SC/coil in the Tavrida OSM recloser. The 155 Vdc across SC/coil (top to bottom) causes the current to flow in the indicated trip direction.

Trace one of the close paths in *Figure 2.62*:

Relay Word Bit RCCL1X (Close 1; see *Figure 7.26*) turns on the top close FET (155 Vdc connected to terminal J206-3 (then terminal 18 of the intermediate terminal block) and the bottom close FET (ground) connected to terminal J206-9 (then terminal 20 of the intermediate terminal block). This wiring continues through control cable Pin 3 and Pin 1 to SC/coil in the Tavrida OSM recloser. The 155 Vdc across SC/coil (bottom to top) causes the current to flow in the indicated close direction.

The other paralleled trip/close circuits in *Figure 2.62* operate similarly. Relay Word bits RCTR1X, RCTR2X, and RCTR3X all operate the same—their controlling SELOGIC settings (see *Figure 7.26*) are set the same in default settings. Likewise, Relay Word bits RCCL1X, RCCL2X, and RCCL3X all operate the same—their controlling SELOGIC settings (see *Figure 7.26*) are set the same in default settings.

A single 52b contact (AS1) is connected in parallel to inputs IN201, IN202, and IN203 as shown in *Figure 2.62* for recloser status. With the following *Factory Default Settings on page 9.56* for the Tavrida OSM recloser:

Global setting BKTYP:= **1**

Group setting ESPB:= **N**

Group settings 52A_A:= **NOT IN201**, 52A_B:= **NOT IN202**, 52A_C:= **NOT IN203** these three paralleled inputs only provide a three-phase open/three-phase closed status, not a per-pole recloser status (see resultant 52A3P Relay Word bit in *Figure 6.2*). It is irrelevant that IN201 is apparently assigned to an A-phase designation (52A_A:= NOT IN201) and likewise IN202 with B-phase (52A_B:= NOT IN202) and IN203 with C-phase (52A_C:= NOT IN203). Resultant Relay Word bit 52A3P only conveys three-phase open/three-phase closed status, not any single-phase status.

Contacts AS2, AS3, and AS4 are brought to the intermediate terminal block in *Figure 2.62*, but are not connected to the SEL-651R.

When the external yellow operating handle on the Tavrida OSM recloser is pulled to the lock-open position, the following occurs:

- ➤ The Tavrida OSM recloser trips open (if not already open)
- ➤ The 69 contact in the trip/close circuit (*Figure 2.62*) opens and stays open

With contact 69 open, there is no way to close the Tavrida recloser until the yellow operating handle is reset again. With the yellow operating handle reset, contact 69 in the trip/close circuit is closed again and the Tavrida recloser can then be closed by the SEL-651R.

Yellow Operating Handle Status

Input IN105 in *Figure 2.62* indicates yellow operating handle status:

- ➤ IN105 asserted (yellow operating handle in reset position and contact 69 closed in trip/close circuit)
- ➤ IN105 deasserted (yellow operating handle in lock-open position and contact 69 open in trip/close circuit)

The OSM Detection Module senses contact 69 position (open or closed) in the trip/close circuit, via the continuity source and detect connections. The OSM Detection Module then controls the assertion/deassertion of input IN105.

The following factory default settings for the Tavrida OSM recloser provide a front-panel display indication of the yellow operating handle status (reset or lock-open), qualified for 150 cycles.

SHO L Command

ESV := **3**

SV02PU := **150.00**

SV02DO := **150.00**

SV02 := **IN105 # QUALIFY YELLOW HANDLE OPERATION**

SHO F Command

EDP:= **4**

DP03:= **SV02T,"YELLOW HANDLE",RESET,LOCK-OPEN**

Disconnected Control Cable Alarm

Input IN105, from *Figure 2.62*, combined with recloser status (Relay Word bit 52A3P) provides a disconnected control cable alarm. If the control cable is disconnected in *Figure 2.62*, then inputs IN105, IN201, IN202, and IN203 are all deasserted, thus indicating the following contradictory condition:

- yellow operating handle in lock-open position (input IN105 deasserted)
- recloser closed (52b inputs IN201, IN202, and IN203 are all deasserted)

If "recloser closed," then the yellow operating handle must be reset. Pulling the yellow operating handle to lock-open causes the recloser to open and remain open. Thus, the condition "recloser closed" and yellow operating handle "lock-open" is an abnormal/alarm condition and is indicative of a disconnected control cable.

The following factory default settings for the Tavrida OSM recloser provide a front-panel display indication of a disconnected control cable, qualified for 150 cycles.

SHO L Command

ESV := **3**

SV03PU := **150.00**

SV03DO := **150.00**

SV03 := **NOT(IN105) AND 52A3P # QUALIFY DISCONNECTED CABLE**

SHO F Command

EDP := **4**

DP04 := **SV03T,,"CABLE DISCONNECTED"**

Siemens SDR Reclosers

Figure 2.63 and *Figure 2.64* show the SEL-651R factory wiring for current connections for Siemens SDR Triple-Single and Siemens SDR Three-Phase reclosers, respectively. Note that the phase current terminals are labeled I1, I2, I3 (not IA, IB, IC) in *Figure 2.63* and *Figure 2.64*. A-B-C designations are given to the current channels with global setting IPCONN. Current transformer polarity can effectively be changed with the global CTPOL setting, which is helpful for designating forward or reverse power flow and similar things.

The Siemens SDR reclosers have optional built-in resistive voltage sensors (signified with resistance R in the recloser tanks in *Figure 2.63* and *Figure 2.64*) that are connected to the VZ-terminal Siemens LEA voltage inputs of the SEL-651R (resistance R in the recloser tank and resistance in the Siemens LEA voltage inputs making an effective voltage divider). See *Table 9.13* and Table *Table 9.17* for the required phase angle correction settings and potential transformer ratio settings, respectively, that allow the SEL-651R to meter primary voltage correctly with the resistive voltage sensors of the Siemens SDR reclosers.

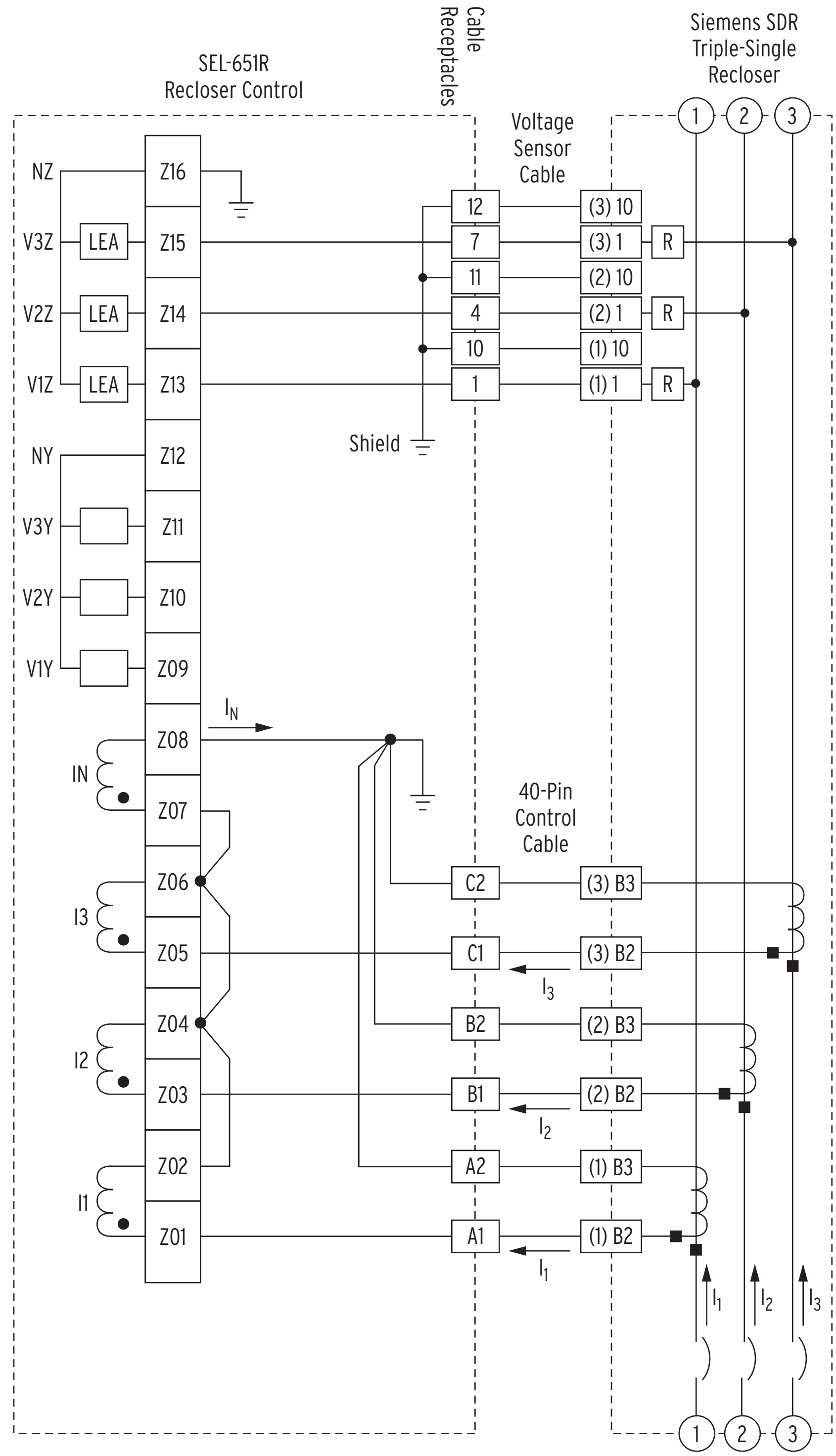


Figure 2.63 Current Connections and Polarity from Siemens SDR Triple-Single Recloser Primary to SEL-651R Recloser Control Current Inputs

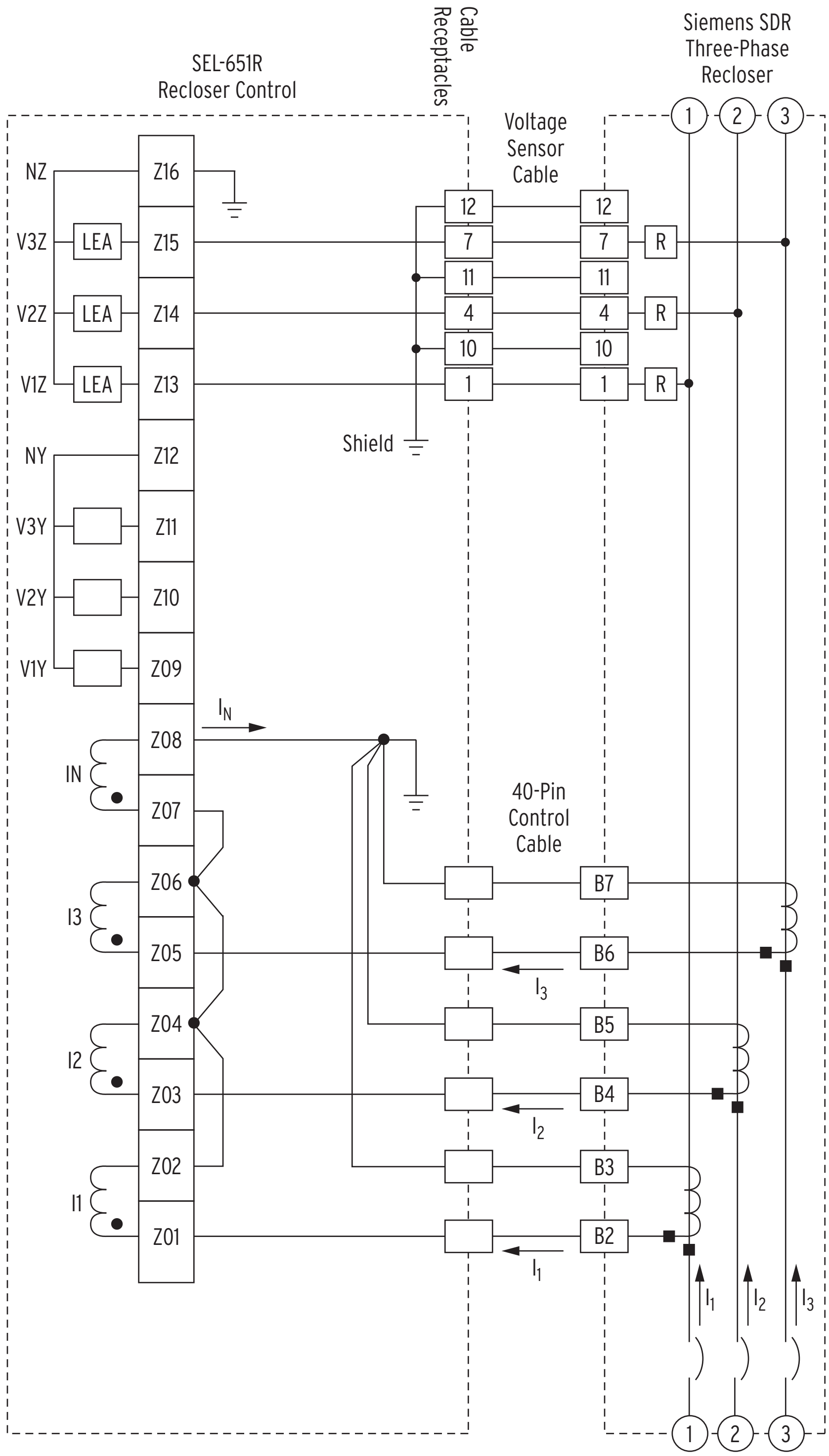


Figure 2.64 Current Connections and Polarity from Siemens SDR Three-Phase Recloser Primary to SEL-651R Recloser Control Current Inputs

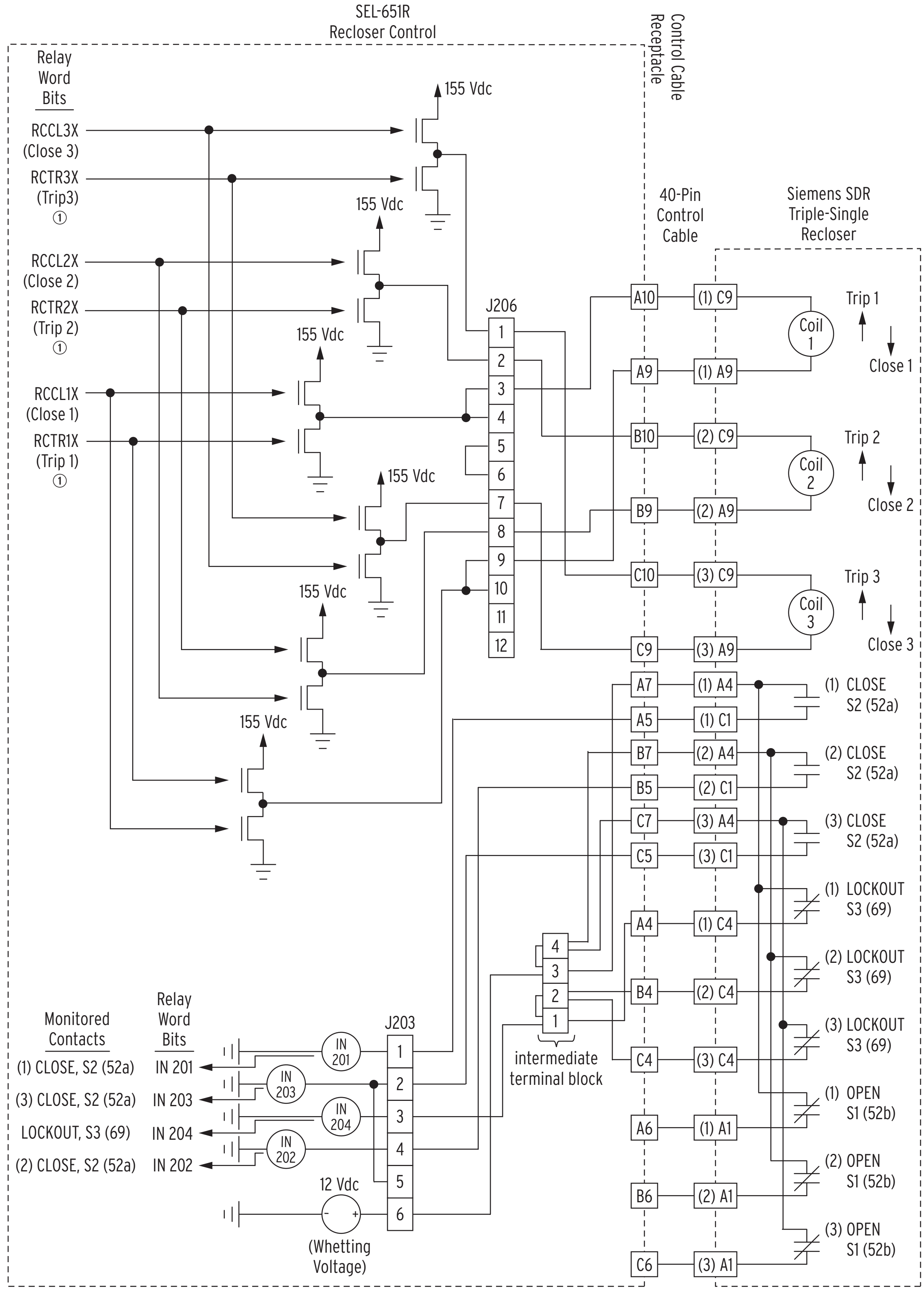
The Siemens SDR Triple-Single recloser in *Figure 2.65* has single-phase tripping/closing capability, while the Siemens SDR Three-Phase recloser in *Figure 2.66* does not. Thus, the Siemens SDR Triple-Single recloser in *Figure 2.65* has the additional complexity of per-phase tripping/closing and per-phase recloser status via the "CLOSE, S2 (52a)" contacts. The "OPEN, S1 (52b)" contacts in *Figure 2.65* are not used by the SEL-651R.

The operation of any individual lockout handle on the Siemens SDR Triple-Single recloser results in the opening/lockout of that phase (if not already open) and the assertion of the corresponding “LOCKOUT, S3 (69)” contact in *Figure 2.65* and the subsequent assertion of input IN204 in the SEL-651R. The operation of the yellow lockout handle on the Siemens SDR Three-Phase recloser results in the opening/lockout of all three phases (if not already open) and the assertion of the “LOCKOUT, S3 (69)” contact in *Figure 2.66* and the subsequent assertion of input IN204 in the SEL-651R. Input IN204 can be used in SELOGIC control equation settings to functionally keep the SEL-651R in lockout (settings 79DTL__), block the issuing of a close (settings ULCL__), or (in the case of the Siemens SDR Triple-Single recloser) trip the other phases (settings TR__).

RELAY WORD BIT TCCAP

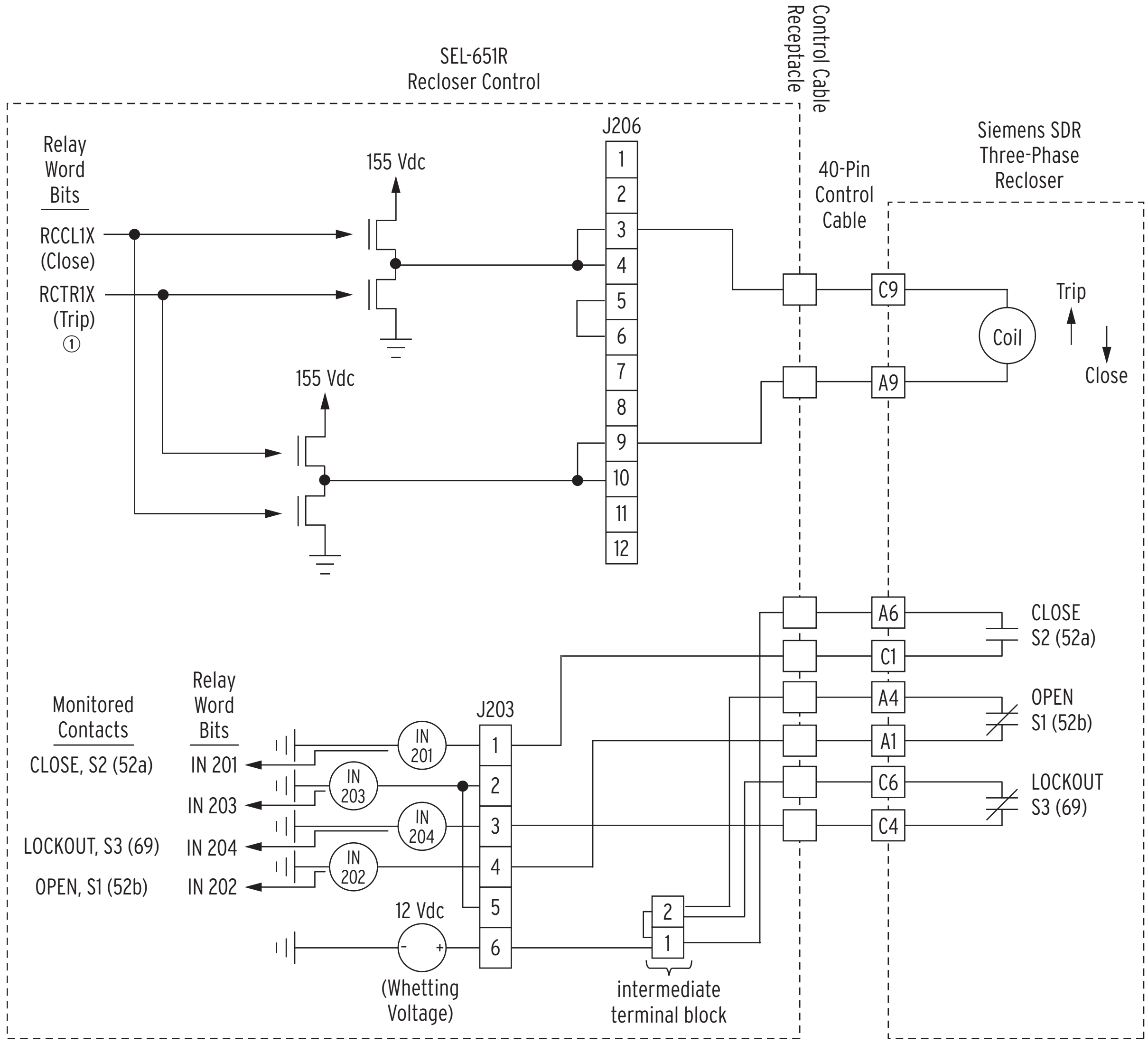
Relay Word bit TCCAP indicates that the 155 Vdc voltage in Figure 2.65 and Figure 2.66 is present for recloser operations (TCCAP = logical 1). The 155 Vdc voltage comes into the relay module via connector J205 (CAPACITORS), from the trip/close capacitors in the power module (see Figure 2.3, Figure 2.6, Figure 2.9, and Figure 2.11). If there is a problem with this connection or otherwise in the power module, then Relay Word bit TCCAP = logical 0. Relay Word bit TCCAP is used in factory-default close logic settings (see Figure 6.4 and Figure 6.5) and reclose supervision settings (see Table 6.8).

In *Figure 2.65* and *Figure 2.66*, note that the trip and close FETs in the SEL-651R are stacked on top of one another, between 155 Vdc power and ground, with a tap in the middle. For a given FET stack, both FETs can never be on at the same time or else there would be a direct short between the 155 Vdc power and ground. Interlocking logic prevents both FETs from being on at the same time.



① See Figure 7.26

Figure 2.65 Trip/Close, Recloser Pole Status, and Lockout Handle Status Circuit Connections Between Siemens SDR Triple-Single Recloser and SEL-651R Recloser Control



① See Figure 7.26

Figure 2.66 Trip/Close, Recloser Status, and Lockout Handle Status Circuit Connections Between Siemens SDR Three-Phase Recloser and SEL-651R Recloser Control

Trace one of the trip paths in *Figure 2.65*:

> Relay Word Bit RCTR1X (Trip 1; see *Figure 7.26*) turns on the bottom trip FET (ground) connected to terminal J206-3 and the top trip FET (155 Vdc) connected to terminal J206-9. This wiring continues through control cable pins A10/(1)C9 and A9/(1)A9 to Coil 1 in the Siemens SDR Triple-Single recloser. The 155 Vdc across Coil 1 (bottom to top) causes the current to flow in the indicated trip direction.

Trace one of the close paths in *Figure 2.65*:

> Relay Word Bit RCCL1X (Close 1; see *Figure 7.26*) turns on the top close FET (155 Vdc) connected to terminal J206-3 and the bottom close FET (ground) connected to terminal J206-9. This wiring continues through control cable pins A10/(1)C9 and A9/(1)A9 to Coil 1 in the Siemens SDR Triple-Single recloser. The 155 Vdc across Coil 1 (top to bottom) causes the current to flow in the indicated close direction.

The other trip/close circuits in *Figure 2.65* and *Figure 2.66* operate similarly.

Figure 2.67 and *Figure 2.68* show the routing of 120 Vac power through the 40-pin control cable to heaters in the Siemens SDR reclosers.

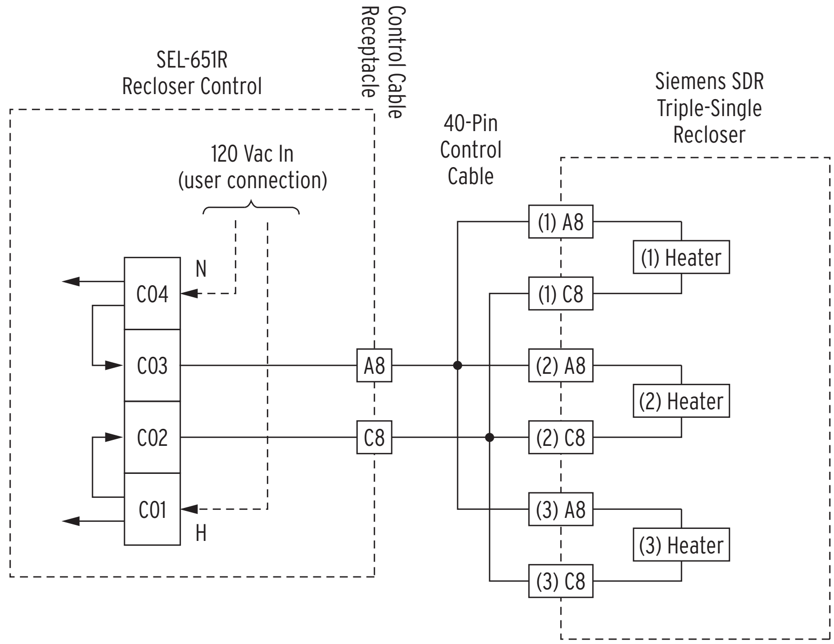


Figure 2.67 120 Vac Power Circuit Connections Between SEL-651R Recloser Control and Siemens SDR Triple-Single Recloser

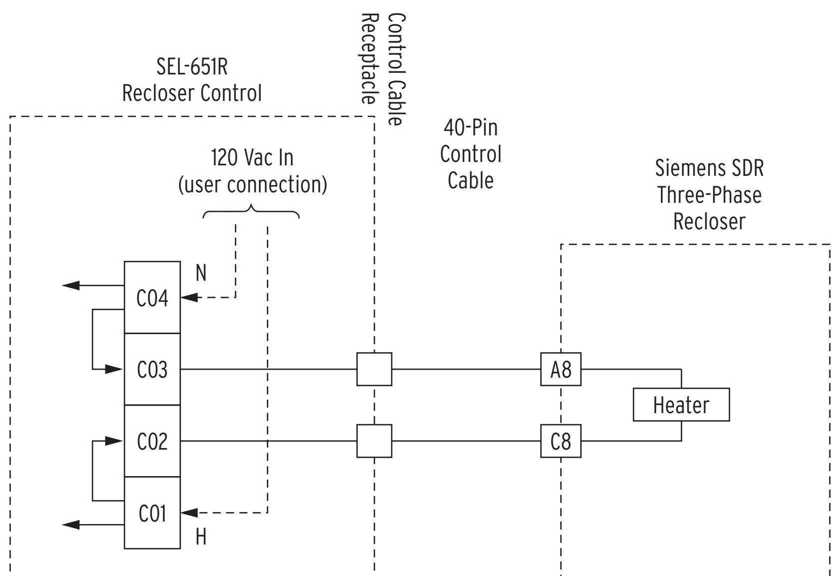


Figure 2.68 120 Vac Power Circuit Connections Between SEL-651R Recloser Control and Siemens SDR Three-Phase Recloser

Inputs Connector J204/G&W Viper-S Recloser

INPUTS connector **J204** on the rear panel of the SEL-651R relay module is for extra signaling back from the G&W Viper®-S recloser, a Traditional Retrofit type recloser. *Figure 2.69* shows whetting voltage (24 Vdc) coming from connector **J204** Pin 1, routing through signaling contacts on the G&W Viper-S, and back to inputs IN205 and IN206 on connector **J204**.

The Form A contact connected to input IN205 indicates low SF6 gas pressure inside the G&W Viper-S recloser. The Form B contact connected to input IN206 indicates loss of 120 Vac low voltage close power at the G&W Viper-S recloser. Unused Pin 3 on connector **J204** can be used as a ground return for a separate optoisolated input (e.g., IN101) whetted by the 24 Vdc on Pin 1.

NOTE: Wires not included.

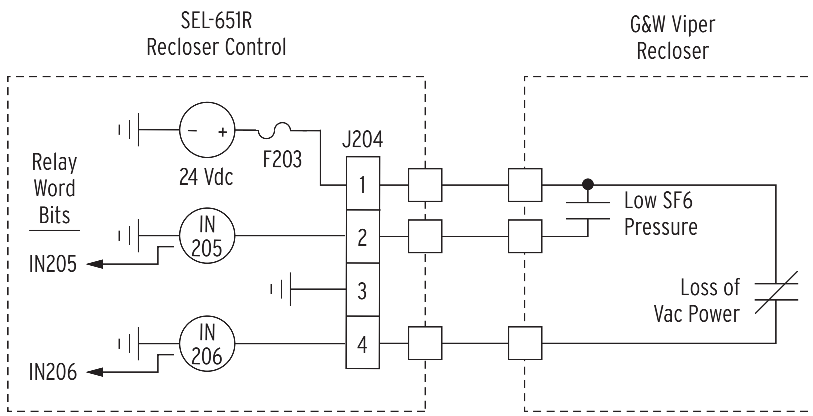


Figure 2.69 G&W Viper-S Recloser Extra Alarm Connections to SEL-651R

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Section 3
PC Software

SEL provides many PC software solutions (applications) that support the SEL-651R and other SEL devices. SEL-651R software solutions are listed in *Table 3.1*.

Table 3.1 SEL Software Solutions

Part Number	Product Name	Description
SEL-5010	Relay Assistant software	This application uses a database to manage a connection directory and settings of multiple devices.
SEL-5030	ACSELERATOR QuickSet® SEL-5030 software	See *Table 3.2*.
SEL-5040	Power System Report Manager software	This application uses a database to manage event reports. It automatically collects and file 1/4-cycle resolution event reports.
SEL-5601	Analytic Assistant software	Converts SEL compressed ASCII event reports files to oscillography
SEL-5801	Cable Selector software	Selects the proper SEL cables for your application.

ACSELERATOR is a powerful setting, event analysis, and measurement tool that aids in applying and using the recloser control. *Table 3.2* shows the suite of ACSELERATOR applications provided for the SEL-651R. This section describes how to get started with the SEL-651R and ACSELERATOR.

Table 3.2 ACSELERATOR Applications

Application	Description
Terminal	Provides a direct connection to the SEL device. Use this feature to ensure proper communications and directly interface with the device.
Meter and Control HMI	Provides a summary view of device operation. Use this feature to simplify commissioning testing.
Rules Based Settings Editor	Provides on-line or off-line device settings that include interdependency checks. Use this feature to create and manage settings for multiple devices in a database.
Event Analysis	Provides oscillography and other event analysis tools.
Settings Database Management	ACSELERATOR uses a database to manage the settings of multiple devices.
Help	Provides general ACSELERATOR and device specific ACSELERATOR context sensitive help.

ACSELERATOR Setup

Follow the steps outlined in *Section 2: Installation* to prepare the SEL-651R for use. Perform the following steps to initiate communications:

Step 1. Connect the appropriate communications cable between the SEL-651R and the PC.

Step 2. Apply power to the SEL-651R.

Step 3. Start ACSELERATOR.

Main Menu Bar

Figure 3.1 shows which menu item to select for the desired application.

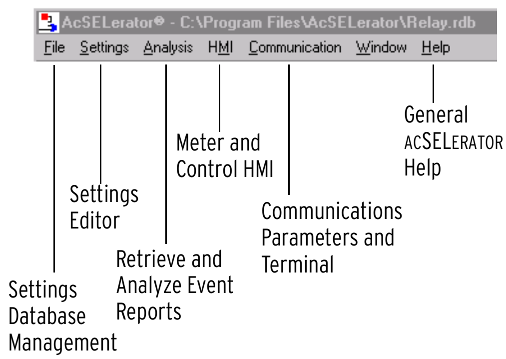


Figure 3.1 ACSELERATOR Main Menu Bar

Follow the directions in *Terminal Window on page 3.3* to verify proper communications with the recloser control.

Parameters

ACSELERATOR uses recloser control communications Port 1, 2, 3, or F (front panel) to communicate with the SEL-651R. Perform the following steps to configure ACSELERATOR to communicate effectively with the recloser control.

NOTE: See the Preface for an explanation of typographic conventions used to describe menus.

Step 1. Select **Communication > Parameters** from the ACSELERATOR main menu bar to open the **Communication Parameters** dialog box.

Step 2. Configure the PC port to match the recloser communications settings.

Figure 3.2 shows the ACSELERATOR **Communication Parameters** dialog box with default serial port parameters 9600, 8, N, 1.

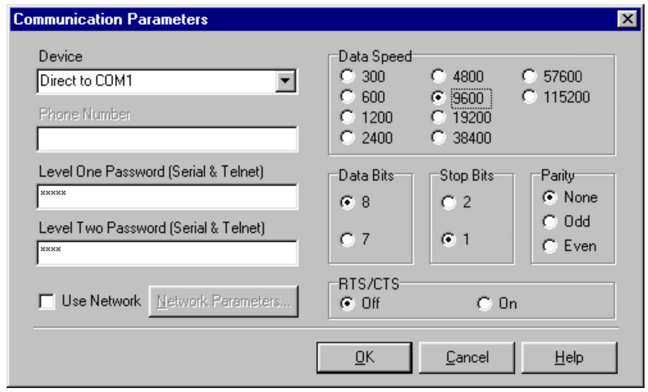


Figure 3.2 ACSELERATOR Communication Parameters Dialog Box

Step 3. Enter the recloser Access Level One and Access Level Two passwords in the respective text boxes.

Step 4. If a telephone modem is chosen from the **Device** text box, enter the dial-up telephone number in the **Phone Number** text box.

Step 5. Click **OK** when finished.

ACSELERATOR Terminal

Terminal Window

Select the **Communication** menu on the ACSELERATOR main menu bar to see the terminal menu items shown in *Table 3.3*.

Table 3.3 Terminal Menu

Menu Item	Description
Terminal	Open the terminal connection window.
Terminal Logging	Start or stop the terminal connection log.
Connection Log	View the terminal connection log.
Clear Connection Log	Clear the terminal connection log.

The terminal window is an ASCII interface with the recloser control. This is a basic terminal emulation with no file transfer capabilities. Many third-party terminal emulation programs are available with file transfer encoding schemes. Press **<Insert>** to disable communications and enable scrolling. Press **<Insert>** again to reverse the process.

Open the terminal window by either clicking **Communication > Terminal** or by pressing **<Ctrl+T>**.

Verify proper communications with the recloser control by opening a terminal window, pressing **<Enter>** a few times, and verifying that a prompt is received, as shown in *Figure 3.3*. If a prompt is not received, verify proper setup.

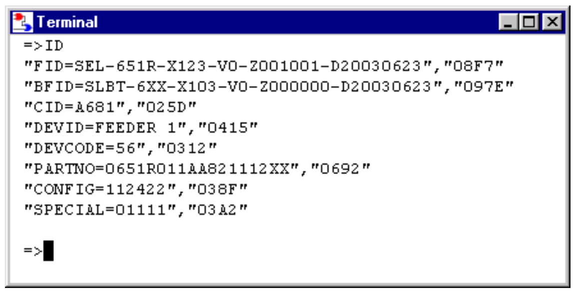
Figure 3.3 Terminal Prompt

Terminal Logging

If the **Terminal Logging** item in the **Communication** menu is checked, ACSELERATOR records communications events and errors in a log. Click **Communication > Connection Log** to view the log. Clear the log by selecting **Communication > Clear Connection Log**.

Drivers

Enter Access Level 1 and issue the **ID** command to receive an identification report similar to the one shown in *Figure 3.4*.



```
=>ID
"FID=SEL-651R-X123-V0-Z001001-D20030623","08F7"
"BFID=SLBT-6XX-X103-V0-Z000000-D20030623","097E"
"CID=A681","025D"
"DEVID=FEEDER 1","0415"
"DEVCODE=56","0312"
"PARTNO=0651R011AA821112XX","0692"
"CONFIG=112422","038F"
"SPECIAL=01111","03A2"

=>
```

Figure 3.4 Identification Report

Locate and record the Z-number in the FID string. It will look similar to *Figure 3.5*. The first portion of the Z-number (Z001xxx, for example) determines the ACSELERATOR relay settings driver version when you are creating or editing relay settings files. The later portion of the Z-number (Zxxx001, for example) determines the HMI version number. These numbers are used by the **HMI** applications to ensure proper interaction between the SEL-651R and ACSELERATOR. The use of the Relay Editor driver version will be discussed in more detail later in this section.

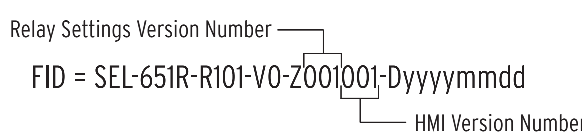


Figure 3.5 ACSELERATOR Driver Information in the FID String

ACSELERATOR reads the latter portion of the Z-number to determine the correct HMI to display when you select the menu. View the bottom of the HMI window shown in *Figure 3.6* to check the HMI driver number (see *Open the ACSELERATOR HMI on page 3.5* for instructions).

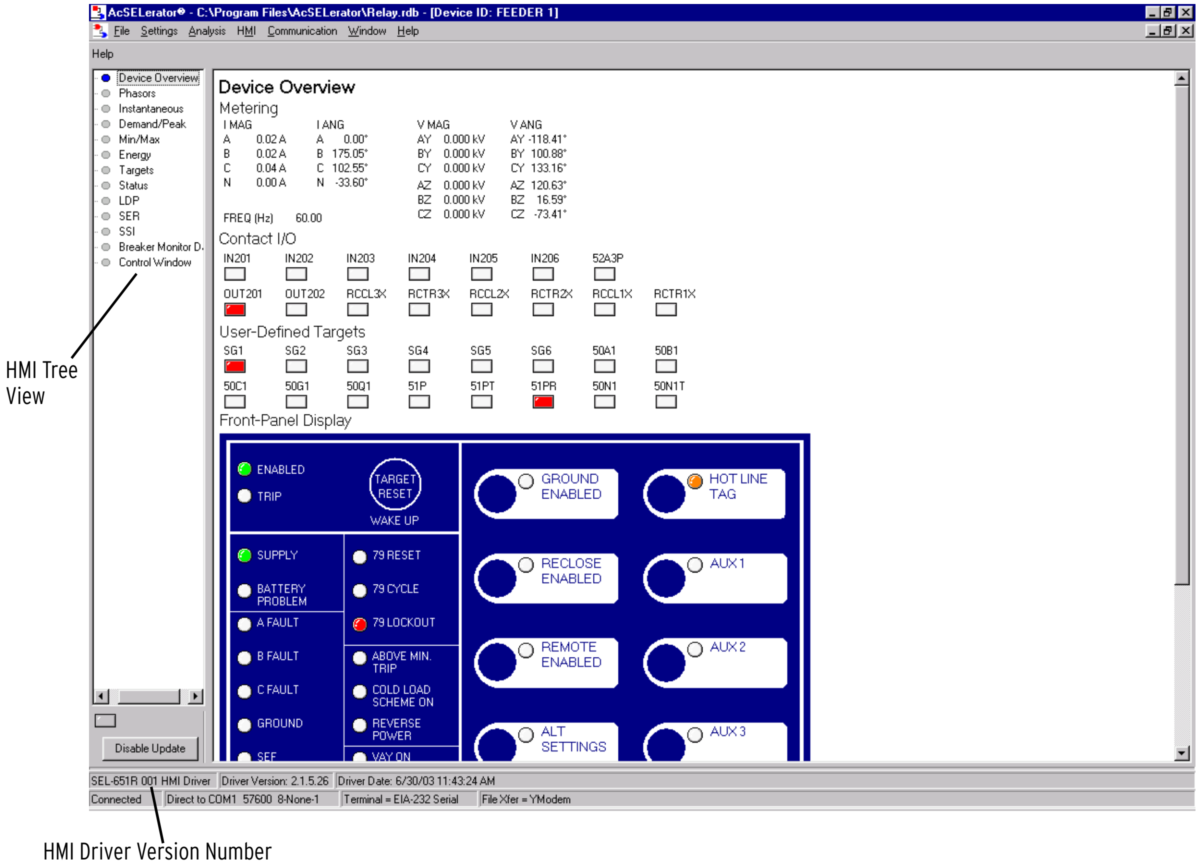


Figure 3.6 HMI Driver Version Number

ACSELERATOR Meter and Control HMI

Use the ACSELERATOR HMI feature to view real-time recloser control information in a graphical format. Use the virtual recloser control front panel to read metering and targets and to operate the recloser control. This window quickly verifies proper operation of the recloser control.

Open the ACSELERATOR HMI

Click **HMI** in the ACSELERATOR menu bar, then select and click the **Meter and Control** menu item. ACSELERATOR opens the HMI window and downloads the interface data.

ACSELERATOR HMI Features

Use ACSELERATOR to access many types of recloser control information and controls. Click **HMI > Meter and Control** to access the ACSELERATOR HMI. *Figure 3.7* shows the HMI tree view; *Table 3.4* lists the functions in the HMI tree view and a brief explanation of each function.

The flashing LED representation in the lower left of each HMI screen indicates an active data update via the communications channel. Click the button marked **Disable Update** to suspend HMI use of the communications channel.

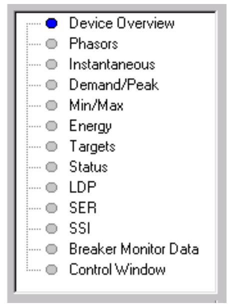


Figure 3.7 ACSELERATOR HMI Features

HMI Device Overview

Select the **Device Overview** branch to display an overview of the recloser control operation. This view includes a summary of information from many of the other HMI branches and includes fundamental metering, contact input/output status, and front-panel LED status.

The **Device Overview** colors and text can be reconfigured. White LED symbols indicate a deasserted condition and LED symbols with any other color indicate an asserted condition. Click an LED symbol to change its assert color. Double-click the LED label to change the label.

Click an operator control pushbutton label to change the label.

HMI Control Window

Select the **Control Window** branch to reset metering values, clear event records, trip and close reclosers/breakers, pulse output contacts, and set and clear remote bits.

Other HMI Branches

The remaining HMI branches display metering, targets, status, reporting, and monitoring information. Many of these branches support reset, clear, update, and/or trigger buttons.

Table 3.4 ACSELERATOR HMI Tree View Functions (Sheet 1 of 2)

Function	Description
Device Overview	View general metering, selected targets, control input, control outputs, and the virtual front panel.
Phasors	A graphical and textual representation of phase and sequence voltage and current phasors.
Instantaneous	A table of instantaneous voltages, currents, powers, and frequency.
Demand/Peak	A table showing demand and peak demand values. This display includes reset buttons.
Min/Max	A table showing maximum/minimum metering quantities. This display includes a reset button.
Energy	A table showing energy import/export. This display includes a reset button.
Targets	View Relay Word bits in a row/column format.
Status	A list of recloser control status conditions.
LDP	View load profile data.

Table 3.4 ACSELERATOR HMI Tree View Functions (Sheet 2 of 2)

Function	Description
SER	Sequential Events Recorder data listed oldest to newest, top to bottom. Set the range of SER records with the dialog boxes at the bottom of the display.
SSI	View voltage Sag, Swell, and Interruption data.
Breaker Monitor Data	A table showing the latest circuit breaker monitor data.
Control Window	Metering and records reset buttons, trip and close control, output pulsing, target reset, time and date set, group switch, and remote bit control.

ACSELERATOR Settings

ACSELERATOR provides the ability to create settings for one or more SEL-651R recloser controls. Store existing recloser settings downloaded from SEL-651R recloser controls with ACSELERATOR, creating a library of recloser settings (see *Database Manager on page 3.17*). Then modify and upload these settings from the settings library to an SEL-651R. ACSELERATOR makes setting the recloser easy and efficient.

Enter settings with one of two Relay Editor methods. **Setting Form** displays a small subset of the settings with a series of tabs. This settings subset provides a template that enables you to concentrate on only the settings that your utility typically uses. **Editor Mode** displays all settings for more advanced applications.

SEL provides ACSELERATOR for easier, more efficient configuration of recloser control settings. However, you do not have to use ACSELERATOR to configure the SEL-651R; you can use an ASCII terminal or a computer running terminal emulation software. ACSELERATOR provides the advantages of rules-based settings checks, SELOGIC® Control Equation Expression Builder, operator control and metering HMI, event analysis, and help.

Relay Editor

ACSELERATOR Relay Editor (**Editor Mode**) arranges recloser control settings in easy-to-understand categories. The SEL-651R settings structure makes setting the recloser control easy and efficient. Settings are grouped logically, and recloser control elements that are not used in the selected protection scheme are not visible. For example, if only three levels of a particular type of overcurrent protection are selected, the corresponding Level 4 overcurrent element settings do not appear on the communications terminal screen. Hiding unused elements and settings that are not enabled greatly simplifies the task of setting the SEL-651R.

ACSELERATOR uses a similar method to focus attention on the active settings. Unused recloser control elements and inactive settings are dimmed (grayed) in the ACSELERATOR menus. *Figure 3.8* is an example of recloser control settings categories in the **Relay Editor Settings** tree view. See *Relay Editor (Editor Mode) on page 3.11* for details on using the editor.

ACSELERATOR shows all of the settings categories in the settings tree view. The settings tree view remains constant whether settings categories are enabled or disabled. However, any disabled settings are dimmed when accessed by clicking an item in the tree view. *Figure 3.8* illustrates this feature of ACSELERATOR.

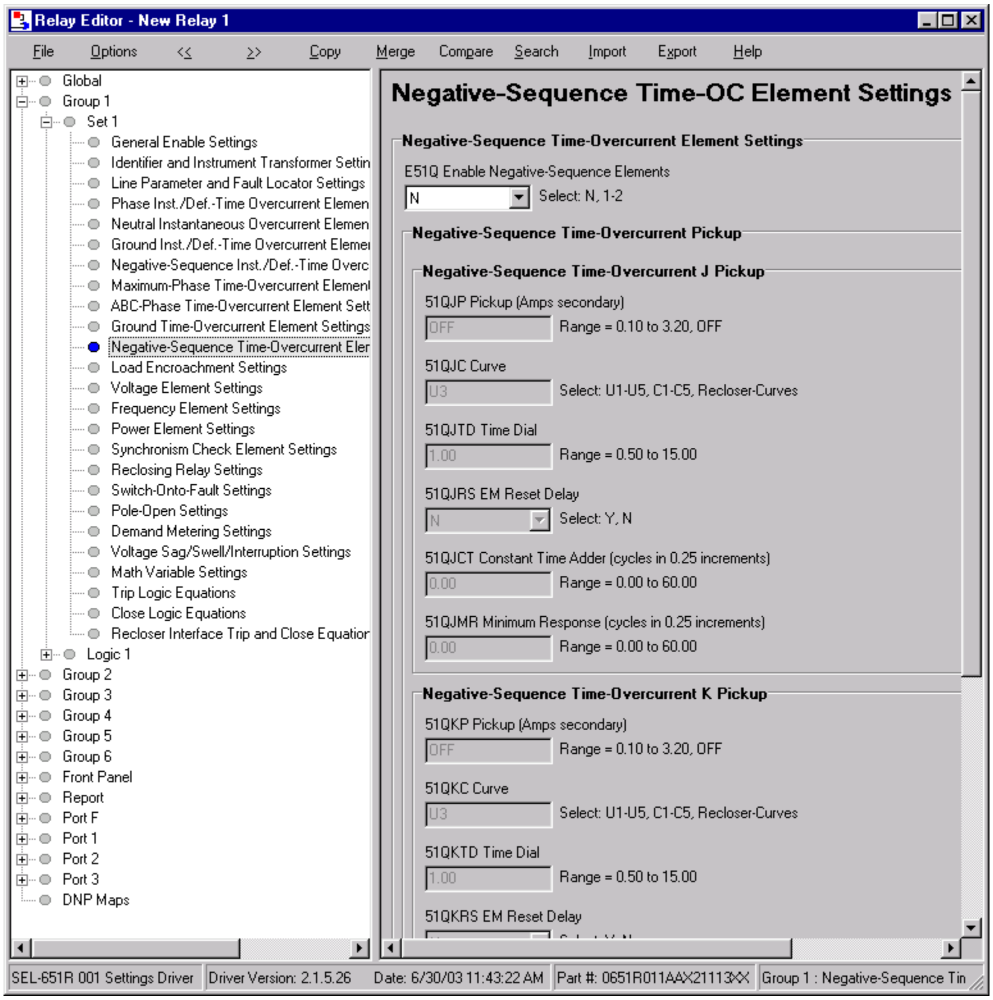


Figure 3.8 Relay Editor (Editor Mode)

Settings Menu

ACSELERATOR uses a database to store and manage SEL device settings. Each unique device has its own record of settings. Use the **Settings** menu to **Open** an existing record, create and open a **New** record, **Read** device settings and then create and open a new record, or **Convert** and open an existing record. The record will be opened in **Editor Mode** (see *Relay Editor (Editor Mode) on page 3.11*).

To get started making SEL-651R settings with the **Relay Editor** in the **Editor Mode**, select **Settings > New** from the main menu bar, SEL-651R, **001**, and **OK** from the **Relay Editor Selection** window, and **OK** from the **Relay Part Number** window. Proceed to *Relay Editor (Editor Mode) on page 3.11* after the **Relay Editor** window opens.

New

Selecting the **New** menu item creates new settings files. ACSELERATOR makes the new settings files from the driver that you specify in the **Relay Editor Selection** dialog box (see *Figure 3.9*). ACSELERATOR uses the Z-number in the FID string to create a particular version of settings (see *Drivers on page 3.4*).

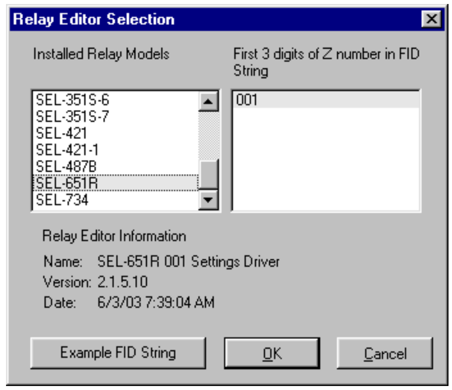


Figure 3.9 Selecting a Settings Driver

After the recloser control model and settings driver are selected, ACSELERATOR presents the **Relay Part Number** dialog box (shown in *Figure 3.10*). Use this dialog box to configure the **Relay Editor** to produce settings for a recloser control with options determined by the part number (see *Options—Part Number on page 3.13*).

View the bottom of the **Relay Editor** window to check the **Settings Driver** number (see *Figure 3.11*). Compare the ACSELERATOR driver number and the first portion of the Z-number in the FID string. These numbers must match. ACSELERATOR uses this first portion of the Z-number to determine the correct **Relay Editor** to display.

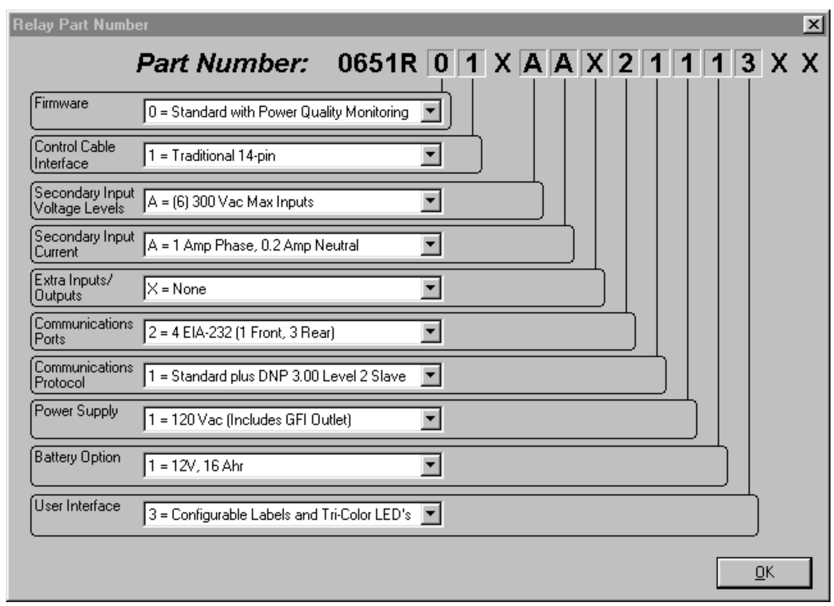


Figure 3.10 Setting the Part Number

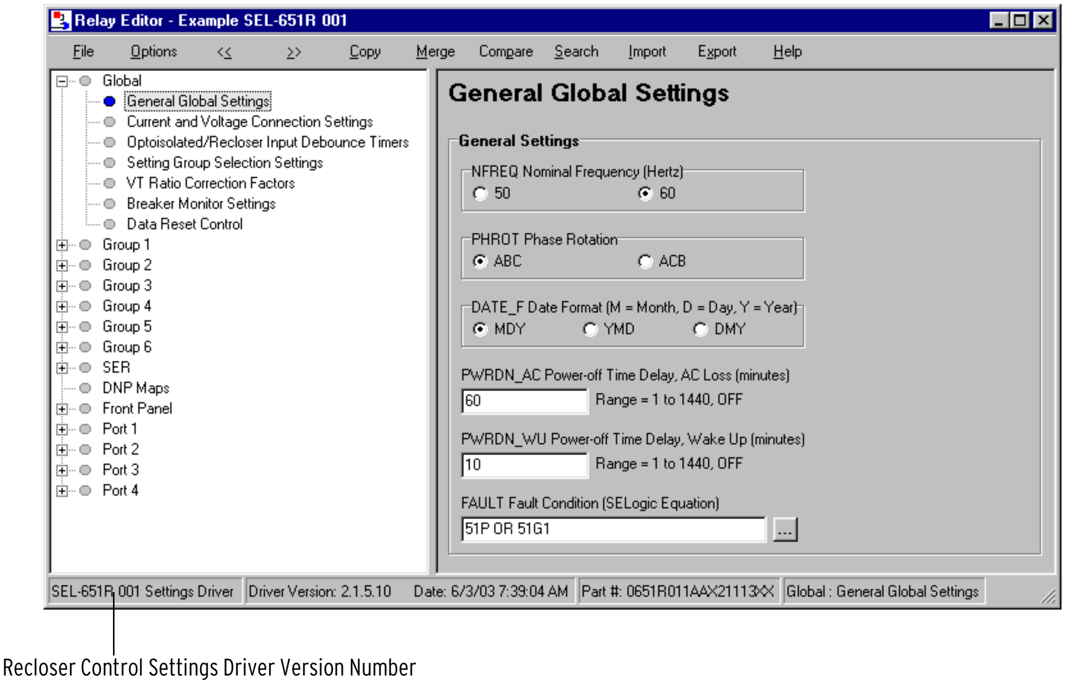


Figure 3.11 Settings Driver

Open

The **Open** menu item opens an existing recloser control from the active database folder (see *Figure 3.12*). ACSELERATOR prompts for a device to load into the **Relay Editor**.

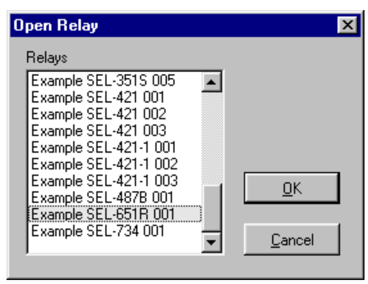


Figure 3.12 Opening Settings

Read

When the **Read** menu item is selected, ACSELERATOR reads the device settings from a connected device. As ACSELERATOR reads the device, a **Transfer Status** window similar to *Figure 3.13* appears. ACSELERATOR uses serial protocols to read settings from SEL devices.

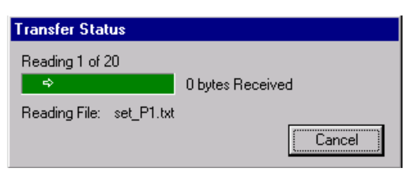


Figure 3.13 Reading Settings

Convert

Use the **Convert** menu item to convert from one settings version to another. Typically this utility is used to upgrade an existing settings file to a newer version because recloser controls are using a newer version number. ACSELERATOR provides a **Convert Settings** report that shows missed, changed, and invalid settings created as a result of the conversion. Review this report to determine whether changes are required.

Relay Editor (Editor Mode)

Use the **Relay Editor (Editor Mode)** to enter settings. *Figure 3.14* illustrates the important features of the editor. These features include the ACSELERATOR settings driver version number (the first three digits of the Z-number) in the lower left corner of the **Relay Editor**.

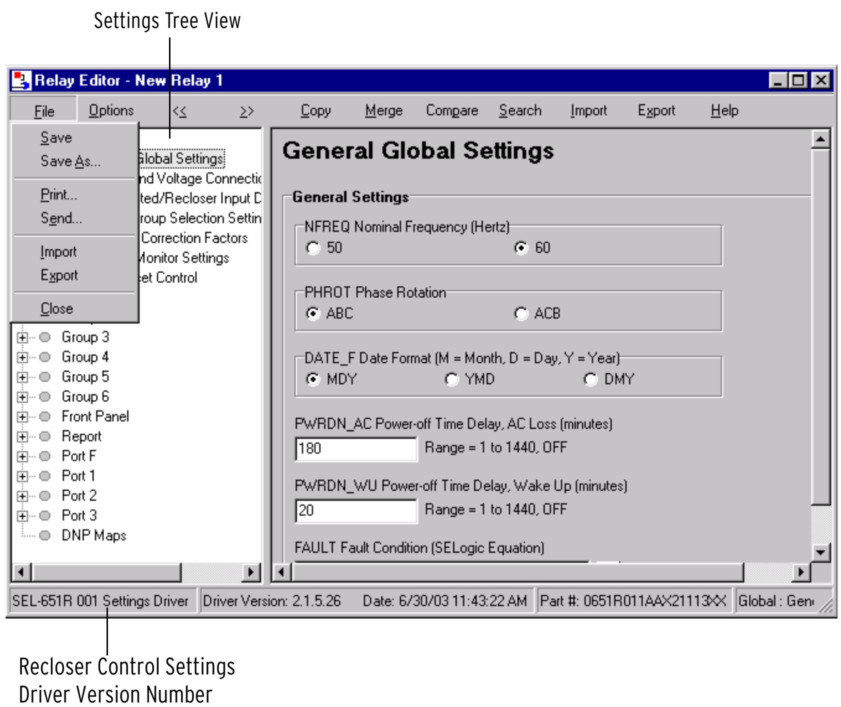


Figure 3.14 Editor Mode

Entering Settings

Click the + marks and the buttons in the Settings Tree View to expand and select the settings you want to change. Use **Tab** to navigate through the settings, or click on a setting.

To restore the previous value for a setting, right-click the mouse over the setting and select **Previous Value**. To restore the factory default setting value, right-click in the settings dialog box and select **Default Value**.

If you enter a setting that is out of range or has an error, ACSELERATOR shows the error at the bottom of the **Relay Editor**. Double-click the error listing to go to the setting to enter a valid input.

Relay Editor menus that facilitate settings entry are included in *Table 3.5*.

Table 3.5 Relay Editor Menus

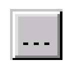
Menus	Description
<<, >>	Use these navigation menu items to move from one category to the next.
Copy	Use this menu item to copy group (set and logic) settings.
Merge	Use this menu item to merge the open record with another record.
Compare	Use this menu item to compare the open record with another record.
Search	Use this menu item to search for a particular setting.

Expression Builder

SELOGIC control equations are a powerful means for customizing recloser control performance. Creating these equations can be difficult, because of the large number of recloser control elements (Relay Word bits) and analog quantities in the recloser control. ACSELERATOR simplifies this process with the Expression Builder, a rules-based editor for programming SELOGIC control equations. The Expression Builder organizes recloser control elements, analog quantities, and SELOGIC control equation variables and focuses equation decision-making.

Access the Expression Builder

Settings dialog boxes in the **Relay Editor** window show the following (ellipsis) button:



Click this button to use the Expression Builder.

Expression Builder Organization

The **Expression Builder** dialog box is organized into two main parts representing the left side (LVALUE) and right side (RVALUE) of the SELOGIC control equation. The LVALUE is fixed for all settings. *Figure 3.15* shows the two sides of the **Expression Builder**, with the SELOGIC control equation being constructed at the top of the dialog box.

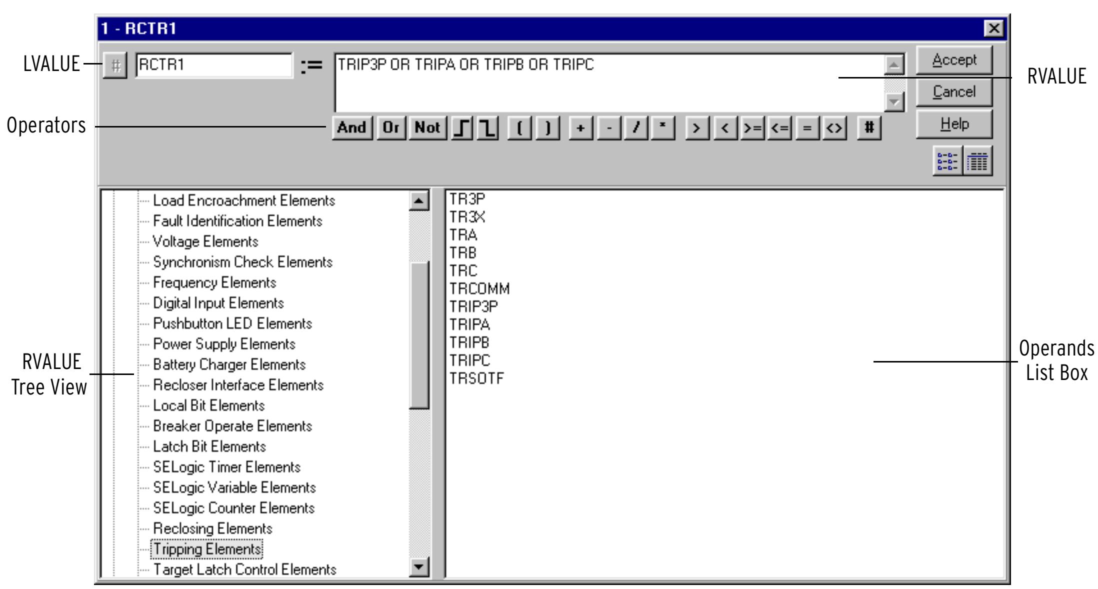


Figure 3.15 Expression Builder

Using the Expression Builder

Use the right side of the equation (RVALUE) to select broad categories of recloser control elements, analog quantities, counters, timers, latches, and logic variables. Select a category in the RVALUE tree view, and the **Expression Builder** displays all operands for that category in the list box at the bottom right side.

Directly underneath the right side of the equation, choose operators to include in the RVALUE. These operators include basic logic, rising and falling edge triggers, expression compares, and comments.

For more information on programming SELOGIC control equations, see *Section 7: SELOGIC Control Equation Programming*.

Sending Settings

Select the **Save**, **Send**, and **Print** menu items from the **File** menu item of the **Relay Editor** once settings are entered into ACSELERATOR. This will help ensure the settings are not lost.

Options—Part Number

Use this menu item to change the part number if it was entered incorrectly during an earlier step.

Text Files

Select **Import** or **File > Import** and **Export** or **File > Export** on the **Relay Editor** (Editor Mode) menu bar to import or export settings from or to a text file. Use this feature to create a small file that can be more easily stored or sent electronically.

ACSELERATOR Event Analysis

ACSELERATOR has integrated analysis tools that help you retrieve information about protection system operations quickly and easily. Use the protection system event information that the SEL-651R stores to evaluate the performance of a protection system.

Event Waveforms

The SEL-651R records power system events for all trip situations and for other operating conditions programmed with SELOGIC control equations (see *Section 12: Analyzing Events*).

The recloser control provides two types of event data captures: event report oscillography that uses filtered sample per cycle data and unfiltered (raw) data. See *Section 12: Analyzing Events* for information on recording events. Use ACSELERATOR to view event report oscillograms, phasor diagrams, harmonic analysis, and settings.

Read History

You can retrieve event files stored in the recloser control and transfer these files to a computer. For information on the types of event files and data capture, see *Section 12: Analyzing Events*.

To download event files from the recloser control, open the ACSELERATOR **Analysis** menu at the top ACSELERATOR toolbar and click **Get Event Files**. The **Event History** dialog box will appear (similar to *Figure 3.16*).

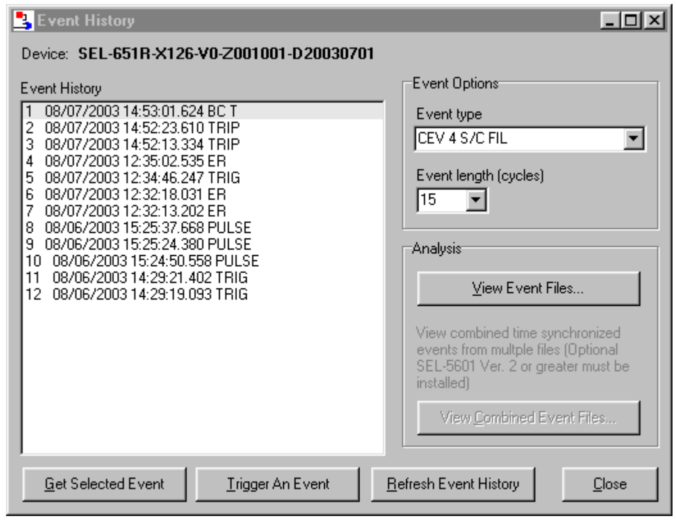


Figure 3.16 Retrieving an Event History

Get Event

Highlight the event you want to view and click the **Get Selected Event** button. The **Event Options** dialog box allows selection of Event Type and Event Length. When downloading is complete, ACSELERATOR asks whether to save the file on your computer. ACSELERATOR displays the **Event Waveform** dialog box and the event oscillogram (see *Figure 3.17* and *Figure 3.18*).

When viewing the event oscillogram, use keyboard function keys to measure the time of oscillogram occurrences. These function keys and related functions help in event analysis.

- **<F2>**: go to trigger
- **<F3>**: Cursor 1
- **<F4>**: Cursor 2

The display shows the time difference between Cursor 1 and Cursor 2.

To see high-accuracy time-stamp information on the event oscillogram, click the **Pref** button at the bottom of the oscillogram and select **Time** (under **Time Units, Starting/Ending Row**); click **OK**. Click on any point in a graph to observe the **Event Time** in microseconds of that data point at the bottom of the oscillogram.

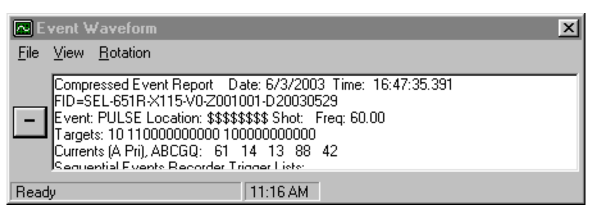


Figure 3.17 Event Waveform Window

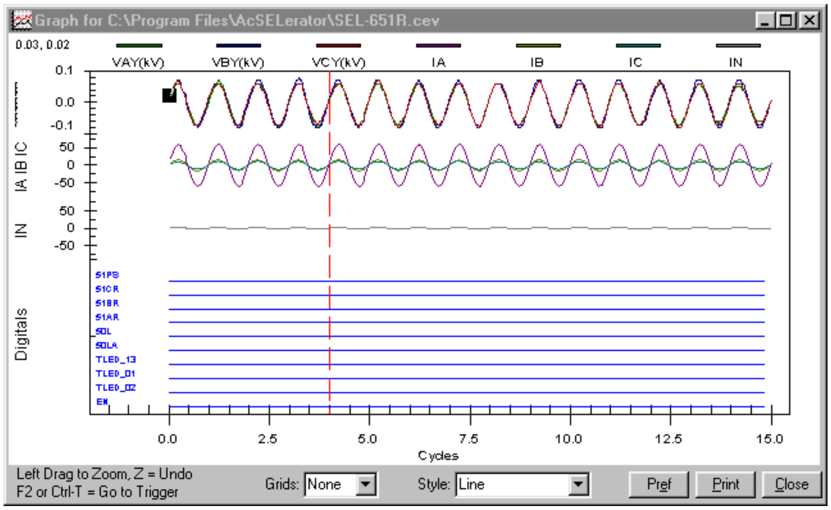


Figure 3.18 Sample Event Oscillogram

Other event displays are available through the **Event Waveform** dialog box. Select the **View** menu and click **Phasors**, as shown in *Figure 3.19*, to view a sample-by-sample phasor display. The phasor display should be similar to *Figure 3.20*.

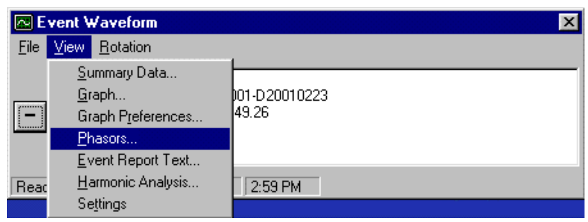


Figure 3.19 Retrieving Event Report Waveforms

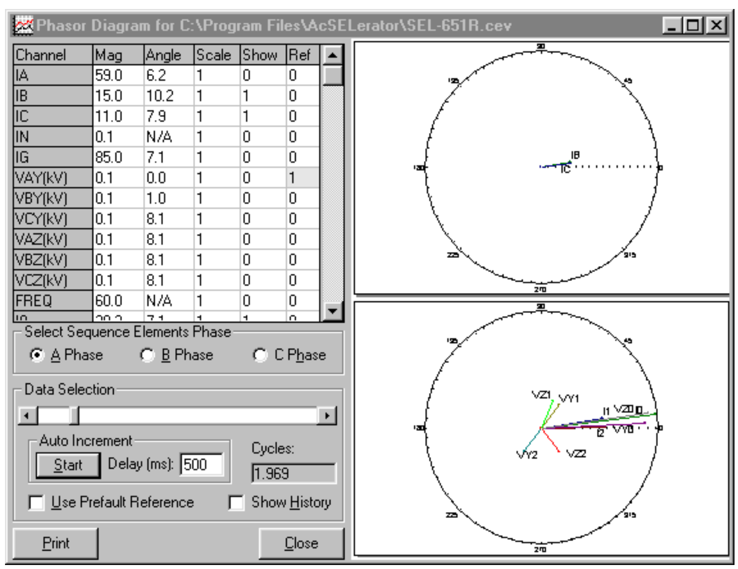


Figure 3.20 Sample Phasors Event Waveform Screen

ACSELERATOR also presents a harmonic analysis of power system data for raw data event captures. From the **Event Waveform View** menu, click **Harmonic Analysis**. The window will be similar to *Figure 3.21*. On the left side of the **Harmonic Analysis** screen, choose the recloser control voltage and current channels to monitor for harmonic content. You can view both a spectral analysis plot and a harmonic analysis bar chart. Click the arrows of the **Data Scroll** box or the **# Cycles** box to change the data analysis range.

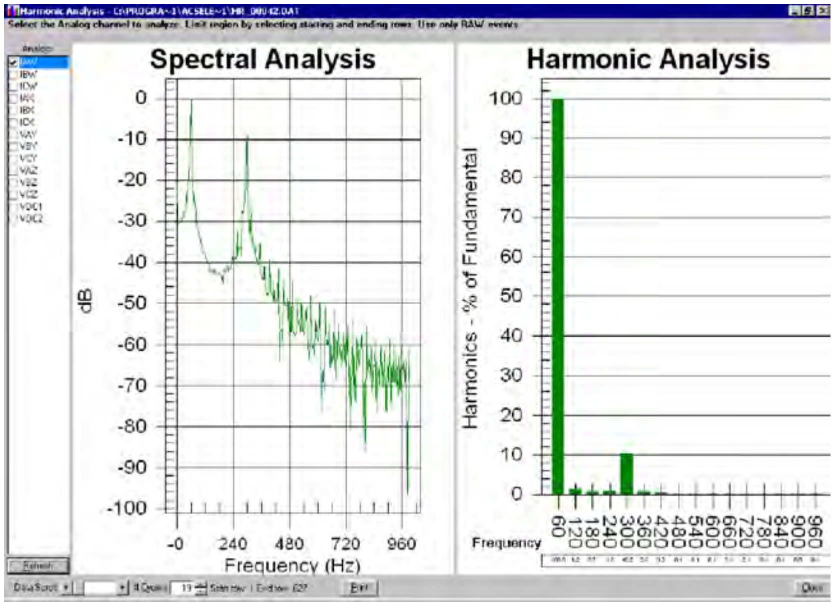


Figure 3.21 Sample Harmonic Analysis Event Waveform Screen

Click **Summary Data** on the **Event Waveform View** menu to see event summary information and to confirm that you are viewing the correct event. *Figure 3.22* shows a sample ACSELERATOR **Event Report Summary** screen.

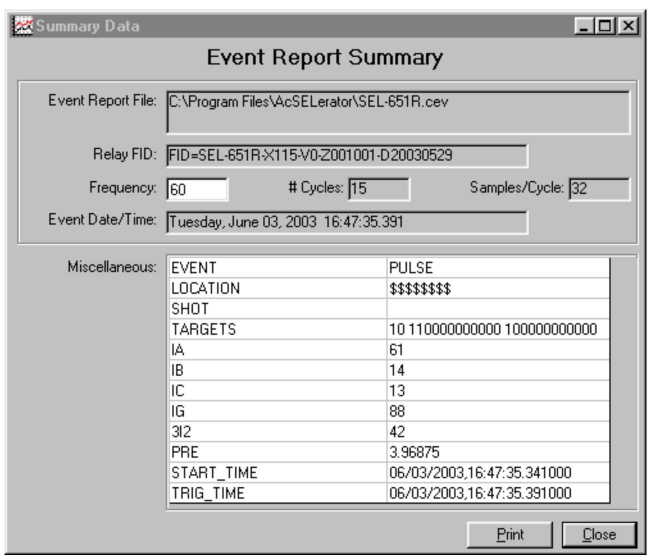


Figure 3.22 Sample Event Report Summary Screen

Click **Settings** on the **Event Waveform View** menu to view the recloser control settings that were active at the time of the event. *Figure 3.23* shows a sample CEV-type event **Settings** screen.

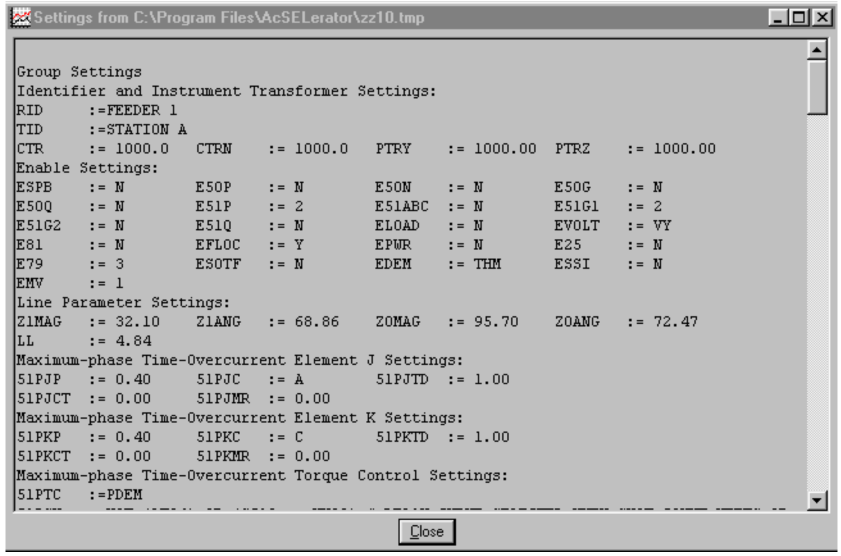


Figure 3.23 Sample Event Waveform Settings Screen

Open File

Computer-stored data captures are available as compressed event report files (*.CEV). Open the ACSELERATOR **Analysis** menu and click **Open File** to view the waveforms in an event file stored on your computer. An **Event Waveform** dialog box similar to *Figure 3.17* and an oscillographic event screen similar to *Figure 3.18* should appear.

At the **Event Waveform** dialog box, select the **Phasors** display, the **Harmonic Analysis** display, the **Summary Data** display, and the **Settings** display from the **Event Waveform** window (see *Read History on page 3.13*).

ACSELERATOR Settings Database Management

ACSELERATOR uses a database to save device settings. ACSELERATOR contains sets of all settings files for each device specified in the **Database Manager**. Choose appropriate storage backup methods and a secure location for storing database files.

Active Database

Change the active database to the one that needs to be modified by selecting **File > Active Database** on the main menu bar.

Database Manager

Select **File > Database Manager** on the main menu bar to create new databases and manage records within existing databases.

Relay Database

Open the **Database Manager** to access the database by clicking **File > Database Manager**. A dialog box similar to *Figure 3.24* appears.

The default database file already configured in ACSELERATOR is **Relay.rdb**. This database contains example settings files for the SEL products with which you can use ACSELERATOR. Enter descriptions for the database and for each relay or recloser control in the database in the **Database Description** and

Relay Description dialog boxes. Enter special operating characteristics that describe the recloser settings in the **Relay Description** dialog box. These can include the protection scheme settings and communications settings.

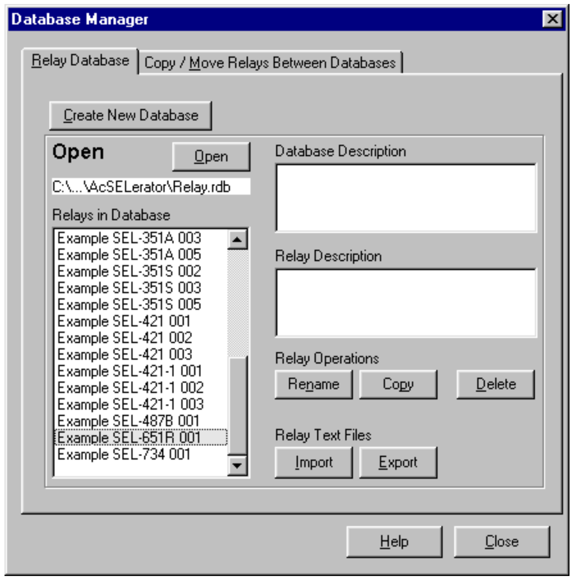


Figure 3.24 Database Manager

Highlight one of the devices listed in **Relays in Database** and select the **Copy** option button to create a new collection of settings. ACSELERATOR prompts for a new name. Be sure to enter a new description in **Relay Description**.

Copy/Move Reclosers Between Databases

Select the **Copy/Move Relays Between Databases** tab to create multiple databases with the **Database Manager**; these databases are useful for grouping similar protection schemes or geographic areas. The dialog box is shown in *Figure 3.25*. Click the **Open B** option button to open a recloser database. Type a filename and click **Open**; for example, Relay2.rdb is the **B** recloser database in *Figure 3.25*.

Highlight a relay or recloser control in the **A** database, select **Copy** or **Move**, and click the **>** button to create a new relay or recloser control in the **B** database. Reverse this process to take reclosers from the **B** database to the **A** database. **Copy** creates an identical recloser that appears in both databases. **Move** removes the recloser from one database and places the recloser in another database.

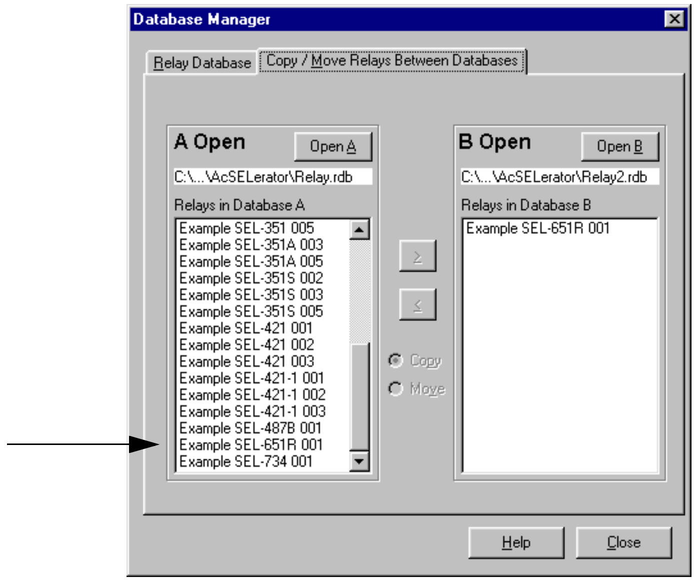


Figure 3.25 Database Manager Copy/Move

Create a New Database

To create and copy an existing database of reclosers to a new database, click **File > Database Manager** and select the **Copy / Move Relays Between Databases** tab on the **Database Manager** dialog box. ACSELERATOR opens the last active database and assigns it as Database **A** (as shown in *Figure 3.25*).

Click the **Open B** button; ACSELERATOR prompts you for a file location. Type a new database name, click the **Open** button, and answer **Yes**; the program creates a new empty database. Load reclosers into the new database as in **Copy /Move Relays Between Databases**.

ACSELERATOR Help

Various forms of ACSELERATOR help are available as shown in *Table 3.6*. Press **<F1>** to open a context-sensitive help file with the appropriate topic as the default.

Table 3.6 Help

Help	Description
General ACSELERATOR	Select **Help** from the main menu bar.
HMI Application	Select **Help > Contents** from the HMI menu bar.
Relay Editor	Select SEL-**5030 Editor Help** from the from the **Relay Editor** menu bar.
SEL-651R Settings	Select SEL **Relay Help** from the from the **Relay Editor** menu bar.
Database Manager	Select **Help** from the bottom of the **Database Manager** window.

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Section 4
Protection Functions

Instantaneous/Definite-Time Overcurrent Elements

Phase Instantaneous/ Definite-Time Overcurrent Elements

Four levels of phase instantaneous/definite-time overcurrent elements are available. Two additional levels of phase instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50P enable setting, as shown in *Figure 4.1* through *Figure 4.7*.

Single-phase (50A, 50B, 50C) and maximum-phase (50P) elements are available. The single-phase elements operate on the individual phase currents, subject to assignment by setting IPCONN—see *Table 9.8*.

The single-phase and maximum-phase elements operate from the same pickup and time delay settings. For example, if 50P1P is set to 6.00 amps, both 50P1 and 50A1 will assert when the A-phase current exceeds 6.00 amps, secondary.

These single-phase and maximum-phase elements are collectively referred to as Phase Instantaneous/Definite-Time Overcurrent Elements.

The single-phase and maximum-phase definite time elements feature separate torque control settings, as shown in *Figure 4.3* through *Figure 4.6*.

Settings Ranges

Setting range for pickup settings 50P1P through 50P6P:

0.05–20.00 A secondary

Setting range for definite-time settings 50P1D through 50P4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Accuracy

See *Specifications on page 1.8*.

NOTE: Do not use these elements for load current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load current levels so that the fault locator will work correctly. Use the 50L element instead for load current detection (see Figure 5.5).

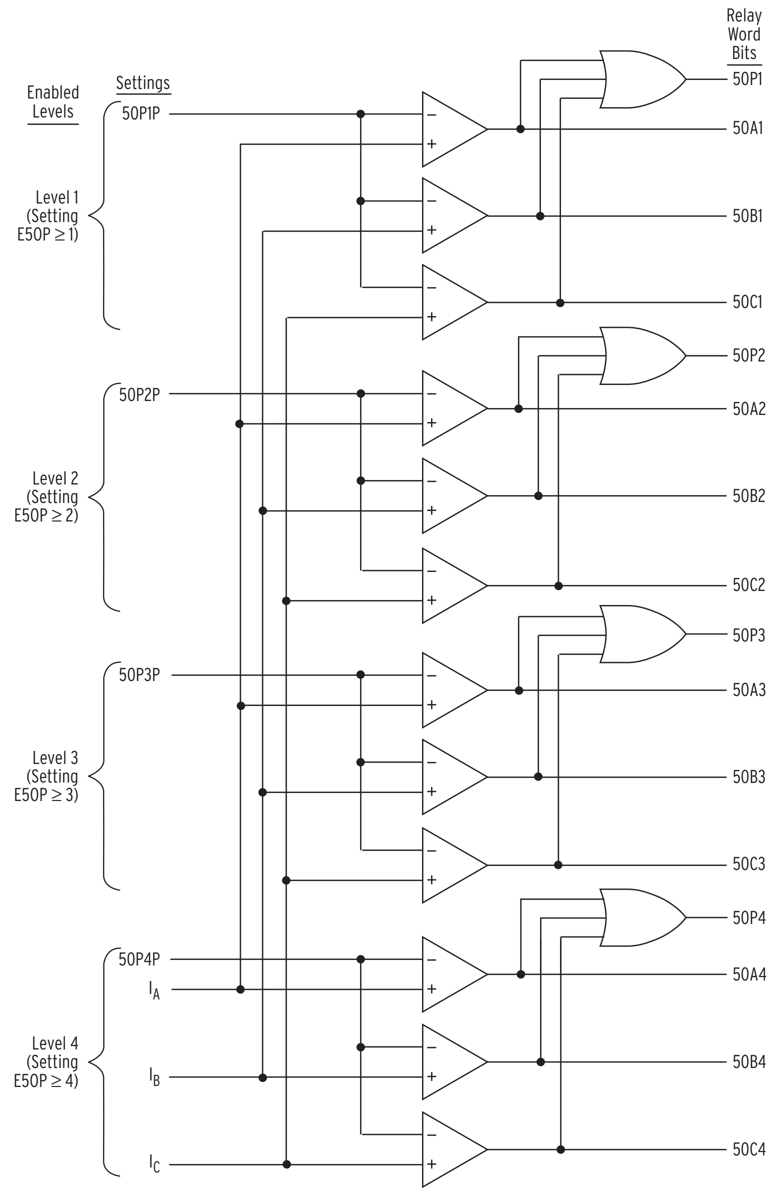


Figure 4.1 Levels 1 through 4 Phase Instantaneous Overcurrent Elements

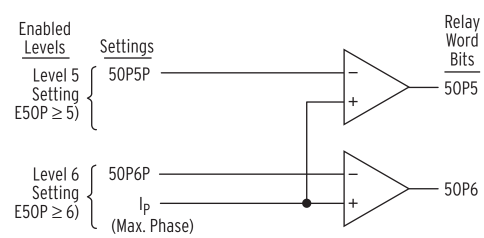


Figure 4.2 Levels 5 through 6 Phase Instantaneous Overcurrent Elements

Pickup Operation

The phase instantaneous/definite-time overcurrent element logic begins with *Figure 4.1* and *Figure 4.2*. The pickup settings for each level (50P1P through 50P6P) are compared to the magnitudes of the individual phase currents I_A, I_B, and I_C. The logic outputs in *Figure 4.1* and *Figure 4.2* are Relay Word bits and operate as follows (Level 1 example shown):

50A1 =	1 (logical 1)	if I_A > pickup setting 50P1P
	0 (logical 0)	if $I_A \leq$ pickup setting 50P1P
50B1 =	1 (logical 1)	if I_B > pickup setting 50P1P
	0 (logical 0)	if $I_B \leq$ pickup setting 50P1P
50C1 =	1 (logical 1)	if I_C > pickup setting 50P1P
	0 (logical 0)	if $I_C \leq$ pickup setting 50P1P
50P1 =	1 (logical 1)	if at least one of the Relay Word bits 50A1, 50B1, or 50C1 is asserted (e.g., 50B1 = 1)
	0 (logical 0)	if all three Relay Word bits 50A1, 50B1, and 50C1 are deasserted (50A1 = 0, 50B1 = 0, and 50C1 = 0)

Note that single-phase overcurrent elements are not available in Levels 5 and 6 (see *Figure 4.2*).

Ideally, set 50P1P > 50P2P > 50P3P > 50P4P so that definite-time overcurrent elements 50P1T through 50P4T will display in an organized fashion in event reports (see *Figure 4.1* and *Table 12.4*).

NOTE: Do not use these elements for load current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load current levels so that the fault locator will work correctly. Use the 50L element instead for load current detection (see Figure 5.5).

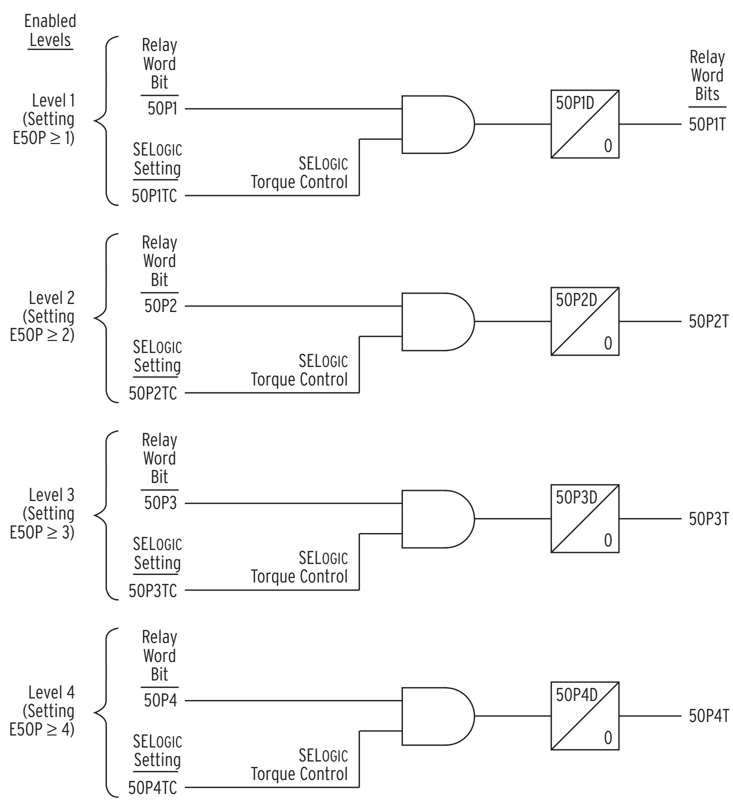


Figure 4.3 Levels 1 through 4 Phase Definite-Time Overcurrent Elements

NOTE: Do not use these elements for load current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load current levels so that the fault locator will work correctly. Use the 50L element instead for load current detection (see Figure 5.5).

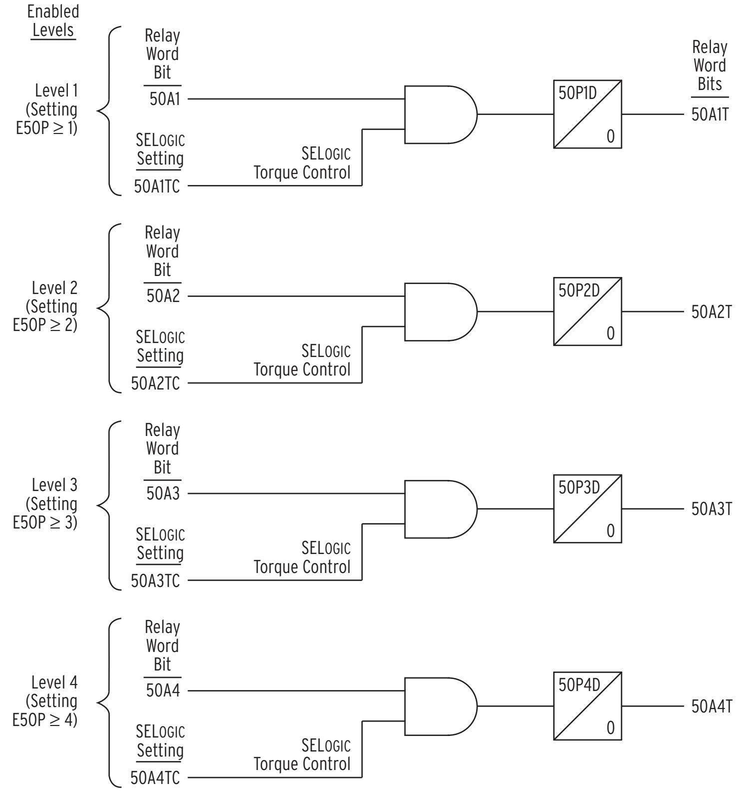


Figure 4.4 Levels 1 through 4 A-Phase Definite-Time Overcurrent Elements

NOTE: Do not use these elements for load current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load current levels so that the fault locator will work correctly. Use the 50L element instead for load current detection (see Figure 5.5).

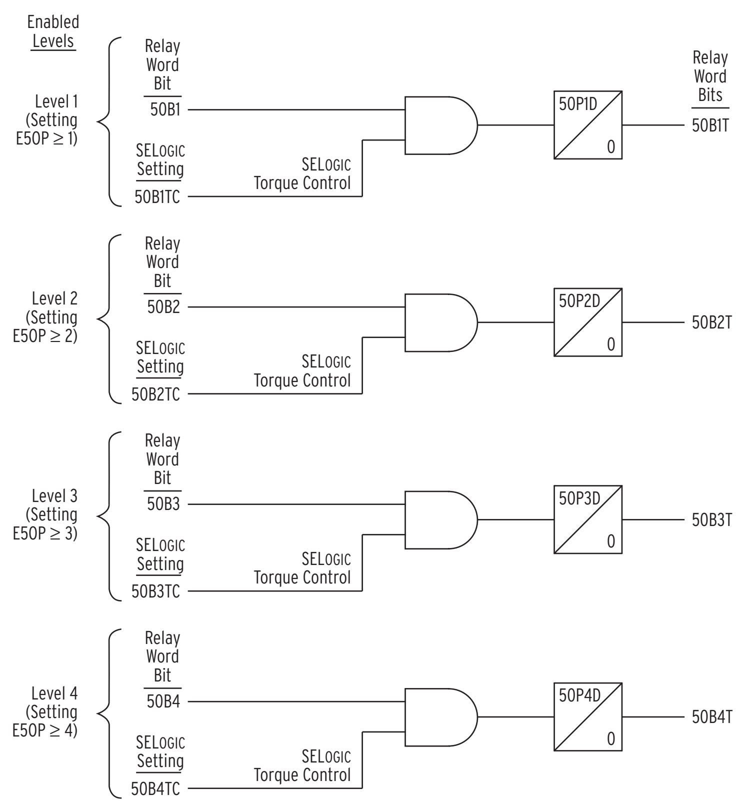


Figure 4.5 Levels 1 through 4 B-Phase Definite-Time Overcurrent Elements

NOTE: Do not use these elements for load current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load current levels so that the fault locator will work correctly. Use the 50L element instead for load current detection (see Figure 5.5).

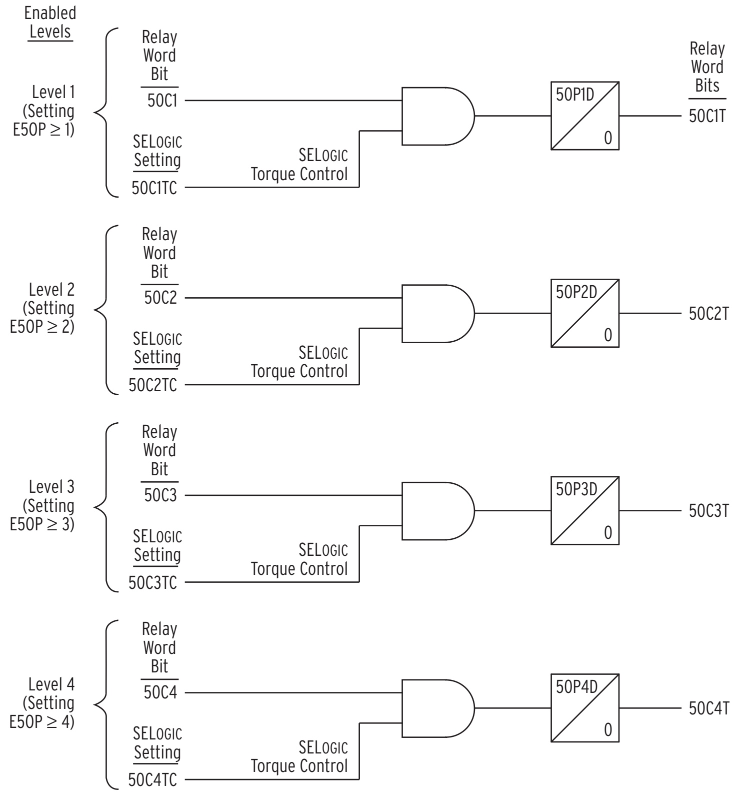


Figure 4.6 Levels 1 through 4 C-Phase Definite-Time Overcurrent Elements

Torque Control

Levels 1 through 4 have corresponding SELOGIC® control equation torque control settings:

- 50P1TC through 50P4TC—Maximum-phase (*Figure 4.3*)
- 50A1TC through 50A4TC—A-phase (*Figure 4.4*)
- 50B1TC through 50B4TC—B-phase (*Figure 4.5*)
- 50C1TC through 50C4TC—C-phase (*Figure 4.6*)

SELOGIC control equation torque control settings cannot be set directly to logical 0. The following are torque control settings examples for Level 1 phase definite-time overcurrent elements 50P1T and 50B1T.

50P1TC := **1** Setting 50P1TC set directly to logical 1:

Phase definite-time overcurrent element 50P1T is enabled.

Note: In the SEL-651R factory default settings, the instantaneous/definite-time overcurrent element torque control settings are set to logical 1. See *Factory Default Settings on page 9.56*.

50B1TC := **IN105** Input IN105 deasserted (50B1TC := IN105 = logical 0):

Then B-phase definite-time overcurrent element 50B1T is defeated and nonoperational, regardless of any other setting.

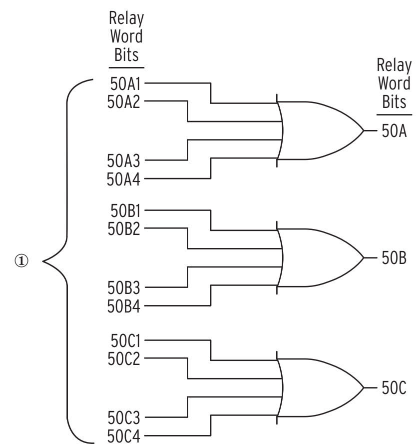
Input IN105 asserted (50B1TC := IN105 = logical 1):

B-phase definite-time overcurrent element 50B1T is enabled.

Combined Single-Phase Instantaneous Overcurrent Elements

The single-phase instantaneous overcurrent element Relay Word bit outputs in *Figure 4.1* are combined together in *Figure 4.7* on a per phase basis, producing Relay Word bit outputs 50A, 50B, and 50C.

Relay Word bits 50A, 50B, and 50C can be used to indicate the presence or absence of current in a particular phase.



① From Figure 4.1.

Figure 4.7 Combined Single-Phase Instantaneous Overcurrent Elements

Pickup and Reset Time Curves

Figure 4.8 and *Figure 4.9* show pickup and reset time curves applicable to all instantaneous overcurrent elements in the SEL-651R Relay (60 Hz or 50 Hz systems). These times do not include output operating time and, thus, are accurate for determining element operation time for use in internal SELOGIC control equations.

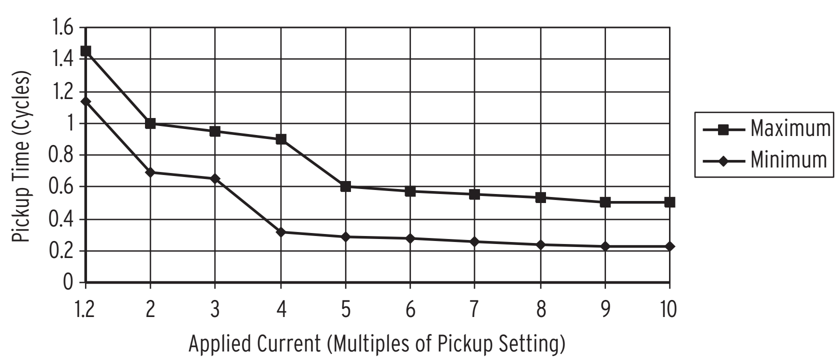


Figure 4.8 SEL-651R Instantaneous Overcurrent Element Pickup Time Curve

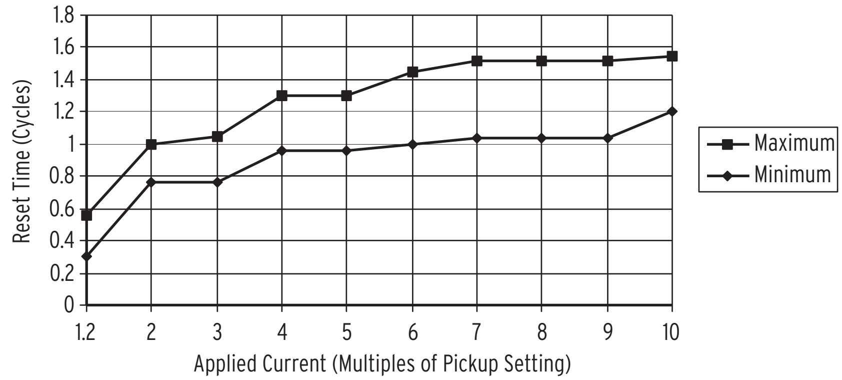


Figure 4.9 SEL-651R Instantaneous Overcurrent Element Reset Time Curve

Neutral Instantaneous/ Definite-Time Overcurrent Elements

When global setting EGNDSW := N, four levels of neutral instantaneous/ definite-time overcurrent elements are available. Two additional levels of neutral instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50N enable setting, as shown in *Figure 4.10* and *Figure 4.11*.

When global setting EGNDSW := Y, the E50N enable setting is forced to N, and the neutral instantaneous/definite-time overcurrent elements are not available. In this application, use the Ground instantaneous/definite-time overcurrent elements (50G1 through 50G6 and 50G1T through 50G4T) described in the next subsection. Also see *Ground Switch Logic on page 4.64*.

To understand the operation of *Figure 4.10* and *Figure 4.11*, follow the explanation given for *Figure 4.1*, *Figure 4.2*, and *Figure 4.3* in the preceding subsection *Phase Instantaneous/Definite-Time Overcurrent Elements on page 4.1*, substituting current I_N (channel IN current) for phase currents and substituting like settings and Relay Word bits.

NOTE: Do not use these elements for load unbalance current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load unbalance current levels so that the fault locator will work correctly.

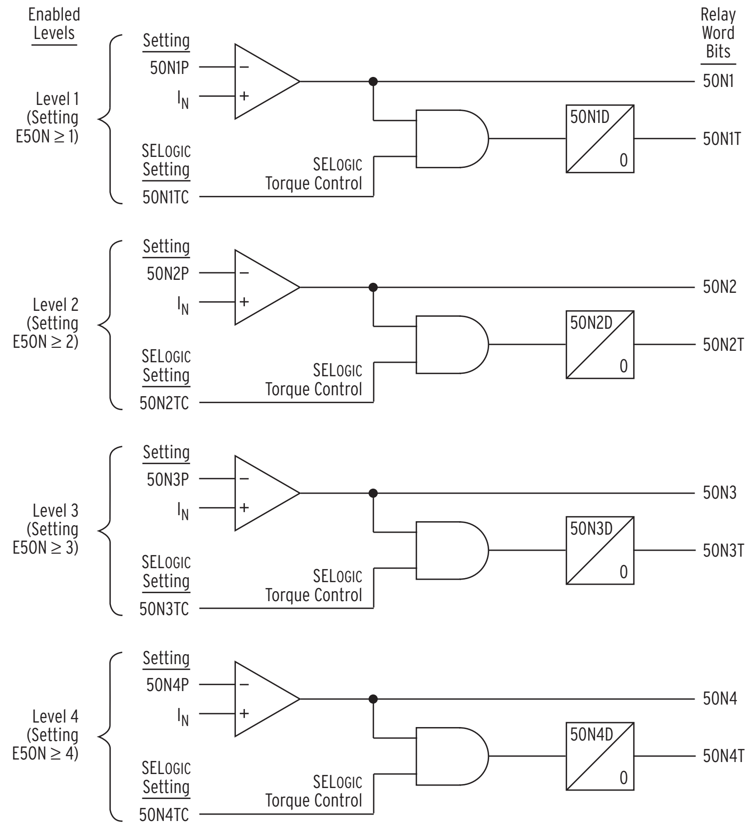


Figure 4.10 Levels 1 Through 4 Neutral Instantaneous/Definite-Time Overcurrent Elements

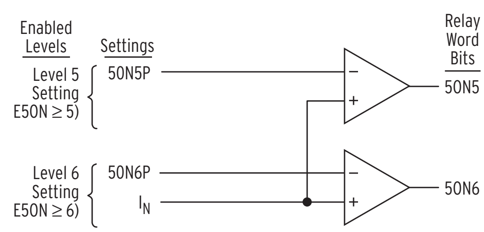


Figure 4.11 Levels 5 Through 6 Neutral Instantaneous Overcurrent Elements

Settings Ranges

NOTE: There is an additional 2-cycle time delay on all the neutral instantaneous (50N1–50N6) and definite-time (50N1T–50N4T) elements. Any time delay provided by the definite-time settings (50N1D–50N4D) is in addition to this 2-cycle time delay.

Setting range for pickup settings 50N1P through 50N6P:

0.005–2.500 A secondary

Setting range for definite-time settings 50N1D through 50N4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Accuracy

See *Specifications on page 1.8*.

Pickup and Reset Time Curves

See *Figure 4.8* and *Figure 4.9*.

Ground Instantaneous/Definite-Time Overcurrent Elements

Four levels of ground instantaneous/definite-time overcurrent elements are available. Two additional levels of ground instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50G enable setting, as shown in *Figure 4.12* and *Figure 4.13*.

When **global setting EGNDSW := Y**, the ground instantaneous/definite-time overcurrent elements operate from the IG quantity, which is automatically switched between channel IN (for small signals), and the calculated residual current |3I0| = IA + IB + IC (vector summation) for large signals—see the subsection *Ground Switch Logic on page 4.64*. In this application, the pickup values 50G1P through 50G6P must be entered on the channel IN current base.

In the factory wiring configuration, channel IN is wired residually with the phase current channels (I1, I2, I3)—see *Figure 2.46* and *Figure 2.48*—and there is no difference between the channel IN current base and the phase current base (because setting CTR = setting CTRN).

For neutral channel wiring configurations that include a separate CT for the neutral channel measuring the zero-sequence current from the same bus section as the phase CTs, see *50G1P Setting Example When EGNDSW := Y and CTR ≠ CTRN on page 4.10*.

When **global setting EGNDSW := N**, the ground instantaneous/definite-time overcurrent elements operate from the calculated residual current IG = |3I0| = IA + IB + IC (vector summation). In this application, the pickup values 50G1P through 50G6P must be entered on the phase current channel base (same as IA, IB, IC).

To understand the operation of *Figure 4.12* and *Figure 4.13*, follow the explanation given for *Figure 4.1*, *Figure 4.2*, and *Figure 4.3* in the preceding subsection *Phase Instantaneous/Definite-Time Overcurrent Elements on page 4.1*, substituting ground current I_G (see *Ground Switch Logic on page 4.64*) for phase currents and substituting like settings and Relay Word bits.

Settings Ranges

Setting range for pickup settings 50G1P through 50G6P:

0.005–20.000 A secondary in 0.001 A steps

(on channel IN base*, when global setting EGNDSW := Y and Group setting CTR = CTRN)

0.005–[20 • (CTR/CTRN)] A secondary in 0.001 A steps

(on channel IN base, when global setting EGNDSW := Y and Group setting CTR ≠ CTRN)

0.010–20.000 A secondary in 0.001 A steps

(on IA, IB, IC base, when global setting EGNDSW := N)

* Note: in the case where EGNDSW := Y and CTR = CTRN, there is no difference between the IN current base and the IA, IB, IC current base. This is the standard configuration for the SEL-651R.

NOTE: For 50G1P through 50G6P elements with settings less than 0.050 A secondary (on the phase current base), or when Relay Word bit GNDSW is asserted, there is an additional 2-cycle time delay on the ground instantaneous (50G1–50G6) and definite-time (50G1T–50G4T) element(s). Any time delay provided by definite-time settings 50G1D–50G4D is in addition to this 2-cycle time delay.

Setting range for definite-time settings 50G1D through 50G4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Accuracy

See *Specifications on page 1.8*.

Pickup and Reset Time Curves

See *Figure 4.8* and *Figure 4.9*.

50G1P Setting Example When EGNDSW := Y and CTR ≠ CTRN

In applications where a separate CT is connected to the neutral channel of the SEL-651R, the CT ratio is often different than the phase CTs (connected to recloser control terminals I1, I2, I3). If the neutral CT is measuring zero-sequence current from the same line or bus location as the phase CTs, make global setting EGNDSW := Y, and enter the proper CTR and CTRN values in the *Group Settings on page SET.5*.

The SEL-651R ground overcurrent pickup settings must be made on the channel IN base. In this example, the system has 1000:1 phase CTs, a 100:1 neutral CT, and a desired pickup level for a ground element of 75 A primary ($3I_0$).

Make global setting EGNDSW := Y, and Group settings CTR := 1000.0; CTRN := 100.0. To determine the proper setting for 50G1P, the primary pickup value (75 A) must be converted to secondary units on the channel IN base.

$$\text{Pickup in secondary}_{(\text{IN base})} = (\text{pickup in primary})/\text{CTRN}$$

Equation 4.1

Example pickup = 75.0 / 100 = 0.750 A secondary

Make settings

E50G := **1**

50G1P := **0.750 A**

With the calculation method shown in *Equation 4.1*, the phase CT ratio is not used. If the SEL-651R is being installed at a location that already had the ground instantaneous overcurrent setting value calculated on the phase current base, the pickup value must be converted to the IN current base.

Continuing with the example, if the secondary ground trip value was provided on the phase CT base, (use *Equation 4.2* to obtain = 75.0 / 1000 = 0.075 A), the secondary value must be converted to the IN base prior to entry in the SEL-651R (using *Equation 4.3*).

$$\text{Pickup in secondary}_{(\text{Phase CT base})} = (\text{pickup in primary})/\text{CTR}$$

Equation 4.2

(Where CTR is the SEL-651R Group setting.)

$$\text{Pickup in secondary}_{(\text{IN base})} = \text{Pickup (IA, IB, IC base)} \bullet (\text{CTR}/\text{CTRN})$$

Equation 4.3

(Where CTR and CTRN are the SEL-651R Group settings.)

Example pickup = Pickup(Phase CT base) • (CTR/CTRN) = 0.075 A • 1000/100 = 0.750 A. The two calculation methods yield the same result.

NOTE: Do not use these elements for load unbalance current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load unbalance current levels so that the fault locator will work correctly.

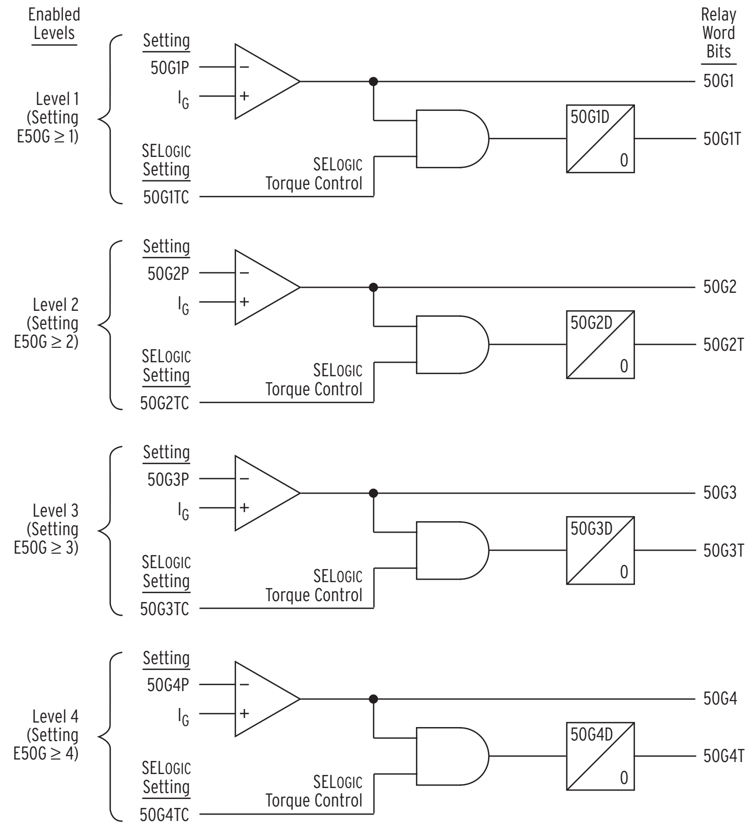


Figure 4.12 Levels 1 Through 4 Ground Instantaneous/Definite-Time Overcurrent Elements

NOTE: Do not use these elements for load unbalance current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load unbalance current levels so that the fault locator will work correctly.

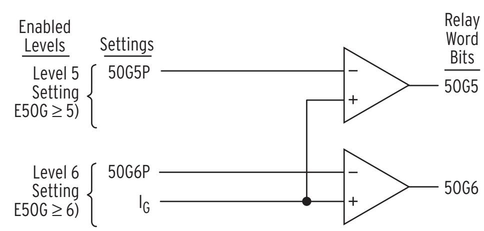


Figure 4.13 Levels 5 Through 6 Ground Instantaneous Overcurrent Elements

Negative-Sequence Instantaneous/ Definite-Time Overcurrent Elements

IMPORTANT: See *Setting Negative-Sequence Overcurrent Elements on page 4.88* for information on setting negative-sequence overcurrent elements.

Four levels of negative-sequence instantaneous/definite-time overcurrent elements are available. Two additional levels of negative-sequence instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50Q enable setting, as shown in *Figure 4.14* and *Figure 4.15*.

To understand the operation of *Figure 4.14* and *Figure 4.15*, follow the explanation given for *Figure 4.1*, *Figure 4.2*, and *Figure 4.3* in the preceding subsection *Phase Instantaneous/Definite-Time Overcurrent Elements on page 4.1*, substituting negative-sequence current $3I_2$ [$3I_2 = I_A + a^2 \cdot I_B + a \cdot I_C$ (ABC rotation), $3I_2 = I_A + a^2 \cdot I_C + a \cdot I_B$ (ACB rotation), where $a = 1 \angle 120º$ and $a^2 = 1 \angle –120º$] for phase currents and substituting like settings and Relay Word bits.

Settings Ranges

Setting range for pickup settings 50Q1P through 50Q6P:

0.05–20.00 A secondary

Setting range for definite-time settings 50Q1D through 50Q4D:

0.00–16000.00 cycles in 0.25-cycle steps

NOTE: Do not use these elements for load unbalance current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load unbalance current levels so that the fault locator will work correctly.

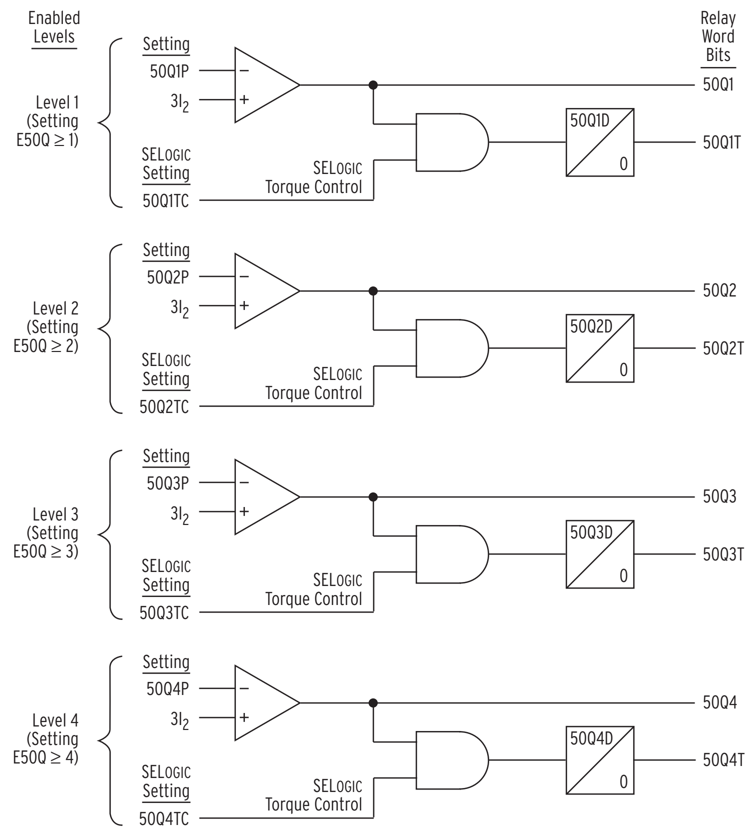


Figure 4.14 Levels 1 Through 4 Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements

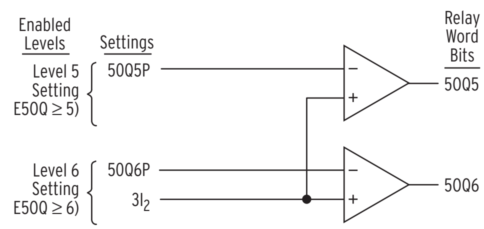


Figure 4.15 Levels 5 Through 6 Negative-Sequence Instantaneous Overcurrent Elements

Accuracy

See *Specifications on page 1.8*.

Pickup and Reset Time Curves

See *Figure 4.8* and *Figure 4.9*.

Time-Overcurrent Elements

The SEL-651R includes seven dual-characteristic time-overcurrent elements, listed in *Table 4.1*.

Table 4.1 Time-Overcurrent Elements in the SEL-651R

Name	Figure	Output Relay Word Bits	Enable Settings	Controlling SELOGIC Equations
Maximum Phase	*Figure 4.16*	51P, 51PT, 51PR, 51PS	E51P	51PTC, 51PSW
A-Phase	*Figure 4.17*	51A, 51AT, 51AR, 51AS	E51ABC	51ATC, 51ASW
B-Phase	*Figure 4.18*	51B, 51BT, 51BR, 51BS	E51ABC	51BTC, 51BSW
C-Phase	*Figure 4.19*	51C, 51CT, 51CR, 51CS	E51ABC	51CTC, 51CSW
Ground #1	*Figure 4.20*	51G1, 51G1T, 51G1R, 51G1S	E51G1	51G1TC, 51G1SW
Ground #2	*Figure 4.21*	51G2, 51G2T, 51G2R, 51G2S	E51G2	51G2TC, 51G2SW
Negative-Sequence	*Figure 4.22*	51Q, 51QT, 51QR, 51QS	E51Q	51QTC, 51QSW

The time-overcurrent elements in *Table 4.1* are run in alternating processing intervals:

- ➤ The phase time-overcurrent elements in one processing interval
- ➤ The ground- and negative-sequence time-overcurrent elements in the following processing interval

Each time-overcurrent element is run twice per power system cycle. If the SELOGIC control equations in *Table 4.1* are set with rising or falling edge trigger operators (see *Table 7.1*), then there is the possibility that the logical 0 to logical 1 (or 1 to 0) transition of some logic will be missed because of the time-overcurrent elements not being run every processing interval.

See the figures referenced in *Table 4.1* for a block diagram of each element.

Enable Settings

The dual characteristic feature allows one of two settings characteristics, labeled J and K, to be used in each time-overcurrent element under SELOGIC control. The dual characteristic feature is only active for a particular element when the enable setting is set to 2. See *Table 4.1* for the enable setting names.

If the enable setting for a time-overcurrent element is set to 1, the time-overcurrent element only operates from the J characteristic.

If the enable setting for a time-overcurrent element is set to 2, the time-overcurrent element operates from the J or the K characteristic, depending on a Relay Word bit controlled by a SELOGIC control equation, as shown in *Table 4.2*.

Table 4.2 Effect of Enable and Characteristic Switch Settings on 51__ Elements[a]

Enable Settings	Characteristic Switch Settings	Controlling Relay Word Bit	J Characteristic	K Characteristic
E51__ := N	None	N/A	Disabled	Disabled
E51__ := 1	None	N/A	Active	Disabled
E51__ := 2	51__SW	51__S	Active when 51__S = logical 0	Active when 51__S = logical 1

[a] The "__" represents P, A, B, C, G1, G2, or Q.

Characteristic Switch Setting

Refer to the figures referenced in *Table 4.1*. Any one of these figures helps in understanding characteristic switching.

The characteristic switch setting, 51__SW, acts as a request to the SEL-651R to change the active characteristic. The Relay Word bit 51__S will normally mimic the state of the characteristic switch setting 51__SW. To prevent a change in characteristic during a power system fault, the 51__SW setting is ignored if the time-overcurrent element is picked-up (Relay Word bit 51__ is asserted). In this case, the 51__S Relay Word bit will remain at its previous state (just before 51__ asserted) as long as the element remains picked-up. After the time-overcurrent element drops-out (Relay Word bit 51__ deasserts), the 51__S Relay Word bit again follows the 51__SW setting.

Make the characteristic switch setting, 51__SW only when the enable setting E51__ := 2. When E51__ := 1, the 51__SW setting is not presented in the **SHO** or **SET** commands (see *Section 10: Communications*), and it is internally set to logical 0.

Relay Word Bits

The time-overcurrent elements in the SEL-651R each use four Relay Word bits, as shown in *Table 4.1*. The J and the K characteristics share the same Relay Word bits, because only one of J or K characteristics can be active at any time.

The standard event reports indicate which characteristic is in effect for each time-overcurrent element by the use of uppercase or lowercase letters in the digital status columns—see *Table 12.4*.

Torque Control

Each of the SEL-651R Dual-Characteristic Time-Overcurrent elements are supervised by a torque control SELOGIC equation setting (see *Table 4.1*). The torque control equation controls the entire element, regardless of which characteristic, J or K, is in use.

Maximum-Phase Time-Overcurrent Elements

The SEL-651R maximum-phase time-overcurrent element is a dual-characteristic element that operates from the maximum phase current, I_A, I_B, or I_C. See *Table 4.1* for figure references, enable setting, Relay Word bits, and controlling SELOGIC equation names.

Settings Ranges

The 51PT maximum-phase time-overcurrent element settings are shown in *Table 4.3*.

Table 4.3 Maximum-Phase Time-Overcurrent Element Settings

Setting[a]	Definition	Range
51PJP 51PKP	pickup	0.10–3.20 A secondary
51PJC 51PKC	curve type	U1–U5 (U.S. curves; see *Table 9.5*), C1–C5 (IEC curves; see *Table 9.6*), recloser curves (see *Table 9.7*)
51PJTD 51PKTD	time dial (has no multiplying effect on constant time adder or minimum response time)	0.50–15.00 (U.S. curves), 0.05–1.00 (IEC curves), 0.10–2.00 (recloser curves)
51PJRS[b] 51PKRS	electromechanical reset timing	Y, N
51PJCT 51PKCT	constant time adder—adds additional time to curve	0.00–60.00 cycles (no effect if set = 0.00)
51PJMR 51PKMR	minimum response time—flattens curve at set time; curve can operate no faster than this set time	0.00–60.00 cycles (no effect if set = 0.00)
51PTC[c]	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table F.1* or set directly to logical 1 (=1)
51PSW[d]	SELOGIC characteristic switch setting	Relay Word bits referenced in *Table F.1*

[a] Dual-Characteristic Time-Overcurrent element settings: the letters J and K in the settings names represent the two characteristics.
[b] The electromechanical reset setting (51PJRS) is not available when the curve selection setting (51PJC) is set to a recloser curve. In this situation, 51PJRS is effectively set to N internally. Similarly, setting 51PKRS is not available when setting 51PKC is set to a recloser curve.
[c] SELOGIC control equation torque control settings (e.g., 51PTC) cannot be set directly to logical 0 or NA.
[d] SELOGIC Characteristic Switch Setting (51PSW) is available only when E51P :=2. 51PSW cannot be set to NA.

See *Time-Overcurrent Curves on page 9.4* for curve selection details.

NOTE: Do not use these elements for load current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load current levels so that the fault locator will work correctly. Use the 50L element instead for load current detection (see Figure 5.5).

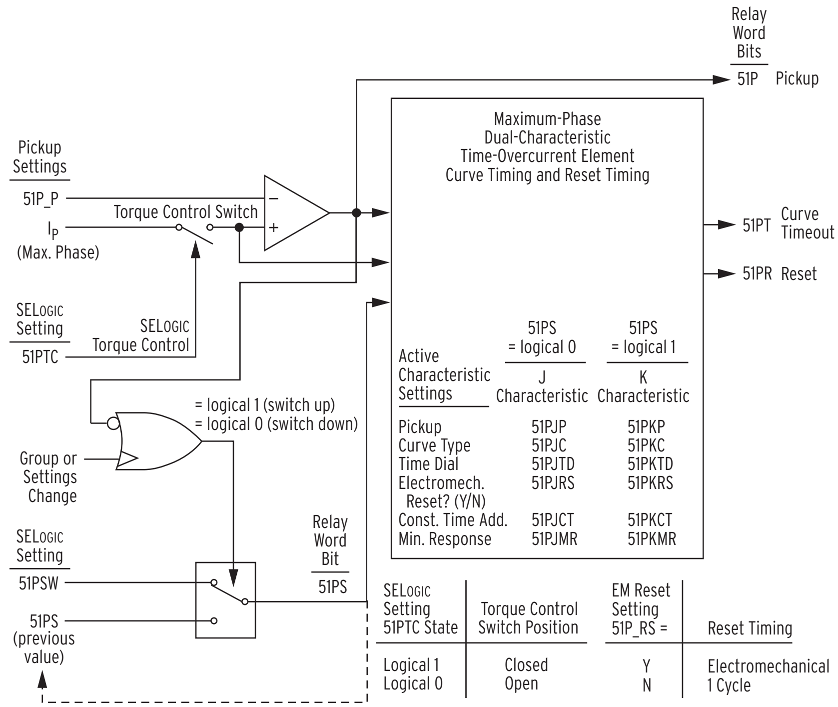


Figure 4.16 Maximum-Phase Dual-Characteristic Time-Overcurrent Element 51PT

Accuracy

See *Specifications on page 1.8*.

Logic Outputs (51PT Element Example)

The resultant logic outputs in *Figure 4.16* are shown in *Table 4.4*.

Table 4.4 Maximum-Phase Time-Overcurrent Element Logic Outputs

Relay Word Bit	Definition/Indication	Application
51P	Maximum phase current, I_P, is greater than phase time-overcurrent element pickup setting 51PJP or 51PKP (depending on 51PS status).	Element pickup testing or other control applications (see *Trip Logic on page 5.1*).
51PT	Phase time-overcurrent element is timed out on its curve.	Tripping and other control applications (see *Trip Logic on page 5.1*).
51PR	Phase time-overcurrent element is fully reset.	Element reset testing or other control applications.
51PS	Maximum-phase time-overcurrent element is operating on the K characteristic.	Indication, targeting, and event report.

Torque Control Switch Operation (51PT Element Example)

The maximum-phase time-overcurrent element J characteristic settings are used in this example, which corresponds to the case where E51P := 1, or where E51P := 2, and the characteristic switch setting 51PSW = logical 0. The same torque control behavior applies to the K characteristic (when 51PSW = logical 1), with the J replaced with K in the settings listed throughout the example.

Torque Control Switch Closed

The pickup comparator in *Figure 4.16* compares the pickup setting (51PJP) to the maximum phase current, I_P, if the Torque Control Switch is closed. I_P is also routed to the curve timing/reset timing functions. The Relay Word bit logic outputs operate as follows with the Torque Control Switch closed:

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

Torque Control Switch Open

If the Torque Control Switch in *Figure 4.16* is open, maximum phase current, I_P, cannot get through to the pickup comparator (setting 51PJP) and the curve timing/reset timing functions. For example, suppose that the Torque Control Switch is closed, I_P is:

I_P > pickup setting 51PJP

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

I_P = 0 A (effective) < pickup setting 51PJP

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

Torque Control Setting

Refer to *Figure 4.16*.

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

51PTC := **1**	Setting 51PTC set directly to logical 1: Torque Control Switch is closed and maximum-phase time-overcurrent element 51PT is enabled. **Note**: Some of the overcurrent element SELOGIC control equation torque control settings are set directly to logical 1 (e.g., 51PTC := 1) for the factory default settings. See *Factory Default Settings on page 9.56* for a list of the factory default settings.
51PTC := **IN105**	Input IN105 deasserted (51PTC := IN105 = logical 0): The Torque Control Switch opens and maximum-phase time-overcurrent element 51PT is defeated and nonoperational, regardless of any other setting. Input IN105 asserted (51PTC := IN105 = logical 1): The Torque Control Switch closes and maximum-phase time-overcurrent element 51PT is enabled.

Reset Timing Details (51PT Element Example)

The maximum-phase time-overcurrent element J characteristic settings are used in this example, which corresponds to the case where E51P :=1, or where E51P :=2, and the characteristic switch setting 51PSW := logical 0. The same reset timing behavior applies to the K characteristic (when 51PSW := logical 1), with the “J” replaced with “K” in the settings listed throughout the example. The J and K characteristics may have different reset settings, for example: 51PJRS := Y and 51PKRS := N. If the characteristic is switched while the element is performing reset timing, the new characteristic will start in the fully reset position.

Refer to *Figure 4.16*.

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

Setting 51PJRS := Y

If electromechanical reset timing setting 51PJRS := Y, the maximum-phase time-overcurrent element reset timing emulates electromechanical reset timing (see *Table 9.5* and *Table 9.6*). If maximum phase current, I_P, goes above pickup setting 51PJP (element is timing or already timed out) and then current I_P goes below 51PJP, the element starts to time to reset, emulating electromechanical reset timing. Relay Word bit 51PR (resetting indication) = logical 1 when the element is fully reset.

Setting 51PRS := N

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

Single-Phase Time-Overcurrent Elements

The SEL-651R single-phase time-overcurrent elements are dual-characteristic elements that operate from the phase currents, I_A, I_B, or I_C. See *Table 4.1* for figure references, enable setting, Relay Word bits, and controlling SELOGIC equation names.

The single-phase elements operate on the individual phase currents, subject to assignment by setting IPCONN—see *Table 9.8*.

The operation of the single-phase time-overcurrent elements is very similar to the maximum-phase time-overcurrent elements. The 51A, 51B and 51C elements are controlled by the enable setting E51ABC. There are separate torque control and characteristic switch SELOGIC control equation settings for each of the single-phase time-overcurrent elements.

To understand the operation of *Figure 4.17* through *Figure 4.19*, follow the explanation given for *Figure 4.16* in the preceding subsection *Maximum-Phase Time-Overcurrent Elements on page 4.14*, substituting current I_A, I_B, or I_C (A-phase, B-phase, or C-phase current) for maximum phase current I_P and substituting like settings and Relay Word bits.

Settings Ranges

The single-phase time-overcurrent element settings are shown in *Table 4.5*:

Table 4.5 A-, B-, or C-Phase Time-Overcurrent Element Settings

Setting[a,b]	Definition	Range
51*n*JP 51*n*KP	pickup	0.10–3.20 A secondary
51*n*JC 51*n*KC	curve type	U1–U5 (U.S. curves; see *Table 9.5*), C1–C5 (IEC curves; see *Table 9.6*), recloser curves (see *Table 9.7*)
51*n*JTD 51*n*KTD	time dial (has no multiplying effect on constant time adder or minimum response time)	0.50–15.00 (U.S. curves), 0.05–1.00 (IEC curves), 0.10–2.00 (recloser curves)
51*n*JRS[c] 51*n*KRS	electromechanical reset timing	Y, N
51*n*JCT 51*n*KCT	constant time adder—adds additional time to curve	0.00–60.00 cycles (no effect if set = 0.00)
51*n*JMR 51*n*KMR	minimum response time—flattens curve at set time; curve can operate no faster than this set time	0.00–60.00 cycles (no effect if set = 0.00)
51*n*TC[d]	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table F.1* or set directly to logical 1 (=1)
51*n*SW[e]	SELOGIC characteristic switch setting	Relay Word bits referenced in *Table F.1*

[a] Dual-Characteristic Time-Overcurrent element settings: the letters J and K in the settings names represent the two characteristics.
[b] n = A, B, or C.
[c] The electromechanical reset setting (51nJRS) is not available when the curve selection setting (51nJC) is set to a recloser curve. In this situation, 51nJRS is effectively set to N internally. Similarly, setting 51nKRS is not available when setting 51nKC is set to a recloser curve.
[d] SELOGIC control equation torque control settings (e.g., 51nTC) cannot be set directly to logical 0 or NA.
[e] SELOGIC Characteristic Switch Setting (51nSW) is available only when E51ABC :=2. 51nSW cannot be set to NA.

See *Time-Overcurrent Curves on page 9.4* for curve selection details.

NOTE: Do not use these elements for load current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load current levels so that the fault locator will work correctly. Use the 50L element instead for load current detection (see Figure 5.5).

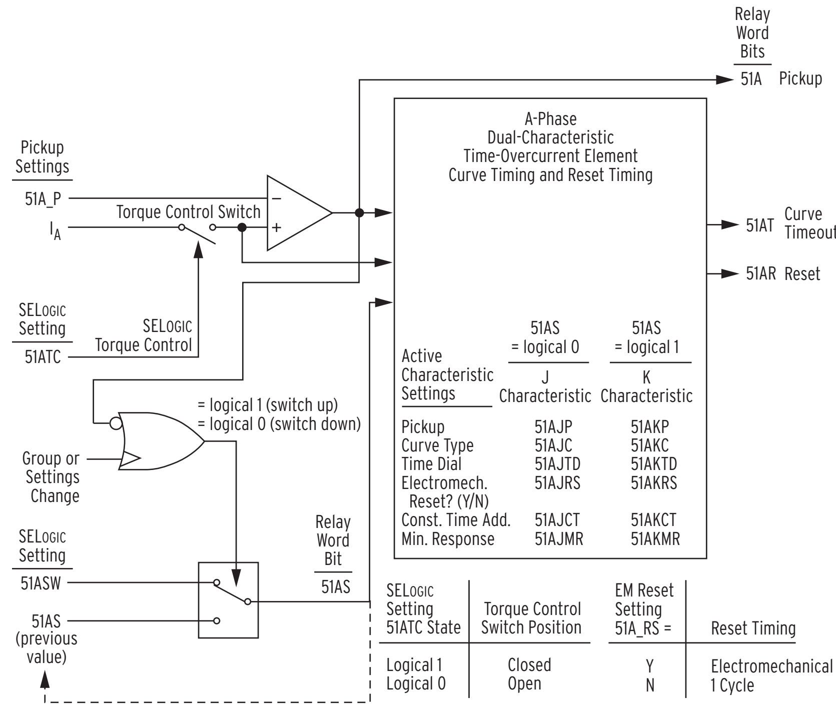


Figure 4.17 A-Phase Time-Overcurrent Element 51AT

NOTE: Do not use these elements for load current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load current levels so that the fault locator will work correctly. Use the 50L element instead for load current detection (see Figure 5.5).

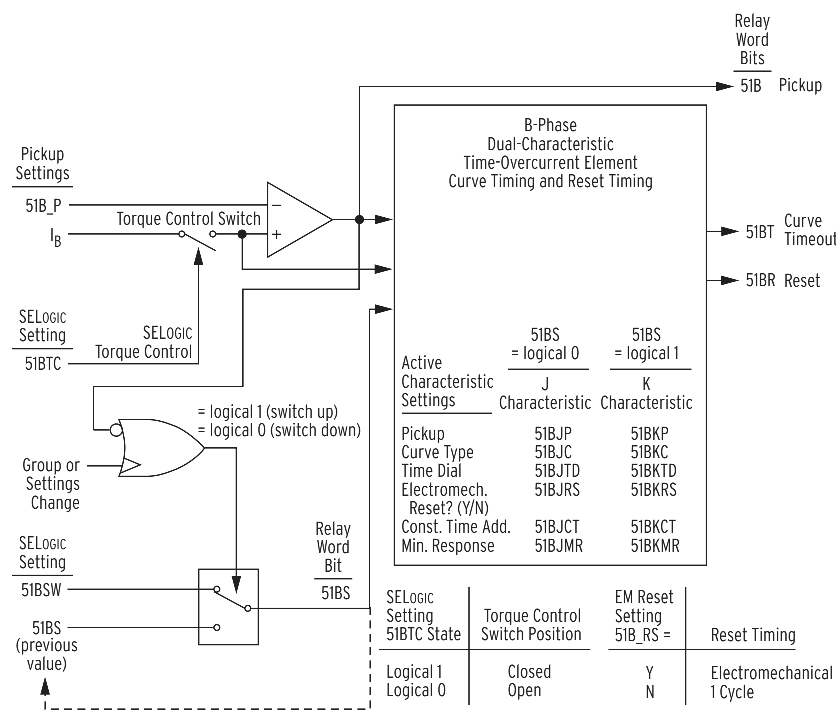


Figure 4.18 B-Phase Time-Overcurrent Element 51BT

NOTE: Do not use these elements for load current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load current levels so that the fault locator will work correctly. Use the 50L element instead for load current detection (see Figure 5.5).

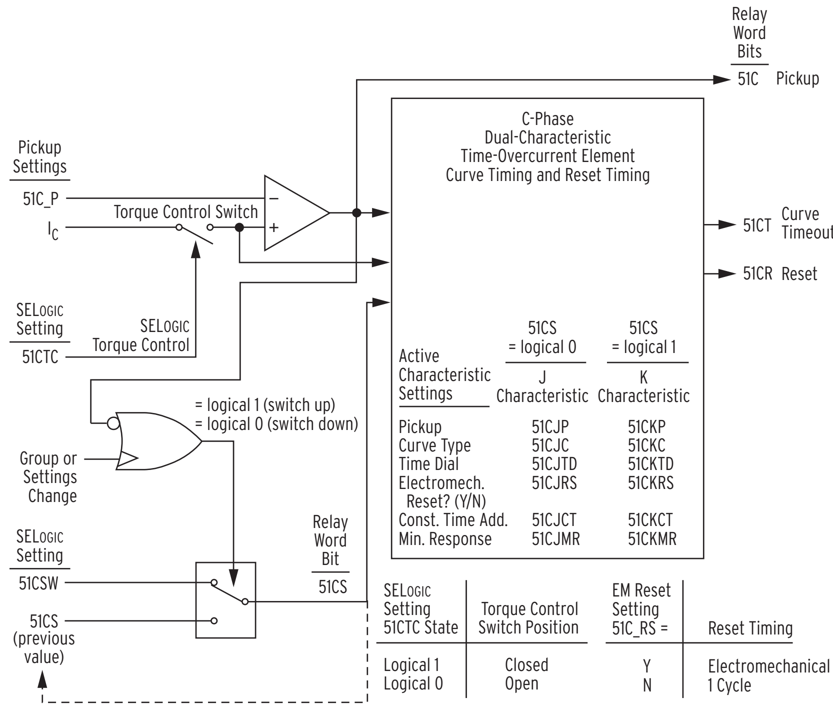


Figure 4.19 C-Phase Time-Overcurrent Element 51CT

Accuracy

See *Specifications on page 1.8*.

Ground Time-Overcurrent Elements

The SEL-651R has two dual-characteristic ground time-overcurrent elements that operate from the current value I_G. The I_G quantity comes from one of two sources: either the calculated residual ground current $3I_0 = I_A + I_B + I_C$, or from the channel IN measured current.

When **global setting EGNDSW := Y**, the I_G quantity is automatically switched between channel IN (for small signals), and the calculated residual ground current $|3I_0| = I_A + I_B + I_C$ (vector summation) for large signals—see the subsection *Ground Switch Logic on page 4.64*. In this application, the pickup values 51G1JP, 51G1KP, 51G2JP, and 51G2KP must be entered on the channel IN current base.

In the factory wiring configuration, channel IN is wired residually with the phase current channels (I1, I2, I3)—see *Figure 2.46* and *Figure 2.48*—and there is no difference between the channel IN current base and the phase current base (because setting CTR = setting CTRN).

For neutral channel wiring configurations that include a separate CT for the neutral channel measuring the zero-sequence current from the same bus section as the phase CTs, see *50G1P Setting Example When EGNDSW := Y and CTR ≠ CTRN on page 4.10*.

When **global setting EGNDSW := N**, the I_G quantity is fixed on the calculated residual ground current $I_G = |3I_0| = I_A + I_B + I_C$ (vector summation). In this application, the pickup values 51G1JP, 51G1KP, 51G2JP, and 51G2KP must be entered on the phase current channel base (same as I_A, I_B, I_C).

See *Table 4.1* for figure references, enable setting, Relay Word bits, and controlling SELOGIC equation names. Note that the ground overcurrent elements (51G1 and 51G2) are controlled by enable settings E51G1 and E51G2. The ground time-overcurrent elements are independent, with separate torque control and characteristic switch SELOGIC control equation settings for 51G1 and 51G2.

Each of the ground time-overcurrent elements (51G1 and 51G2) have Dual Characteristic settings (J and K), which function similarly to the maximum-phase time-overcurrent elements.

To understand the operation of *Figure 4.20* and *Figure 4.21*, follow the explanation given for *Figure 4.16* in the preceding subsection *Maximum-Phase Time-Overcurrent Elements on page 4.14*, substituting ground current I_G (see *Ground Switch Logic on page 4.64*) for maximum phase current I_P and substituting like settings and Relay Word bits.

NOTE: Do not use these elements for load unbalance current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load unbalance current levels so that the fault locator will work correctly.

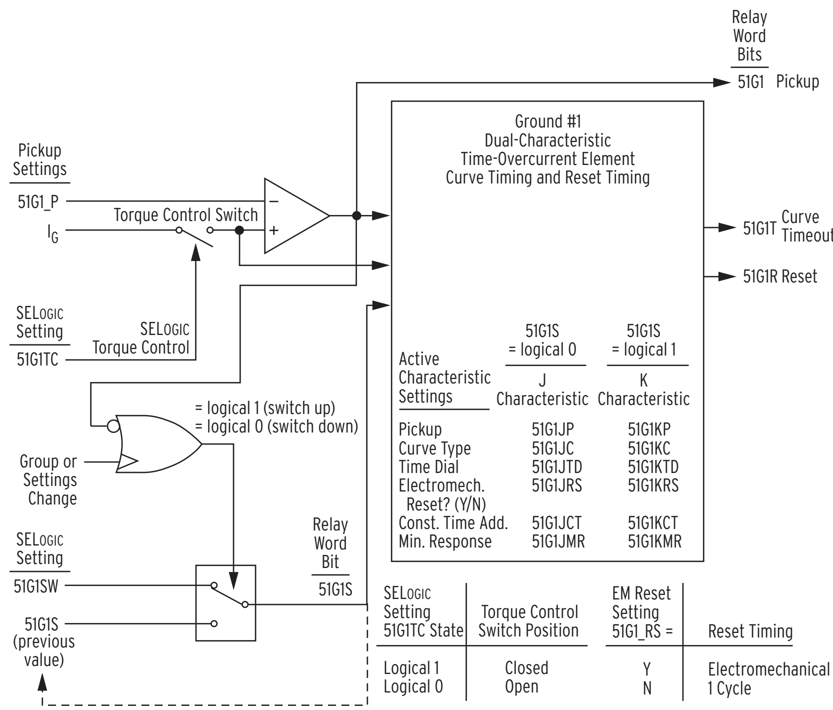


Figure 4.20 Ground Time-Overcurrent Element 51G1T

NOTE: Do not use these elements for load unbalance current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load unbalance current levels so that the fault locator will work correctly.

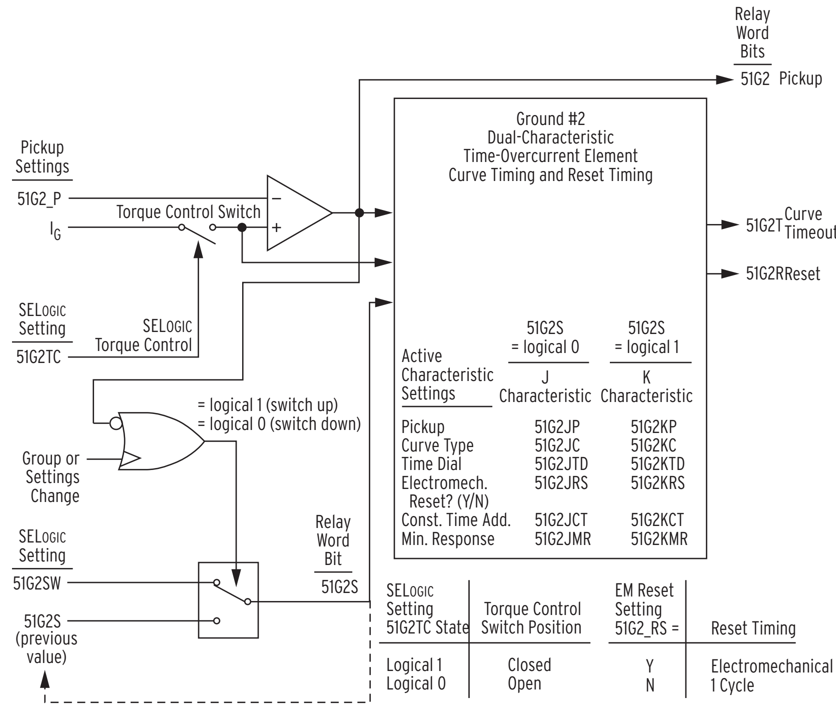


Figure 4.21 Ground Time-Overcurrent Element 51G2T

Settings Ranges

The ground time-overcurrent element settings are shown in *Table 4.6.*

Table 4.6 Ground Time-Overcurrent Element Settings (Sheet 1 of 2)

Setting[a,b]	Definition	Range
51G*n*JP 51G*n*KP	pickup	0.005–3.200 A secondary in 0.001 A steps (on channel IN base[c], when global setting EGNDSW := Y and group setting CTR = CTRN) 0.005–[3.2 • (CTR/CTRN)] A secondary in 0.001 A steps (on channel IN base[c], when global setting EGNDSW := Y and group setting CTR ≠ CTRN) 0.020–3.200 A secondary in 0.001 A steps (on IA, IB, IC base[c], when global setting EGNDSW := N)
51G*n*JC 51G*n*KC	curve type	U1–U5 (U.S. curves; see *Table 9.5*), C1–C5 (IEC curves; see *Table 9.6*), recloser curves (see *Table 9.7*)
51G*n*JTD 51G*n*KTD	time dial (has no multiplying effect on constant time adder or minimum response time)	0.50–15.00 (U.S. curves), 0.05–1.00 (IEC curves), 0.10–2.00 (recloser curves)
51G*n*JRS[d] 51G*n*KRS	electromechanical reset timing	Y, N
51G*n*JCT 51G*n*KCT	constant time adder—adds additional time to curve	0.00–60.00 cycles (no effect if set = 0.00)

Table 4.6 Ground Time-Overcurrent Element Settings (Sheet 2 of 2)

Setting[a,b]	Definition	Range
51G*n*JMR 51G*n*KMR	minimum response time—flattens curve at set time; curve can operate no faster than this set time	0.00–60.00 cycles (no effect if set = 0.00)
51G*n*TC[e]	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table F.1* or set directly to logical 1 (=1)
51G*n*SW[f]	SELOGIC characteristic switch setting	Relay Word bits referenced in *Table F.1*

[a] Dual-Characteristic Time-Overcurrent element settings: the letters J and K in the setting names represent the two characteristics.
[b] n = 1 or 2.
[c] In the case where EGNDSW := Y and CTR = CTRN, there is no difference between the IN current base and the IA, IB, IC current base. This is the standard configuration for the SEL-651R. The scaling considerations for the ground time-overcurrent elements are identical to the ground instantaneous/definite-time overcurrent elements—see 50G1P Setting Example When EGNDSW := Y and CTR ≠ CTRN on page 4.10.
[d] The electromechanical reset setting (51GnJRS) is not available when the curve selection setting (51GnJC) is set to a recloser curve. In this situation, 51GnJRS is effectively set to N internally. Similarly, setting 51GnKRS is not available when setting 51GnKC is set to a recloser curve.
[e] SELOGIC control equation torque control settings (e.g., 51GnTC) cannot be set directly to logical 0 or NA.
[f] SELOGIC Characteristic Switch Setting (51GnSW) is only available when E51Gn :=2. 51GnSW cannot be set to NA.

See *Time-Overcurrent Curves on page 9.4* for curve selection details.

Accuracy

See *Specifications on page 1.8*.

Negative-Sequence Time-Overcurrent Element

The SEL-651R negative-sequence time-overcurrent element is a dual-characteristic element that operates from the calculated negative-sequence currents $3I_2$. See *Table 4.1* for figure references, enable setting, Relay Word bits, and controlling SELOGIC equation names.

The operation of the negative-sequence time-overcurrent element is very similar to the maximum-phase time-overcurrent elements. The 51Q element is controlled by the enable setting E51Q.

NOTE: Do not use these elements for load unbalance current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load unbalance current levels so that the fault locator will work correctly.

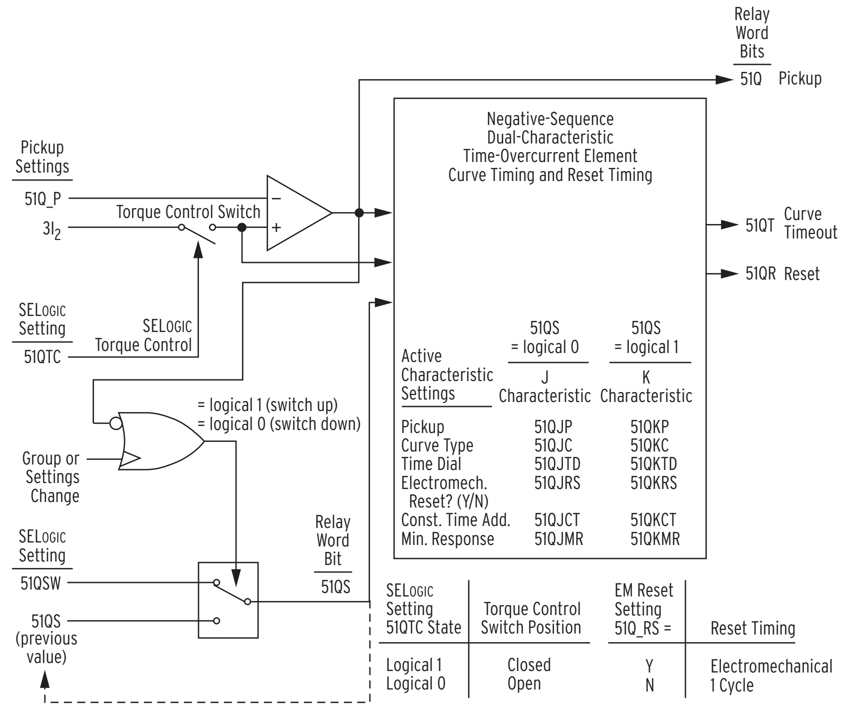


Figure 4.22 Negative-Sequence Time-Overcurrent Element 51QT

IMPORTANT: See *Setting Negative-Sequence Time-Overcurrent Elements on page 4.88* for information on setting negative-sequence overcurrent elements.

To understand the operation of *Figure 4.22*, follow the explanation given for *Figure 4.16* in the preceding subsection *Maximum-Phase Time-Overcurrent Elements on page 4.14*, substituting negative-sequence current $3I_2$ [$3I_2 = I_A + a^2 \bullet I_B + a \bullet I_C$ (ABC rotation), $3I_2 = I_A + a^2 \bullet I_C + a \bullet I_B$ (ACB rotation), where $a = 1 \angle 120°$ and $a^2 = 1 \angle -120°$] for maximum phase current I_P and like settings and Relay Word bits.

Settings Ranges

The negative-sequence time-overcurrent element settings are shown in *Table 4.7*.

Table 4.7 Negative-Sequence Time-Overcurrent Element Settings (Sheet 1 of 2)

Setting[a]	Definition	Range
51QJP 51QKP	pickup	0.10–3.20 A secondary
51QJC 51QKC	curve type	U1–U5 (U.S. curves; see *Table 9.5*), C1–C5 (IEC curves; see *Table 9.6*), recloser curves (see *Table 9.7*)
51QJTD 51QKTD	time dial (has no multiplying effect on constant time adder or minimum response time)	0.50–15.00 (U.S. curves), 0.05–1.00 (IEC curves), 0.10–2.00 (recloser curves)
51QJRS[b] 51QKRS	electromechanical reset timing	Y, N
51QJCT 51QKCT	constant time adder—adds additional time to curve	0.00–60.00 cycles (no effect if set = 0.00)

Table 4.7 Negative-Sequence Time-Overcurrent Element Settings (Sheet 2 of 2)

Setting[a]	Definition	Range
51QJMR 51QKMR	minimum response time—flattens curve at set time; curve can operate no faster than this set time	0.00–60.00 cycles (no effect if set = 0.00)
51QTC[c]	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table F.1* or set directly to logical 1 (=1)
51QSW[d]	SELOGIC characteristic switch setting	Relay Word bits referenced in *Table F.1*

[a] Dual-Characteristic Time-Overcurrent element settings: the letters J and K in the settings names represent the two characteristics.
[b] The electromechanical reset setting (51QJRS) is not available when the curve selection setting (51QJC) is set to a recloser curve. In this situation, 51QJRS is effectively set to "N" internally. Similarly, setting 51QKRS is not available when setting 51QKC is set to a recloser curve.
[c] SELOGIC control equation torque control settings (e.g., 51QTC) cannot be set directly to logical 0 or NA.
[d] SELOGIC Characteristic Switch Setting (51QSW) is available only when E51Q :=2. 51QSW cannot be set to NA.

See *Time-Overcurrent Curves on page 9.4* for curve selection details.

Accuracy

See *Specifications on page 1.8*.

Voltage Elements

Enable numerous voltage elements by making the enable setting:

EVOLT := **N (None), VY, VZ, or BOTH**

The VY-terminal voltage elements are enabled when EVOLT := VY or BOTH. The VZ-terminal voltage elements are enabled if EVOLT := VZ or BOTH.

Voltage Values

The VY-terminal voltage elements operate off of Y-terminal voltage values shown in *Table 4.8* (Z-terminal is similar—see terminals in *Figure 2.37*).

Table 4.8 Voltage Values Used by VY-Terminal Voltage Elements (VZ-Terminal Similar)

Voltage	Description
$V_{A(Y)}$	A-phase voltage[a]
$V_{B(Y)}$	B-phase voltage[a]
$V_{C(Y)}$	C-phase voltage[a]
$V_{AB(Y)}$	Phase-to-phase voltage
$V_{BC(Y)}$	Phase-to-phase voltage
$V_{CA(Y)}$	Phase-to-phase voltage
$3V_{0(Y)}$	Zero-sequence voltage
$V_{2(Y)}$	Negative-sequence voltage
$V_{1(Y)}$	Positive-sequence voltage

[a] Global setting VYCONN determines the assignment of VY-terminal voltage inputs V1Y, V2Y, and V3Y to phases A, B, and C, thus allowing voltages $V_{A(Y)}$, $V_{B(Y)}$, and $V_{C(Y)}$ to be derived (see Table 9.9).

Voltage Element Settings

LOW-END RANGE CHANGE HELPS DETECT ABSENCE OF VOLTAGE: The low-end ranges of certain voltage element pickup settings in Table 4.9 were changed from 12.50 V to 1.00 V and 22.00 V to 1.76 V. This change assists in signaling the absence of voltage for primary systems with nominal voltages down to 4.16 kV and connected to 8 V LEA voltage inputs. See the following discussion Detecting Absence of Voltage with 8 V LEA Connections at the end of this subsection.

Table 4.9 lists available voltage elements and the corresponding voltage inputs and settings ranges for SEL-651R relays.

Table 4.9 VY-Terminal Voltage Elements Settings and Settings Ranges (VZ-Terminal Similar)

Voltage Element (Relay Word Bits)	Operating Voltage	Pickup Setting/ Range	See Figure
27YA1	$V_{A(Y)}$	27YP1P 1.00–300.00 V secondary	*Figure 4.23* (for similar Z-terminal voltage elements, *Figure 4.25*)
27YB1	$V_{B(Y)}$		
27YC1	$V_{C(Y)}$		
3P27Y := 27A1 AND 27B1 AND 27C1			
27YA2	$V_{A(Y)}$	27YP2P 1.00–300.00 V secondary	
27YB2	$V_{B(Y)}$		
27YC2	$V_{C(Y)}$		
59YA1	$V_{A(Y)}$	59YP1P 1.00–300.00 V secondary	
59YB1	$V_{B(Y)}$		
59YC1	$V_{C(Y)}$		
3P59Y := 59YA1 AND 59YB1 AND 59YC1			
59YA2	$V_{A(Y)}$	59YP2P 1.00–300.00 V secondary	
59YB2	$V_{B(Y)}$		
59YC2	$V_{C(Y)}$		
27YAB1	$V_{AB(Y)}$	27YPP1P 1.76–520.00 V secondary	*Figure 4.24* (for similar Z-terminal voltage elements, *Figure 4.26*)
27YBC1	$V_{BC(Y)}$		
27YCA1	$V_{CA(Y)}$		
59YAB1	$V_{AB(Y)}$	59YPP1P 1.76–520.00 V secondary	
59YBC1	$V_{BC(Y)}$		
59YCA1	$V_{CA(Y)}$		
59YN1	$3V_{0(Y)}$	59YN1P 2.00–300.00 V secondary	
59YN2	$3V_{0(Y)}$	59YN2P 2.00–300.00 V secondary	
59YQ1	$V_{2(Y)}$	59YQ1P 2.00–300.00 V secondary	
59YV1	$V_{1(Y)}$	59YV1P 2.00–300.00 V secondary	

The SEL-651R voltage inputs are available as either 300 Vac maximum inputs or as a variety of Low Energy Analog (LEA) inputs. The settings (in *Table 4.9*) are on the 300 Vac base.

If Low-Energy Analog (LEA) inputs are ordered, the voltage element pickup values must be adjusted prior to making the settings (see *PT Ratio Setting Adjustments on page 9.40* and *Voltage-Related Settings and LEA Inputs on page 9.43*).

NOTE: Lindsey SVMI LEA inputs are rated up to 200 Vac. Any voltage-related settings should not exceed 200 V, even when the setting allows more than 200 Vac.

The voltage elements in the SEL-651R are **not affected** by the global settings VSELECT and EPHANT (see *Enable Phantom Voltage Setting (EPHANT) on page 9.33* and *Voltage Source Selection Setting (VSELECT) on page 9.33*).

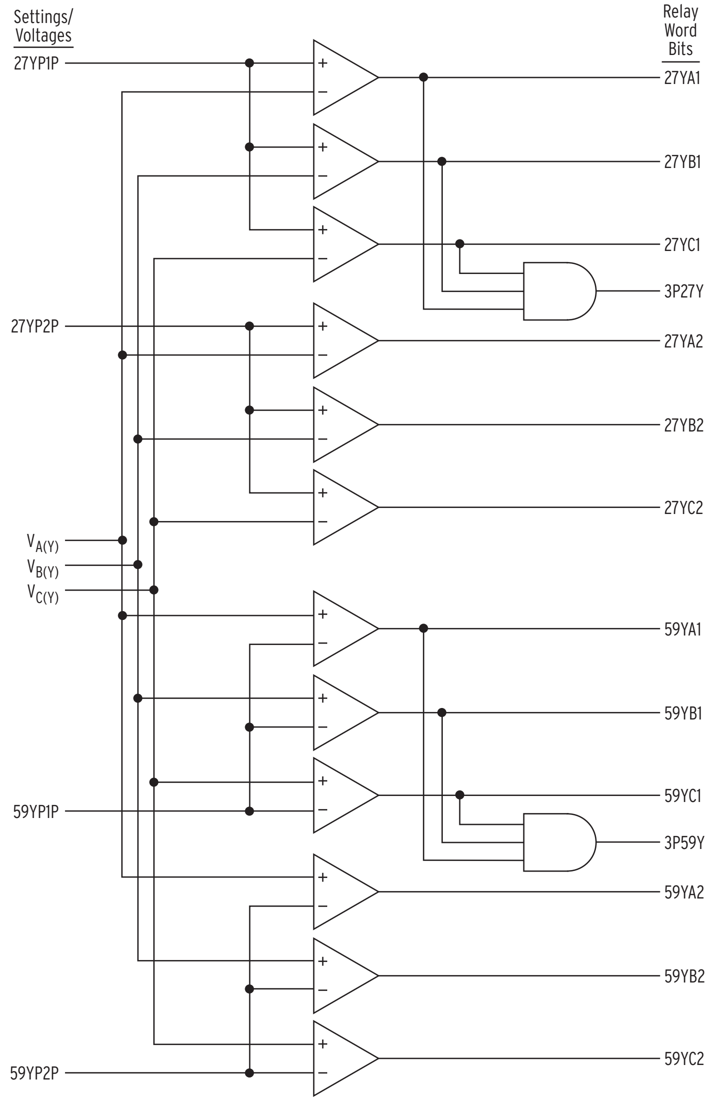


Figure 4.23 VY-Terminal Single-Phase and Three-Phase Voltage Elements

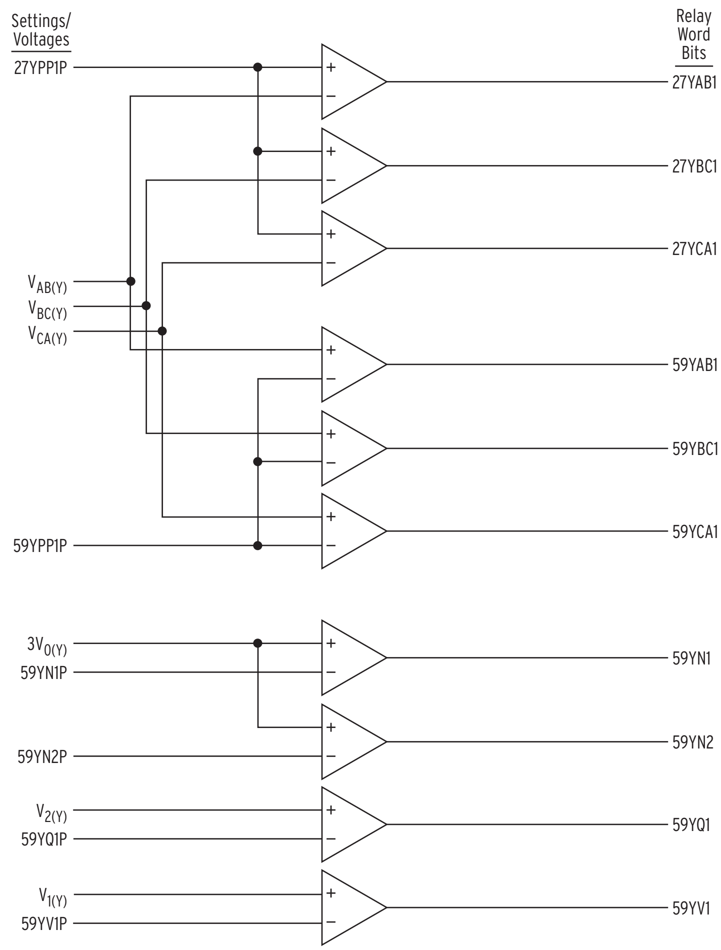


Figure 4.24 VY-Terminal Phase-to-Phase and Sequence Voltage Elements

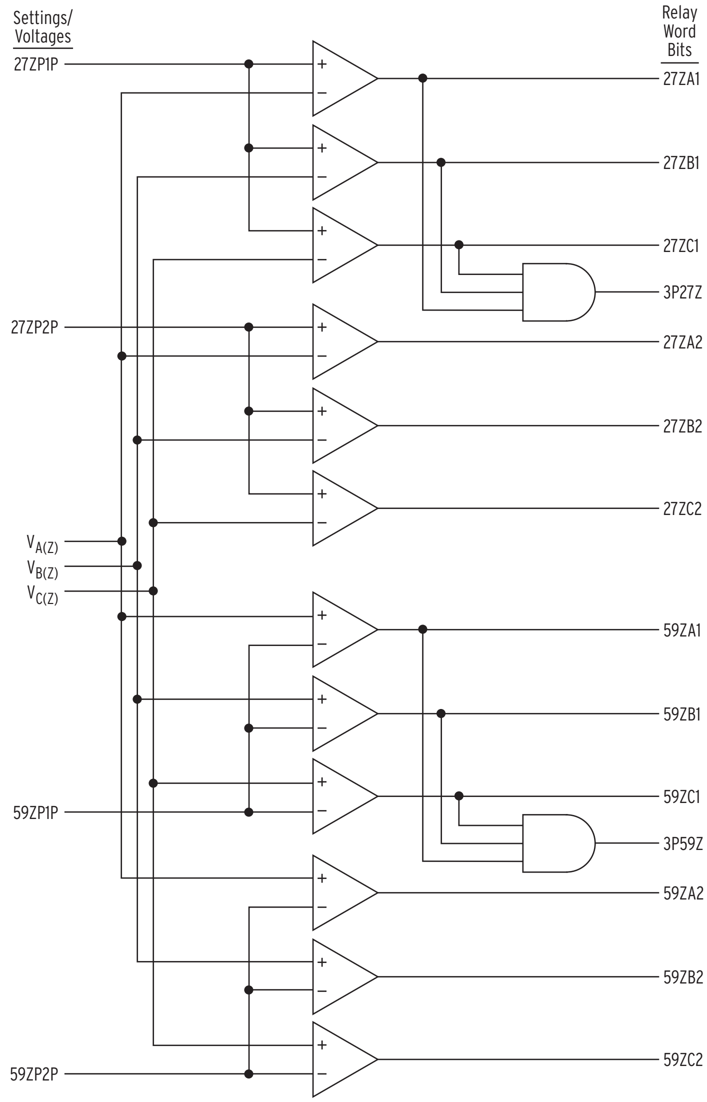


Figure 4.25 VZ-Terminal Single-Phase and Three-Phase Voltage Elements

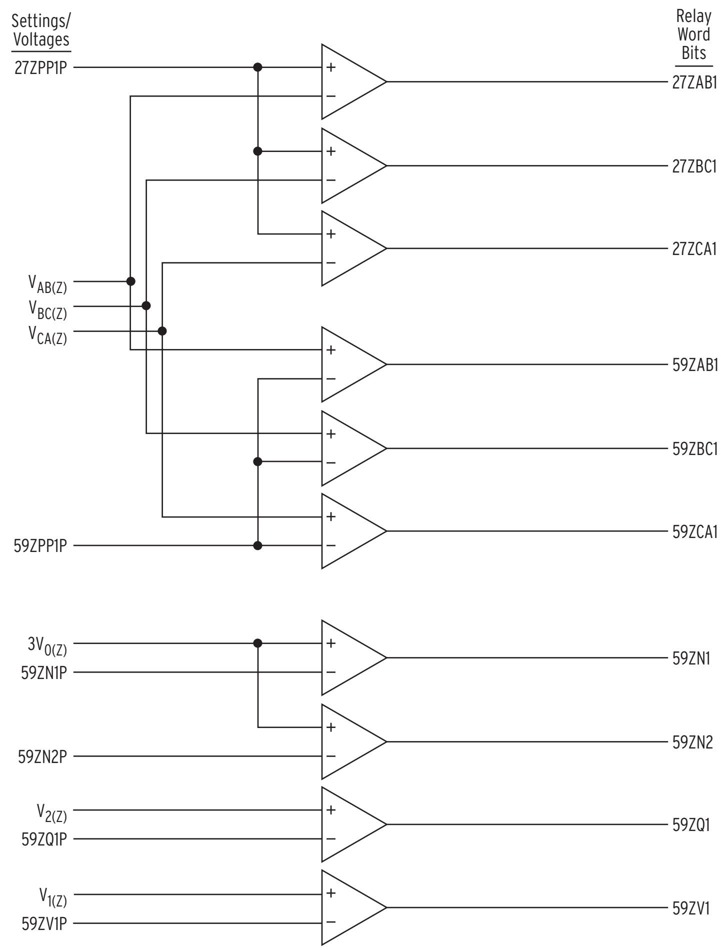


Figure 4.26 VZ-Terminal Phase-to-Phase and Sequence Voltage Elements

Accuracy

See *Specifications on page 1.8*.

Voltage Element Operation

Note that the voltage elements in *Table 4.9* and *Figure 4.23* through *Figure 4.26* are a combination of “undervoltage” (Device 27) and “overvoltage” (Device 59) type elements. Undervoltage elements (Device 27) assert when the operating voltage goes below the corresponding pickup setting. Overvoltage elements (Device 59) assert when the operating voltage goes above the corresponding pickup setting.

Undervoltage Element Operation Example

Refer to *Figure 4.23* (top of the figure).

Pickup setting 27YP1P is compared to the magnitudes of the individual phase voltages $V_{A(Y)}$, $V_{B(Y)}$, and $V_{C(Y)}$. The logic outputs in *Figure 4.23* are the following Relay Word bits:

27YA1 =	1 (logical 1)	if $V_{A(Y)}$ < pickup setting 27YP1P
	0 (logical 0)	if $V_{A(Y)} \geq$ pickup setting 27YP1P
27YB1 =	1 (logical 1)	if $V_{B(Y)}$ < pickup setting 27YP1P
	0 (logical 0)	if $V_{B(Y)} \geq$ pickup setting 27YP1P
27YC1 =	1 (logical 1)	if $V_{C(Y)}$ < pickup setting 27YP1P
	0 (logical 0)	if $V_{C(Y)} \geq$ pickup setting 27YP1P
3P27Y =	1 (logical 1)	if all three Relay Word bits 27YA1, 27YB1, and 27YC1 are asserted (27YA1 = 1, 27YB1 = 1, and 27YC1 = 1)
	0 (logical 0)	if at least one of the Relay Word bits 27YA1, 27YB1, or 27YC1 is deasserted (e.g., 27YA1 = 0)

Overvoltage Element Operation Example

Refer to *Figure 4.23* (bottom of the figure).

Pickup setting 59YP1P is compared to the magnitudes of the individual phase voltages $V_{A(Y)}$, $V_{B(Y)}$, and $V_{C(Y)}$. The logic outputs in *Figure 4.23* are the following Relay Word bits:

59YA1 =	1 (logical 1)	if $V_{A(Y)}$ > pickup setting 59YP1P
	0 (logical 0)	if $V_{A(Y)} \leq$ pickup setting 59YP1P
59YB =1	1 (logical 1)	if $V_{B(Y)}$ > pickup setting 59YP1P
	0 (logical 0)	if $V_{B(Y)} \leq$ pickup setting 59YP1P
59YC1 =	1 (logical 1)	if $V_{C(Y)}$ > pickup setting 59YP1P
	0 (logical 0)	if $V_{C(Y)} \leq$ pickup setting 59YP1P
3P59Y =	1 (logical 1)	if all three Relay Word bits 59YA1, 59YB1, and 59YC1 are asserted (59YA1 = 1, 59YB1 = 1, and 59YC1 = 1)
	0 (logical 0)	if at least one of the Relay Word bits 59YA1, 59YB1, or 59YC1 is deasserted (e.g., 59YA1 = 0)

Detecting Absence of Voltage with 8 V LEA Connections

Refer to *PT Ratio Setting Adjustments on page 9.40* and *Voltage-Related Settings and LEA Inputs on page 9.43* for voltage divider information and background for connecting to various LEA voltage inputs. Using 8 Vac LEA voltage inputs as an example, convert low-end pickup setting 27YP1P = 1.00 V (300 V base) to the 8 V base:

$$1.00 \text{ V} \cdot 8/300 = 0.0267 \text{ V (8 V base)}$$

The accuracy variation for the effective 0.0267 V (8 V base) pickup setting (from *Specifications on page 1.8*) is shown below:

$$0.01 \text{ V} + 0.0267 \text{ V} \cdot (0.01) = 0.01 \text{ V (8 V base)}$$

So, the effective 0.0267 V (8 V base) pickup could vary from:

0.0167 V (= 0.0267 V – 0.01 V)
to
0.0367 V (= 0.0267 V + 0.01 V)

Converting the effective pickup (with "positive" variation) 0.0367 V (8 V base) to the primary voltage level (via the 10,000 ratio voltage divider for 8 V LEA applications) results in:

0.0367 V • 10,000 = 367 V primary

Apply this resultant primary value to a 4.16 kV primary system (2.4 kV phase-neutral):

(367 V/2400 V) • 100% = 15.3%

An adequate voltage measurement to determine absence of voltage on a 4.16 kV primary system is 15.3% of nominal voltage (which includes the above stated "positive" accuracy variation). Again, this is achieved with the previously mentioned example pickup setting 27YP1P = 1.00 V (300 V base).

Alternatively, for a 12.47 kV primary system (7.2 kV phase-neutral), 15% of nominal voltage would extrapolate to the following voltage on the 8 V LEA input:

(15%/100%) • (7200 V/10,000) = 0.108 V (8 V base)

Factoring in accuracy variation, the effective 0.108 V (8 V base) pickup could vary from:

0.098 V (= 0.108 V – 0.01 V)
to
0.118 V (= 0.108 V + 0.01 V)

This is a much tighter variation than the preceding 4.16 kV primary system example, because a 12.47 kV primary system provides more signal to the 10,000 ratio voltage divider than does a 4.16 kV primary system. The 27YP1P pickup setting (300 V base) for this 12.47 kV primary system example (15% of nominal voltage) would be:

0.108 V • 300/8 = 4.05 V (300 V base)

Synchronism-Check Elements

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

E25 := **Y**

Synchronism-check is performed with the voltages connected to voltage terminals V1Y–NY and V1Z–NZ (see *Figure 2.11*, *Figure 2.37*, and *Table 9.9*). In this synchronism-check subsection, these voltages are referred to as the following:

V_P and V_S

Global setting FSELECT selects which voltage functions as V_P (and by default, which functions as V_S), as shown in *Table 4.10*.

Table 4.10 Voltages V_P and V_S for Synchronism Check

Global Setting FSELECT :=	VP = Voltage connected to voltage terminals:	VS = Voltage connected to voltage terminals:
VY	V1Y–NY	V1Z–NZ
VZ	V1Z–NZ	V1Y–NY

The two synchronism-check elements use the same voltage window (to ensure healthy voltage) and slip frequency settings (see *Figure 4.27*). They have separate angle settings (see *Figure 4.28*).

If voltages V_P and V_S are static (not slipping with respect to one another) or the breaker close time setting TCLOSD := 0.00, the two synchronism-check elements operate as shown in the top of *Figure 4.28*. The angle settings are checked for synchronism-check closing.

If voltages V_P and V_S are not static (slipping with respect to one another) the two synchronism-check elements operate as shown in the bottom of *Figure 4.28*. The angle difference is compensated by breaker close time, and the breaker is ideally closed at a zero degree phase angle difference, to minimize system shock.

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

Setting SYNCP

Sometimes synchronism-check voltage V_S cannot be in phase with voltage V_P. This happens in applications where any of the following are true:

- Phase-to-phase voltage is connected to one voltage input and phase-to-neutral voltage is connected to the other voltage input.
- The voltage inputs are connected to different phases.
- One of the voltage inputs is connected beyond a delta-wye transformer.

For such applications requiring VS to be at a constant phase angle difference from V_P, an angle setting is made with the SYNCP setting (see *Table 4.11*). The angle setting choices (0, 30, …, 300, or 330 degrees) for setting SYNCP are referenced to V_P, and they indicate how many degrees V_S constantly lags V_P.

System Rotation Can Affect Setting SYNCP

If system rotation is ABC and V_P is connected to Phase A and V_S is connected to Phase B, then SYNCP := 120 (V_S lags V_P by 120 degrees). If voltage input connections are the same, but system rotation is ACB, then setting SYNCP := 240 degrees (V_S constantly lags V_P by 240°). See the SEL Application Guide *AG2002-02, Compensate for Constant Phase Angle Difference in Synchronism-Check with the SEL-351 Relay Family* for more information on setting SYNCP with an angle setting. This guide is still generally applicable to the SEL-651R.

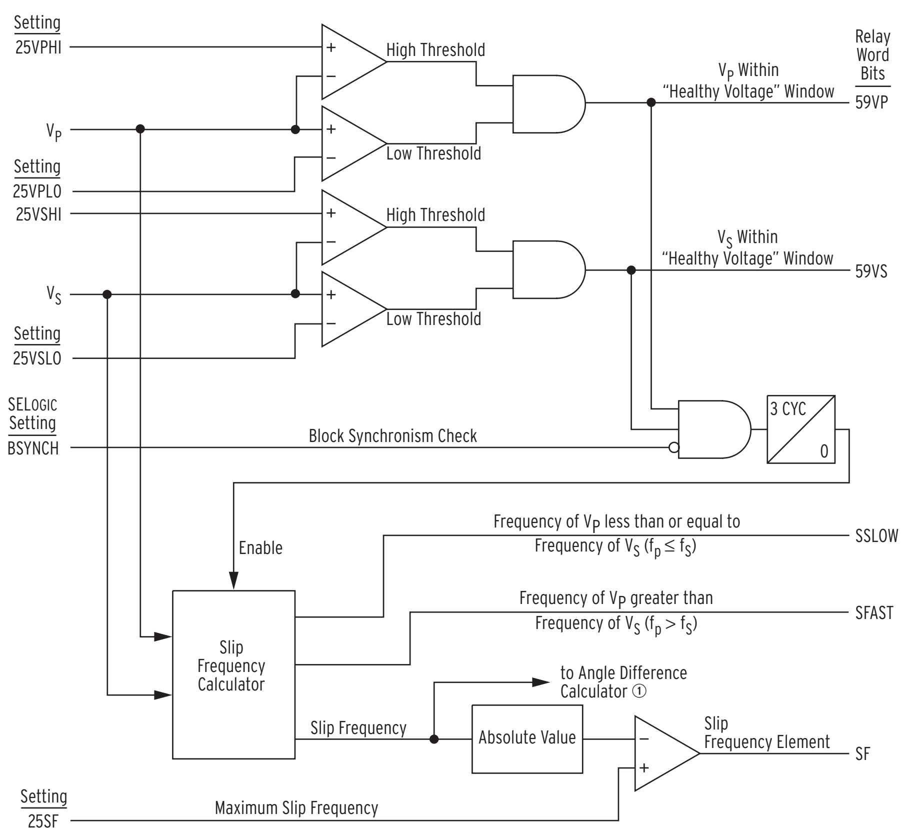
Synchronism-Check Elements Settings

Table 4.11 Synchronism-Check Elements Settings and Settings Ranges

Setting	Definition	Range
25VPLO	low voltage threshold for “healthy V_P voltage” window	12.50–300.00 V secondary
25VPHI	high voltage threshold for “healthy V_P voltage” window	12.50–300.00 V secondary
25VSLO	low voltage threshold for “healthy V_S voltage” window	12.50–300.00 V secondary
25VSHI	high voltage threshold for “healthy V_S voltage” window	12.50–300.00 V secondary
25SF	maximum slip frequency	0.005–0.500 Hz
25ANG1	synchronism-check element 25A1 maximum angle	0°–80°
25ANG2	synchronism-check element 25A2 maximum angle	0°–80°
SYNCP	the number of degrees that synchronism-check voltage V_S constantly lags voltage V_P	0°–330°, in 30° steps
TCLOSD	breaker close time for angle compensation	0.00–60.00 cycles
BSYNCH	SELOGIC control equation block synchronism-check setting	Relay Word bits referenced in *Table F.1*

Accuracy

See *Specifications on page 1.8*.



① See bottom of Figure 4.28.

Figure 4.27 Synchronism-Check Voltage Window and Slip Frequency Elements

Synchronism-Check Elements Operation

Refer to *Figure 4.27* and *Figure 4.28*.

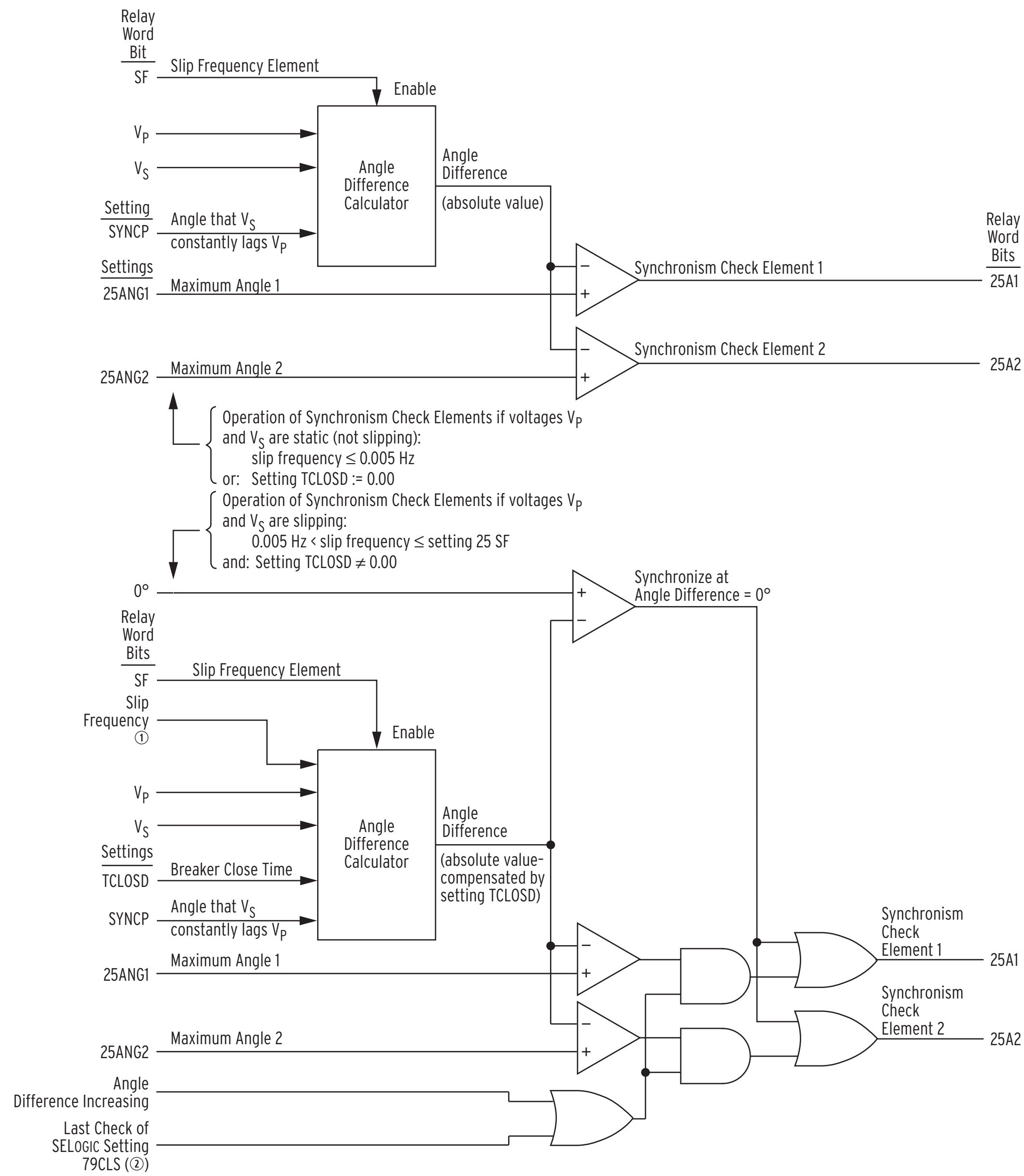
Voltage Window

Refer to *Figure 4.27*.

Single-phase voltage inputs V_P and V_S are compared to voltage windows, to verify that the voltages are “healthy” and lie within settable voltage limits. If both voltages are within their respective voltage windows, the following Relay Word bits assert:

59VP indicates that voltage V_P is within voltage window setting limits 25VPLO and 25VPHI

59VS indicates that voltage V_S is within voltage window setting limits 25VSLO and 25VSHI



① From Figure 4.27; ② See Figure 6.7

Figure 4.28 Synchronism-Check Elements

Other Uses for Voltage Window Elements

If voltage limits 25VPLO/25VPHI and 25VSLO/25VSHI are applicable to other control schemes, Relay Word bits 59VP and 59VS can be used in other logic at the same time they are used in the synchronism-check logic.

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

Block Synchronism-Check Conditions

Refer to *Figure 4.27*.

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

BSYNCH := **52A3P** see *Figure 6.2*

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

BSYNCH := **... OR TRIP3P**

Slip Frequency Calculator

Refer to *Figure 4.27*.

The synchronism-check element Slip Frequency Calculator in *Figure 4.27* runs if voltages V_P and V_S are healthy (59VP and 59VS asserted to logical 1) and the SELOGIC control equation setting BSYNCH (Block Synchronism Check) is deasserted (= logical 0). The Slip Frequency Calculator output is:

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

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

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

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

For example, in *Figure 4.27*, if voltage V_P has a frequency of 59.95 Hz and voltage V_S has a frequency of 60.05 Hz, the difference between them is the slip frequency:

Slip Frequency = 59.95 Hz – 60.05 Hz = –0.10 Hz = –0.10 slip cycles/second

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

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

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

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

Generator Application for SSLOW and SFAST

Relay Word bits SSLOW and SFAST in *Figure 4.27* indicate the relative slip of voltages V_P and V_S:

$f_P < f_S$:SSLOW = logical 1, SFAST = logical 0

$f_P > f_S$:SSLOW = logical 0, SFAST = logical 1

An application idea for SSLOW and SFAST is a small generator installation: V_P is from the generator side and V_S is from the system side (other side of the open circuit breaker). With some logic (perhaps to create pulsing signals), SSLOW and SFAST are used as signals (via output contacts) to the generator governor. SSLOW indicates that the generator (V_P) is slower than (or equal in frequency to) the system (V_S), while “SFAST” indicates that the generator (V_P) is faster than the system (V_S). If the enable into the slip frequency calculator in *Figure 4.27* is disabled (e.g., SELOGIC setting BSYNCH asserts because the breaker closes; BSYNCH := 52A3P OR …), then both SSLOW = logical 0 and SFAST = logical 0, regardless of slip frequency.

Angle Difference Calculator

The synchronism-check element Angle Difference Calculator in *Figure 4.28* runs if the slip frequency is less than the maximum slip frequency setting 25SF (Relay Word bit SF is asserted).

Voltages V_P and V_S are “Static”

Refer to the top of *Figure 4.28*.

If the slip frequency is less than or equal to 0.005 Hz, the Angle Difference Calculator does not take into account breaker close time—it presumes voltages V_P and V_S are “static” (not “slipping” with respect to one another). This would usually be the case for an open breaker with voltages V_P and V_S that are paralleled via some other electric path in the power system. The Angle Difference Calculator calculates the angle difference between voltages V_P and V_S:

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

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

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

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

Voltages V_P and V_S are "Slipping"

Refer to bottom of *Figure 4.28*.

If the slip frequency is greater than 0.005 Hz and breaker close time setting TCLOSD ≠ 0.00, the Angle Difference Calculator takes the breaker close time into account with breaker close time setting TCLOSD (set in cycles; see *Figure 4.29*). The Angle Difference Calculator calculates the Angle Difference between voltages V_P and V_S, compensated with the breaker close time:

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

Equation 4.4

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

Refer to bottom of *Figure 4.28*.

For example, if the breaker close time is ten cycles, set TCLOSD := 10.00. Presume the slip frequency is the example slip frequency calculated previously. The Angle Difference Calculator calculates the angle difference between voltages V_P and V_S, compensated with the breaker close time using *Equation 4.4*.

Intermediate calculations:

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

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

Resulting in (using *Equation 4.4*):

$$= \left|(\angle V_P - \angle V_S) + [-0.10 \bullet 0.167 \bullet 360°]\right|$$
$$= \left|(\angle V_P - \angle V_S) - 6°\right|$$

NOTE: The angle compensation in Figure 4.29 appears much greater than six degrees. Figure 4.29 is for general illustrative purposes only.

During the breaker close time (TCLOSD), the voltage angle difference between voltages V_P and V_S changes by six degrees. This six degree angle compensation is applied to voltage V_S, resulting in derived voltage V_S*, as shown in *Figure 4.29*.

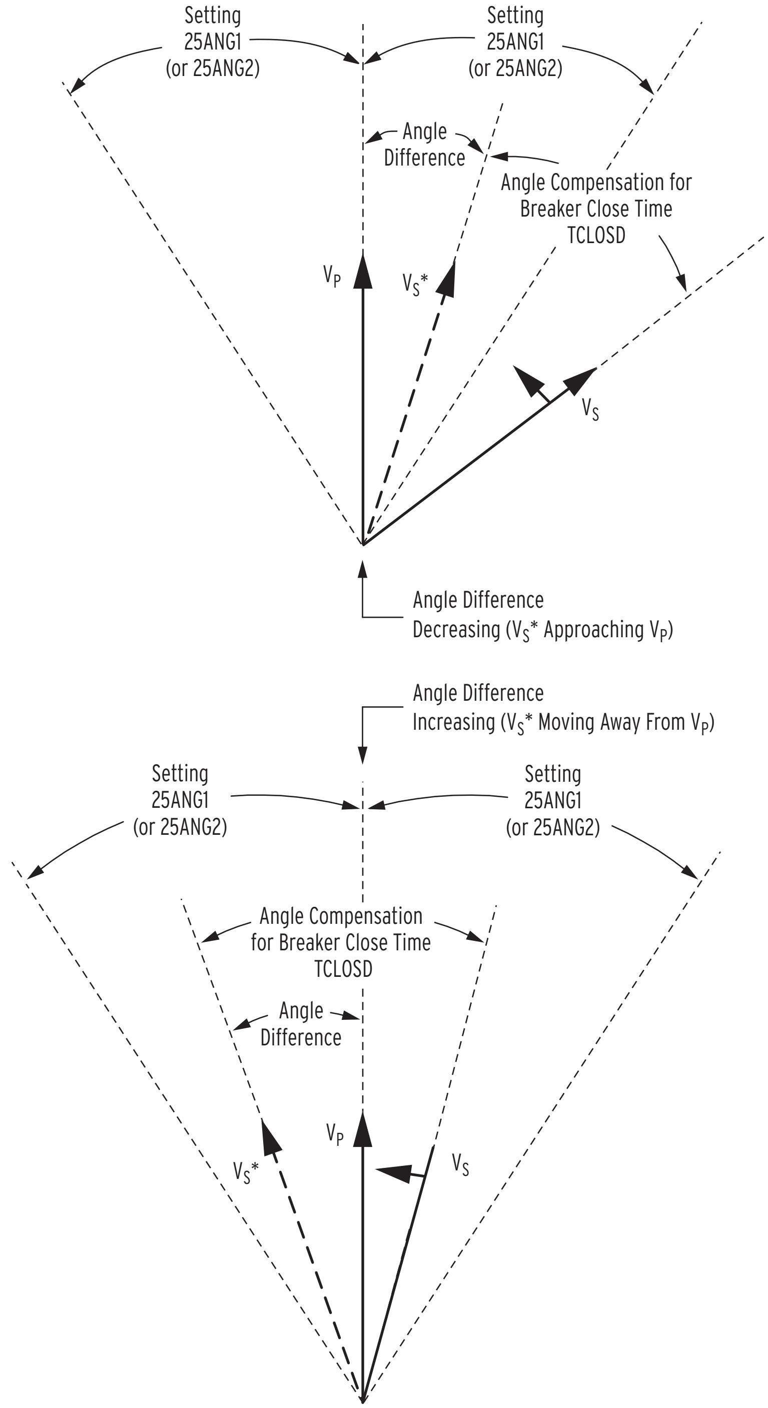


Figure 4.29 Angle Difference Between V_P and V_S Compensated by Breaker Close Time ($f_P < f_S$ and V_P Shown as Reference in This Example)

The top of *Figure 4.29* shows the Angle Difference **decreasing**—V_S* is approaching V_P. Ideally, circuit breaker closing is initiated when V_S* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in phase with V_P, minimizing system shock.

The bottom of *Figure 4.29* shows the Angle Difference **increasing**—V_S* is moving away from V_P. Ideally, circuit breaker closing is initiated when V_S* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in phase with V_P. But in this case,

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

Synchronism-Check Element Outputs

Synchronism-check element outputs (Relay Word bits 25A1 and 25A2 in *Figure 4.28*) assert to logical 1 for the conditions explained in the following text.

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

Refer to top of *Figure 4.28*.

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

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

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

Refer to bottom of *Figure 4.28*. If V_P and V_S are "slipping" with respect to one another and breaker close time setting TCLOSD ≠ 0.00, the Angle Difference (compensated by breaker close time TCLOSD) changes through time. Synchronism-check element 25A1 or 25A2 asserts to logical 1 for any one of the following three scenarios.

1. The top of *Figure 4.29* shows the Angle Difference **decreasing**—V_S* is approaching V_P. When V_S* is in phase with V_P (Angle Difference = 0 degrees), synchronism-check elements 25A1 and 25A2 assert to logical 1.
2. The bottom of *Figure 4.29* shows the Angle Difference **increasing**—V_S* is moving away from V_P. V_S* was in phase with V_P (Angle Difference = 0 degrees), but has now moved past V_P. If the Angle Difference is **increasing**, but the Angle Difference is still less than maximum angle settings 25ANG1 or 25ANG2, then corresponding synchronism-check elements 25A1 or 25A2 assert to logical 1.

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

NOTE: In scenario 3, concerning reclose supervision, SELOGIC control equation setting 79CLS3P (reclose supervision for three-phase reclosing) is used. The logic discussed in scenario 3 is equally applicable to reclose supervision settings 79CLSA, 79CLSB, and 79CLSC if single-pole reclosing is enabled (group setting ESPB := Y).

3. Refer to *Reclose Supervision Logic on page 6.10*.

   Refer to the bottom of *Figure 6.6*. If timer 79CLSD is set greater than zero (e.g., 79CLSD := 60.00 cycles) and it times out without SELOGIC control equation setting 79CLS3P (Reclose Supervision) asserting to logical 1, the relay goes to the Lockout State (see top of *Figure 6.7*).

   Refer to the top of *Figure 6.6*. If timer 79CLSD is set to zero (79CLSD := 0.00), SELOGIC control equation setting 79CLS3P (Reclose Supervision) is checked only once to see if it is asserted to logical 1. If it is not asserted to logical 1, the relay goes to the Lockout State.

   Refer to the top of *Figure 4.29*. Ideally, circuit breaker closing is initiated when V_S* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in-phase with V_P, minimizing system shock. But with time limitations imposed by timer 79CLSD, this may not be possible. To try to avoid going to the Lockout State, the following logic is employed:

      If 79CLS3P has not asserted to logical 1 while timer 79CLSD is timing (or timer 79CLSD is set to zero and only one check of 79CLS3P is made), the synchronism-check logic at the bottom of *Figure 4.28* becomes **less restrictive** at the "instant" timer 79CLSD is going to time out (or make the single check). It drops the requirement of waiting until the **decreasing** Angle Difference (V_S* approaching V_P) brings V_S* in phase with V_P (Angle Difference = 0 degrees). Instead, it just checks to see that the Angle Difference is less than angle settings 25ANG1 or 25ANG2.

      If the Angle Difference is less than angle setting 25ANG1 or 25ANG2, then the corresponding Relay Word bit, 25A1 or 25A2, asserts to logical 1 for that "instant" (asserts for 1/4 cycle).

      For example, if SELOGIC control equation setting 79CLS3P (Reclose Supervision) is set as follows:

      79CLS3P := **25A1 OR ...**

      and the angle difference is less than angle setting 25ANG1 at that "instant," setting 79CLS asserts to logical 1 for 1/4 cycle, allowing the sealed-in open interval time-out to propagate to the close logic in *Figure 6.3*. Element 25A2 operates similarly.

Synchronism-Check Applications for Automatic Reclosing and Manual Closing

Refer to *Close Logic on page 6.5* and *Reclose Supervision Logic on page 6.10*.

For example, set 25ANG1 := 15 degrees and use the resultant synchronism-check element in the reclosing relay logic to supervise automatic reclosing:

79CLS3P := **25A1 OR ...** see *Figure 6.6*

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

CL3P := **IN106 AND (25A2 OR ...)** see *Figure 6.3*

In this example, the angular difference across the circuit breaker can be greater for a manual close (25 degrees) than for an automatic reclose (15 degrees).

Frequency Elements

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

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

The enable setting is shown in *Figure 4.34*. Frequency is determined from the voltage applied to the recloser control voltage terminals V1Y–NY or V1Z–NZ, as shown in *Table 4.12*.

Table 4.12 Voltage Source for Frequency Elements

Global Setting FSELECT :=	Frequency for 81 elements measured on voltage terminals:
OFF	N/A[a]
VY	V1Y-NY
VZ	V1Z-NZ

[a] When Global setting FSELECT := OFF, the SEL-651R will measure the frequency from the V1Y-NZ terminals for frequency tracking and metering. When global setting FSELECT := OFF, the enable setting E81 is forced to N, and cannot be changed.

Frequency Element Logic Diagrams

The frequency element logic in *Figure 4.34* is controlled by the Relay Word bit 27B81, which is derived from voltage signals in one of the undervoltage block diagrams *Figure 4.30* through *Figure 4.33*, depending on global settings FSELECT, and VYCONN or VZCONN.

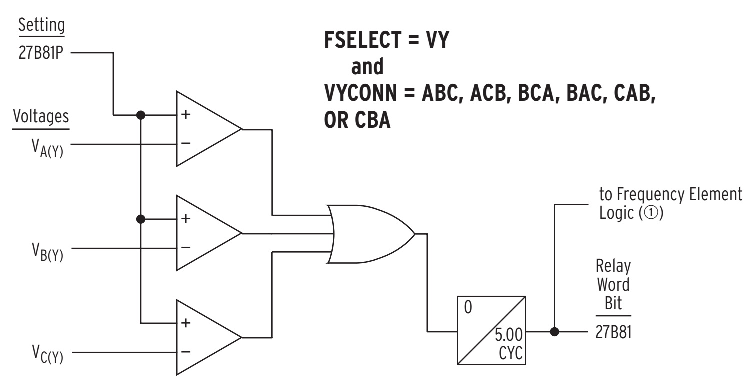


Figure 4.30 Undervoltage Block for Frequency Elements When FSELECT := VY and Three-Phase Voltage Connected

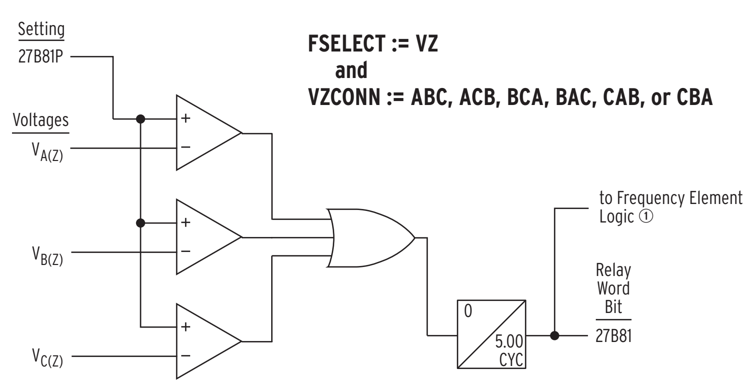


Figure 4.31 Undervoltage Block for Frequency Elements When FSELECT := VZ and Three-Phase Voltage Connected

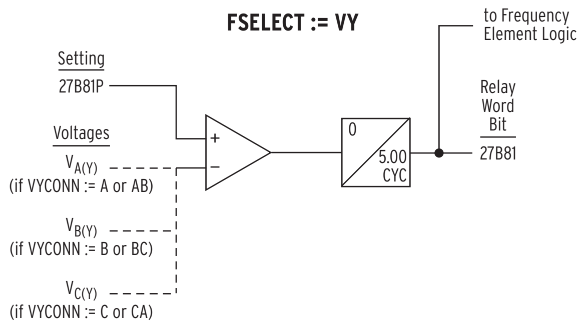


Figure 4.32 Undervoltage Block for Frequency Elements When FSELECT := VY and Single-Phase Voltage Connected

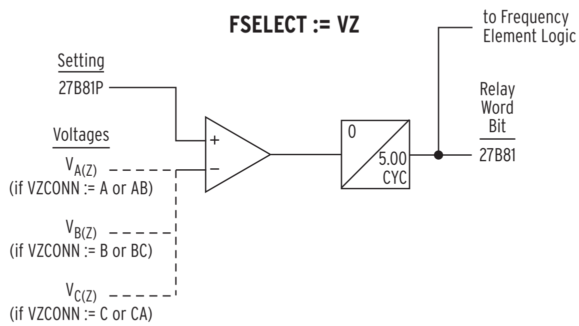


Figure 4.33 Undervoltage Block for Frequency Elements When FSELECT := VZ and Single-Phase Voltage Connected

Frequency Element Settings

Table 4.13 Frequency Elements Settings and Settings Ranges

Setting	Definition	Range
27B81P	undervoltage frequency element block (see *Figure 4.30* through *Figure 4.33*)	12.50–300.00 V secondary
81D1P	frequency element 1 pickup	40.00–65.00 Hz
81D1D[a]	frequency element 1 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D2P	frequency element 2 pickup	40.00–65.00 Hz
81D2D[a]	frequency element 2 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D3P	frequency element 3 pickup	40.00–65.00 Hz
81D3D[a]	frequency element 3 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D4P	frequency element 4 pickup	40.00–65.00 Hz
81D4D[a]	frequency element 4 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D5P	frequency element 5 pickup	40.00–65.00 Hz
81D5D[a]	frequency element 5 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D6P	frequency element 6 pickup	40.00–65.00 Hz
81D6D[a]	frequency element 6 time delay	2.00–16000.00 cycles, in 0.25-cycle steps

[a] Frequency element time delays are best set to no less than 5 cycles. Frequency is determined by a zero-crossing technique on voltage terminal V1Y or V1Z. If voltage waveform offset occurs (e.g., due to a fault), then frequency can be off for a few cycles. A 5-cycle or greater time delay (e.g., 81D1D := 6.00 cycles) overrides this occurrence.

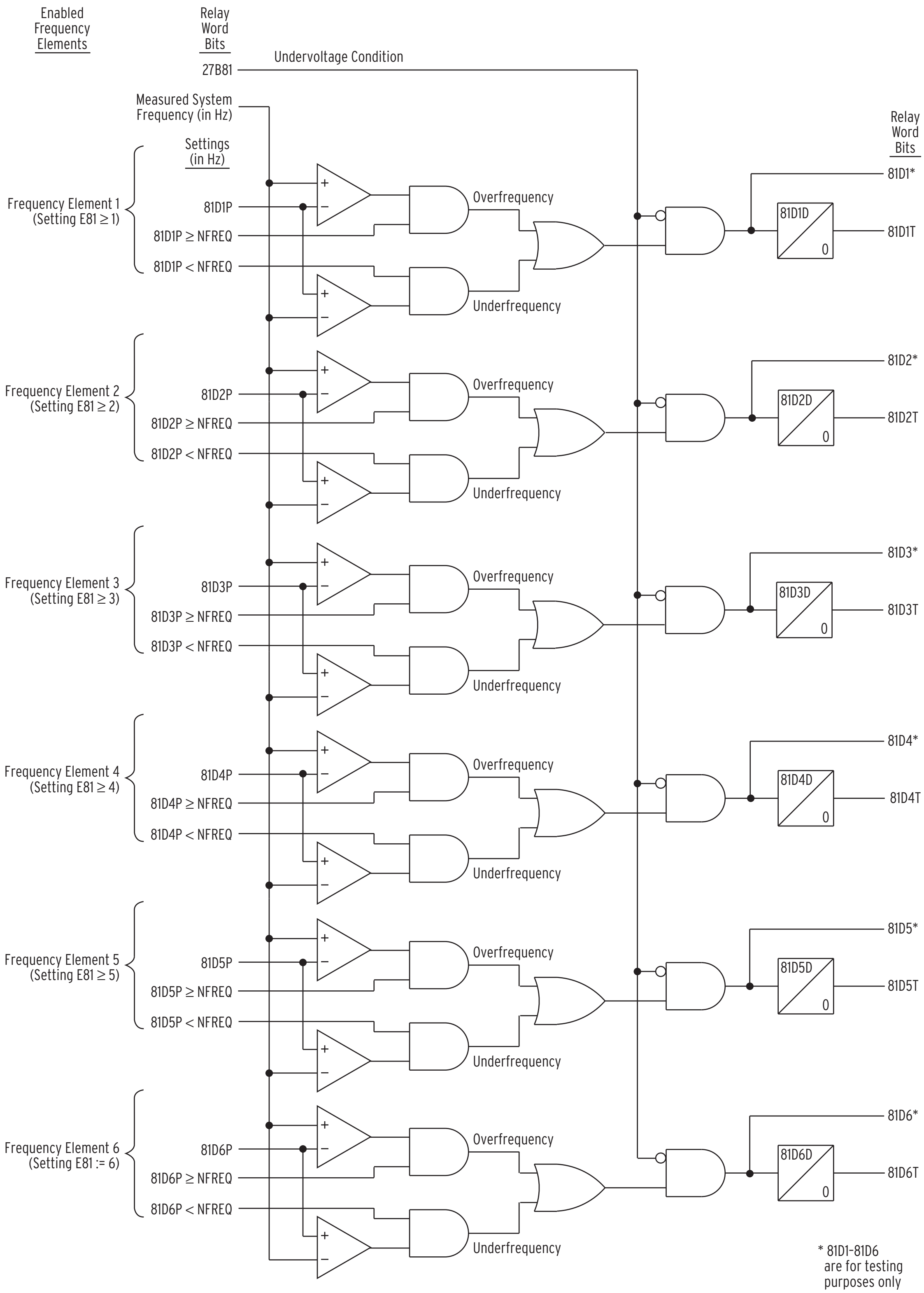


Figure 4.34 Levels 1 Through 6 Frequency Elements

Accuracy

See *Specifications on page 1.8*.

Create Over- and Underfrequency Elements

Refer to *Figure 4.34*.

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

Overfrequency Element

For example, make the following settings:

NFREQ := **60 Hz** nominal system frequency is 60 Hz

E81 ≥ **1** enable frequency element 1

81D1P := **61.25 Hz** frequency element 1 pickup

With these settings (81D1P ≥ NFREQ), the overfrequency part of frequency element 1 logic is enabled.

81D1 and 81D1T operate as overfrequency elements. 81D1 is used in **testing only**.

Underfrequency Element

For example, make the following settings:

NFREQ := **60 Hz** nominal system frequency is 60 Hz

E81 ≥ **2** enable frequency element 2

81D2P := **59.65 Hz** frequency element 2 pickup

With these settings (81D2P < NFREQ) the underfrequency part of frequency element 2 logic is enabled. 81D2 and 81D2T operate as underfrequency elements. 81D2 is used in testing only.

Frequency Element Operation

Refer to *Figure 4.34*.

Overfrequency Element Operation

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

81D1 := **logical 0** instantaneous element

81D1T := **logical 0** time delayed element

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

81D1 := **logical 1** instantaneous element

81D2T := **logical 1** time delayed element

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

Underfrequency Element Operation

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

81D2 := **logical 1** instantaneous element

81D2T := **logical 1** time delayed element

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

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

81D2 := **logical 0** instantaneous element

81D2T := **logical 0** time delayed element

Frequency Element Voltage Control

Refer to *Figure 4.30* through *Figure 4.34*.

Note that all six frequency elements are controlled by the same undervoltage element (Relay Word bit 27B81). For example, when global setting FSELECT := VY, and global setting VYCONN := BAC, Relay Word bit 27B81 asserts to logical 1 and blocks the frequency element operation if any voltage ($V_{A(Y)}$, $V_{B(Y)}$, or $V_{C(Y)}$) goes below voltage pickup 27B81P. This control prevents erroneous frequency element operation following fault inception.

However, if global setting FSELECT := VY and global setting VYCONN := B, Relay Word bit 27B81 is affected only by the voltage applied to the V1Y–NY terminals (which is the quantity $V_{B(Y)}$; see *Figure 9.21*). This is useful in applications where there is only single-phase voltage available to the relay.

Other Uses for Undervoltage Element 27B81

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

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

Frequency Element Uses

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

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

Underfrequency Loadshedding

For example, to implement underfrequency loadshedding with time-delayed frequency element 81D1T, make the SELOGIC control equations trip setting:

TR3P := **... OR 81D1T**

Also make the following settings:

79DTL3P := **... OR 81D1T** drive-to-lockout—see *Figure 6.11* and following explanation

T11_LED := **81D1T** over/under frequency target LED—see *Figure 11.13* and *Table 5.3*

See the note at the end of the *Table 5.2* for background on making these two settings when making trip settings changes/modifications.

Voltage Sag, Swell, and Interruption Elements

The SEL-651R has three types of elements to detect voltage disturbances. These elements detect voltage sags, swells, and interruptions (abbreviated as VSSI or SSI). These elements are enabled by group setting ESSI := Y and controlled by the VINT, VSWELL, and VSAG settings.

The SEL-651R VSSI elements monitor and respond to the three-phase voltages connected to either the VY- or VZ-voltage terminals, as designated by global setting VSELECT := VY or VZ. If global setting VSELECT := OFF, enable setting ESSI is forced to N, and cannot be changed.

Enter the VSSI element threshold settings VSAG, VSWELL, and VINT in percentage units, which relate to the Positive-Sequence Reference Voltage: Vbase. The use of percentage settings instead of absolute voltage limits allows the SSI elements to perform better in systems that have a range of nominal voltages, with no need to adjust settings for seasonal loading or to set them far apart to accommodate the action of a tap-changing transformer. The SSI elements respond to phase-to-neutral voltages.

The Positive-Sequence Reference Voltage is discussed in its own subsection.

The Voltage Sag, Swell, Interruption Recorder automatically uses the SSI elements. These elements are also available as Relay Word bits, so they can be used in any SELOGIC control equation (see *Sag/Swell/Interruption (SSI) Report on page 12.36*).

Voltage Sag Elements

As shown in *Figure 4.35*, if the magnitude of a voltage drops below the voltage sag pickup threshold for one cycle, the corresponding SAG Relay Word bit for that phase asserts (SAGA, SAGB, or SAGC). If all three SAG*p* elements assert, an additional Relay Word bit asserts—SAG3P. The SAG*p* elements remain asserted until the magnitude of the corresponding voltage rises and remains above the sag dropout threshold for one cycle.

The sag pickup and dropout thresholds depend on Vbase and the VSAG setting.

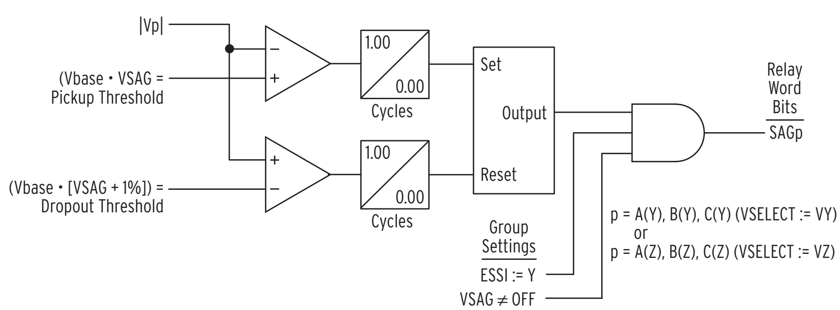


Figure 4.35 Voltage Sag Elements

Voltage Swell Elements

As shown in *Figure 4.36*, if the magnitude of a voltage rises above the voltage swell pickup threshold for one cycle, the corresponding SW Relay Word bit for that phase asserts (SWA, SWB, or SWC). If all three SW*p* elements assert, an additional Relay Word bit asserts—SW3P. The SW*p* elements remain asserted until the magnitude of the corresponding voltage drops and remains below the swell dropout threshold for one cycle.

The swell pickup and dropout thresholds depend on Vbase and the VSWELL setting.

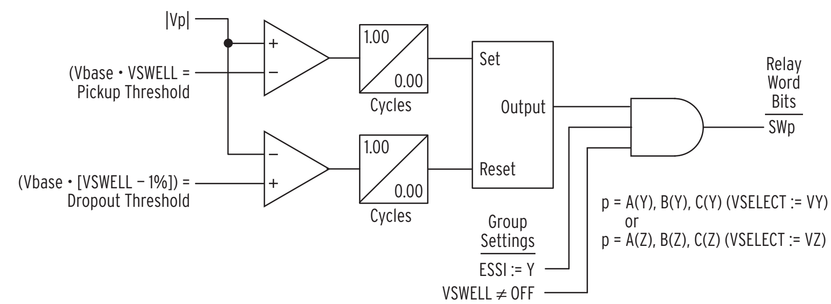


Figure 4.36 Voltage Swell Elements

Voltage Interruption Elements

As shown in *Figure 4.37*, if the magnitude of a voltage drops below the voltage interruption pickup threshold for one cycle, the corresponding INT Relay Word bit for that phase asserts (INTA, INTB, or INTC). If all three INT*p* elements assert, an additional Relay Word bit asserts—INT3P. The INT*p* elements remain asserted until the magnitude of the corresponding voltage rises and remains above the interruption dropout threshold for one cycle.

The interruption pickup and dropout thresholds depend on Vbase and the VINT setting.

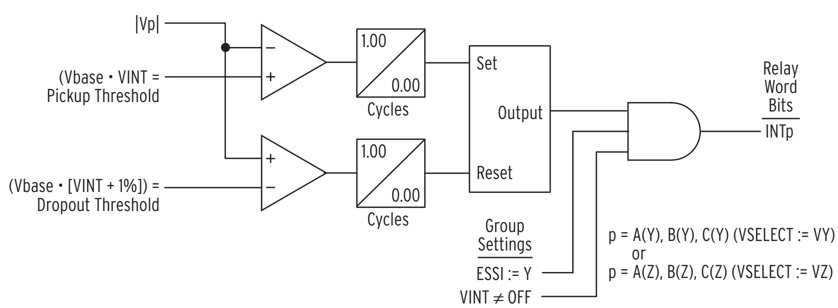


Figure 4.37 Voltage Interruption Elements

Voltage Sag, Swell, and Interruption Elements Settings

The settings ranges for the SSI thresholds are shown in *Table 4.14*.

The factory default settings match the Interruption, Sag, and Swell definitions in IEEE Standard 1159-1995 “Classifications of RMS Variations.”

Table 4.14 Sag/Swell/Interruption Elements Settings (must first set ESSI := Y)

Settings	Definition	Range	Default
VINT[a]	Percentage of memory voltage compared to phase-to-neutral voltage to assert INT elements	OFF, 5 to 95 percent of reference voltage, Vbase	10.00%
VSAG	Percentage of memory voltage compared to phase-to-neutral voltage to assert SAG elements	OFF, 10 to 95 percent of reference voltage, Vbase	90.00%
VSWELL	Percentage of memory voltage compared to phase-to-neutral voltage to assert SW elements	OFF, 105 to 180 percent of reference voltage, Vbase (300 V secondary maximum upper limit)	110.00%

[a] VINT cannot be set higher than VSAG

Positive-Sequence Reference Voltage, Vbase

The relay converts the positive-sequence voltage quantity, |V1|, to a reference voltage, Vbase, that has a thermal demand characteristic with a time constant of 100 seconds. This allows the Vbase quantity to slowly track normal system voltage variations (tap changer operations and load effects), but not follow fast system voltage changes (unless the change is held for several seconds).

The |V1| quantity for Vbase is obtained from the voltage terminals selected by the global setting VSELECT := VY or VZ.

In a balanced three-phase system, |V1| is the average of the three phase-to-neutral voltages.

Vbase tracks |V1|, and represents the average phase-to-neutral voltage.

The present value of Vbase can be viewed by issuing the **MET** command (see *METER Command (Metering Data) on page 10.26*).

Vbase Thermal Element Block

To prevent the Vbase quantity from tracking during transient voltage conditions, the calculation of the Vbase thermal element is blocked during the assertion of any of the SAG*p*, SW*p*, or INT*p* Relay Word bits or the SSI_TRIG or FAULT SELOGIC control equation settings. When blocked, the Vbase quantity will not change. This allows the SAG, SWELL, and INT elements voltage comparisons to be made with the reference Vbase locked at a “healthy” system voltage level. Once the disturbance is over and all of the SAG*p*, SW*p*, and INT*p* Relay Word bits deassert, and the FAULT SELOGIC control equation setting deasserts, the thermal element for Vbase is unblocked.

Figure 4.38 shows an example of how Vbase tracking is suspended during a voltage disturbance. The example voltage disturbance is the result of an overload condition (three-phase sag), followed by a source-side breaker operation (three-phase interruption). To illustrate the dynamic nature of the VSSI thresholds, the Interrupt, Sag, and Swell pickup levels are also plotted, using the factory default settings for VINT, VSAG, and VSWELL. For this hypothetical three-phase disturbance, V1 has the same magnitude as V_A, V_B, and V_C (as shown). Single-phase disturbances are handled in a similar fashion, except that the phases and V1 will have different voltage magnitudes.

The use of a VSAG setting higher than 90 percent, at the same time as a VSWELL setting lower than 110 percent, should be carefully considered. Moving these thresholds too close together increases the probability that an end of disturbance condition is missed. This could create a false sag or swell condition that may not clear itself until the next disturbance, thus causing the Vbase thermal element to remain blocked.

The SSI_TRIG SELOGIC is described in *SSI Triggering and Recording on page 12.36*.

Vbase thermal element blocking by the FAULT Relay Word bit is programmable via SELOGIC setting FAULT. The FAULT Relay Word bit also controls other relay functions; see subsection *SELOGIC Control Equation Setting FAULT on page 5.13*.

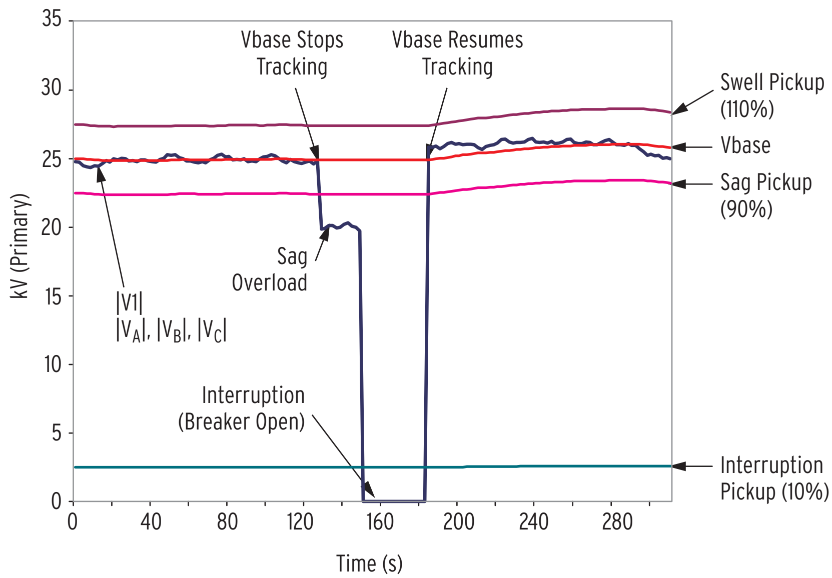


Figure 4.38 Vbase Tracking Example (Three-Phase Disturbance)

Vbase Initialization

The Vbase thermal element is automatically initialized when the relay is powered up, and also after a settings change or group change that results in a new ESSI := Y condition.

You can also force Vbase to initialize by issuing the **SSI R** command (Access Level 1—see *SSI Command (Voltage Sag/Swell/Interruption Report) on page 10.36*).

During initialization, the SSI elements are deasserted and the SSI Recorder is disabled until all of the following conditions are met (for Y-terminal voltages when global setting VSELECT := VY, and Z-terminal voltages when VSELECT := VZ):

- |V1| > |3V2| (correct phase rotation check)
- |V1| > |3V0| (correct phase connection check)
- V_A, V_B, V_C are all greater than 25 V secondary
- SELOGIC control equation setting FAULT is deasserted
- |V1| is within three percent of the calculated Vbase value
- At least twelve seconds have elapsed

As soon as the above Vbase initialization conditions are satisfied, the SSI Relay Word bits will be allowed to change state according to their settings and the present voltage conditions, and the SSI Recorder will be enabled.

Vbase Tracking Range

The Vbase quantity will track the positive-sequence voltage over a large range of system voltages. The tracking limits are explained below. In normal relay use, these limits are not likely to be reached, because one of the Sag, Swell, or Interruption Relay Word bits would most likely assert for a large voltage deviation, thus blocking the Vbase thermal element from tracking to one of the range limits.

The minimum value that Vbase can achieve is equivalent to a positive-sequence (V1) value of 25 volts secondary. In primary units, the lowest value is the following:

When VSELECT := VY, minimum Vbase = $\frac{25V \bullet PTRY}{1000}$ kV.

Equation 4.5

NOTE: If the SEL-651R is ordered with LEA ac inputs on the VY terminals, Equation 4.5 still applies, provided that the PTRY setting is properly scaled—see PT Ratio Setting Adjustments on page 9.40.

When VSELECT := VZ, minimum Vbase = $\frac{25V \bullet PTRZ}{1000}$ kV.

Equation 4.6

The maximum value that Vbase can achieve is equivalent to 300 volts secondary divided by VSWELL,; therefore, when VSELECT := VY the maximum Vbase in primary kV is the following:

$$\frac{300V \bullet PTRY \bullet 100}{VSWELL \bullet 1000} = \frac{30V \bullet PTRY}{VSWELL}$$ **Equation 4.7**

When VSELECT := VZ, the maximum Vbase in primary kV is the following:

$$\frac{300V \bullet PTRZ \bullet 100}{VSWELL \bullet 1000} = \frac{30V \bullet PTRZ}{VSWELL}$$ **Equation 4.8**

If the expected higher end of the “normal” system voltage range is close to 300 V, secondary, then the VSWELL setting may need to be reduced, or turned “OFF,” in order to allow Vbase to track the actual system voltage and not run into the maximum value limit. For example, if connecting to an industrial service rated at 277 V_{LN} / 480 V_{LL}, using the wye-connection (with no PTs), and the normal operating range goes up to 285 V_{LN}, then the maximum VSWELL setting that will allow for proper Vbase tracking is 105 percent.

SSI Reset Command

After commissioning tests or other maintenance activities that have applied test voltages to the SEL-651R, the Vbase element may have locked onto a test voltage. Use the **SSI R** (reset) command once normal system voltages are restored on the voltage terminals. Powering up the relay automatically performs this reset.

See *Commissioning Testing on page 12.40* for more details.

Power Elements

Four independent three-phase power elements are available. The group setting EPWR setting determines how many (and what type of) power elements are enabled:

EPWR := **N, 3P1, 3P2, 3P3, 3P4**

where

N	None
3P1	Enable one (1) three-phase power element
3P2	Enable two (1, 2) three-phase power elements
3P3	Enable three (1, 2, 3) three-phase power elements
3P4	Enable four (1, 2, 3, 4) three-phase power elements

Each enabled power element can be set to detect real power or reactive power, with the settings in *Table 4.15*. With SELOGIC control equations, the power elements provide a wide variety of protection and control applications. Typical applications are:

- ➤ Overpower and/or underpower protection/control
- ➤ Reverse power protection/control
- ➤ VAR control for capacitor banks

Power Elements Settings

Table 4.15 Three-Phase Power Element Settings and Settings Ranges (EPWR := 3P1, 3P2, 3P3, or 3P4)

Settings	Definition	Range
3PWR1P, 3PWR2P, 3PWR3P, 3PWR4P	Power element pickup	OFF, 1.20–7800.00 VA secondary, three-phase
PWR1T, PWR2T, PWR3T, PWR4T	Power element type	+WATTS, –WATTS, +VARS, –VARS
PWR1D, PWR2D, PWR3D, PWR4D	Power element time delay	0.00–16000 cycles, in 0.25-cycle steps

NOTE: The CT Polarity Setting (CTPOL) on page 9.29 affects the sign of the calculated power quantities.

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

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

Power Element Time Delay Settings Considerations

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

Using Power Elements in the Relay Trip Equation

The power elements are not supervised by any relay elements other than the minimum voltage and current level checks shown in *Figure 4.39*. If the protection application requires overcurrent protection in addition to the power elements, there may be a race condition, during a fault, between the overcurrent element(s) and the power element(s) if the power element(s) are still receiving sufficient operating quantities. In some protection schemes this may jeopardize coordination. One method of accommodating this is to increase the power element time delay settings.

Another method is to supervise the power element Relay Word bit(s) with the overcurrent element pickup (the overcurrent element has effective priority over the power element). For example, if the application requires that the relay trip the attached circuit breaker when a forward power flow threshold is exceeded, and a phase definite-time overcurrent element is also in the relay trip equation, extra security can be achieved with these SELOGIC control equation settings:

SV01 := **3PWR1 AND NOT 50P1**

SV01PU := **1.50 cycle**

SV01DO := **0.00 cycles**

And group settings:

50P1P := **5.00 A**

50P1D := **10.00 cycles**

3PWR1P := **360.00 VA**

PWR1T := **+WATTS**

PWR1D := **5.00 cycles**

TR3P := **... OR ... OR SV01T OR 50P1T**

During a fault that can pick-up both the power element and the overcurrent element, these settings will ensure that the definite-time overcurrent element (50P1T) will trip the relay for the fault, even if the PWR1D setting is set to a smaller time delay than the 50P1D setting. Relay Word bit 3PWR1 is ANDed with Relay Word bit NOT(50P1), which effectively blocks 3PWR1 when 50P1 is asserted. The SELOGIC variable timer SV01 is employed in this example to avoid another race condition that could occur if the fault was cleared by another device before the definite-time element time-out, which could potentially deassert 50P1 a few quarter-cycles before 3PWR1 deasserts. Without this timer, an incorrect trip operation may occur.

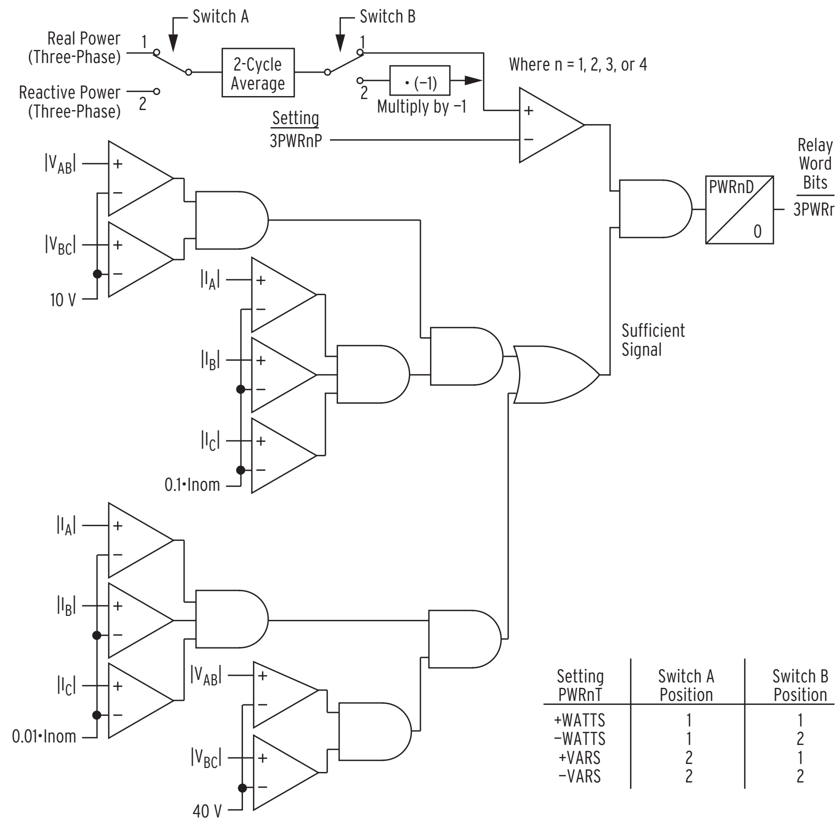
Accuracy

See *Specifications on page 1.8*.

Three-Phase Power Element Calculations

The numeric method used in the three-phase power elements uses line-to-line voltage and phase current quantities, corrected with zero-sequence voltage and current when unbalanced. The resulting power quantities are subject to the minimum voltage and current tests shown in the lower half of *Figure 4.39*.

Power Elements Logic Operation



Setting PWRnT	Switch A Position	Switch B Position
+WATTS	1	1
−WATTS	1	2
+VARS	2	1
−VARS	2	2

Figure 4.39 Three-Phase Power Elements Logic

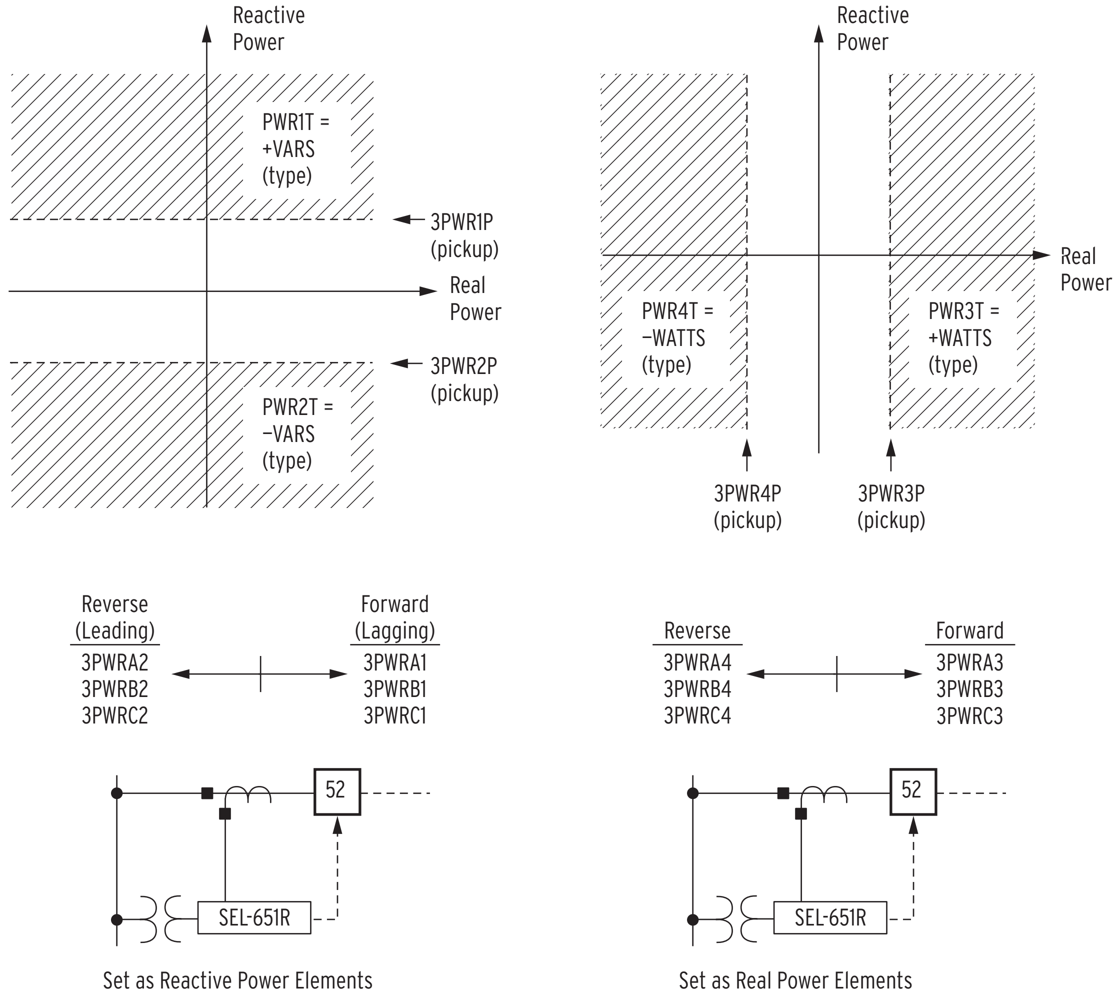


Figure 4.40 Power Elements Operation in the Real/Reactive Power Plane

In *Figure 4.40*, if the three-phase reactive power level is above pickup setting 3PWR*n*P, Relay Word bit 3PWR*n* asserts (3PWR*n* = logical 1) after time delay setting PWR*n*D (*n* = 1 through 4), subject to the “sufficient signal” conditions.

The “sufficient signal” conditions in *Figure 4.40* require at least 1 percent nominal current if the corresponding phase voltage is greater than 40 V secondary. If the voltage is between 10 and 40 V secondary, at least 10 percent nominal current is required.

Pickup setting 3PWR*n*P is always a positive number value (see *Table 4.15*). Thus, if –WATTS or –VARS are chosen with setting PWR*n*T, the corresponding real or reactive power values have to effectively be multiplied by –1 so that element PWR*n* asserts for negative real or reactive power.

Power Elements Application—VAR Control for a Capacitor Bank

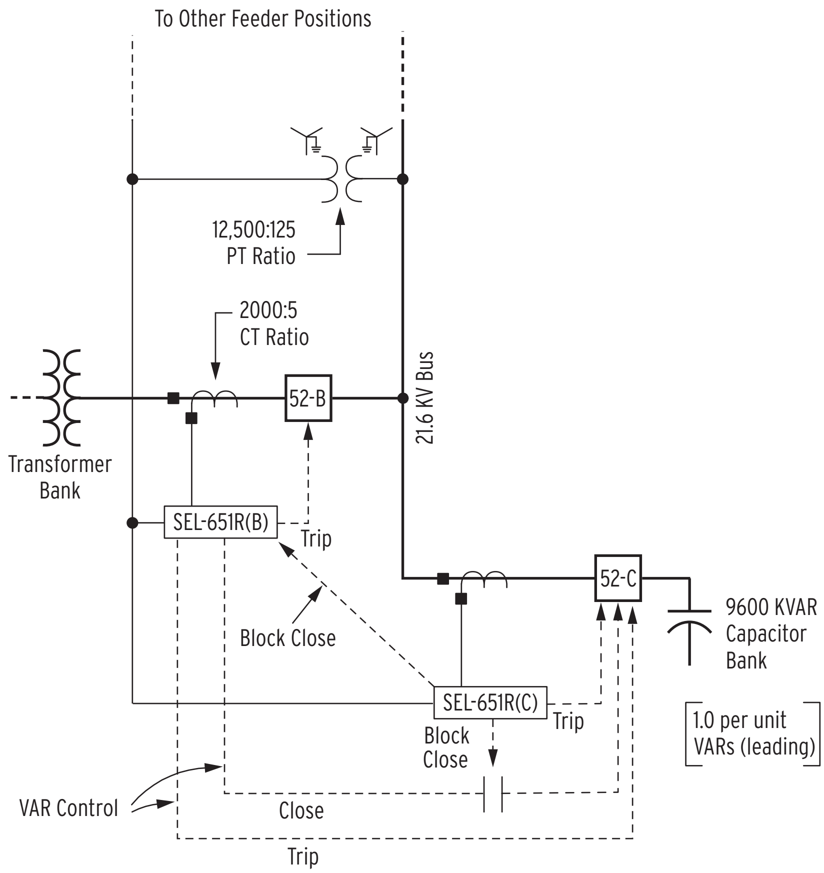


Figure 4.41 SEL-651R(B) Provides VAR Control for 9600 kVAR Capacitor Bank

The 9600 kVAR capacitor bank in *Figure 4.41* is put on-line and taken off-line according to the VAR loading on the transformer bank feeding the 21.6 kV bus. The VAR loading is measured with the SEL-651R(B) located at bus circuit breaker 52-B.

Two SEL-651R recloser controls operate the capacitor bank—both recloser controls are connected to capacitor bank circuit breaker 52-C. The SEL-651R(C) provides capacitor overcurrent protection and trips circuit breaker 52-C for a fault in the capacitor bank. The SEL-651R(B) provides VAR control and automatically puts the capacitor bank on-line (closes circuit breaker 52-C) or takes it off-line (trips circuit breaker 52-C) according to the measured VAR level. The SEL-651R(B) also provides bus overcurrent protection and trips circuit breaker 52-B for a fault on the 21.6 kV bus.

In *Figure 4.41*, if the SEL-651R(C) trips circuit breaker 52-C for a fault in the capacitor bank, then a block close signal is sent from the SEL-651R(C) to the SEL-651R(B). This prevents the SEL-651R(B) from issuing an automatic close to circuit breaker 52-C.

For additional security, the close circuit from the SEL-651R(B) to circuit breaker 52-C is supervised by a block close output contact from the SEL-651R(C). This block close output contact opens if the SEL-651R(C) trips circuit breaker 52-C for a fault in the capacitor bank—no automatic closing can then take place.

These block close signals seal in when the SEL-651R(C) trips circuit breaker 52-C for a fault in the capacitor bank. Automatic closing of circuit breaker 52-C with the SEL-651R(B) can then take place only after the block close signals are reset. The exact implementation of this block close logic requires an application note beyond the scope of this discussion.

The rest of this discussion focuses on the determination of VAR levels (and corresponding power element settings) for automatic tripping and closing of circuit breaker 52-C with the SEL-651R(B).

Convert three-phase 9600 kVAR (kVA) to three-phase VA (voltamperes) secondary, assuming a 1000:1 current transformer ratio and 100:1 potential transformer ratio:

$$9600 \text{ kVA pri} \bullet \frac{1000 \text{ V}}{1 \text{ kV}} \bullet \frac{1}{100} \bullet \frac{1}{1000} = 96 \text{ VA sec}$$

The three-phase 9600 kVAR capacitor is converted to 1.0 per unit VARs (leading) for demonstration convenience in *Figure 4.41*. *Figure 4.42* shows the per unit VAR levels for putting on-line (closing circuit breaker 52-C) or taking off-line (tripping circuit breaker 52-C) the capacitor bank.

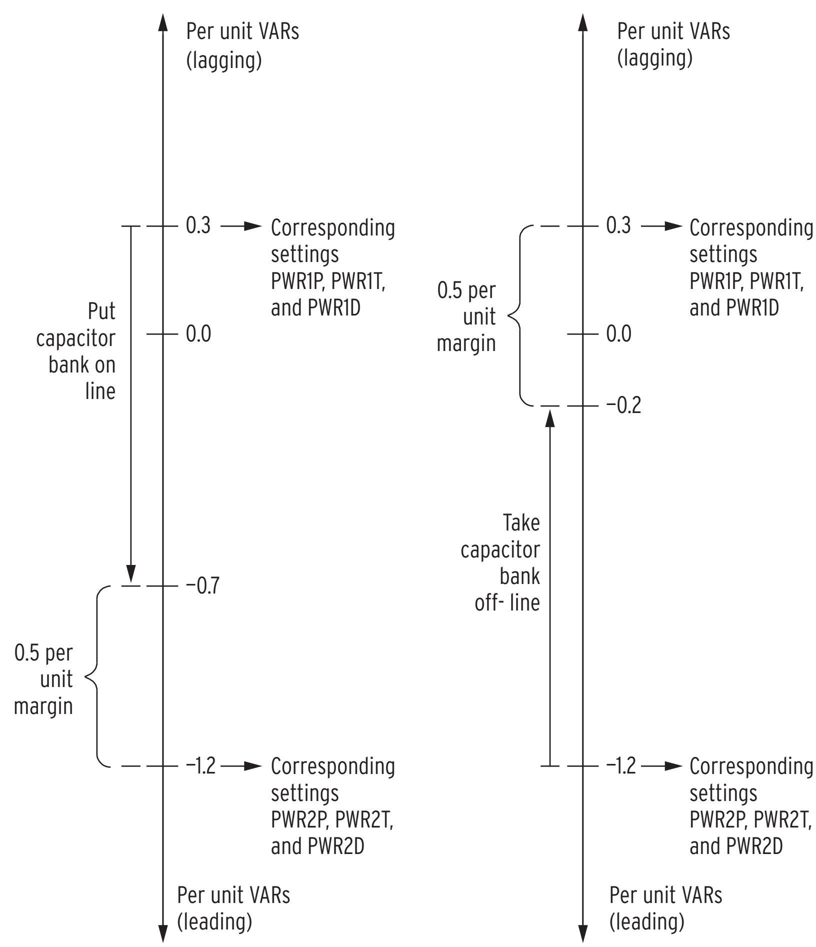


Figure 4.42 Per Unit Settings Limits for Switching 9600 kVAR Capacitor Bank On- and Off-Line

The capacitor bank is put on-line at the 0.3 per unit VAR level (lagging) on the bus. The per unit VAR level immediately changes to the –0.7 per unit VAR level (leading) when the capacitor bank is put on-line (0.3 – 1.0 = –0.7). There is a margin of 0.5 per unit VARs until the capacitor bank is then taken off-line (–0.7 – 0.5 = –1.2).

The capacitor bank is taken off-line at the –1.2 per unit VAR level (leading) on the bus. The per unit VAR level immediately changes to –0.2 per unit VAR level (leading) when the capacitor bank is taken off-line (–1.2 + 1.0 = –0.2). There is a margin of 0.5 per unit VARs until the capacitor bank is put on-line again (–0.2 + 0.5 = 0.3).

Settings for Three-Phase Power Elements

From preceding calculations and figures:

9600 kVAR ≈ 1.0 per unit VARs ≈ 96.0 VA secondary (three-phase)

Convert the per unit VAR levels 0.3 and –1.2 to single-phase VA (voltamperes) secondary:

0.3 • 96.0 VA secondary (single-phase) = 28.8 VA secondary (three-phase)

–1.2 • 96.0 VA secondary (single-phase) = –115.2 VA secondary (three-phase)

Make the following power element settings for the SEL-651R(B):

EPWR := **2** (enable two power elements)

3PWR1P := **28.8** (power element pickup; VA secondary [single-phase])

PWR1T := **+VARS** (power element type; lagging VARs)

PWR1D := _____ (power element time delay; cycles; see following discussion for settings idea)

3PWR2P := **115.2** (power element pickup; VA secondary [single-phase])

PWR2T := **–VARS** (power element type; leading VARs)

PWR2D := _____ (power element time delay; cycles; see following discussion for settings idea)

To override transient reactive power conditions, set the above power element time delay settings equivalent to several seconds (or perhaps minutes).

Resulting three-phase power element 3PWR1 asserts when the lagging VAR level exceeds the 0.3 per unit VAR level (lagging) (See *Figure 4.42* and left-hand side of *Figure 4.40*.) This element is used in close logic in the SEL-651R(B) to automatically put the 9600 kVAR capacitor bank on-line.

Resulting three-phase power element 3PWR2 asserts when the leading VAR level exceeds the –1.2 per unit VAR level (leading) for each respective phase (see *Figure 4.42* and left-hand side of *Figure 4.40*). This element is used in trip logic in the SEL-651R(B) to automatically take the 9600 kVAR capacitor bank off-line.

Load-Encroachment Logic

The load-encroachment logic (see *Figure 4.43*) and settings are enabled/disabled with setting ELOAD (:= Y or N). (If global setting VSELECT := OFF, then ELOAD can be set only to N. See *Voltage Source Selection Setting (VSELECT) on page 9.33* for more details on the VSELECT setting.)

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

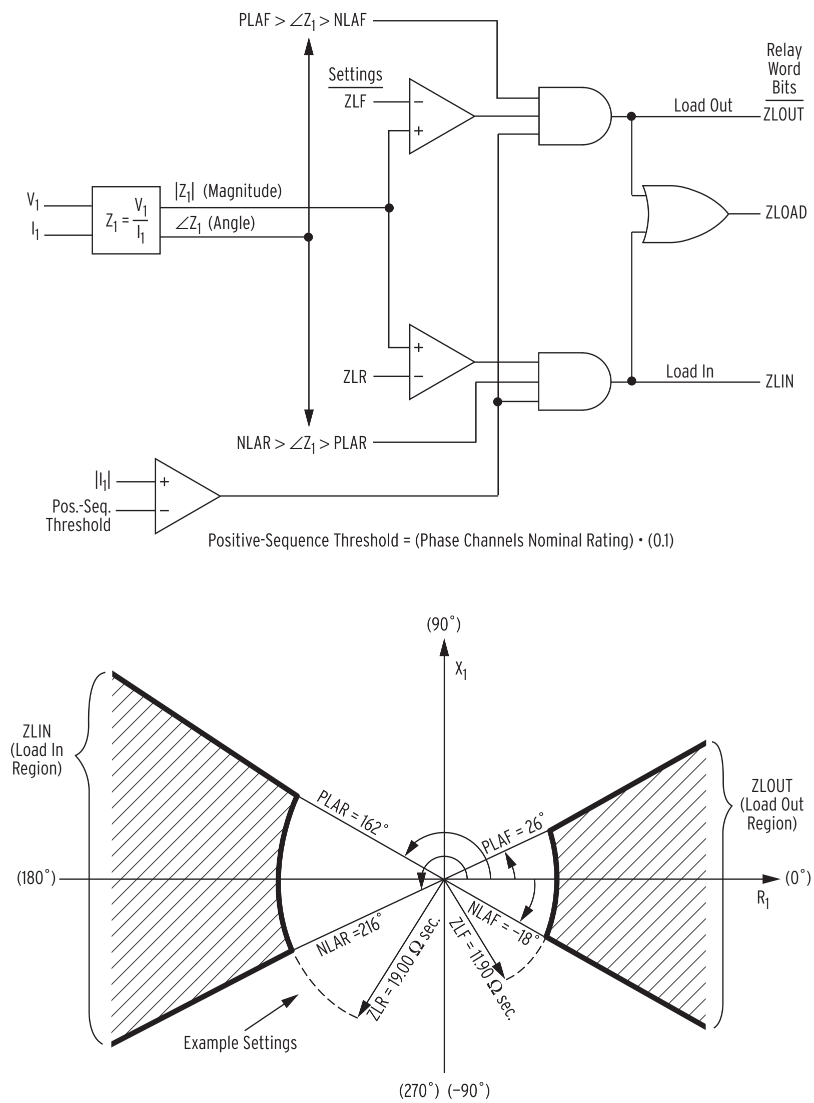


Figure 4.43 Load-Encroachment Logic

Note that a positive-sequence impedance calculation (Z_1) is made in the load-encroachment logic in *Figure 4.43*. Load is largely a balanced condition, so apparent positive-sequence impedance is a good load measure. The load-encroachment logic operates only if the positive-sequence current (I_1) is greater than the Positive-Sequence Threshold defined in *Figure 4.43*. For a balanced load condition, I_1 = phase current magnitude.

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

NOTE: The CT Polarity Setting (CTPOL) on page 9.29 affects the sign of the positive-sequence impedance calculation.

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

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

ZLOAD := **ZLOUT OR ZLIN**

Settings Ranges

Refer to *Table 4.16*.

Table 4.16 Load Encroachment Settings Ranges

Setting[a]	Description and Range
ZLF	Forward Minimum Load Impedance-corresponding to maximum load flowing out 0.50-640.00 ohms secondary
ZLR	Reverse Minimum Load Impedance-corresponding to maximum load flowing in 0.50-640.00 ohms secondary
PLAF	Maximum Positive Load Angle Forward (–90° to +90°)
NLAF	Maximum Negative Load Angle Forward (–90° to +90°)
PLAR	Maximum Positive Load Angle Reverse (+90° to +270°)
NLAR	Maximum Negative Load Angle Reverse (+90° to +270°)

[a] If global setting VSELECT := VY, and LEA ac inputs are ordered, the impedance values for ZLF and ZLR must be scaled (see Impedance Settings Conversions on page 9.47).

Load-Encroachment Settings Example

Example system conditions:

Nominal Line-Line Voltage:	230 kV
Maximum Forward Load:	800 MVA
Maximum Reverse Load:	500 MVA
Power Factor (Forward Load):	0.90 lag to 0.95 lead
Power Factor (Reverse Load):	0.80 lag to 0.95 lead
CT ratio:	400/1 = 400
PT ratio:	134000/67 = 2000

The PTs are connected line-to-neutral.

Convert Maximum Loads to Equivalent Secondary Impedances

Start with maximum forward load:

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

Now, calculate the equivalent secondary impedance:

66.4 V secondary/5.03 A secondary = 13.2 Ω secondary

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

[(line-line voltage in kV)^2 • (CT ratio)]/[(three-phase load in MVA) • (PT ratio)]

Again, for the maximum forward load:

[(230)^2 • (400)]/[(800) • (2000)] = 13.2 Ω secondary

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

ZLF := **13.2 Ω secondary • 0.9 = 11.90 Ω secondary**

For the maximum reverse load:

[(230)^2 • (400)]/[(500) • (2000)] = 21.1 Ω secondary

Again, to provide a margin for setting ZLR:

ZLR := **21.1 Ω secondary • 0.9 = 19.00 Ω secondary**

Convert Power Factors to Equivalent Load Angles

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

PLAF := **$\cos^{-1}$ (0.90) = 26°**

NLAF := **$\cos^{-1}$ (0.95) = –18°**

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

PLAR := **180° – $\cos^{-1}$ (0.95) = 180° – 18° = 162°**

NLAR := **180° + $\cos^{-1}$ (0.80) = 180° + 37° = 217°**

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

Again, from *Figure 4.43*:

ZLOAD := **ZLOUT OR ZLIN**

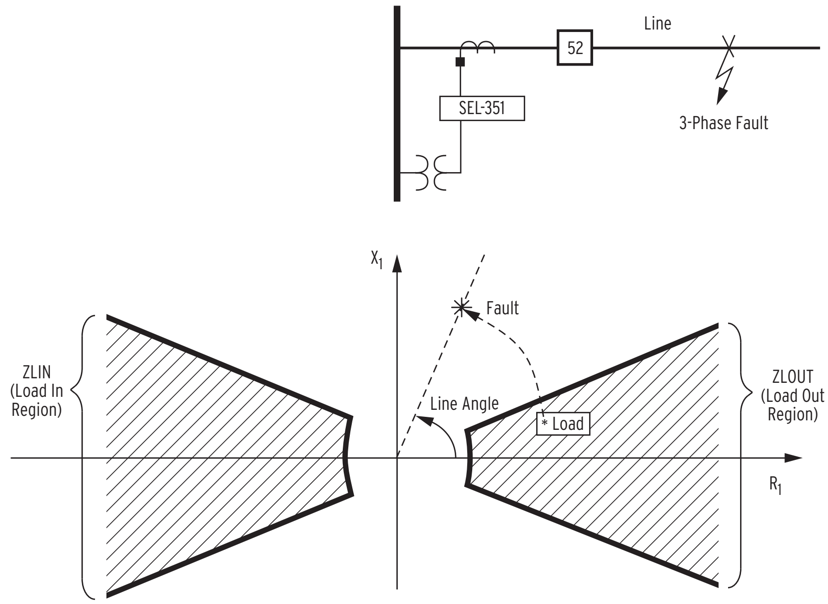


Figure 4.44 Migration of Apparent Positive-Sequence Impedance for a Fault Condition

Refer to *Figure 4.44*. In a load condition, the apparent positive-sequence impedance is within the ZLOUT area, resulting in:

ZLOAD := **ZLOUT OR ZLIN = logical 1 OR ZLIN = logical 1**

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

ZLOAD := **ZLOUT OR ZLIN = logical 0 OR logical 0 = logical 0**

To prevent phase time-overcurrent element 51PT from operating for high load conditions, make the following SELOGIC control equation torque control setting:

51PTC := **NOT(ZLOAD) AND NOT(LOP) OR 50P6**

As shown in *Figure 4.43*, load-encroachment logic is a positive-sequence calculation. During LOP conditions (loss-of-potential; see *Figure 4.45*), positive-sequence voltage (V1) can be substantially depressed in magnitude or changed in angle. This change in V1 can possibly cause ZLOAD to deassert (= logical 0), erroneously indicating that a “fault condition” exists. Thus, NOT(ZLOAD) should be supervised by NOT(LOP) in a torque control setting. This also effectively happens in the directional element in *Figure 4.55*, where ZLOAD and LOP are part of the logic.

In the above setting example, phase instantaneous overcurrent element 50P6 is set above any maximum load current level—if 50P6 picks up, there is assuredly a fault. For faults below the pickup level of 50P6, but above the pickup of phase time-overcurrent element 51PT, the NOT(ZLOAD) AND NOT(LOP) logic discriminates between high load and fault current. If an LOP condition occurs (LOP = logical 1), the pickup level of 50P6 becomes the effective pickup of phase time-overcurrent element 51PT (51PT loses its sensitivity when an LOP condition occurs):

51PTC := **NOT(ZLOAD)AND NOT(LOP) OR 50P6**
= **NOT(ZLOAD)AND NOT(logical 1) OR 50P6**
= **50P6**

If phase time-overcurrent element 51PT is used in a directional application (e.g., tripping in the forward direction), then the above torque control logic is not used and the corresponding torque control setting is simply set like

51PTC := **32PF** (see *Figure 4.16* and *Figure 4.56*).

Embedded logic handles load encroachment concerns for directional phase overcurrent elements. In *Figure 4.55*, notice that the NOT(ZLOAD) AND NOT(LOP) condition is effectively embedded in the positive-sequence voltage polarized directional element logic, thus preventing directional operation on heavy load or erroneous indication due to loss-of-potential. The 32QE Relay Word bit input into the negative-sequence voltage-polarized directional element logic (*Figure 4.54*) also has LOP control embedded in it (see *Figure 4.47*). These positive-sequence and negative-sequence voltage-polarized directional elements (*Figure 4.55* and *Figure 4.54*, respectively) combine in *Figure 4.56* (e.g., Relay Word bit output 32PF, shown in the preceding sample setting 51PTC := 32PF).

Use SEL-321 Relay Application Guide for the SEL-651R

The load-encroachment logic and settings in the SEL-651R are similar to those in the SEL-321. Refer to SEL Application Guide *AG93-10, SEL-321 Relay Load-Encroachment Function Setting Guidelines* for applying the load-encroachment logic in the SEL-651R. Note that *Application Guide AG93-10* discusses applying the load-encroachment feature to phase distance elements in the SEL-321. The SEL-651R does not have phase distance elements, but the principles and settings example are still generally applicable to the SEL-651R.

Ground Switch Logic

In the factory configuration, the SEL-651R uses a dual-source for the zero-sequence current quantity I_G, used in the ground instantaneous/definite-time overcurrent elements, and in the ground time-overcurrent elements.

Table 4.17 gives the details on the conditions used in the ground switch logic.

For small currents, the wired-residual channel IN measured current is used in I_G, and for larger currents, the calculated 3I0 (= $I_A + I_B + I_C$ vector sum) quantity is used in I_G. The Relay Word bit GNDSW identifies the current source that is being used for I_G at any time. Refer to *Figure 2.46* and *Figure 2.48* for factory wiring details.

Global setting EGNDSW controls the ground switch logic. When EGNDSW := N, Relay Word bit GNDSW = logical 0, permanently.

Table 4.17 Ground Switch Logic

Scenario	Channel IN Wiring Configuration	Required Global Setting EGNDSW :=	CTRN Setting	I_G Source	
				When |IN| < 4.7 A **GNDSW = 1**	**When |IN| ≥ 4.7 A** **GNDSW = 0**
1	Residual with I1, I2, I3[a]	Y	must be = CTR	IN	$3I_0$
2	Separate core-balance CT, encompassing all three-phases, on same line section as I1, I2, I3 CTs	Y	must be ≤ CTR	IN	$3I_0 \cdot \left(\frac{CTR}{CTRN}\right)$
				At all times **GNDSW = 0**	
3	Separate current source (unrelated to I1, I2, I3)	N	no relation to CTR	$3I_0$	
4	Not connected	N	N/A	$3I_0$	

[a] The factory configuration is Scenario 1.

NOTE: When you are testing the SEL-651R, if the wiring is changed from that shown in Figure 2.46 or Figure 2.48, the recloser control may not respond as expected to zero-sequence currents. If the IN terminal wires are removed, either change the wiring to include channel IN, disable the ground overcurrent elements, or change Global Setting EGNDSW to N.

The 4.7 A switchover point shown in *Table 4.17* is approximate. The GNDSW Relay Word bit logic includes some intentional hysteresis to prevent rapid changes in status.

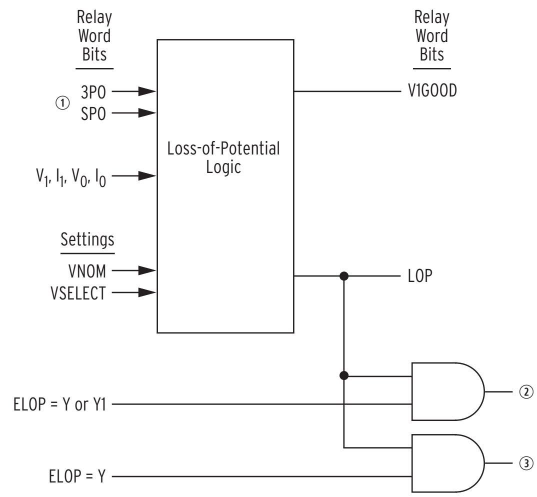
Note that in Scenario 2 of *Table 4.17* the I_G quantity is on the channel IN current base. In Scenario 1, CTR = CTRN, so there is no difference between the channel IN and the channel I1, I2, I3 secondary base.

When the Scenario 2 configuration is being used (*Table 4.17*), the overcurrent pickup values for the 50GnP, 51GnJP, 51GnKP, and GDEMP settings must be entered on the channel IN base. See *50G1P Setting Example When EGNDSW := Y and CTR ≠ CTRN on page 4.10* for an example on calculating the proper pickup settings.

The SEL-651R metering functions, described in *Ground Switch Option on page 8.3*, perform a similar current selection for the I_G quantity. The demand meter element GDEM is based on the metering system I_G value. The pickup setting, GDEMP, must be entered on the channel IN current base when EGNDSW := Y, as shown above.

Loss-of-Potential Logic

The loss-of-potential (LOP) logic operates as shown in *Figure 4.45*.



① From Figure 5.4; ② To Figure 4.47 and Figure 4.48; ③ To Figure 4.52 and Figure 4.56.

Figure 4.45 Loss-of-Potential Logic

Inputs into the LOP logic are described in *Table 4.18*:

Table 4.18 LOP Logic Inputs

Input	Description
3PO	Three-pole open condition (indicates circuit breaker open condition).
SPO	Single-pole open condition (indicates one or two phases are open, of a single-pole trip capable recloser)
V_1	Positive-sequence voltage (V secondary).
I_1	Positive-sequence current (A secondary).
I_0	Zero-sequence current (A secondary).
V_0	Zero-sequence voltage (V secondary).
VNOM	PT nominal voltage setting (line-to-neutral secondary).
VSELECT	Voltage source selection [global] setting—selects three-phase source (VY or VZ) for LOP, directional logic, etc.

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

Loss-of-potential is declared (Relay Word bit LOP = logical 1) when a 10 percent or larger drop in V_1 is detected, with no corresponding change in I_1 or I_0. If the LOP condition persists for 60 cycles, it latches in.

LOP resets (Relay Word bit LOP = logical 0) when V_1 returns above 85 percent of setting VNOM (Relay Word bit V1GOOD also asserts) and V_0 is less than 7.8 percent of setting VNOM.

The loss-of-potential enable setting, ELOP, does not enable or disable the LOP logic. It just routes the LOP Relay Word bit to different logic, as shown in *Figure 4.45* and explained in the remainder of this subsection.

Setting VSELECT := OFF

If setting VSELECT := OFF, the loss-of-potential logic is disabled (Relay Word bits LOP and V1GOOD are forced to logical 0), and setting ELOP can only be set to "N."

Setting ELOP := Y or Y1

If setting ELOP := Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts to logical 1), all directional element enables are disabled (see *Figure 4.47*, *Figure 4.48*, and *Figure 4.55*). The loss-of-potential condition makes the voltage-polarized directional elements (which are controlled by these internal enables) unreliable. Thus, they are disabled. The overcurrent elements controlled by these voltage-polarized directional elements are disabled also (unless overridden by conditions explained in the following Setting ELOP := Y discussion).

Setting ELOP := Y

Additionally, if setting ELOP := Y and a loss-of-potential condition occurs (Relay Word bit LOP asserts to logical 1), overcurrent elements set direction forward are enabled (see *Figure 4.52* and *Figure 4.56*). These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

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

Setting ELOP := N

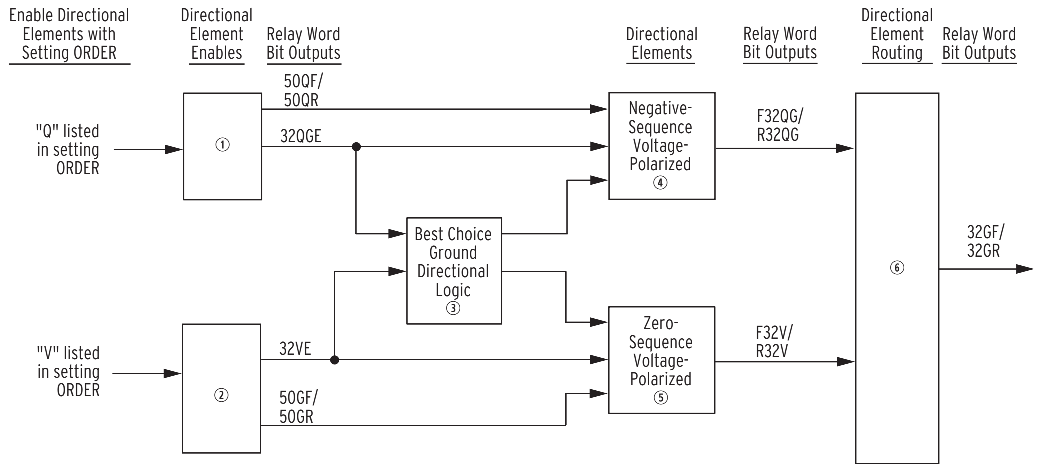
If setting ELOP := N, the loss-of-potential logic still operates (Relay Word bit LOP asserts to logical 1 for a loss-of-potential condition) but does not disable any voltage-based directional elements (as occurs with ELOP := Y or Y1) or enable overcurrent elements set direction forward (as occurs with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

Directional Control for Ground Overcurrent Logic

Setting E32 enables directional control for overcurrent elements. Setting E32 and other directional control settings are described in *Directional Control Settings on page 4.78*.

Two elements are available to control the ground overcurrent elements. These two directional elements are:

- Negative-sequence voltage-polarized directional element
- Zero-sequence voltage-polarized directional element



① Figure 4.47; ② Figure 4.48; ③ Figure 4.49; ④ Figure 4.50; ⑤ Figure 4.51; ⑥ Figure 4.52

Figure 4.46 General Logic Flow of Directional Control for Ground Overcurrent Elements

Figure 4.46 gives an overview of how these directional elements are enabled and routed for control of the ground overcurrent elements.

Note in *Figure 4.46* that setting ORDER enables the directional elements. Set ORDER with any combination of Q and V. They have the following correspondence to the directional elements:

- Q (Negative-sequence voltage-polarized directional element)
- V (Zero-sequence voltage-polarized directional element)

The **order** in which these directional elements are listed in setting ORDER determines the priority in which they operate to provide Best Choice Ground Directional™ logic control. See discussion on setting ORDER in *Directional Control Settings on page 4.78*.

Directional Element Enables

Refer to *Figure 4.46*, *Figure 4.47*, and *Figure 4.48*.

The directional element enables, Relay Word bits 32QGE and 32VE, have the following correspondence to the directional elements:

- 32QGE (Negative-sequence voltage-polarized directional element)
- 32VE (Zero-sequence voltage-polarized directional element)

Note in *Figure 4.47*, and *Figure 4.48* that if:

- enable setting ELOP = Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts; see *Table 4.45*)
- or a single-pole open condition occurs (Relay Word bit SPO asserts; see *Table 5.4*)

then both directional element enables are disabled. The directional element enables also have current signal thresholds that have to be met (settings 50QFP/50QRP and 50GFP/50GRP, respectively).

Figure 4.47 has extra directional element enable 32QE, which is used in the logic that controls the negative-sequence and phase overcurrent elements (see *Figure 4.53* and *Figure 4.54*).

The settings involved with 32QGE and 32VE in *Figure 4.47* and *Figure 4.48* (e.g., settings a2, k2, a0G, E32IV) are explained in *Directional Control Settings on page 4.78*.

Ground Current I_G

Ground current I_G in *Figure 4.47*, *Figure 4.48*, and *Figure 4.51* can possibly switch between sources, depending on global setting EGNDSW (see *Table 4.17* and accompanying text).

Best Choice Ground Directional Logic

Refer to *Figure 4.46* and *Figure 4.49*.

Relay Word bits 32QGE and 32VE and setting ORDER are used in the Best Choice Ground Directional logic in *Figure 4.49*. The Best Choice Ground Directional logic determines the order in which the directional element should be enabled to operate. The ground overcurrent elements set for directional control are then controlled by this directional element.

Directional Elements

Refer to *Figure 4.46*, *Figure 4.50*, and *Figure 4.51*.

The enable output of Best Choice Ground Directional logic in *Figure 4.49* determines which directional element will run.

Presuming sufficient current signal is present (Relay Word bit 50GF, 50GR, 50QF, or 50QR asserted), an impedance-based directional calculation is then made. Technical paper “Negative-Sequence Impedance Directional Element” by Bill Fleming goes into more detail on this impedance-based calculation for the negative-sequence voltage-polarized directional element (paper available from website: selinc.com, SEL Literature, Technical Papers). The principals discussed in this paper also generally apply to the zero-sequence voltage-polarized directional element.

Directional Element Routing

Refer to *Figure 4.46* and *Figure 4.52*.

The directional element outputs are routed to the forward (Relay Word bit 32GF) and reverse (Relay Word bit 32GR) logic points, for use in controlling ground overcurrent elements.

Table 4.20 and accompanying text give examples of directional control implementation (i.e., using the outputs of *Figure 4.52* and *Figure 4.56* in overcurrent element torque control settings and other SELOGIC settings to realize desired directional control).

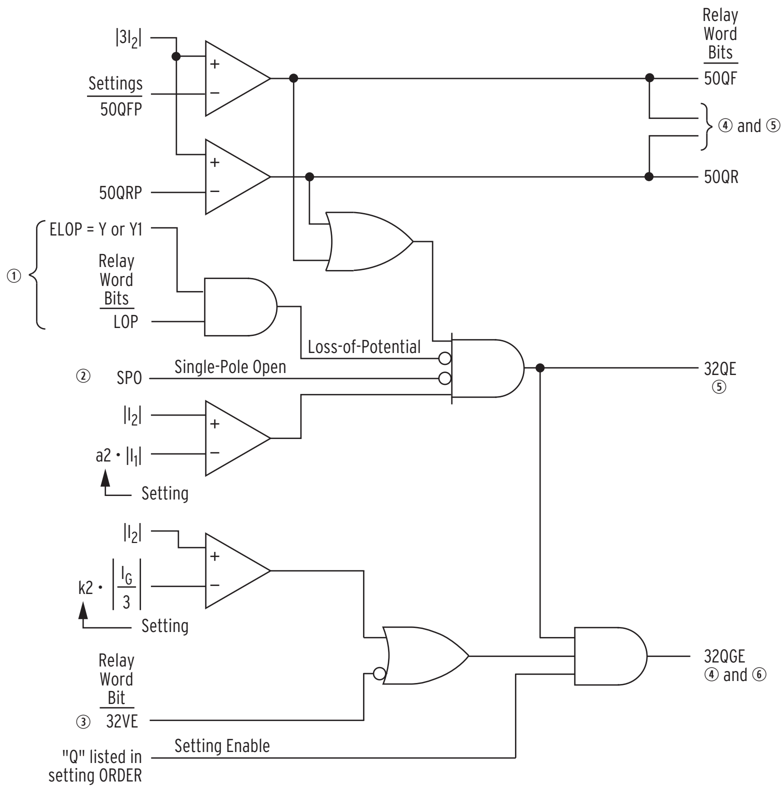
Loss-of-Potential

Note in *Figure 4.52* that if **both** the following are true:

- enable setting ELOP = Y
- a loss-of-potential condition occurs (Relay Word bit LOP asserts; see *Figure 4.45*)

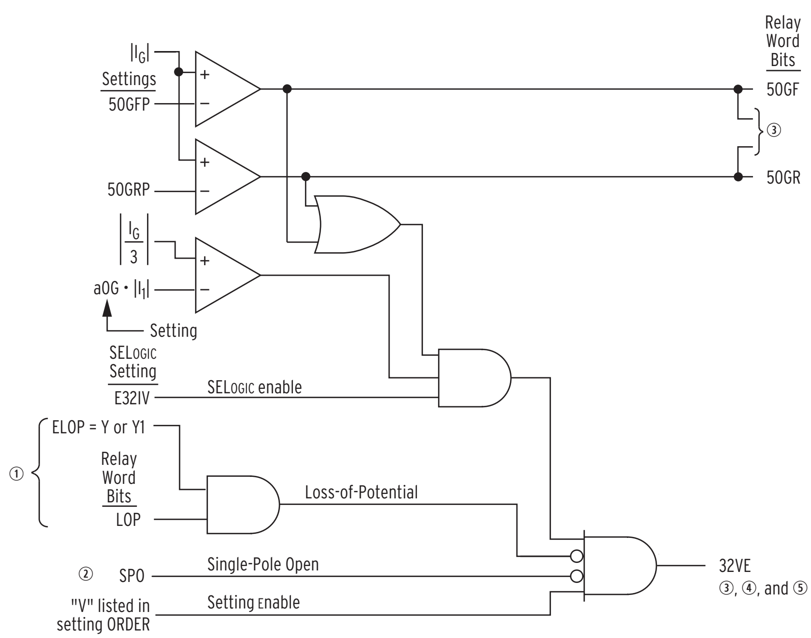
then the forward logic point (Relay Word bit 32GF) asserts to logical 1, thus enabling the ground overcurrent elements that are set direction forward. These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

As detailed in *Figure 4.47* and *Figure 4.48*, voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements that are directionally controlled by these voltage-based directional elements are disabled also. But this disable condition is overridden if setting ELOP := Y, as explained above.



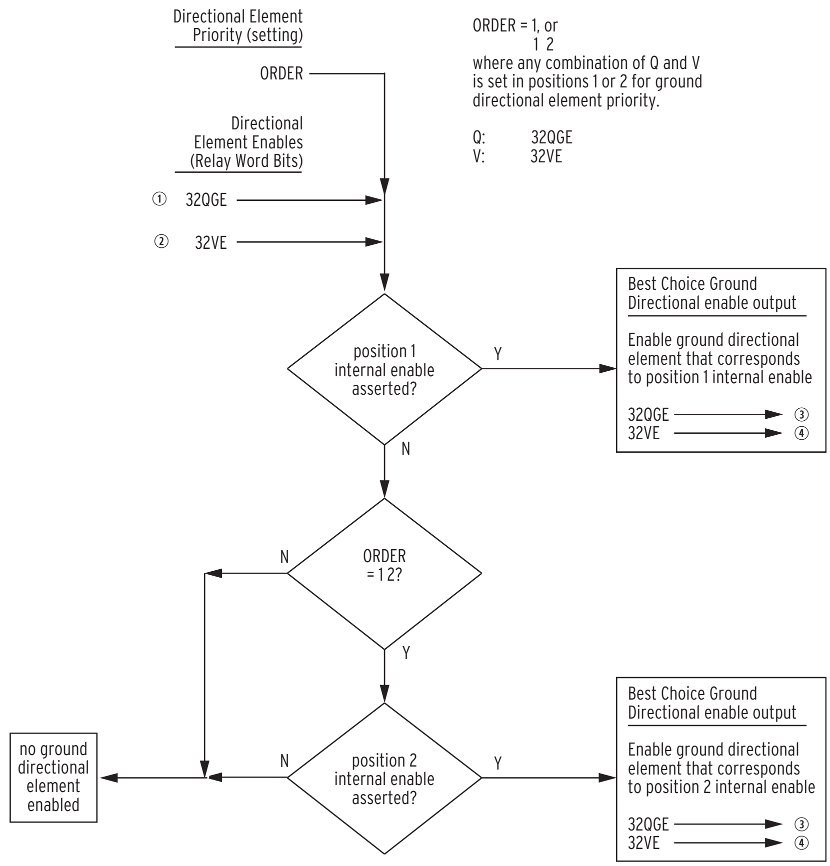
① From Figure 4.45; ② From Figure 5.4; ③ From Figure 4.48; ④ To Figure 4.50; ⑤ To Figure 4.54; ⑥ To Figure 4.49

Figure 4.47 Directional Element Enables (32QE and 32QGE) Logic for Negative-Sequence Voltage-Polarized Directional Elements



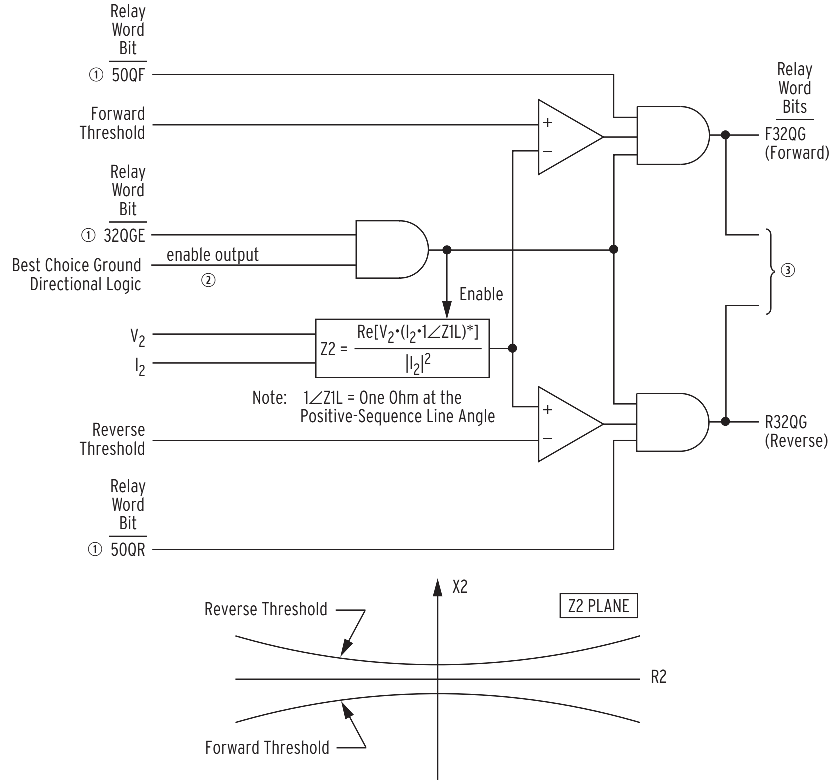
① From Figure 4.45; ② From Figure 5.4; ③ To Figure 4.51; ④ To Figure 4.47; ⑤ To Figure 4.49

Figure 4.48 Directional Element Enable (32VE) Logic for Zero-Sequence Voltage-Polarized Directional Elements



① From Figure 4.47; ② From Figure 4.48; ③ To Figure 4.50; ④ To Figure 4.51

Figure 4.49 Best Choice Ground Directional Logic



Forward Threshold:

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

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

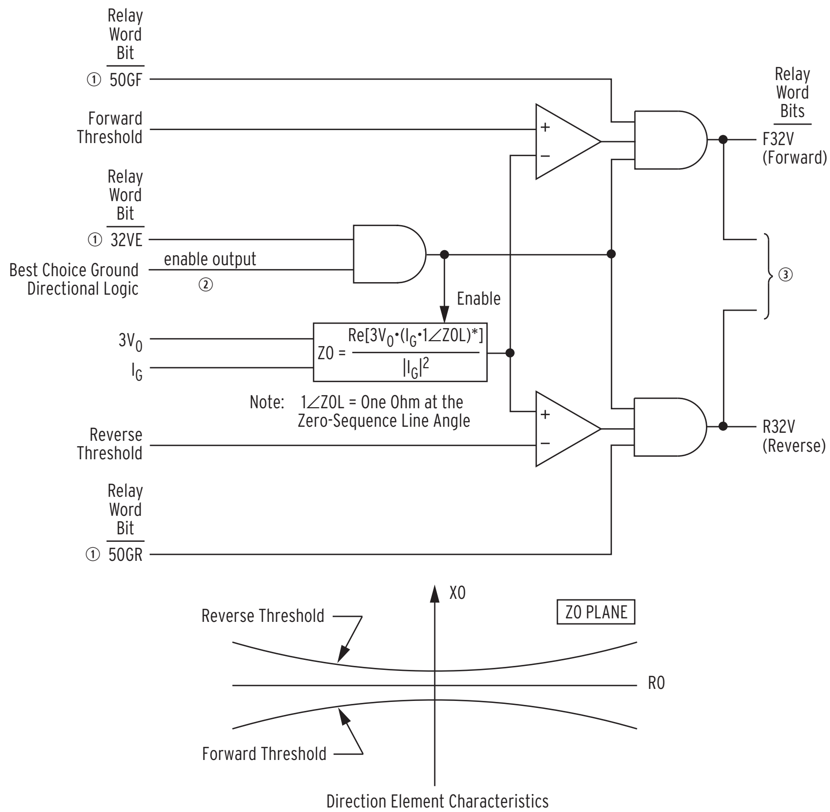
Reverse Threshold:

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

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

① From Figure 4.47; ② from Figure 4.49; ③ to Figure 4.52.

Figure 4.50 Negative-Sequence Voltage-Polarized Directional Element for Ground Overcurrent Elements



Forward Threshold:

If Z0F Setting ≤ 0, Forward Threshold = $0.75 \cdot Z0F - 0.25 \cdot \left|\frac{V_0}{I_0}\right|$

If Z0F Setting > 0, Forward Threshold = $1.25 \cdot Z0F - 0.25 \cdot \left|\frac{V_0}{I_0}\right|$

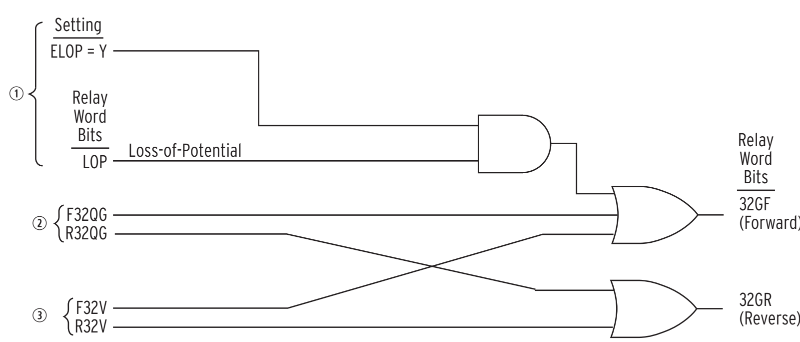
Reverse Threshold:

If Z0R Setting ≥ 0, Reverse Threshold = $0.75 \cdot Z0R + 0.25 \cdot \left|\frac{V_0}{I_0}\right|$

If Z0F Setting < 0, Reverse Threshold = $1.25 \cdot Z0R + 0.25 \cdot \left|\frac{V_0}{I_0}\right|$

① From Figure 4.48; ② from Figure 4.49; ③ to Figure 4.52.

Figure 4.51 Zero-Sequence Voltage-Polarized Directional Element for Ground Overcurrent Elements



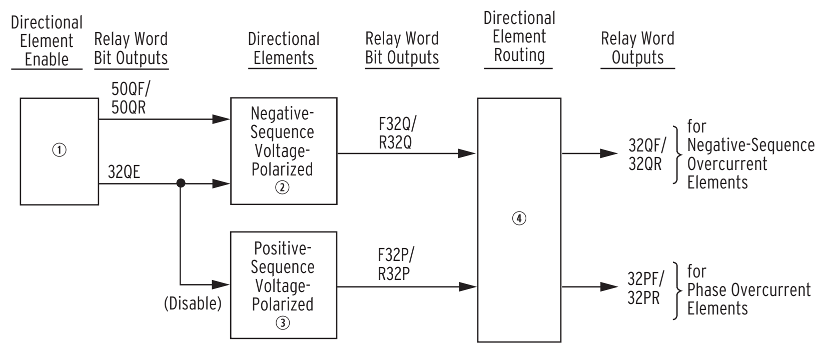
① From Figure 4.45; ② from Figure 4.50; ③ from Figure 4.51.

Figure 4.52 Routing of Directional Elements for Ground Directional Elements

Directional Control for Negative-Sequence and Phase Overcurrent Elements

Setting E32 enables directional control for overcurrent elements. Setting E32 and other directional control settings are described in *Directional Control Settings on page 4.78*.

The negative-sequence voltage-polarized directional element controls the negative-sequence overcurrent elements. Negative-sequence voltage-polarized and positive-sequence voltage-polarized directional elements control the phase overcurrent elements. *Figure 4.53* gives an overview of how the negative-sequence voltage-polarized and positive-sequence voltage-polarized directional elements are enabled and routed to control the negative-sequence and phase overcurrent elements.



① Figure 4.47; ② Figure 4.54; ③ Figure 4.55; ④ Figure 4.56.

Figure 4.53 General Logic Flow of Directional Control for Negative-Sequence Overcurrent and Phase Overcurrent Elements

Directional Element Enable

Refer to *Figure 4.47* and *Figure 4.53*.

The Relay Word bit 32QE enables the negative-sequence voltage-polarized directional element and disables the positive-sequence voltage-polarized directional element. The positive-sequence voltage-polarized directional element is only operative for three-phase faults, where negative-sequence current (I_2) is minimal or nonexistent, compared to positive-sequence current (I_1; see the a2 setting factor in *Figure 4.47*).

Note in *Figure 4.47* that if:

- ➤ enable setting ELOP := Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts; see *Figure 4.45*)
- ➤ or a single-pole open condition occurs (Relay Word bit SPO asserts; see *Figure 5.4*)

then the 32QE directional element enable is disabled. The loss-of-potential condition (Relay Word bit LOP) also applies to the positive-sequence voltage-polarized directional element (*Figure 4.55*) and a single-pole open condition (or lack thereof) is effectively checked for in *Figure 4.55* with three-phase overcurrent element 50P32. The 32QE directional element enable also has current signal thresholds that have to be met (settings 50QFP/50QRP).

Figure 4.47 has extra directional element enable 32QGE, which is used in the directional element logic that controls the ground overcurrent elements (see *Figure 4.50*).

The settings involved with 32QE in *Figure 4.47* (e.g., setting a2) are explained in *Directional Control Settings on page 4.78*.

Directional Elements

Refer to *Figure 4.53*, *Figure 4.54*, and *Figure 4.55*.

For an unbalanced fault, presuming sufficient negative-sequence current signal is present (Relay Word bit 50QF or 50QR asserted), an impedance-based directional calculation is then made in *Figure 4.54*. The technical paper "Negative-Sequence Impedance Directional Element" by Bill Fleming goes into more detail on this impedance-based calculation for the negative-sequence voltage-polarized directional element (paper available from website: selinc.com, SEL Literature, Technical Papers).

The negative-sequence voltage-polarized directional element operates for unbalanced faults while the positive-sequence voltage-polarized directional element operates for three-phase faults.

VPOLV in *Figure 4.55* indicates that there is sufficient positive-sequence voltage for the positive-sequence voltage-polarized directional element to operate. If there is a three-phase fault close-in to the SEL-651R, all three phase voltages depress to zero magnitude. In such a scenario, the SEL-651R then internally generates a positive-sequence memory voltage for a time period of about 30 cycles or more after the voltage depression. This memory voltage is used in the internal phase-to-phase distance-type elements indicated in *Figure 4.55* to keep directional decisions going for several more cycles in the face of such a voltage depression. VPOLV remains asserted until this memory voltage expires.

Note in *Figure 4.55* that the assertion of ZLOAD disables the positive-sequence voltage-polarized directional element. ZLOAD asserts when the relay is operating in a user-defined load region (see *Figure 4.43*).

Directional Element Routing

Refer to *Figure 4.53* and *Figure 4.56*.

The directional element outputs are routed to the forward (Relay Word bits 32QF and 32PF) and reverse (Relay Word bits 32QR and 32PR) logic points, for use in controlling negative-sequence and phase overcurrent elements.

Table 4.20 and accompanying text give examples of directional control implementation (i.e., using the outputs of *Figure 4.52* and *Figure 4.56* in overcurrent element torque control settings and other SELOGIC settings to realize desired directional control).

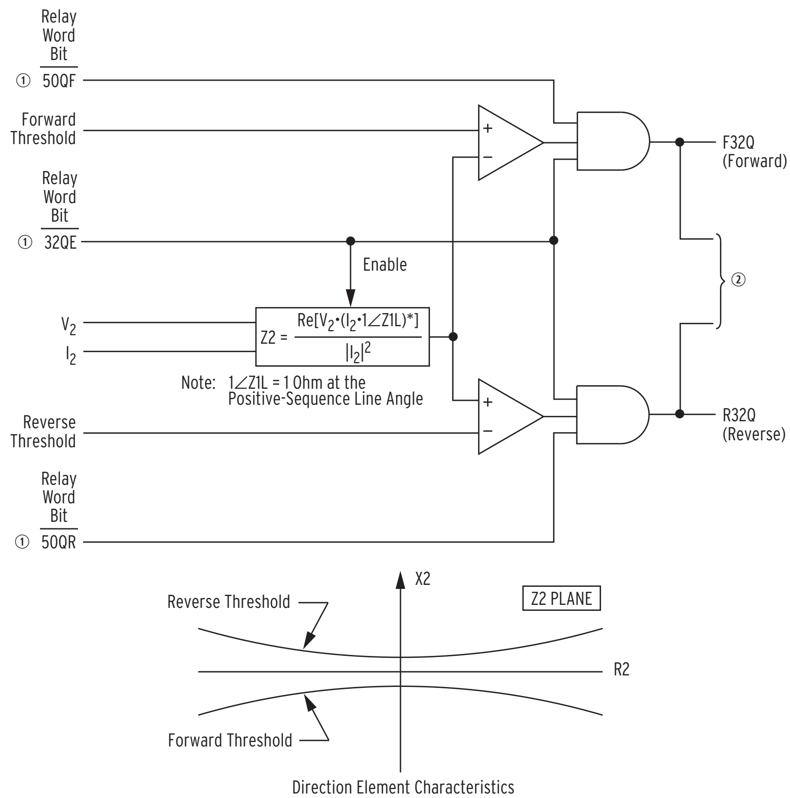
Loss-of-Potential

Note in *Figure 4.56* that if **both** the following are true:

- enable setting ELOP := Y
- a loss-of-potential condition occurs (Relay Word bit LOP asserts)

then the forward logic points (Relay Word bits 32QF and 32PF) assert to logical 1, thus enabling elements that are set direction forward. These direction forward elements effectively become nondirectional and provide protection during a loss-of-potential condition.

As detailed previously (in *Figure 4.47* and *Figure 4.55*), voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements controlled by these voltage-based directional elements are also disabled. But this disable condition is overridden for the overcurrent elements set direction forward if setting ELOP := Y, as explained above.



Forward Threshold:

If Z2F Setting ≤ 0, Forward Threshold = 0.75 • Z2F − 0.25 • $\left|\frac{V_2}{I_2}\right|$

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

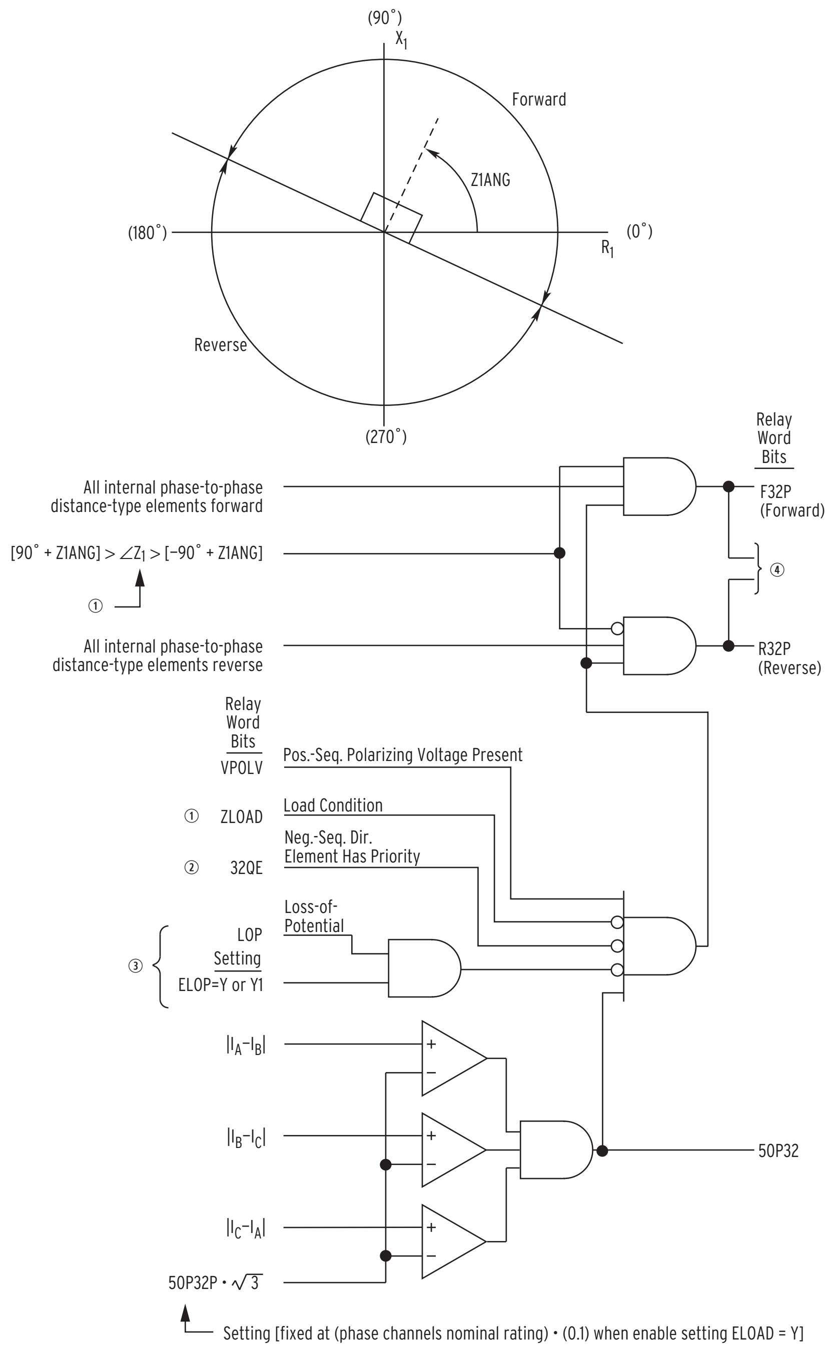
Reverse Threshold:

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

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

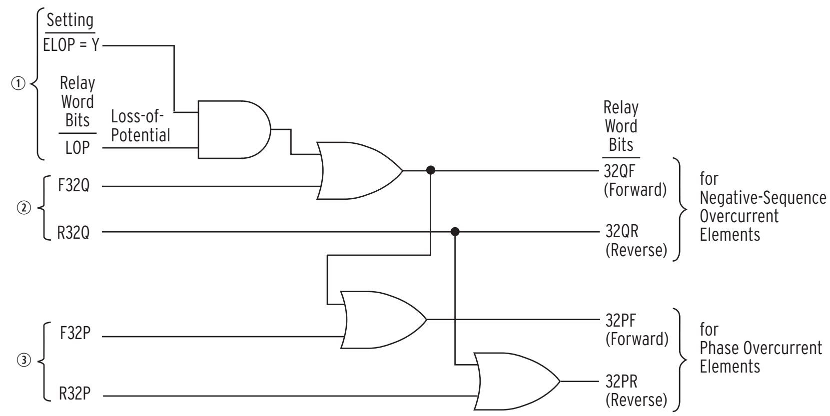
① From Figure 4.47; ② to Figure 4.56.

Figure 4.54 Negative-Sequence Voltage-Polarized Directional Element for Negative-Sequence and Phase Overcurrent Elements



① From Figure 4.43; ② from Figure 4.47; ③ from Figure 4.45; ④ to Figure 4.56.

Figure 4.55 Positive-Sequence Voltage-Polarized Directional Element for Phase Overcurrent Elements



① From Figure 4.45; ② from Figure 4.54; ③ from Figure 4.55.

Figure 4.56 Routing of Directional Elements to Negative-Sequence and Phase Overcurrent Elements

Directional Control Settings

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

- Y (All directional control settings made manually)
- N (Disable directional control)
- AUTO (Sets most of the directional control settings automatically)

Settings Made Automatically

If the directional control enable setting E32 is set:

E32 := **AUTO**

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

Z2F, Z2R, 50QFP, 50QRP, a2, k2, 50GFP, 50GRP, a0G, Z0F, and Z0R

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

Use caution when you set E32 = AUTO. It is not appropriate for all applications. Systems with a strong negative-sequence source (e.g., equivalent negative-sequence impedance of less than $2.5/I_{NOM}$ in ohms) can use E32 = AUTO. It is best to use the settings in *Table 4.19* if any of the following apply:

- the negative-sequence impedance of the source is greater than $2.5/I_{NOM}$ in ohms
- the line impedance is unknown
- a non-fault condition occurs, such as a switching transformer energization causing the negative-sequence voltage to be approximately zero

Table 4.19 Ground Directional Element Preferred Settings (Sheet 1 of 2)

Name	5 A nominal	1 A nominal
E32	Y	Y
Z2F	–0.30	–1.5

Table 4.19 Ground Directional Element Preferred Settings (Sheet 2 of 2)

Name	5 A nominal	1 A nominal
Z2R	0.30	1.5
Z0F	–0.30	–1.5
Z0R	0.30	1.5
Z0MTA	Set equal to Z0ANG	Set equal to Z0ANG
50QFP /50GFP	0. 50 A	0.10 A
50QRP /50GRP	0. 25 A	0.05 A
a2	0.10	0.10
k2	0.20	0.20
a0	0.10	0.10

The preferred settings in *Table 4.19* will provide equal or better protection than E32 = AUTO for most systems.

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

ORDER, 50P32P, and E32IV (E32IV is a SELOGIC setting)

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

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

Settings Hidden/Not Made:	For Condition:
50P32P	setting ELOAD = Y
50GFP, 50GRP, a0G, Z0F, Z0R, E32IV	setting ORDER does not contain V

Settings

ORDER-Ground Directional Element Priority Setting

Setting Range:

Q (Negative-sequence voltage-polarized directional element)

V (Zero-sequence voltage-polarized directional element)

OFF (Disable ground directional control)

Setting ORDER can be set with any combination of Q and V. The order in which these directional elements are listed determines the priority in which they operate to provide Best Choice Ground Directional logic control. See *Figure 4.49*.

For example, if setting:

ORDER := **QV**

then the first listed directional element (Q = negative-sequence voltage-polarized directional element; see *Figure 4.50*) is the first priority directional element to provide directional control for the ground overcurrent elements.

If the negative-sequence voltage-polarized directional element is not operable (i.e., it does not have sufficient operating quantity as indicated by its internal enable, 32QGE, not being asserted), then the second listed directional element (V = zero-sequence voltage-polarized directional element; see *Figure 4.51*) provides directional control for the ground overcurrent elements.

Another example, if setting:

ORDER := **V**

then the zero-sequence voltage-polarized directional element (V = zero-sequence voltage-polarized directional element; see *Figure 4.51*) provides directional control for the ground overcurrent elements all the time.

Setting ORDER can be set with any element combination (i.e., ORDER := QV, ORDER := VQ, ORDER := V, ORDER := Q, or ORDER := OFF).

50P32P-Phase Directional Element Three-Phase Current Pickup

Setting Range:

0.10–2.00 A secondary

The 50P32P setting is set to pick up for all three-phase faults that need to be covered by the phase overcurrent elements. It supervises the positive-sequence voltage-polarized directional elements F32P and R32P (see *Figure 4.21*).

If the load-encroachment logic is enabled (enable setting ELOAD := Y), then setting 50P32P is not made or displayed, but is fixed internally at:

0.1 A secondary

Z2F-Forward Directional Z2 Threshold

Z2R-Reverse Directional Z2 Threshold

Setting Range:

–640.00 to 640.00 Ω secondary

Z2F and Z2R are used to calculate the Forward and Reverse Thresholds, respectively, for the negative-sequence voltage-polarized directional elements (see *Figure 4.50* and *Figure 4.54*).

If configuration setting E32 := Y, settings Z2F and Z2R (negative-sequence impedance values) are calculated by the user and entered by the user, but setting Z2R must be greater in value than setting Z2F by 0.10 Ω secondary.

Figure 4.57 and *Figure 4.58* and supporting text concern the zero-sequence impedance network, relay polarity, and the derivation of settings Z0F and Z0R. The same general approach outlined for deriving settings Z0F and Z0R can also be applied to deriving settings Z2F and Z2R in the negative-sequence impedance network. If the basis for Z2F and Z2R values (Ω secondary) is primary impedance values (Ω primary), convert these primary impedance values to secondary impedance values, using *Equation 9.8* (global setting VSELECT:= VY) or *Equation 9.9* (global setting VSELECT:= VZ).

Z2F and Z2R Set Automatically

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

Z2F = **Z1MAG/2** (Ω secondary)

Z2R = **Z1MAG/2 + 1.00** (Ω secondary)

50QFP-Forward Directional Negative-Sequence Current Pickup

50QRP-Reverse Directional Negative-Sequence Current Pickup

Setting Range:

0.05–1.00 A secondary

The 50QFP setting ($3I_2$ current value) is the pickup for the forward fault detector 50QF of the negative-sequence voltage-polarized directional elements (see *Figure 4.47*). Ideally, the setting is above normal load unbalance and below the lowest expected negative-sequence current magnitude for unbalanced forward faults.

The 50QRP setting ($3I_2$ current value) is the pickup for the reverse fault detector 50QR of the negative-sequence voltage-polarized directional elements (see *Figure 4.47*). Ideally, the setting is above normal load unbalance and below the lowest expected negative-sequence current magnitude for unbalanced reverse faults.

50QFP and 50QRP Set Automatically

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

50QFP := **0.10 A secondary**

50QRP := **0.05 A secondary**

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

Setting Range:

0.02–0.50 (unitless)

Refer to *Figure 4.47*.

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

a2 Set Automatically

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

a2 := **0.1**

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

k2—Zero-Sequence Current Restraint Factor, $|I_2|/|I_0|$

Setting Range:

0.10–1.20 (unitless)

Note the directional enable logic outputs in *Figure 4.47*:

- 32QE (enable for the negative-sequence voltage-polarized directional element that controls the negative-sequence and phase overcurrent elements)
- 32QGE (enable for the negative-sequence voltage-polarized directional element that controls the ground overcurrent elements)

Factor k2 is an additional threshold to be met by directional element enable 32QGE if the zero-sequence voltage-polarized directional element enable 32VE is already asserted. The negative-sequence current (I_2) magnitude has to be greater than the zero-sequence current (I_0) magnitude multiplied by k2 in order for the 32QGE enable (and following negative-sequence voltage-polarized directional element in *Figure 4.50*) to be enabled:

$$|I_2| > k2 \bullet |I_0| \qquad \textbf{Equation 4.9}$$

This check assures that the relay uses the most robust analog quantities in making directional decisions for the ground overcurrent elements.

If directional element enable 32VE is deasserted, then factor k2 (and its effective threshold) is not a requirement for directional element enable 32QGE operation.

Setting k2 is often derived using zero-sequence current (I_0) values and negative-sequence current (I_2) values from system studies, load profiles, or metering. Make sure these current values are on the same base. The easiest way to assure the same base is to use primary values.

The zero-sequence current ($I_0 = I_G/3$; I_G is the ground current) source can switch between residual ground ($I_G = 3I_0 = I_A + I_B + I_C$) and neutral ground ($I_G = I_N$; channel IN) for some scenarios (see *Table 4.17*). This apparent switching of zero-sequence current base (if CTR ≠ CTRN) is handled internally for setting k2 applied in *Figure 4.47*.

k2 Set Automatically

If configuration setting E32 = AUTO, setting k2 is set automatically at:

k2 := **0.2**

For setting k2 := 0.2, the negative-sequence current (I_2) magnitude has to be greater than 1/5 of the zero-sequence current (I_0) magnitude in order for the negative-sequence voltage-polarized directional elements to be enabled ($|I_2| > 0.2 \bullet |I_0|$). Again, this further threshold requirement presumes enable 32VE is asserted, as described previously.

50GFP-Forward Directional Ground Current Pickup

50GRP-Reverse Directional Ground Current Pickup

Setting Range:

NOTE: In the case where EGNDSW := Y and CTR = CTRN, there is no difference between the IN current base and the IA, IB, IC current base. This is the standard configuration for the SEL-651R, because the factory wiring includes a wired residual connection to the IN channel.

0.005–1.00 A secondary
on channel IN base (see Note), when global setting EGNDSW := Y and group setting CTR = CTRN

0.005–[1.00 • (CTR/CTRN)] A secondary
on channel IN base, when global setting EGNDSW := Y and group setting CTR ≠ CTRN

0.010–1.00 A secondary
on IA, IB, IC base, when global setting EGNDSW := N

If preceding setting ORDER does not contain V (the zero-sequence voltage-polarized directional element is not enabled), then settings 50GFP and 50GRP are not made or displayed.

The 50GFP setting (I_G ground current value) is the pickup for the forward fault detector 50GF of the zero-sequence voltage-polarized directional element (see *Figure 4.48*). Ideally, the setting is above normal load unbalance and below the lowest expected zero-sequence current magnitude for unbalanced forward faults.

The 50GRP setting (I_G ground current value) is the pickup for the reverse fault detector 50GR of the zero-sequence voltage-polarized directional element (see *Figure 4.48*). Ideally, the setting is above normal load unbalance and below the lowest expected zero-sequence current magnitude for unbalanced reverse faults.

50GFP and 50GRP Set Automatically

If configuration setting E32 := AUTO, settings 50GFP and 50GRP are set automatically at:

50GFP := **0.100 A secondary**

50GRP := **0.050 A secondary**

a0G—Positive-Sequence Current Restraint Factor, $|I_0|/|I_1|$

Setting Range:

0.001–0.500 (unitless)

If preceding setting ORDER does not contain V (the zero-sequence voltage-polarized directional element is not enabled), then setting a0G is not made or displayed.

Refer to *Figure 4.48*.

The a0G factor increases the security of the zero-sequence voltage-polarized directional element. It keeps the elements from operating for zero-sequence current (system unbalance), which circulates due to line asymmetries, CT saturation during three-phase faults, etc.

Setting a0G is often derived using zero-sequence current (I_0) values and positive-sequence current (I_1) values from system studies, load profiles, or metering. Make sure these current values are on the same base. The easiest way to assure the same base is to use primary values.

The zero-sequence current ($I_0 = I_G/3$; I_G is the ground current) source can switch between residual ground ($I_G = 3I_0 = I_A + I_B + I_C$) and neutral ground ($I_G = I_N$; channel IN) for some scenarios (see *Table 4.17*). This apparent switching of zero-sequence current base (if CTR ≠ CTRN) is handled internally for setting a0G applied in *Figure 4.48*.

a0G Set Automatically

If configuration setting E32 := AUTO, setting a0G is set automatically at:

a0G := **0.1**

For setting a0G := 0.1, the zero-sequence current (I_0) magnitude has to be greater than 1/10 of the positive-sequence current (I_1) magnitude in order for the zero-sequence voltage-polarized directional element to be enabled ($|I_0| > 0.1 \cdot |I_1|$).

Z0F-Forward Directional Z0 Threshold

Z0R-Reverse Directional Z0 Threshold

Setting Range:

–640.00 to 640.00 Ω secondary

If preceding setting ORDER does not contain V (the zero-sequence voltage-polarized directional element is not enabled), then settings Z0F and Z0R are not made or displayed.

Z0F and Z0R are used to calculate the Forward and Reverse Thresholds, respectively, for the zero-sequence voltage-polarized directional element (see *Figure 4.51*).

If configuration setting E32 := Y, settings Z0F and Z0R (zero-sequence impedance values) are calculated by the user and entered by the user, but setting Z0R must be greater in value than setting Z0F by 1.00 Ω secondary.

If the basis for Z0F and Z0R values (Ω secondary) is primary impedance values (Ω primary), convert these primary impedance values to secondary impedance values, using *Equation 9.8* (global setting VSELECT := VY) or *Equation 9.9* (global setting VSELECT := VZ).

The zero-sequence current ($I_0 = I_G/3$; I_G is the ground current) source can switch between residual ground ($I_G = 3I_0 = I_A + I_B + I_C$) and neutral ground ($I_G = I_N$; channel IN) for some scenarios (see *Table 4.17*). This apparent switching of zero-sequence current base (if CTR ≠ CTRN) is handled internally for settings Z0F and Z0R applied in the bottom equations in *Figure 4.51*.

Z0F and Z0R Set Automatically

If configuration setting E32 := AUTO, settings Z0F and Z0R (zero-sequence impedance values) are calculated automatically, using the zero-sequence line impedance magnitude setting Z0MAG as follows:

Z0F = **Z0MAG/2** (Ω secondary)

Z0R = **Z0MAG/2 + 1.00** (Ω secondary)

Deriving Z0F and Z0R Settings

Figure 4.57 shows the voltage and current polarity for an SEL-651R in a zero-sequence impedance network (the same approach can be instructive for negative-sequence impedance analysis, too; settings Z2F and Z2R). For a forward fault, the SEL-651R effectively sees the sequence impedance behind it as:

$Z_M = V_0/(-I_0) = -(V_0/I_0)$ $V_0/I_0 = -Z_M$ (what the relay sees for a forward fault)

For a reverse fault, the SEL-651R effectively sees the sequence impedance in front of it:

$Z_N = V_0/I_0$ $V_0/I_0 = Z_N$ (what the relay sees for a reverse fault)

If the system in *Figure 4.57* is a solidly-grounded system (mostly inductive; presume uniform system angle), the impedance plot (in the R + jX plane) would appear as in *Figure 4.58a*, with resultant Z0F and Z0R settings as in *Figure 4.58b*. The zero-sequence line angle noted in *Figure 4.58a* (∠Z0L) is the same angle found in *Figure 4.10* and *Figure 4.12* (in the equation box with the Enable line).

The preceding method of automatically making settings Z0F and Z0R (where both Z0F and Z0R are positive values; still Z0R > Z0F) usually suffices for mostly inductive systems—*Figure 4.57* and *Figure 4.58* just provide a theoretic background.

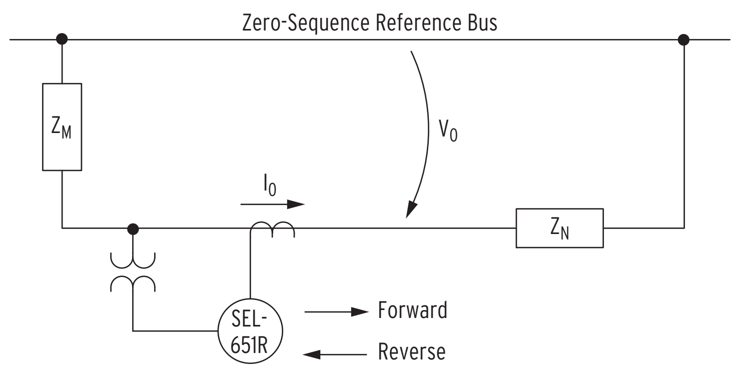
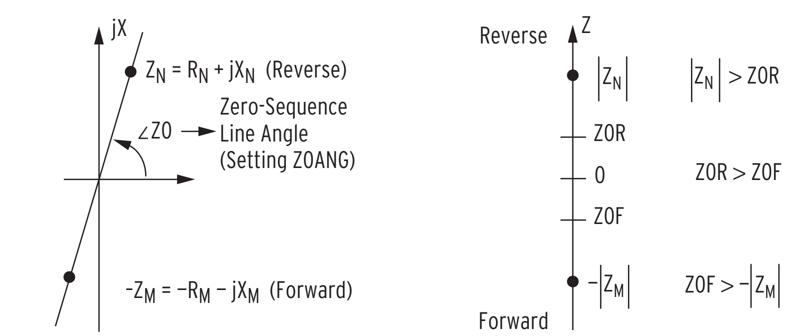


Figure 4.57 Zero-Sequence Impedance Network and Relay Polarity



(a) Impedance Plot (b) Z0F and Z0R Settings

Figure 4.58 Zero-Sequence Impedance Plot for Solidly-Grounded, Mostly Inductive System

E32IV–SELOGIC Control Equation Enable

Refer to *Figure 4.48*.

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

Most often, this setting is set directly to logical 1:

E32IV := **1** (numeral 1)

For situations where zero-sequence source isolation can occur (e.g., by the opening of a circuit breaker) and result in possible mutual coupling problems for the zero-sequence voltage-polarized directional element, SELOGIC control equation setting E32IV should be deasserted to logical 0. In this example, this is accomplished by connecting a circuit breaker auxiliary contact from the identified circuit breaker to the SEL-651R:

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

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

Overcurrent Directional Control Provided by Torque Control Settings

The Relay Word bit outputs of *Figure 4.52* and *Figure 4.56* are used in the torque control settings to provide directional control for overcurrent elements. These Relay Word bit outputs are listed in the middle column of *Table 4.20*. Each line in *Table 4.20* (left to right) lists the torque control setting, the suggested Relay Word bits to provide directional control, and the overcurrent element controlled by the torque control setting. The torque control setting (left column) can be found in the same figure reference as the corresponding overcurrent element (right column).

Table 4.20 Providing Directional Control for Overcurrent Elements With Torque Control Settings (Sheet 1 of 2)

Torque Control Settings	Relay Word Bits Providing Directional Control (Figure Reference)	Controlled Overcurrent Elements (Figure Reference)
50P1TC–50P4TC	32PF/32PR (*Figure 4.56*)	50P1T–50P4T (*Figure 4.3*)
50A1TC–50A4TC	32PF/32PR (*Figure 4.56*)	50A1T–50A4T (*Figure 4.4*)
50B1TC–50B4TC	32PF/32PR (*Figure 4.56*)	50B1T–50B4T (*Figure 4.5*)
50C1TC–50C4TC	32PF/32PR (*Figure 4.56*)	50C1T–50C4T (*Figure 4.6*)
50N1TC–50N4TC		50N1T–50N4T (*Figure 4.10*)
50G1TC–50G4TC	32GF/32GR (*Figure 4.52*)	50G1T–50G4T (*Figure 4.12*)
50Q1TC–50Q4TC	32QF/32QR (*Figure 4.56*)	50Q1T–50Q4T (*Figure 4.14*)
51PTC	32PF/32PR (*Figure 4.56*)	51PT (*Figure 4.16*)
51ATC	32PF/32PR (*Figure 4.56*)	51AT (*Figure 4.17*)
51BTC	32PF/32PR (*Figure 4.56*)	51BT (*Figure 4.18*)
51CTC	32PF/32PR (*Figure 4.56*)	51CT (*Figure 4.19*)

Table 4.20 Providing Directional Control for Overcurrent Elements With Torque Control Settings (Sheet 2 of 2)

Torque Control Settings	Relay Word Bits Providing Directional Control (Figure Reference)	Controlled Overcurrent Elements (Figure Reference)
51G1TC	32GF/32GR (*Figure 4.52*)	51G1T (*Figure 4.20*)
51G2TC	32GF/32GR (*Figure 4.52*)	51G2T (*Figure 4.21*)
51QTC	32QF/32QR (*Figure 4.56*)	51QT (*Figure 4.22*)

For example, to provide forward directional control for time-overcurrent element 51G1T, make the following torque control setting:

51G1TC := **32GF**

In factory default settings, this torque control setting is set as:

51G1TC := **LT01** (see *Figure 9.27*)

Latch output LT01 (see *Figure 7.6*) is set to enable/disable ground overcurrent tripping (see setting SET01 and RST01 in *Figure 9.28*), via the {GROUND ENABLED} operator control pushbutton (see *Table 11.9*). To incorporate this factory-default front-panel operator control capability with forward directional control, make the following combined setting:

51G1TC := **LT01 AND 32GF**

Channel IN Overcurrent Elements

Note channel IN overcurrent elements 50N1T–50N4T listed in the right column in *Table 4.20*. Refer to the given reference (*Figure 4.10*) and accompanying text. Note that no suggested Relay Word bits for directional control are given in the corresponding middle column in *Table 4.20*.

As explained in the text accompanying *Figure 4.10*, these channel IN overcurrent elements only become available if global setting EGNDSW:=N (Relay Word bit GNDSW = logical 0). *Table 4.17* shows that channel IN current is treated as a totally separate current source for this scenario (separate from internal residually-derived ground current $I_G = 3I_0 = I_A + I_B + I_C$). Thus, it is unlikely that these channel IN overcurrent elements 50N1T–50N4T would be used in a directional scheme, where ground directionality would come from currents I_G (ground/zero-sequence) and I_2 (negative-sequence) derived from currents I_A, I_B, and I_C (see *Figure 4.50* and *Figure 4.51*).

Instantaneous Overcurrent Elements

The 50__TC torque control settings in *Table 4.20* do not control the corresponding instantaneous elements. For example, at the top of *Figure 4.12*, torque control setting 50G1TC controls the ground definite-time overcurrent element 50G1T, but not ground instantaneous overcurrent element 50G1. To make an instantaneous overcurrent element directional, supervise it with a directional element in SELOGIC control equations (e.g., 50G1 AND 32GR).

Single-Phase Tripping

If a recloser is set for single-phase or three-phase tripping (group setting ESPB := Y; see *Figure 5.1*), the ground directional elements (*Figure 4.50* and *Figure 4.51*) and negative-sequence directional element (*Figure 4.54*) automatically shut down/turn off when one or two phases are tripped. This is due to the single-pole open logic (*Figure 5.4*) and Relay Word bit output SPO that supervises the ground directional element enables 32QGE and 32VE (*Figure 4.47* and *Figure 4.48*) and the negative-sequence directional element enable 32QE (*Figure 4.47*).

The phase directional element (*Figure 4.55*) is not supervised by the Relay Word bit output SPO. But once one or two phases are tripped, the phase directional element effectively shuts down/turns off—it cannot make a three-phase decision (all three phases have to agree for a directional decision).

Setting Negative-Sequence Overcurrent Elements

Setting Negative-Sequence Definite-Time Overcurrent Elements

Negative-sequence instantaneous overcurrent elements 50Q1 through 50Q6 should not be set to trip directly. This is because negative-sequence current can transiently appear when a circuit breaker is closed and balanced load current suddenly appears.

To avoid tripping for this transient condition, use negative-sequence definite-time overcurrent elements 50Q1T through 50Q4T with at least 1.5 cycles of time delay (transient condition lasts less than 1.5 cycles). For example, make the following time delay setting for negative-sequence definite-time overcurrent element 50Q1T:

50Q1D := **1.50**

Refer to *Figure 4.14* and *Figure 4.15* for more information on negative-sequence instantaneous and definite-time overcurrent elements.

Negative-sequence instantaneous overcurrent elements 50Q5 and 50Q6 do not have associated timers (compare *Figure 4.15* to *Figure 4.14*). If 50Q5 or 50Q6 need to be used for tripping, run them through SELOGIC® control equation variable timers (see *Figure 7.3*) and use the outputs of the timers for tripping.

Continue reading in *Coordinating Negative-Sequence Overcurrent Elements on page 4.89* for guidelines on coordinating negative-sequence definite-time overcurrent elements and a following coordination example. The coordination example uses time-overcurrent elements, but the same principles can be applied to definite-time overcurrent elements.

Setting Negative-Sequence Time-Overcurrent Elements

Negative-sequence time-overcurrent element 51QT should not be set to trip directly when it is set with low time-dial settings 51QJTD or 51QKTD, that result in curve times below 3 cycles (see curves in *Figure 9.1* through *Figure 9.20*). This is because negative-sequence current can transiently appear when a circuit breaker is closed and balanced load current suddenly appears. Refer to *Figure 4.22* for more information on negative-sequence time-overcurrent element 51QT.

To avoid having negative-sequence time-overcurrent element 51QT with such low time-dial settings trip for this transient negative-sequence current condition, make corresponding minimum response time setting:

51Q_MR := **1.50 cycles** (minimum response time; transient condition lasts less than 1.5 cycles) (replace "_" with J or K).

Continue reading in *Coordinating Negative-Sequence Overcurrent Elements on page 4.89* for guidelines on coordinating negative-sequence time-overcurrent elements and a following coordination example.

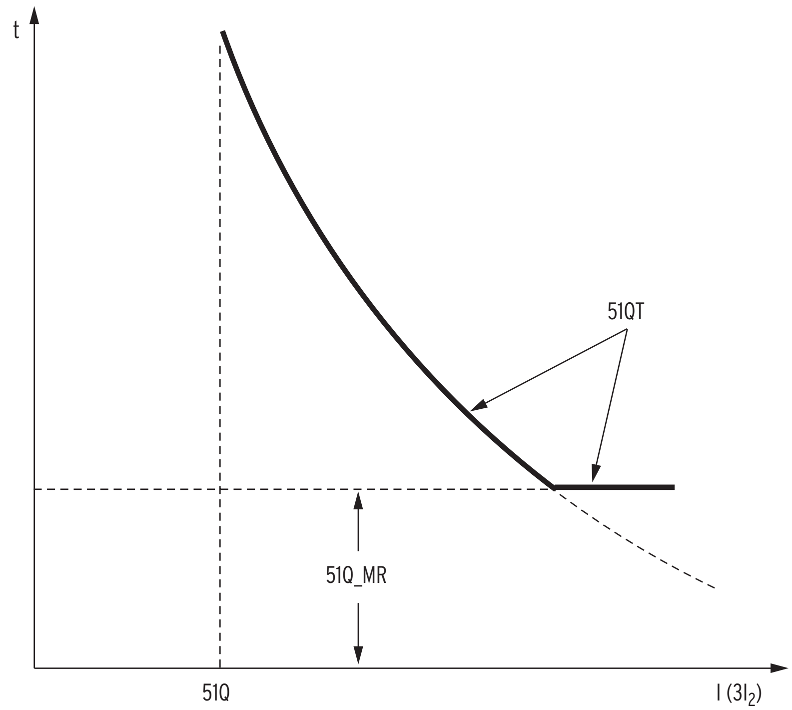


Figure 4.59 Minimum Response Time Added to a Negative-Sequence Time-Overcurrent Element 51QT

Coordinating Negative-Sequence Overcurrent Elements

NOTE: The overcurrent element labels in the example are not the same as the labels of the corresponding SEL-651R overcurrent elements.

The following coordination guidelines and example assume that the negative-sequence overcurrent elements operate on $3I_2$ magnitude negative-sequence current and that the power system is radial. The negative-sequence overcurrent elements in the SEL-651R Relay operate on $3I_2$ magnitude negative-sequence current.

The coordination example is a generic example that can be used with any relay containing negative-sequence overcurrent elements that operate on $3I_2$ magnitude negative-sequence current. The SEL-651R can be inserted as the feeder relay in this example.

Coordination Guidelines

1. Start with the furthest downstream negative-sequence overcurrent element (e.g., distribution feeder relay in a substation).
2. Identify the phase overcurrent device (e.g., line recloser, fuse) downstream from the negative-sequence overcurrent element that is of greatest concern for coordination. This is usually the phase overcurrent device with the longest clearing time.
3. Consider the negative-sequence overcurrent element as an “equivalent” phase overcurrent element. Derive pickup, time dial (lever), curve type, or time-delay settings for this equivalent element to coordinate with the downstream phase overcurrent device, as any phase coordination would be performed. Load considerations can be disregarded when deriving the equivalent phase overcurrent element settings.

4. Multiply the equivalent phase overcurrent element pickup setting by $\sqrt{3}$ to convert it to the negative-sequence overcurrent element pickup setting in terms of $3I_2$ current.

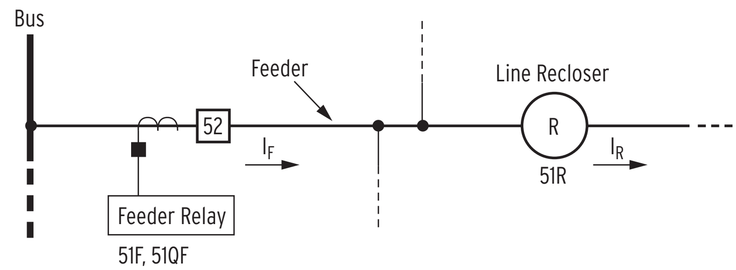
$$\begin{pmatrix}\text{Negative-sequence overcurrent}\\ \text{element pick-up}\end{pmatrix} = \sqrt{3} \bullet \begin{pmatrix}\text{equivalent phase overcurrent}\\ \text{element pickup}\end{pmatrix}$$

   Any time dial (lever), curve type, or time delay calculated for the equivalent phase overcurrent element is also used for the negative-sequence overcurrent element with no conversion factor applied.

5. Set the next upstream negative-sequence overcurrent element to coordinate with the first downstream negative-sequence overcurrent element and so on. Again, coordination is not influenced by load considerations.

Coordination Example

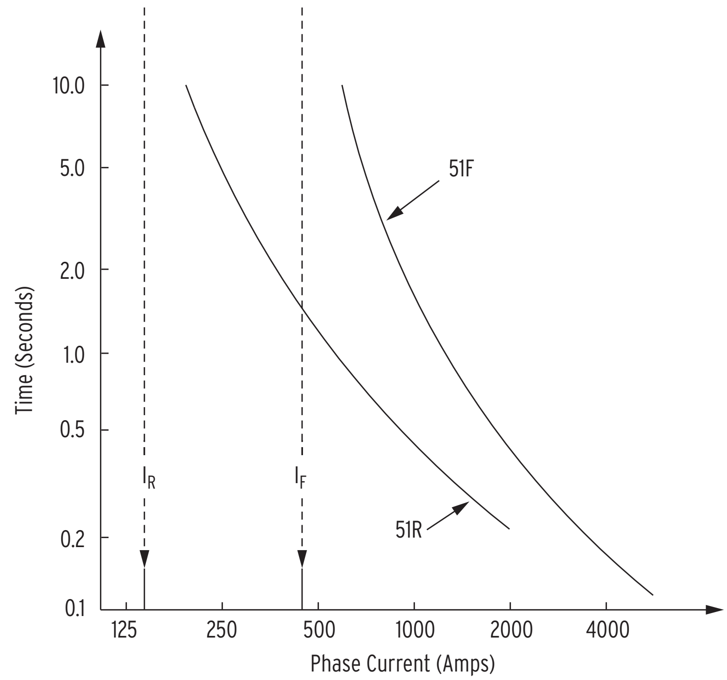
In *Figure 4.60*, the phase and negative-sequence overcurrent elements of the feeder relay (51F and 51QF, respectively) must coordinate with the phase overcurrent element of the line recloser (51R).



I_F = Maximum load current through feeder relay = 450 A
I_R = Maximum load current through line recloser = 150 A
51F = Feeder relay phase time-overcurrent element
51QF = Feeder relay negative-sequence time-overcurrent element
51R = Line recloser phase time-overcurrent element (phase "slow curve")

Figure 4.60 Distribution Feeder Protective Devices

Traditional Phase Coordination



51F: pickup = 600 A (above max. feeder load, I_F)
51R: pickup = 200 A (above max. line recloser load, I_R)

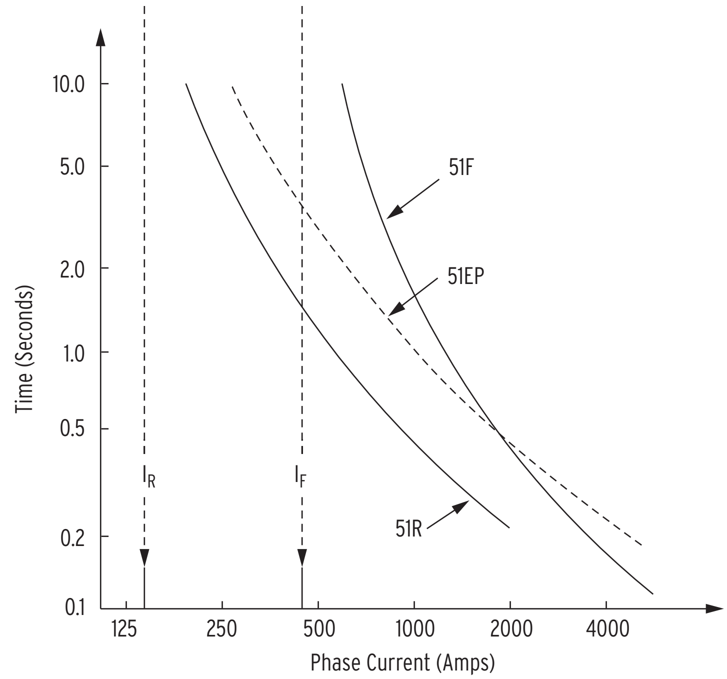
Figure 4.61 Traditional Phase Coordination

Figure 4.61 shows traditional phase overcurrent element coordination between the feeder relay and line recloser phase overcurrent elements. Phase overcurrent elements must accommodate load and cold load pickup current. The 450 A maximum feeder load current limits the sensitivity of the feeder phase overcurrent element, 51F, to a pickup of 600 A. The feeder relay cannot back-up the line recloser for phase faults below 600 A.

Apply the Feeder Relay Negative-Sequence Overcurrent Element (Guidelines 1 to 3)

Applying negative-sequence overcurrent element coordination Guidelines 1 to 3 results in the feeder relay equivalent phase overcurrent element (51EP) in *Figure 4.62*. Curve for 51F is shown for comparison only.

Considerable improvement in sensitivity and speed of operation for phase-to-phase faults is achieved with the 51EP element. The 51EP element pickup of 300 A has twice the sensitivity of the 51F element pickup of 600 A. The 51EP element speed of operation for phase-to-phase faults below about 2000 A is faster than that for the 51F element.



51EP: pickup = 300 A (below max. feeder load, I_F)

Figure 4.62 Phase-to-Phase Fault Coordination

Convert Equivalent Phase Overcurrent Element Settings to Negative-Sequence Overcurrent Element Settings (Guideline 4)

The equivalent phase overcurrent element (51EP element in *Figure 4.62*) converts to true negative-sequence overcurrent element settings (51QF in *Figure 4.63*) by applying the equation given in Guideline 4. The time dial (lever) and curve type of the element remain the same (if the element is a definite-time element, the time delay remains the same).

Having achieved coordination between the feeder relay negative-sequence overcurrent element (51QF) and the downstream line recloser phase overcurrent element (51R) for phase-to-phase faults, coordination between the two devices for other fault types is also achieved.

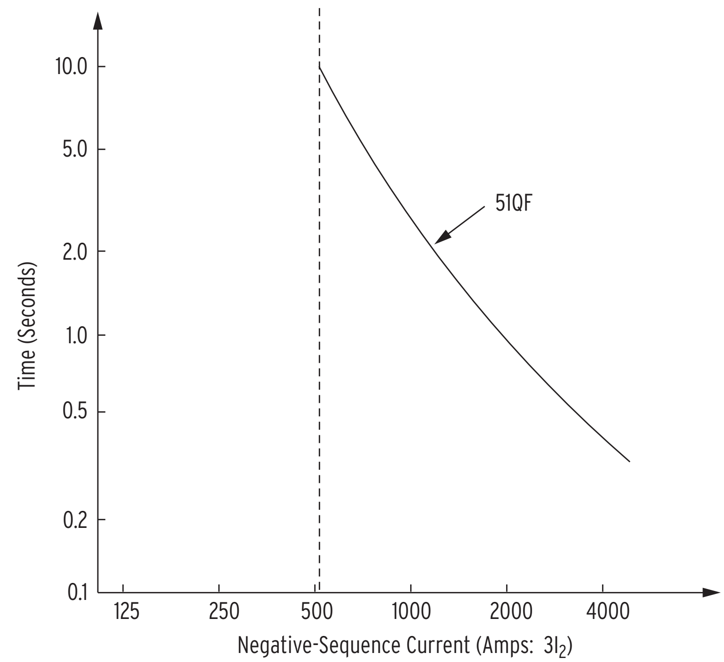


Figure 4.63 Negative-Sequence Overcurrent Element Derived From Equivalent Phase Overcurrent Element, 51EP

Negative-Sequence Overcurrent Element Applied at a Distribution Bus (Guideline 5)

The preceding example was for a distribution feeder. A negative-sequence overcurrent element protecting a distribution bus provides an even more dramatic improvement in phase-to-phase fault sensitivity.

The distribution bus phase overcurrent element pickup must be set above the combined load of all the feeders on the bus, plus any emergency load conditions. The bus phase overcurrent element pickup is often set at least four times greater than the pickup of the feeder phase overcurrent element it backs up. Thus, sensitivity to both bus and feeder phase faults is greatly reduced. Feeder relay backup by the bus relay is limited.

Negative-sequence overcurrent elements at the distribution bus can be set significantly below distribution bus load levels and provide dramatically increased sensitivity to phase-to-phase faults. It is coordinated with the distribution feeder phase or negative-sequence overcurrent elements and provides more-sensitive and faster phase-to-phase fault backup.

Ground Coordination Concerns

If the downstream protective device includes ground overcurrent elements, in addition to phase overcurrent elements, there should be no need to check the coordination between the ground overcurrent elements and the upstream negative-sequence overcurrent elements. The downstream phase overcurrent element, whether it operates faster or slower than its complementary ground overcurrent element, will operate faster than the upstream negative-sequence overcurrent element for all faults, including those that involve ground.

Other Negative-Sequence Overcurrent Element References

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

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

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

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

Section 5
Trip and Target Logic

Trip Logic

The trip logic in *Figure 5.1* provides flexible tripping for single-phase reclosers and three-phase reclosers. Single-phase reclosers can trip/reclose in a single-phase mode (each phase operates independently) or a three-phase mode (all three phases operate in unison). Three-phase reclosers can only trip/reclose in a three-phase mode.

Single-phase reclosers (set for single-phase or three-phase tripping; setting ESPB := Y) can make use of the following logic, also shown in *Figure 5.1*:

- ➤ Switch-Onto-Fault Trip Logic
- ➤ Three-Phase Trip Input Logic
- ➤ Single-Phase Trip Logic

Three-phase reclosers (and single-phase reclosers set for three-phase tripping only; setting ESPB := N) can use the following logic, also shown in *Figure 5.1*:

- ➤ Switch-Onto-Fault Trip Logic
- ➤ Three-Phase Trip Input Logic
- ➤ Three-Phase Trip Output Logic

Table 5.1 includes explanations of the SELOGIC® control equation settings in the trip logic in *Figure 5.1*.

Table 5.1 SELOGIC Settings Explanations for Figure 5.1

SELOGIC Setting	Description
TRSOTF	Switch-Onto-Fault Trip Conditions. Setting TRSOTF is supervised by the switch-onto-fault logic output SOTFE (switch-onto-fault logic is described in *Switch-Onto-Fault Logic Output (SOTFE) on page 5.10*). Relay Word bit output SOTFT is provided for testing purposes. Note that the switch-onto-fault tripping routes to both the three-phase trip logic and the single-phase trip logic. Switch-onto-fault tripping is a three-phase tripping action, that has its origin in transmission line protection applications. Switch-onto-fault tripping is not used as much in distribution applications.
TR3P, TR3X	Three-Phase Trip Input Conditions. Three-phase trip input conditions settings TR3P and TR3X route to both the three-phase trip output logic (ESPB := N) and the single-phase trip logic (ESPB := Y). TR3P and TR3X are functionally equivalent. TR3X is for extra three-phase trip logic and is seen as a supplement to TR3P. For the single-phase trip logic, settings TR3P and TR3X provide convenient locations to insert three-phase trip conditions, rather than repetitively inserting them in each single-phase trip setting (TRA, TRB, and TRC).
ULTR3P	Unlatch Three-Phase Trip Conditions. Unlatch three-phase trip conditions setting ULTR3P only routes to the three-phase trip output logic (ESPB := N). Note that if setting ULTR3P is set directly to logical 1 (ULTR3P := 1), then the three-phase trip output logic (Relay Word bit TRIP3P) effectively becomes like the individual single-phase trip output logic arrangements (Relay Word bits TRIPA, TRIPB, and TRIPC).
TRA, TRB, TRC	Single-Phase Trip Conditions. Single-phase trip conditions settings TRA, TRB, and TRC only route to the single-phase trip logic (ESPB := Y).

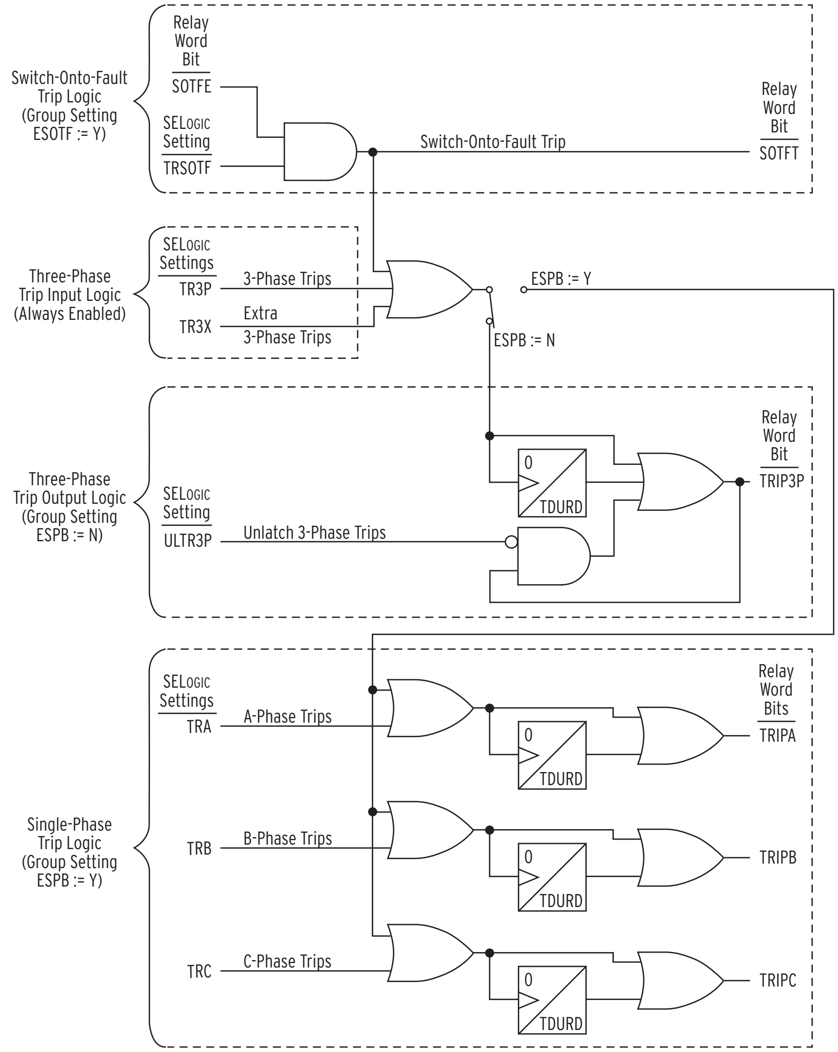


Figure 5.1 Trip Logic

Factory-Default Trip Settings

The factory-default settings for the trip logic in *Figure 5.1* are the following:

TDURD := **40.00 cycles**

TR3P := **51PT OR 51G1T OR PB12_PUL OR OC3**

TR3X := **R_TRIG SV02T** make setting for G&W Viper®-ST, Siemens SDR Triple-Single, and Kyle NOVA-TS or NOVA-STS Triple-Single recloser applications only

ULTR3P := **1** set directly to logical 1

All the other SELOGIC settings in *Figure 5.1* are set directly to logical 0.

"YELLOW OPERATING HANDLE" TRIP AND DRIVE-TO-LOCKOUT

The factory-default TR3X trip setting (Figure 5.2) and 79DTL3X drive-to-lockout setting (Figure 6.5) are set the same for G&W Viper-ST, Siemens SDR Triple-Single, and Kyle NOVA-TS or NOVA-STS Triple-Single reclosers. These settings propagate the pulling of a single yellow operating handle (on a single phase) to trip and lock out all three phases.

The Joslyn TriMod 600R recloser does not need the TR3X "yellow operating handle" trip setting because the single yellow operating handle on the unit opens all three phases directly.

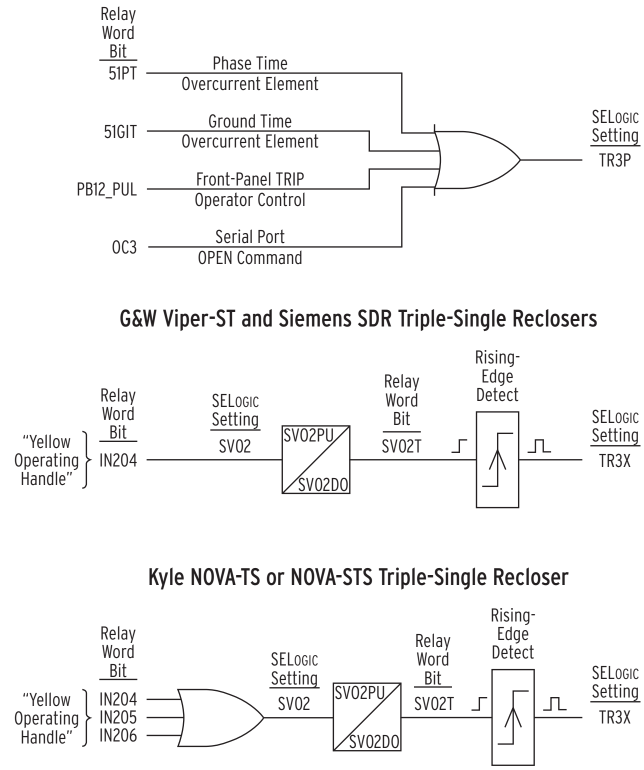


Figure 5.2 Factory Default Trip Logic Settings

As shown in SELOGIC trip setting TR3P in *Figure 5.2*, overcurrent tripping is by either the phase (51PT) or ground time-overcurrent (51G1T) elements. Each of these overcurrent elements can operate in a fast curve or delay curve mode (see *Section 4*). Additional tripping comes from the front-panel **{TRIP}** pushbutton (PB12_PUL) or the serial port **OPEN** command (**OC3**).

Yellow Operating Handle (G&W Viper-ST, Siemens SDR Triple-Single, and Kyle NOVA-TS or NOVA-STS Triple-Single Reclosers)

For the G&W Viper-ST and Siemens SDR Triple-Single reclosers, additional tripping can occur for the time-qualified, rising-edge assertion (SELOGIC operator R_TRIG) of input IN204. Input IN204 detects the operation of any one of the yellow operating handles on the single-phase units of the recloser (see *Figure 2.49* and *Figure 2.65*). For the Kyle NOVA-TS or NOVA-STS Triple-Single recloser, inputs IN204, IN205, or IN206 detect the operation of the yellow operating handles on Phase 1, 2, or 3, respectively (see *Figure 2.60*). These manual trip conditions are propagated to all three phases, via SELOGIC trip setting TR3X. Each single-phase unit has its own yellow operating handle; operation of this handle manually opens up the single-phase unit and effectively locks it out.

The yellow operating handle could be used in an emergency situation, where tripping of all three phases is necessary. In such a situation, it would take too long to manually operate each individual yellow operating handle on each single-phase recloser unit. Thus, the factory-default TR3X setting propagates the trip operation of one yellow operating handle to the other two single-phase recloser units.

The factory-default settings for timer SV02T in *Figure 5.2* are SV02PU := 5.00 cycles and SV02DO := 60.00 cycles. The 5 cycles setting gives time for the yellow operating handle actuated single-phase unit to lockout its trip/close circuit, before a trip signal is issued to all the units, including the one that is locked out. The 60 cycles setting helps prevent any spurious signal dropout and subsequent apparent rising edge, thus avoiding any unintentional trip.

Minimum Trip Duration Timer

The Minimum Trip Duration Timer (with setting TDURD) establishes the minimum time duration for which the TRIP3P, TRIPA, TRIPB, and TRIPC Relay Word bits assert in *Figure 5.1*.

The factory-default setting of TDURD := 40.00 cycles covers the operation requirements of all compatible reclosers. This 40-cycle minimum trip time effectively adds on to any open-interval time for autoreclosing (see *Skip-Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively) on page 6.28*; setting 79STL3P := TRIP3P). If the recloser is not a motor-operated recloser (see *Motor-Operated Traditional Retrofit Reclosers on page 2.56*) and this 40 cycles is too much additional delay for open-interval timing, then set:

TDURD := **12 cycles**

ULTR3P := **NOT 52A3P** (if recloser is also a Traditional Retrofit standard recloser)

As shown in the time line example in *Figure 5.3*, the Minimum Trip Duration Timer (with setting TDURD) outputs a logical 1 (Signal 2) for a time duration of TDURD cycles any time it sees a rising edge on its input (logical 0 to logical 1 transition on Signal 1), if it is not already timing (timer is reset). If Signal 1 in *Figure 5.3* is logical 1 beyond the TDURD time, Signal 3 remains asserted at logical 1 for as long as Signal 1 remains at logical 1, regardless of other trip logic conditions.

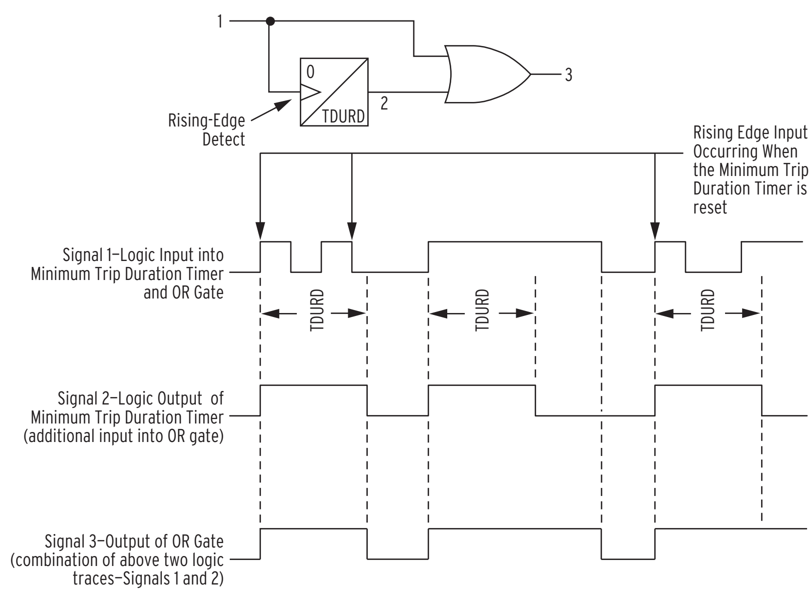


Figure 5.3 Minimum Trip Duration Timer Operation

Program Outputs for Tripping the Recloser

See *Trip and Close Mapping and Output Logic on page 7.29* for more information on programming outputs for tripping the recloser. Relay Word bits TRIP3P, TRIPA, TRIPB, and TRIPC from *Figure 5.1* are used to program trip outputs.

Trip Output Logic Used in Other Settings

In addition to operating trip outputs, the TRIP3P, TRIPA, TRIPB, and TRIPC Relay Word bits from *Figure 5.1* are traditionally used in a number of other SELOGIC control equations settings, such as the following (discussed in *Section 6*):

- ULCL (unlatch close settings)
- 79RI (reclose initiate settings)
- 79DTL (drive-to-lockout settings)
- 79STL (stall open interval timing settings)

Change the Trip Settings— Check Other Settings

Any time trip logic settings TRSOTF, TR3X, TR3P, ULTR3P, TRA, TRB, or TRC from *Figure 5.1* are changed/modified, the following SELOGIC control equations should be checked or considered for modification.

Table 5.2 Settings to Modify When Modifying Trip Logic Settings

Setting	Modification
79DTL3P, 79DTL3X	Drive-to-lockout settings—see *Section 6* For example, if frequency element 81D1T is added to the three-phase trip setting (TR3P := … OR 81D1T …), but no autoreclosing should occur after an underfrequency load-shedding trip, then frequency element 81D1T should be added to the three-phase drive-to-lockout setting (79DTL3P := … OR 81D1T …).
50xTC-51xTC	Torque control for overcurrent elements—see *Section 4* For example, if ground time-overcurrent element 51G2T is added to the factory-default trip settings (TR3P := … 51G2T …), check its corresponding torque control setting (51G2TC). Should it be enabled all the time (51G2TC := 1)? Should it be controlled by the **{GROUND ENABLED}** operator control (51G2TC := LT01; see *Table 11.9*)?
T01_LED–T24_LED	Programmable target LEDs *Front-Panel Target LEDs on page 5.10* shows the correlation between tripping elements in factory-default SELOGIC control equation trip settings and the programmable front-panel target LEDs. For example, if ground time-overcurrent element 51G2T is added to the three-phase trip settings (TR3P := … OR 51G2T …), it should perhaps be added to the FAST CURVE or DELAY CURVE trip target LED setting (e.g., T09_LED := … OR 51G2T …) and its pickup indication (51G2) should be added to the GROUND fault type target LED setting (T06_LED := … OR 51G2 …). An additional example, if frequency element 81D1T is added to the factory-default trip setting (TR3P := … OR 81D1T …), then frequency element 81D1T should be assigned to the dedicated FREQUENCY trip target LED setting (T11_LED := 81D1T).
ER	Event report trigger conditions—see *Section 12* For example: if residual ground time-overcurrent element 51G2T is added to the three-phase trip settings (TR3P := … OR 51G2T …), consider adding its pickup indication (51G2) to the event report trigger conditions setting (ER := … OR R_TRIG 51G2 …). A rising edge operator (R_TRIG) is added on front of the element.
FAULT	Fault indication-used to help determine phases involved in faults and to block certain metering functions during faults For example, if residual ground time-overcurrent element 51G2T is added to the three-phase trip settings (TR3P := … OR 51G2T …), consider adding its pickup indication (51G2) to the fault indication setting (FAULT := … OR 51G2 …).

Pole Open Logic

Combinations of the following items make up the single-pole open and three-pole open logic in *Figure 5.4*.

- ➤ load current detection
- ➤ breaker (recloser) pole status (52a auxiliary contacts)

This logic verifies that the poles/phases of the breaker (recloser) are open.

NOTE: The logic in Figure 5.5 can be used for load current detection, independent of the pole open logic in Figure 5.4.

Figure 5.5 shows the load current detection logic, with available single-phase values. Phase pickup setting 50LP is set below minimum load current levels.

In *Figure 5.4*, the breaker (recloser) type setting BKTYP makes the large demarcation for the following recloser types:

- ➤ BKTYP := 1 (single-phase)
- ➤ BKTYP := 3 (three-phase)

In general, the following is required to indicate single-pole open (SPO) or three-pole open (3PO) conditions:

- ➤ an absence of current (Relay Word bit 50L*x* deasserted)
- ➤ a breaker auxiliary contact indication of open recloser poles (Relay Word bit 52A*x* deasserted).

The 3POD and SPOD dropout time settings qualify circuit breaker closure and are usually set around one cycle.

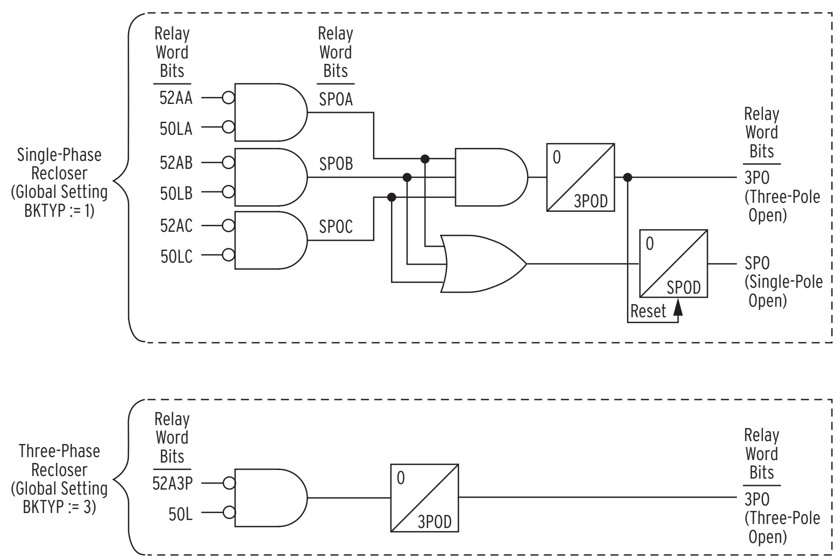


Figure 5.4 Pole Open Logic

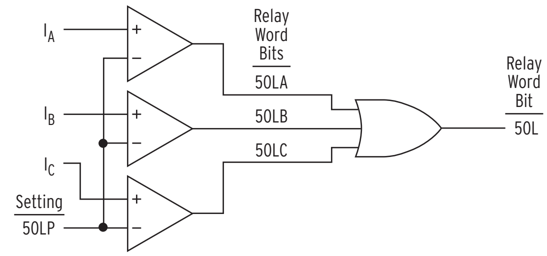


Figure 5.5 Load Current Detection Logic

Overcurrent Element Torque Control Setting Application

If a single-phase recloser is operating in a single-phase trip/reclose mode, one or two phases can trip open, while at least one phase remains closed, carrying load current. This can result in large unbalance current (zero-sequence and negative-sequence current). To keep zero-sequence (ground) and negative-sequence overcurrent elements from operating for this unbalance situation, the SPO (single-pole open) Relay Word bit is entered in the respective torque control SELOGIC settings of these overcurrent elements. The SPO Relay Word bit is programmed in the torque control SELOGIC settings such that when SPO asserts (= logical 1), the torque control SELOGIC settings effectively deassert (= logical 0). For example, set a ground time-overcurrent element as follows:

51GITC := **... AND NOT (SPO AND SPE)**

SPE asserts to logical 1 when group setting ESPB := Y (enabling single-phase settings/operation). This matches the recommended torque control settings for ground time-overcurrent elements in SEL Quickset Design Template Guide (LDG002-01), *Single-Phase Operation Setting for the SEL-651R 32-Pin Recloser Control*.

The three-pole open logic output (Relay Word bit 3PO) is used in the following switch-onto-fault logic subsection.

Switch-Onto-Fault (SOTF) Trip Logic

Switch-Onto-Fault (SOTF) trip logic is enabled with group setting ESOTF := Y and provides a programmable time window for selected elements to trip right after the circuit breaker/recloser closes. Switch-onto-fault implies that a recloser is closed into an existing fault condition.

For example, suppose safety grounds are accidentally left attached to a line after a clearance. If the recloser is closed into such a condition, the resulting fault needs to be cleared right away and reclosing blocked. An instantaneous overcurrent element is usually set to trip in the SOTF trip logic.

Refer to the SOTF trip logic in *Figure 5.1*. This logic permits tripping if both of the following occur:

- An element asserts in SELOGIC control equation trip setting TRSOTF
- Relay Word bit SOTFE is asserted to logical 1

Relay Word bit SOTFE (the output of the SOTF logic) provides the effective time window for an element in trip setting TRSOTF (e.g., TRSOTF := 50P2) to trip after the circuit breaker closes. *Figure 5.6* and the following discussion describe the SOTF logic.

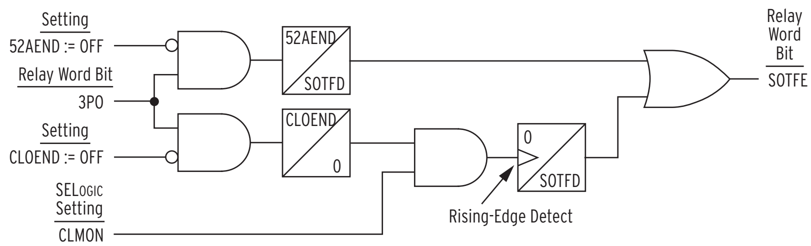


Figure 5.6 Switch-Onto-Fault (SOTF) Logic

Circuit Breaker Operated SOTF Logic

Circuit-breaker operated switch-onto-fault logic is enabled by making time setting 52AEND (52AEND ≠ OFF). Time setting 52AEND qualifies the three-pole open (3PO) condition and then asserts Relay Word bit SOTFE:
SOTFE = logical 1.

Note that SOTFE is asserted when the circuit breaker is qualified as open (see *Figure 5.7*). This allows elements set in the SELOGIC control equation trip setting TRSOTF to operate if a fault occurs when the circuit breaker is open. In such a scenario (e.g., flashover inside the circuit breaker tank), the tripping via setting TRSOTF cannot help in tripping the circuit breaker, which is already open, but can initiate breaker failure protection, if a breaker failure scheme is implemented in the SEL-651R or externally.

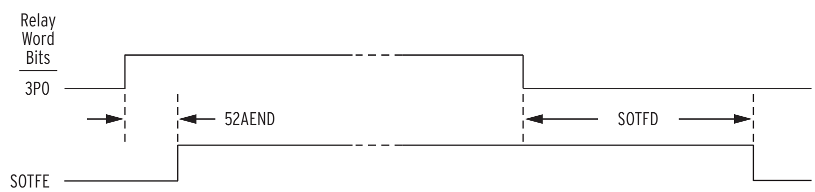


Figure 5.7 SOTF Logic Output (52AEND ≠ OFF)

When the circuit breaker is closed, the 3PO condition deasserts (3PO = logical 0) after the 3POD dropout time (setting 3POD is usually set for no more than a cycle). The SOTF logic output, SOTFE, continues to remain asserted at logical 1 for dropout time SOTFD.

Close Bus Operated SOTF Logic

Close bus operated switch-onto-fault logic is enabled by making time setting CLOEND (CLOEND ≠ OFF). Time setting CLOEND qualifies the three-pole open (3PO) condition, indicating that the circuit breaker is open.

Circuit breaker closure is detected by monitoring the dc close bus. This is accomplished by wiring an optoisolated input on the SEL-651R (e.g., IN101) to the dc close bus. When a manual close or automatic reclosure occurs, optoisolated input IN101 is energized. SELOGIC control equation setting CLMON (close bus monitor) monitors the optoisolated input IN101:

CLMON := **IN101**

When optoisolated input IN101 is energized, CLMON asserts to logical 1. At the instant that optoisolated input IN101 is energized (close bus is energized), the circuit breaker is still open (3PO = logical 1), so the output of the CLOEND timer continues to be asserted to logical 1. Thus, the ANDed combination of these conditions latches in the SOTFD timer (see *Figure 5.8*). The SOTFD timer outputs a logical 1 for a time duration of SOTFD cycles any time it sees a rising edge on its input (logical 0 to logical 1 transition), if it is not already timing. The SOTF logic output, SOTFE, asserts to logical 1 for SOTFD time, like the edge-triggered timer in *Figure 5.3*.

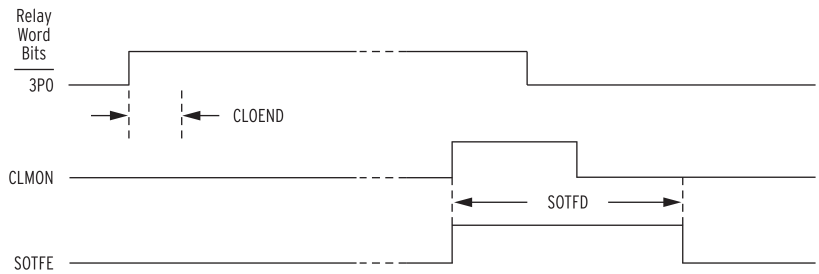


Figure 5.8 SOTF Logic Output (CLOEND ≠ OFF)

Switch-Onto-Fault Logic Output (SOTFE)

Relay Word bit SOTFE is the output of the circuit-breaker operated SOTF logic or the close bus operated SOTF logic described previously. Time setting SOTFD in each of these logic paths provides the effective time window for the overcurrent elements in SELOGIC control equation trip setting TRSOTF to trip after the circuit breaker closes (see *Figure 5.1*). Time setting SOTFD is usually set around 30 cycles.

Front-Panel Target LEDs

Refer to *Figure 11.13* for the layout of the front-panel target LEDs. The functions and associated settings for these target LEDs are described in *Table 5.3*.

Not All Front-Panel Target LEDs Are Set and Functional

Even though there is a front-panel inscription for every target LED, not all of these LEDs are programmed from the factory—some are just left set to logical 0. For example, the SELOGIC setting T07_LED for the SEF labeled LED is programmed T07_LED := 0.

Table 5.3 SEL-651R Front-Panel Target LED Labels and Settings (Factory Defaults) (Sheet 1 of 2)

Label/Definition	LED Color (Front-Panel Setting) [R = red, G = green, A = amber][a]	Logic Input (Front-Panel SELOGIC Setting)	Latch In On Trip? (Front-Panel Setting)	Logic Output (Relay Word Bit)
ENABLED	LEDENAC := G			EN
TRIP	LEDTRAC := R			TRIPLED
SUPPLY —control power source OK	T01LEDC := G	T01_LED := PWR_SRC1	T01LEDL := N	TLED_01
BATTERY PROBLEM	T02LEDC := R	T02_LED := BTFAIL	T02LEDL := N	TLED_02
A FAULT —A-phase involved	T03LEDC := R	T03_LED := PHASE_A	T03LEDL := Y	TLED_03
B FAULT —B-phase involved	T04LEDC := R	T04_LED := PHASE_B	T04LEDL := Y	TLED_04
C FAULT —C-phase involved	T05LEDC := R	T05_LED := PHASE_C	T05LEDL := Y	TLED_05
GROUND —involved in fault	T06LEDC := R	T06_LED := 51G1	T06LEDL := Y	TLED_06
SEF —SEF element tripped for fault	T07LEDC := R	T07_LED := 0	T07LEDL := Y	TLED_07

Table 5.3 SEL-651R Front-Panel Target LED Labels and Settings (Factory Defaults) (Sheet 2 of 2)

Label/Definition	LED Color (Front-Panel Setting) [R = red, G = green, A = amber][a]	Logic Input (Front-Panel SELOGIC Setting)	Latch In On Trip? (Front-Panel Setting)	Logic Output (Relay Word Bit)
FAST CURVE —trip	T08LEDC := R	T08_LED := NOT(51G1S) AND 51G1T OR NOT(51PS) AND 51PT	T08LEDL := Y	TLED_08
DELAY CURVE —trip	T09LEDC := R	T09_LED := 51G1S AND 51G1T OR 51PS AND 51PT	T09LEDL := Y	TLED_09
HIGH CURRENT —inst. or def.-time overcurrent trip	T10LEDC := R	T10_LED := 0	T10LEDL := Y	TLED_10
OVER/UNDER FREQUENCY —trip	T11LEDC := R	T11_LED := 0	T11LEDL := Y	TLED_11
OVER/UNDER VOLTAGE —trip	T12LEDC := R	T12_LED := 0	T12LEDL := Y	TLED_12
79 RESET —reclosing relay state	T13LEDC := G	T13_LED := 79RS3P	T13LEDL := N	TLED_13
79 CYCLE —reclosing relay state	T14LEDC := R	T14_LED := 79CY3P	T14LEDL := N	TLED_14
79 LOCKOUT —reclosing relay state	T15LEDC := R	T15_LED := 79LO3P	T15LEDL := N	TLED_15
ABOVE MIN TRIP —current level	T16LEDC := R	T16_LED := 51P OR 51G1	T16LEDL := N	TLED_16
COLD LOAD SCHEME ON —scheme active	T17LEDC := R	T17_LED := 0	T17LEDL := N	TLED_17
REVERSE POWER —flow	T18LEDC := R	T18_LED := 0	T18LEDL: = N	TLED_18
VAY ON	T19LEDC := R	T19_LED := 59YA1	T19LEDL := N	TLED_19
VBY ON	T20LEDC := R	T20_LED := 59YB1	T20LEDL := N	TLED_20
VCY ON	T21LEDC := R	T21_LED := 59YC1	T21LEDL := N	TLED_21
VAZ ON	T22LEDC := R	T22_LED := 0	T22LEDL := N	TLED_22
VBZ ON	T23LEDC := R	T23_LED := 0	T23LEDL := N	TLED_23
VCZ ON	T24LEDC := R	T24_LED := 0	T24LEDL := N	TLED_24

[a] The target LED color settings LEDTRAC (for the TRIP LED) and TxxLEDC (for the SOURCE through VCZ ON LEDs) are only present when tricolor LEDs are ordered for the SEL-651R. If tricolor LEDs are not ordered, then these LEDs are all red, except for the two green LEDs (SUPPLY and 79 RESET). The ENABLED LED always comes as a tricolor LED.

Front-Panel Target LEDs ENABLED and TRIP

The **ENABLED** and **TRIP** LEDs (top of *Table 5.3*) are not programmable except for choosing the LED illuminated color; they are fixed-function LEDs. The **ENABLED** LED illuminates when the SEL-651R is powered correctly, is functional, and has no self-test failures. The **TRIP** LED illuminates and latches in at the rising-edge of any trip that comes from the trip logic in *Figure 5.1*.

Programmable Front-Panel Target LEDs

Refer to *Table 5.3* and *Figure 5.9*.

The LEDs in *Table 5.3*, factory-default labeled as SUPPLY through VCZ ON, are programmable via the front-panel settings shown in *Table 5.3*. SELOGIC setting T*xx*_LED is the condition/element being monitored. Setting T*xx*LEDL determines whether the state of the condition/element being monitored is latched in on trip (setting T*xx*LEDL := Y) or not (setting T*xx*LEDL := N).

For an individual LED to be latched in (constantly illuminated) at the occurrence of a trip, the following have to be true:

- "latch in on trip?" setting T*xx*LEDL := Y
- a new trip has to occur, from the trip logic in *Figure 5.1*
- the SELOGIC setting T*xx*_LED (the condition/element being monitored) has to be asserted (effectively, T*xx*_LED = logical 1) sometime during a 1.5 cycle time window. The time window starts at the occurrence of the trip.

Latched-in LEDs, including the dedicated **TRIP** LED, remain latched in (constantly illuminated) until one of the following occurs:

- a new trip occurs, from the trip logic in *Figure 5.1*
- or the reset trip-latched LEDs on close setting RSTLED := Y and the recloser closes (any phase) and no trip is present
- or a target reset condition occurs and no trip is present

A target reset condition can be any of the following:

- front-panel **{TARGET RESET}** pushbutton
- **TAR R** serial port command
- target reset SELOGIC setting RSTTRGT
- target reset through DNP protocol

Latched-in LEDs retain their state, even when the relay is powered down, then powered up again.

To program an LED to not be latched in on trip, but to just follow some condition/element, make the following settings for the particular LED:

- "latch in on trip?" setting T*xx*LEDL := N
- SELOGIC setting T*xx*_LED (the condition/element being monitored)

Then, when T*xx*_LED = logical 1, the LED illuminates (Relay Word bit output TLED_*xx* = logical 1). When T*xx*_LED = logical 0, the LED extinguishes (Relay Word bit output TLED_*xx* = logical 0).

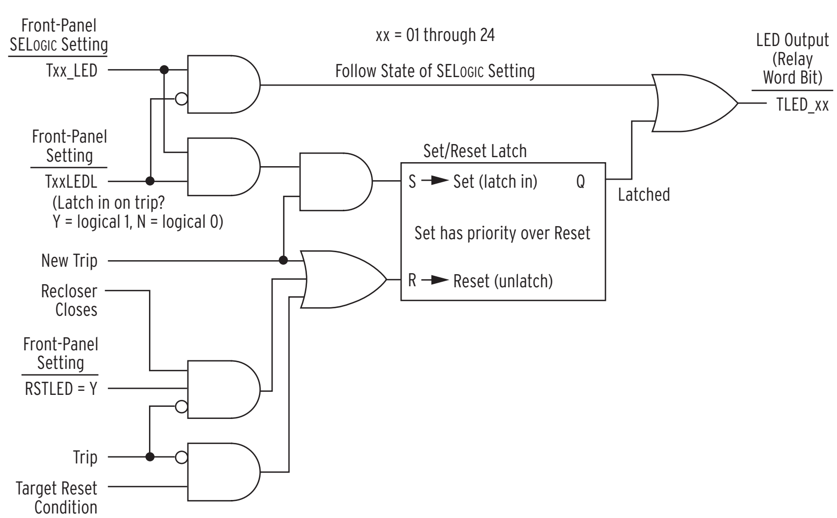


Figure 5.9 Programmable Front-Panel Target LED Logic

Other Uses for Front-Panel Target LED Relay Word Bits

The LED logic outputs, Relay Word bits TLED*xx*, actually drive the front-panel target LEDs. These Relay Word bits can also be used to drive other things, such as output contacts for a discrete-wired SCADA system. For example, to route phase/ground involvement in a fault to SCADA, set separate output contacts individually to TLED_03, TLED_04, TLED_05, and TLED_06, respectively (e.g., OUT101 := TLED_03, OUT102 := TLED_04, OUT103 := TLED_05, OUT104 := TLED_06; see *Table 5.3*).

Correlation Between Trip Target LEDs and Trip Settings

The SELOGIC control equation factory-default trip settings are shown in *Figure 5.2*. The following LED descriptions discuss how some of elements that make up the factory-default trip settings are incorporated into LED settings. If trip settings are changed, front-panel target LED settings changes may also be needed. Front-panel target LED relabeling may also be needed, especially for custom schemes (see SEL-651R Configurable Labels instructions).

TRIP LED

As discussed earlier, the **TRIP** LED illuminates and latches in at the rising-edge of any trip, single-phase or three-phase, that comes from the trip logic in *Figure 5.1*.

GROUND LED

Note in *Table 5.3* that the **GROUND** LED directly contains the pickup indicator of the ground time-overcurrent tripping element (TR3X := … OR 51G1T …), indicating ground involvement in the fault:

T06_LED := **51G1**

FAST CURVE and DELAY CURVE LEDs

The phase and ground time overcurrent elements (51PT and 51G1T, respectively) each switch between operating as a fast curve and as a delay curve. This switching is indicated by the 51PS and 51G1S Relay Word bits, respectively, for elements 51PT and 51G1T (51*x*S = logical 0, indicates fast curve operating mode; 51*x*S = logical 1, indicates delay curve operating mode). See *Time-Overcurrent Elements on page 4.13* for more details.

T08_LED := **NOT(51G1S) AND 51G1T OR NOT(51PS) AND 51PT**

T09_LED := **51G1S AND 51G1T OR 51PS AND 51PT**

ABOVE MIN TRIP LED

The monitored minimum trip pickups are for the phase and ground time-overcurrent elements (51PT and 51G1T, respectively). When current is above one of the pickup indicators, the **ABOVE MIN TRIP** LED illuminates.

T16_LED := **51P OR 51G1**

Note that the **ABOVE MIN TRIP** LED does not latch in on trip.

SELOGIC Control Equation Setting FAULT

SELOGIC control equation setting FAULT has control over or is used in the following:

- ➤ Front-panel target LEDs A FAULT, B FAULT, and C FAULT (with factory Front Panel settings, T03_LED, through T05_LED set as shown in *Table 5.3*).
- ➤ Demand Metering-FAULT is used to suspend demand metering peak recording. See *Demand Metering on page 8.6*.

- Maximum/Minimum Metering-FAULT is used to block Maximum/Minimum metering updating. See *Maximum/ Minimum Metering Update and Storage on page 8.17*.
- Voltage Sag, Swell Interruption elements-FAULT is used to suspend the calculation of Vbase. See *Voltage Sag, Swell, and Interruption Elements on page 4.48*.

The FAULT setting is located in the Global settings class—see *Global Settings on page SET.1*.

Section 6
Close and Reclose Logic

Introduction

Figure 6.1 provides an overview of the close logic and reclosing relay logic described in this section. This logic is provided for the following:

- ➤ Three-phase reclosers or single-phase reclosers operating in a three-phase mode (group setting ESPB := N; one reclosing relay available—one for all three phases)
- ➤ Single-phase reclosers operating in a single-phase mode (group setting ESPB := Y; three separate reclosing relays available—one for each phase)

Figure 6.1 shows a logic migration:

- ➤ From main reclosing relay logic
- ➤ To reclose supervision logic
- ➤ To close logic

In this section, these logic subsections are discussed in reverse order, starting with Breaker Status Logic. If you are not using the SEL-651R for automatic reclosing, but using it to close the recloser for other close conditions (such as manual close initiation via serial port or optoisolated outputs), focus on the Breaker Status Logic and Close Logic subsections. Note particularly the description of SELOGIC® control equation setting CL in the Close Logic subsection.

Breaker Status Logic. Breaker Status Logic shows how the effective breaker status (Relay Word bits 52A*x*; *x* = 3P, A, B, or C) is derived for the required application, three-phase or single-phase mode.

Close Logic. Close Logic describes the final logic that controls the close output. This output controls the recloser for automatic reclosures and other close conditions.

NOTE: Reclose enable setting E79 := N defeats the reclosing relay, but does not defeat the ability of the close logic described in the first subsection (Figure 6.3) to close the circuit breaker for other close conditions via SELOGIC control equation setting CL.

Reclose Supervision 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.

Reclosing Relay Logic. Reclose Logic describes the remaining reclosing relay settings and logic needed for automatic reclosing.

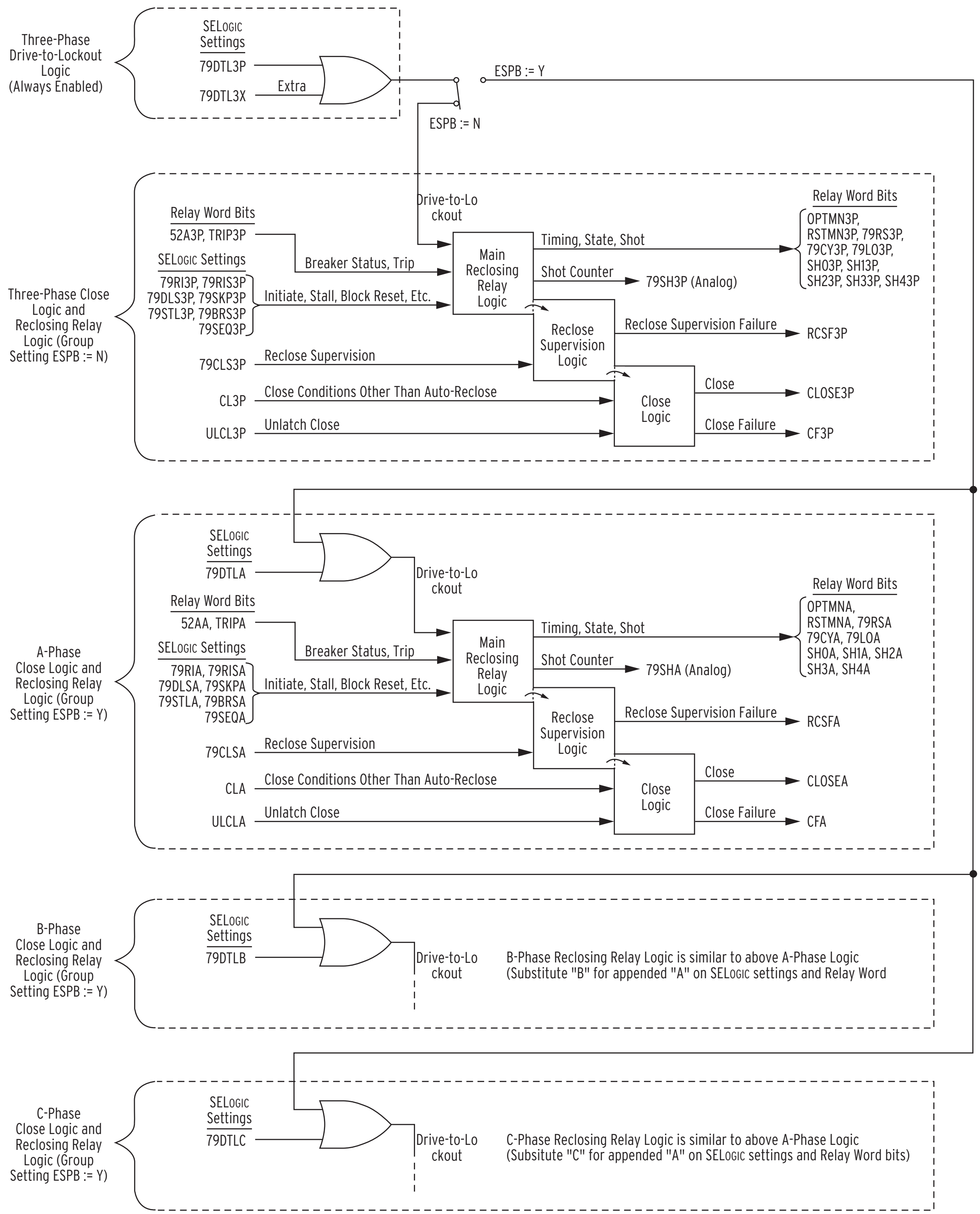


Figure 6.1 Close Logic and Reclosing Relay Logic Overview for Three-Phase and Single-Phase Reclosers

Three-Phase (3P) vs. Single-Phase (A, B, and C)

Figure 6.1 and *Figure 6.2* show specific SELOGIC settings and Relay Word bits for the three-phase and single-phase modes. Notice in these figures that:

- 3P is appended for the three-phase mode (ESPB := N)
- A, B, C are appended for the single-phase mode (ESPB := Y)

In the remaining figures and examples of this section, these appended characters are not always shown on the SELOGIC settings and Relay Word bits. For instance, 79RI is shown, rather than 79RI3P or 79RIA, 79RIB, 79RIC.

From *Figure 6.3* on, most of the figures demonstrate the three-pole mode. However, the logic is readily extrapolated and applicable to single-phase applications.

Breaker Status Logic

Table 6.1 Breaker Status Settings/Outputs

	Three-Phase Recloser (Global Setting BKTYP := 3)	Single-Phase Recloser (Global Setting BKTYP := 1)
SELOGIC Settings	52A_3P	52A_A, 52A_B, 52A_C
Relay Word Bits	52A3P	52AA, 52AB, 52AC

Figure 6.2 shows how settings:

- BKTYP: Breaker/recloser Trip Type (global setting)
- ESPB: Enable Single-Phase Breaker/recloser settings (group setting)

enable reclosing relays (and accompanying close logic—see *Figure 6.1*):

- Three separate reclosing relays enabled for single-phase reclosing
- One reclosing relay enabled for three-phase reclosing

and configure the required breaker status:

- Relay Word bits 52AA, 52AB, and 52AC for single-phase reclosing
- Relay Word bit 52A3P for three-phase reclosing

At the upper tier in *Figure 6.2*, the breaker/recloser type setting BKTYP makes the large demarcation for recloser type:

- BKTYP := **1** single-phase
- BKTYP := **3** three-phase

Note that even if a single-phase recloser (setting BKTYP := 1) is set for three-phase reclosing (setting ESPB := N), the single-phase breaker/recloser statuses (Relay Word bits 52AA, 52AB, and 52AC) are still available for monitoring. It is just that the one enabled reclosing relay (one reclosing relay to operate all three phases) uses the derived breaker status 52A3P.

Conversely, even if a single-phase recloser (setting BKTYP := 1) is set for single-phase reclosing (setting ESPB := Y), the three-phase breaker/recloser status (Relay Word bit 52A3P) is still available for monitoring (see first entry for manual date code 20080814 in *Table A.1*). It is just that the three separate, enabled reclosing relays (one reclosing relay per phase) use respective breaker status 52AA, 52AB, and 52AC.

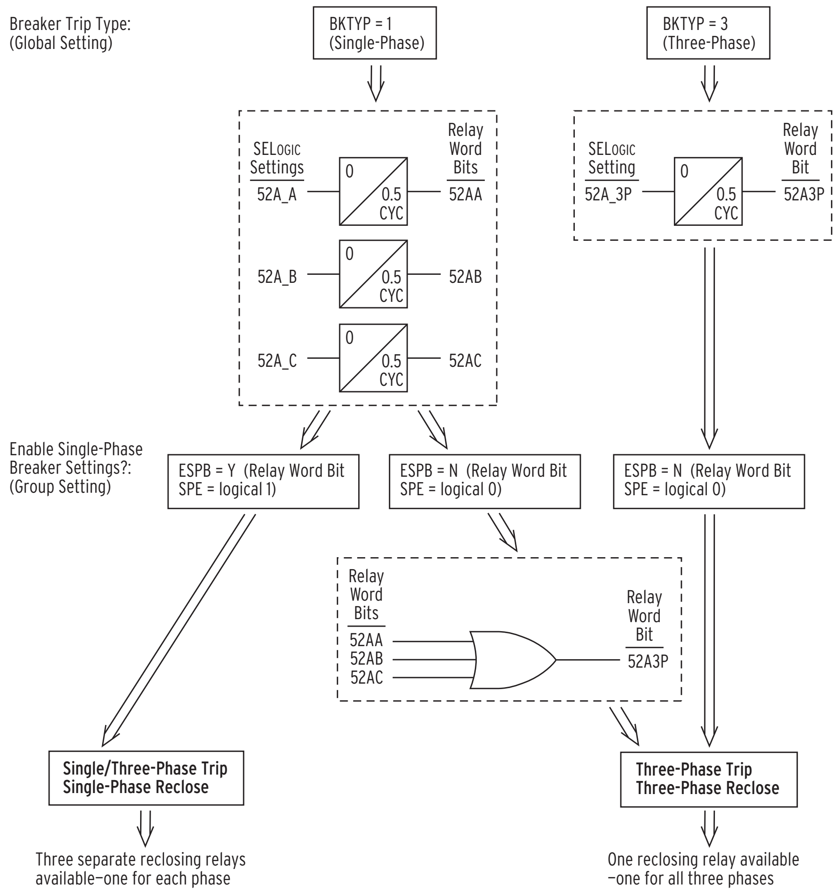


Figure 6.2 Breaker Status Logic

Factory 52A Settings Example (Traditional Retrofit Recloser)

Figure 2.46 shows the monitored trip and close circuit points on Traditional Retrofit reclosers. Switch SW1 is the 52a auxiliary contact in the trip circuit. Relay Word bit SW1 is derived from the monitored trip circuit points (inputs IN203 and IN204) and trip output (controlled by Relay Word bit RCTR1X) status:

SW1 = logical 1 (switch SW1 [52a auxiliary contact] closed)
SW1 = logical 0 (switch SW1 [52a auxiliary contact] open)

SELOGIC setting 52A_3P includes the close output (Relay Word bit RCCL1X) to delay the change of state of Relay Word bit 52A3P until the unlatch close logic (see *Figure 6.5*) unlatches the close signal output CLOSE3P (see *Figure 6.3*):

52A_3P := **SW1 AND NOT RCCL1X**

This ensures that the 52b auxiliary in the close circuit is open (as indicated by input IN201, connected to the close circuit in *Figure 2.46*) before the close signal output is unlatched (CLOSE3P = logical 0). Close signal output CLOSE3P drives the actual close output RCCL1X via SELOGIC setting RCCL1 := CLOSE3P (see *Figure 7.26*).

Factory 52A Settings Example (G&W Viper-ST Recloser)

Figure 2.49 shows the required breaker status wiring for the 52A_*x* (*x* = A, B, C) SELOGIC settings.

52A_A := **IN201**

52A_B := **IN202**

52A_C := **IN203**

Table 9.20 shows variations of the 52A_*x* (*x* = A, B, C) SELOGIC settings for different IPCONN settings.

52A Used in Many Settings

The following factory-default SELOGIC control equations settings use the resultant 52A Relay Word bit:

79RIS3P := **52A3P OR 79CY3P** reclose initiate—see *Table 6.8* and following explanation

PB11_LED := **52A3P...** RECLOSER CLOSED LED—see *Table 11.9*

PB12_LED := **NOT 52A3P...** RECLOSER OPEN LED—see *Table 11.9*

BSYNCH := **52A3P** block synchronism-check elements—see *Figure 4.27*

Close Logic

NOTE: Review Three-Phase (3P) vs. Single-Phase (A, B, and C) on page 6.2.

Table 6.2 Close Logic Settings/Outputs

	Three-Phase Closing (Factory-Default Setting ESPB := N)	Single-Phase Closing (Setting ESPB := Y)
Setting	CFD	CFD
SELOGIC Settings	CL3P	CLA, CLB, CLC
	ULCL3P	ULCLA, ULCLB, ULCLC
Relay Word Bits	CLOSE3P	CLOSEA, CLOSEB, CLOSEC
	CF3P	CFA, CFB, CFC

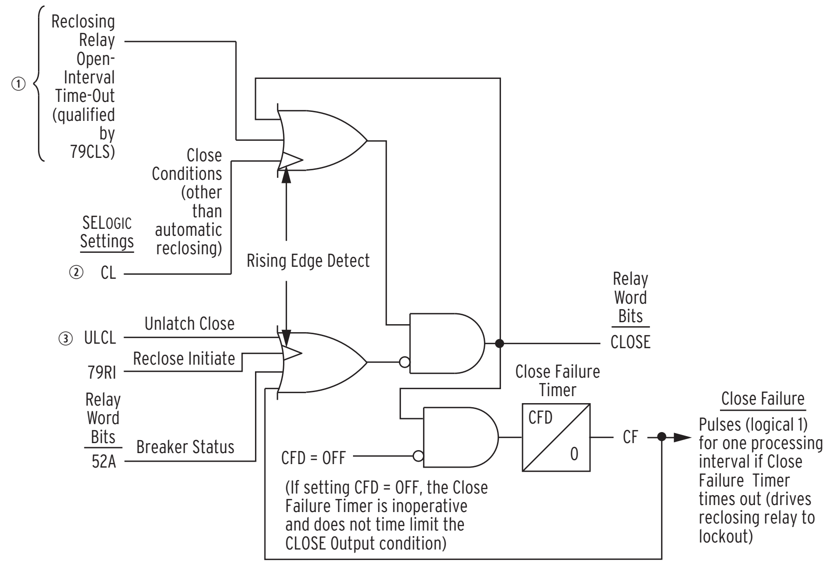
The close logic in *Figure 6.3* provides flexible circuit breaker closing/automatic reclosing with SELOGIC control equation settings:

CL (close conditions, other than automatic reclosing—also see *Figure 6.4*)

ULCL (unlatch close conditions, other than circuit breaker status, close failure, or reclose initiation—also see *Figure 6.5*)

and setting:

CFD (Close Failure Time)



① From Figure 6.6; ② Example in Figure 6.4; see Table 6.2;
③ Example in Figure 6.5; see Table 6.2.

Figure 6.3 Close Logic

Set Close

In *Figure 6.3*, if **all** the following are true:

- ➤ The unlatch close condition is not asserted (ULCL = logical 0).
- ➤ The circuit breaker is open (52A = logical 0).
- ➤ The reclose initiation condition (79RI) is not making a rising edge (logical 0 to logical 1) transition.
- ➤ And a close failure condition does not exist (Relay Word bit CF = 0).

then the CLOSE Relay Word bit asserts to logical 1 if either of the following occurs:

- ➤ A reclosing relay open-interval times out (qualified by SELOGIC control equation setting 79CLS—see *Figure 6.6*).
- ➤ Or SELOGIC control equation setting CL goes from logical 0 to logical 1 (rising edge transition).

Unlatch Close

In *Figure 6.3*, if the CLOSE Relay Word bit is asserted at logical 1, it stays asserted at logical 1 until **one** of the following occurs:

- ➤ The unlatch close condition asserts (ULCL = logical 1).
- ➤ The circuit breaker closes (52A = logical 1).
- ➤ The reclose initiation condition (79RI) makes a rising edge (logical 0 to logical 1) transition.
- ➤ Or the Close Failure Timer times out (Relay Word bit CF = logical 1).

The Close Failure Timer is inoperative if setting CFD := OFF.

Factory CL/ULCL Settings Example

The factory settings for the three-phase (3P) close logic SELOGIC control equation settings are as follows:

CL3P := **(PB11_PUL AND LT05 OR CC3) AND LT06 AND TCCAP**

ULCL3P := **TRIP3P OR (NOT IN201 AND SW1) OR NOT(LT06 AND TCCAP OR CLOSE3P) OR NOT(LT05 OR CLOSE3P OR CC3 OR 79CY3P)**

[= **TRIP3P OR (NOT IN201 AND SW1) OR (NOT LT06 OR NOT TCCAP) AND NOT(CLOSE3P) OR NOT(LT05) AND NOT(CLOSE3P) AND NOT(CC3) AND NOT(79CYC3P)**]

The (NOT IN201 and SW1) logic term in the above ULCL3P factory setting is just for Traditional Retrofit recloser applications—it is not present in factory settings for the other recloser applications.

The factory setting for the Close Failure Timer setting is:

CFD := **60.00 cycles**

Set Close

If the Reclosing Relay Open-Interval Time-Out logic input at the top of *Figure 6.3* is ignored (reclosing is discussed in detail in a following subsection), then SELOGIC control equation setting CL is the only logic input that can set the CLOSE Relay Word bit.

In SELOGIC control equation setting CL (see *Figure 6.4*), closing is provided by:

- {CLOSE} operator control (local)
- Serial port **CLOSE** command (remote)

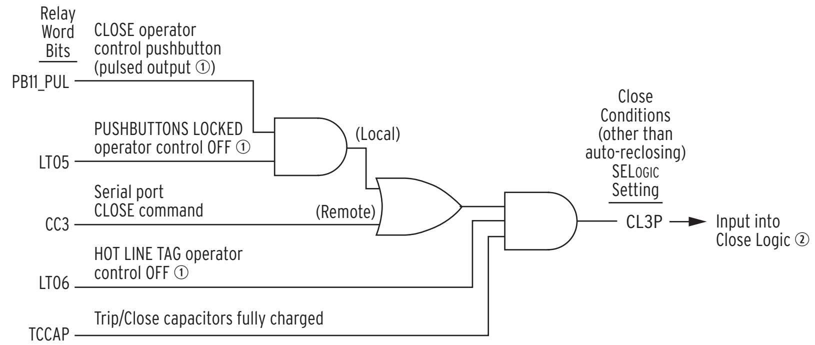
Supervision of these local and remote close signals is provided by:

- {PUSHBUTTONS LOCKED} operator control—supervises {CLOSE} operator control
- {HOT LINE TAG} operator control and TCCAP Relay Word bit—supervise both the {CLOSE} operator control and the serial port **CLOSE** command

Other details:

- The {PUSHBUTTONS LOCKED} operator control also supervises other front-panel operator controls (see *Table 11.9*).
- The {HOT LINE TAG} operator control also supervises automatic reclosing (see *Table 11.9*).
- No “standing close” is possible with the close logic in *Figure 6.4*. The {CLOSE} operator control (Relay Word bit PB11_PUL) and serial port **CLOSE** command (Relay Word bit CC3) pulse for only one processing interval (one quarter cycle) when activated.

  Also, in *Figure 6.3*, SELOGIC control equation setting CL is rising-edge triggered. Thus, if the {PUSHBUTTONS LOCKED} operator control (Relay Word bit LT05) or the {HOT LINE TAG} operator control (Relay Word bit LT06) in *Figure 6.4* are turned ON or OFF, no unexpected close takes place, because there is no standing close condition waiting to get through.



① See Table 11.9, ② See Table 6.3.

Figure 6.4 Close Conditions—Other Than Automatic Reclosing (Three-Phase, Factory-Default)

Unlatch Close

Figure 6.5 shows the additional means to unlatch the close logic, besides those embedded in *Figure 6.3*. The TRIP3P Relay Word bit in setting ULCL3P keeps the TRIP3P and CLOSE3P Relay Word bits from being asserted at the same time—TRIP3P has priority.

The logic in the upper part of *Figure 6.5* is as follows:

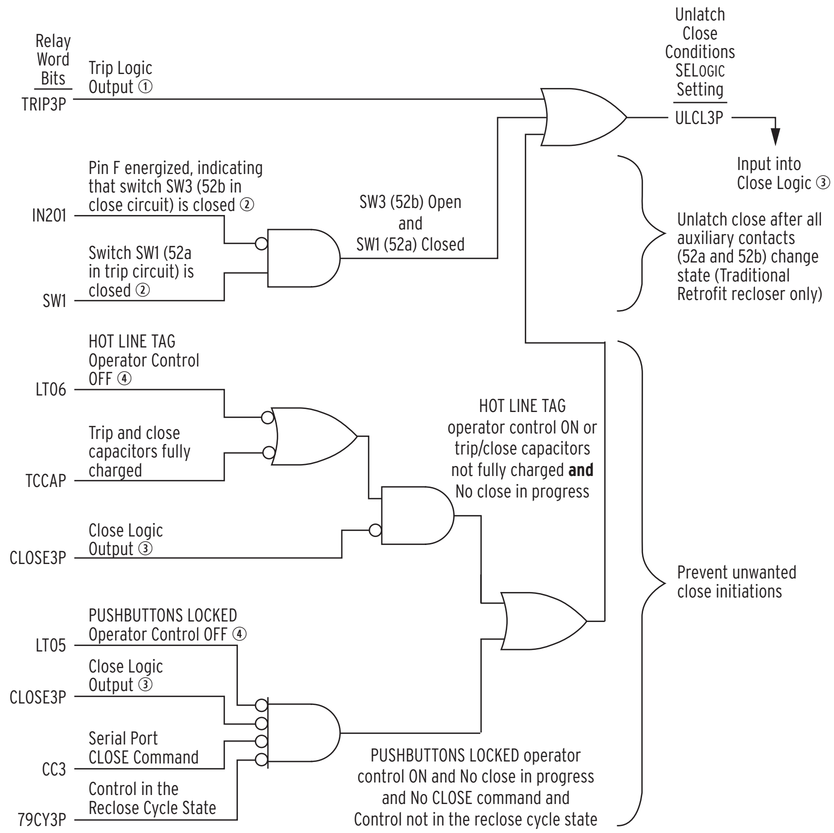
ULCL3P := **... OR (NOT IN201 AND SW1) OR ...**

Logic term (NOT IN201 and SW1) applies only to Traditional Retrofit reclosers. This logic delays unlatching of the close output signal (Relay Word bit CLOSE) in *Figure 6.3* until both auxiliary contacts SW1 (52a) and SW3 (52b) change state for the close operation (see *Figure 2.46*).

The logic in the lower part of *Figure 6.5* is as follows:

ULCL3P := **... OR (NOT LT06 OR NOT TCCAP) AND NOT(CLOSE3P) OR NOT(LT05) AND NOT(CLOSE3P) AND NOT(CC3) AND NOT(79CYC3P)**

This logic is security against unwanted close initiations. The {HOT LINE TAG} operator control and trip/close capacitor monitor are preeminent; if there is no close in progress **and** {HOT LINE TAG} is on or the trip/close capacitors are not fully charged, no new closing can be initiated. The {PUSHBUTTONS LOCKED} operator control is less restrictive; serial port **CLOSE** commands and automatic reclosing are not affected by it. But, in *Figure 6.4*, the {CLOSE} operator control is still supervised by the {PUSHBUTTONS LOCKED} operator control.



① See Figure 5.1, ② See Figure 2.46, ③ See Figure 6.3, ④ See Table 11.9.

Figure 6.5 Unlatch Close Conditions (Three-Phase, Factory-Default)

Close Failure

With setting CFD := 60.00 cycles, once the CLOSE Relay Word bit asserts in *Figure 6.3*, it remains asserted at logical 1 no longer than a **maximum** of 60 cycles. If the Close Failure Timer times out, Relay Word bit CF asserts to logical 1, forcing the CLOSE Relay Word bit to logical 0.

Defeat the Close Logic

Defeat the close logic and reclosing relay logic by setting the corresponding SELOGIC breaker auxiliary settings (52A_) directly to logical 0 (see *Figure 6.2*):

- ➤ For three-phase reclosers or single-phase reclosers operating in a three-phase mode (group setting ESPB := N; one reclosing relay available: one for all three phases), set 52A_3P directly to logical 0 (52A_3P := 0).
- ➤ For single-phase reclosers operating in a single-phase mode (group setting ESPB := Y; three separate reclosing relays available: one for each phase), set at least one of 52A_A, 52A_B, or 52A_C directly to logical 0 (e.g., 52A_B := 0).

  Having one or more SELOGIC breaker auxiliary settings set directly to logical 0 (e.g., 52A_B := 0) defeats the close logic and reclosing relay logic for all three phases.

Program an Output Contact for Closing

See *Trip and Close Mapping and Output Logic on page 7.29* for more information on programming outputs for closing the recloser. Relay Word bits CLOSE3P, CLOSEA, CLOSEB, and CLOSEC from *Figure 6.1* are used to program close outputs.

Reclose Supervision Logic

NOTE: Review Three-Phase (3P) vs. Single-Phase (A, B, and C) on page 6.2.

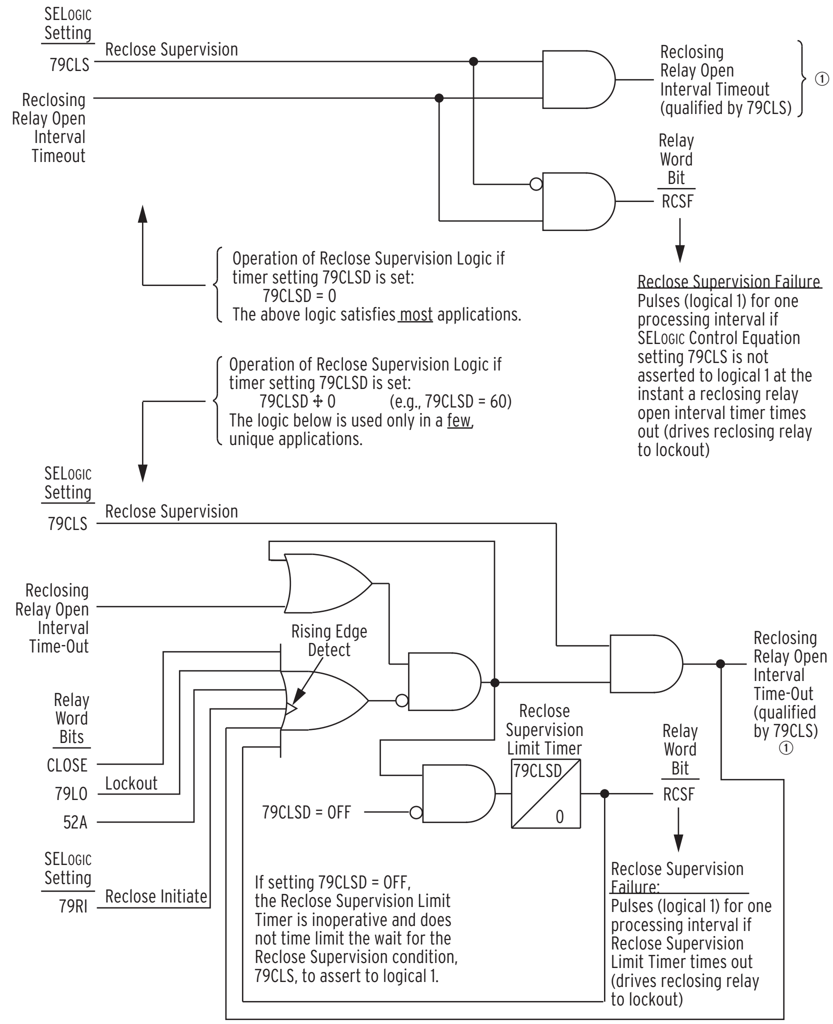
Table 6.3 Reclose Supervision Settings/Outputs

	Three-Phase Reclosing (Factory-Default Setting ESPB := N)	Single-Phase Reclosing (Setting ESPB := Y)
Setting	79CLSD	79CLSD
SELOGIC Settings	79CLS3P	79CLSA, 79CLSB, 79CLSC
Relay Word Bits	RCSF3P	RCSFA, RCSFB, RCSFC

One of the inputs into the close logic in *Figure 6.3* is:

Reclosing Relay Open-interval Time-Out (qualified by 79CLS)

This input is the indication that a reclosing relay open interval has timed out (see *Figure 6.10*), a qualifying condition (SELOGIC control equation setting 79CLS) has been met, and thus automatic reclosing of the circuit breaker should proceed by asserting the CLOSE Relay Word bit to logical 1. This input into the close logic in *Figure 6.3* is an output of the reclose supervision logic in the following *Figure 6.6*.



① See Figure 6.3.

Figure 6.6 Reclose Supervision Logic (Following Open-Interval Time-Out)

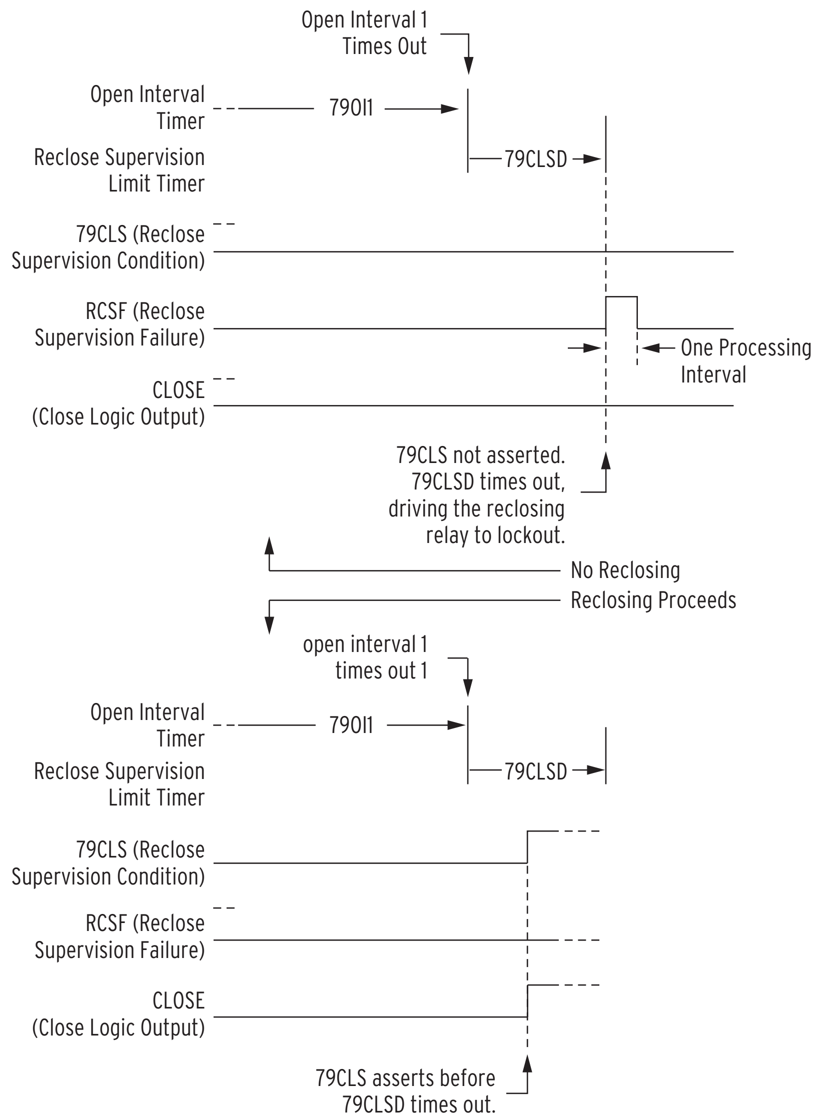


Figure 6.7 Reclose Supervision Limit Timer Operation (Refer to Bottom of Figure 6.6)

Settings and General Operation

Figure 6.6 contains the following SELOGIC control equation setting:

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

and setting:

79CLSD (Reclose Supervision Limit Time)

See *Reclosing Relay on page SET.24* for setting ranges.

For Most Applications (Top of Figure 6.6)

For most applications, the Reclose Supervision Limit Time setting should be set to zero cycles:

79CLSD := **0.00**

With this setting, the logic in the top of *Figure 6.6* is operative. When an open interval times out, the SELOGIC control equation reclose supervision setting 79CLS is **checked just once**.

If 79CLS is **asserted** to logical 1 at the instant of an open-interval time-out, then the now-qualified open-interval time-out will propagate onto the final close logic in *Figure 6.3* to automatically reclose the circuit breaker.

If 79CLS is **deasserted** to logical 0 at the instant of an open-interval time-out:

- ➤ No automatic reclosing takes place.
- ➤ Relay Word bit RCSF (Reclose Supervision Failure indication) asserts to logical 1 for one processing interval.
- ➤ The reclosing relay is driven to the Lockout State.

See *Factory 79CLS Settings Example on page 6.14* and *Additional 79CLS Settings Example 1 on page 6.15*.

For A Few, Unique Applications (Bottom of Figure 6.6 and Figure 6.7)

For a few unique applications, the Reclose Supervision Limit Time setting is **not** set to zero cycles, for example:

79CLSD := **60.00**

With this setting, the logic in the bottom of *Figure 6.6* is operative. When an open-interval times out, the SELOGIC control equation reclose supervision setting 79CLS is then **checked for a time window** equal to setting 79CLSD.

If 79CLS **asserts** to logical 1 at any time during this 79CLSD time window, then the now-qualified open-interval time-out will propagate onto the final close logic in *Figure 6.3* to automatically reclose the circuit breaker.

If 79CLS remains **deasserted** to logical 0 during this entire 79CLSD time window, when the time window times out:

- ➤ No automatic reclosing takes place.
- ➤ Relay Word bit RCSF (Reclose Supervision Failure indication) asserts to logical 1 for one processing interval.
- ➤ The reclosing relay is driven to the Lockout State.

The logic in the bottom of *Figure 6.6* is explained in more detail in the following text.

Set Reclose Supervision Logic (Bottom of Figure 6.6)

Refer to the bottom of *Figure 6.6*. If **all** the following are true:

- ➤ The close logic output CLOSE (also see *Figure 6.3*) is **not** asserted (Relay Word bit CLOSE = logical 0).
- ➤ The reclosing relay is **not** in the Lockout State (Relay Word bit 79LO = logical 0).
- ➤ The circuit breaker is open (52A = logical 0).
- ➤ The reclose initiation condition (79RI) is **not** making a rising edge (logical 0 to logical 1) transition.
- ➤ The Reclose Supervision Limit Timer is **not** timed out (Relay Word bit RCSF = logical 0).

then a reclosing relay open-interval time-out seals in *Figure 6.6*. this allows any assertion of 79CLS to propagate through *Figure 6.6* and on to the close logic in *Figure 6.3*.

Unlatch Reclose Supervision Logic (Bottom of Figure 6.6)

Refer to the bottom of *Figure 6.6*. 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 (also see *Figure 6.3*) asserts (Relay Word bit CLOSE = logical 1).
- ➤ The reclosing relay goes to the Lockout State (Relay Word bit 79LO = logical 1).
- ➤ The circuit breaker closes (52A = logical 1).
- ➤ The reclose initiation condition (79RI) makes a rising edge (logical 0 to logical 1) transition.
- ➤ SELOGIC control equation setting 79CLS asserts (79CLS = logical 1).
- ➤ Or the Reclose Supervision Limit Timer times out (Relay Word bit RCSF = logical 1 for one processing interval).

⚠WARNING
Setting 79CLSD = OFF can create an indefinite "standing close" condition. This is usually not desirable in practice.

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

The unlatching of the sealed-in reclosing relay open-interval time-out condition by the assertion of SELOGIC control equation setting 79CLS indicates successful propagation of a reclosing relay open-interval time-out condition on to the close logic in *Figure 6.3*.

See *Additional 79CLS Settings Example 2 on page 6.16*.

Factory 79CLS Settings Example

Refer to the top of *Figure 6.6*.

The factory-default settings for the SELOGIC reclose supervision setting are as follows:

79CLS3P := **PWR_SRC1 AND TCCAP AND NOT (BTFAIL)** Traditional Retrofit recloser

79CLS3P := **TCCAP AND NOT (BTFAIL)** all others

NOTE: In units withe 125 Vdc power supplies, Relay Word bit BTFAIL is always asserted. BTFAIL should be removed from reclose supervision on these units.

The difference between these factory-default settings is Relay Word bit PWR_SRC1. Relay Word bit PWR_SRC1 indicates the presence of AC power. AC power, such as 120 Vac power, is used by the Traditional Retrofit reclosers to provide the final close energy. If this AC power is not present for these reclosers, there is no need to proceed with the reclosure.

Relay Word bit TCCAP indicates that the trip and close capacitors have sufficient stored energy for trips/reclosures. The monitoring point for TCCAP incorporates the capacitor charger, the capacitors themselves and the connection from the capacitors to the relay module (J205 in *Figure 2.6*, *Figure 2.10*, and *Figure 2.11*). A failure of any one of these elements will be observed by the deassertion of TCCAP. BTFAIL indicates some failure related to the battery or battery system.

The factory-default setting for the reclose supervision time limit setting is as follows:

79CLSD := **900.00 cycles**

Within this 900-cycle time window, following the open-interval time (see *Figure 6.7*), if SELOGIC reclose supervision setting 79CLS3P effectively asserts to logical 1, then reclosing proceeds. Otherwise, if the reclose supervision time limit setting 79CLSD times out before SELOGIC reclose supervision setting 79CLS3P effectively asserts to logical 1, then no reclosure occurs and the reclosing relay is driven to lockout. This relatively long factory-set time was mostly chosen for testing purposes—it can most likely be changed to zero (0.00) cycles for most applications.

Additional 79CLS Settings Example 1

Refer to the top of *Figure 6.6* and *Figure 6.8*.

SEL-651R controls are installed at both ends of a transmission line in a high-speed reclose scheme. After both circuit breakers open for a transmission line fault, the SEL-651R(1) recloses circuit breaker 52/1 first, followed by the SEL-651R(2) reclosing circuit breaker 52/2, after a synchronism check across circuit breaker 52/2.

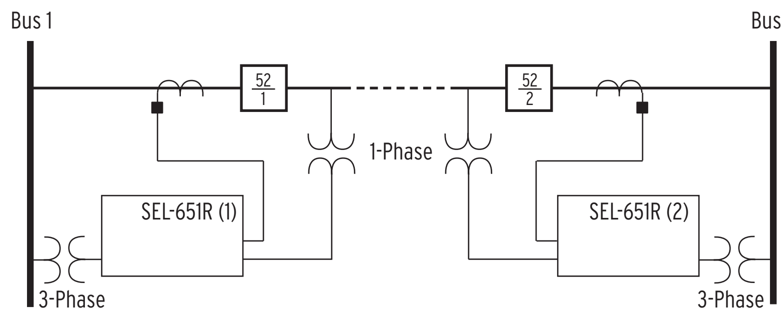


Figure 6.8 SEL-651R Recloser Controls Installed at Both Ends of a Transmission Line in a High-Speed Reclose Scheme

SEL-651R(1)

Before allowing circuit breaker 52/1 to be reclosed after an open-interval time-out, the SEL-651R(1) checks whether Bus 1 voltage is hot and the transmission line voltage is dead. This requires reclose supervision settings:

79CLSD := **0.00 cycles** only one check

79CLS3P := **3P59Y AND 27ZA1**

where:

3P59Y = all three Bus 1 phase voltages are hot

27ZA1 = monitored single-phase transmission line voltage is dead

SEL-651R(2)

Before allowing circuit breaker 52/2 to be reclosed after the reclosing relay open interval times out, the SEL-651R (2) checks whether Bus 2 voltage is hot, the transmission line voltage is hot, and both are in synchronism. This requires reclose supervision settings:

79CLSD := **0.00 cycles** only one check

79CLS3P := **25A1**

where:

25A1 = selected Bus 2 phase voltage is in synchronism with monitored single-phase transmission line voltage and both are hot

Other Setting Considerations for SEL-651R(1) and SEL-651R(2)

Refer to *Skip-Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively) on page 6.28*.

SELOGIC control equation setting 79STL stalls open-interval timing if it asserts to logical 1. If setting 79STL is deasserted to logical 0, open-interval timing can continue.

The SEL-651R(1) has no intentional open-interval timing stall condition (circuit breaker 52/1 closes first after a transmission line fault):

79STL := **0** set directly to logical 0

The SEL-651R(2) starts open-interval timing after circuit breaker 52/1 at the remote end has re-energized the line. The SEL-651R(2) has to see that Bus 2 is hot, the transmission line is hot, and in synchronism across open circuit breaker 52/2 for open-interval timing to begin. Thus, SEL-651R(2) open-interval timing is stalled when the transmission line voltage and Bus 2 voltage are **not** in synchronism across open circuit breaker 52/2:

79STL := **NOT 25A1**

NOTE. A transient synchronism-check condition across open circuit breaker 52/2 could possibly occur if circuit breaker 52/1 recloses into a fault on one phase of the transmission line. The other two unfaulted phases would be briefly energized until circuit breaker 52/1 is tripped again. If the SEL-651R(2) is connected to one of these briefly energized phases, synchronism-check element 25A1 could momentarily assert to logical 1.

So that this possible momentary assertion of synchronism-check element 25A1 does not cause any inadvertent reclose of circuit breaker 52/2, make sure the open-interval timers in the SEL-651R(2) are set with some appreciable time greater than the momentary energization time of the faulted transmission line. Or, run the synchronism-check element 25A1 through a programmable timer before using it in the preceding 79CLS and 79STL settings for the SEL-651R(2). Note the built-in 3-cycle qualification of the synchronism-check voltages shown in *Figure 4.27*.

Additional 79CLS Settings Example 2

Refer to subsection *Synchronism-Check Elements on page 4.33*. Also refer to *Figure 6.7* and *Figure 6.8*.

If the synchronizing voltages across open circuit breaker 52/2 are “slipping” with respect to one another, the Reclose Supervision Limit Timer setting 79CLSD should be set greater than zero so there is time for the slipping voltages to come into synchronism. For example:

79CLSD := **60.00 cycles**

79CLS3P := **25A1**

The status of synchronism-check element 25A1 is checked continuously during the 60-cycle window. If the slipping voltages come into synchronism while timer 79CLSD is timing, synchronism-check element 25A1 asserts to logical 1 and reclosing proceeds.

In the above referenced subsection *Synchronism-Check Elements*, refer to *Synchronism-Check Element Outputs on page 4.41*, Voltages V_P and V_S are “Slipping and Setting TCLOSD ≠ 0.00.” Item 3 describes a last attempt for a synchronism-check reclose before timer 79CLSD times out or setting 79CLSD := 0.00 and only one check is made.

Reclosing Relay

NOTE: Figure 6.1 shows one reclosing relay operative for three-phase reclosing (group setting ESPB := N) and three separate reclosing relays operative for single-phase reclosing (group setting ESPB := Y). Most of the examples in this reclosing relay subsection are three-phase reclosing examples, unless otherwise stated. These three-phase reclosing examples can be readily extrapolated to corresponding single-phase reclosing applications.

Table 6.4 Reclosing Relay Settings/Outputs

	Three-Phase Reclosing (Factory-Default Setting ESPB := N)	Single-Phase Reclosing (Setting ESPB := Y)
Settings	790I1, 79OI2, 79OI3, 79OI4, 79RSD, 79RSLD	790I1, 79OI2, 79OI3, 79OI4, 79RSD, 79RSLD
SELOGIC Settings	79RI3P	79RIA, 79RIB, 79RIC
	79RIS3P	79RISA, 79RISB, 79RISC
	79DTL3P	79DTL3P
	79DTL3X	79DTL3X
		79DTLA, 79DTLB, 79DTLC
	79DLS3P	79DLSA, 79DLSB, 79DLSC
	79SKP3P	79SKPA, 79SKPB, 79SKPC
	79STL3P	79STLA, 79STLB, 79STLC
	79BRS3P	79BRSA, 79BRSB, 79BRSC
	79SEQ3P	79SEQA, 79SEQB, 79SEQC
	79CLS3P	79CLSA, 79CLSB, 79CLSC
Relay Word Bits	OPTMN3P	OPTMNA, OPTMNB, OPTMNC
	RSTMN3P	RSTMNA, RSTMNB, RSTMNC
	79RS3P	79RSA, 79RSB, 79RSC
	79CY3P	79CYA, 79CYB, 79CYC
	79LO3P	79LOA, 79LOB, 79LOC
	SH03P	SH0A, SH0B, SH0C
	SH13P	SH1A, SH1B, SH1C
	SH23P	SH2A, SH2B, SH2C
	SH33P	SH3A, SH3B, SH3C
	SH43P	SH4A, SH4B, SH4C
Analog Outputs	79SH3P	79SHA, 79SHB, 79SHC

Note that input:

Reclosing Relay Open-Interval Time-Out

in *Figure 6.6* is the logic input that is qualified by SELOGIC control equation setting 79CLS, and then propagated on to the close logic in *Figure 6.3* 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 6.6*. Other aspects of the reclosing relay are also explained. Up to four (4) automatic reclosures (shots) are available.

The reclose enable setting, E79, has setting choices N, 1, 2, 3, and 4. Setting E79 := N defeats the reclosing relay. Setting choices 1 through 4 are the number of desired automatic reclosures, with corresponding open-interval time settings.

Reclosing Relay States and General Operation

Table 6.5 Relay Word Bit and Front-Panel Correspondence to Reclosing Relay States

Reclosing Relay State	Corresponding Relay Word Bit	Corresponding Front-Panel LED
Reset	79RS	79 RESET
Reclose Cycle	79CY	79 CYCLE
Lockout	79LO	79 LOCKOUT

The reclosing relay is in one, and only one, of these states (listed in *Table 6.5*) at any time. When in a given state, the corresponding Relay Word bit asserts to logical 1, thus causing the corresponding LED to illuminate. Automatic reclosing only takes place when the relay is in the Reclose Cycle State. *Table 5.3* gives more information about front-panel LED programming.

Figure 6.9 explains in general the different states of the reclosing relay and its operation.

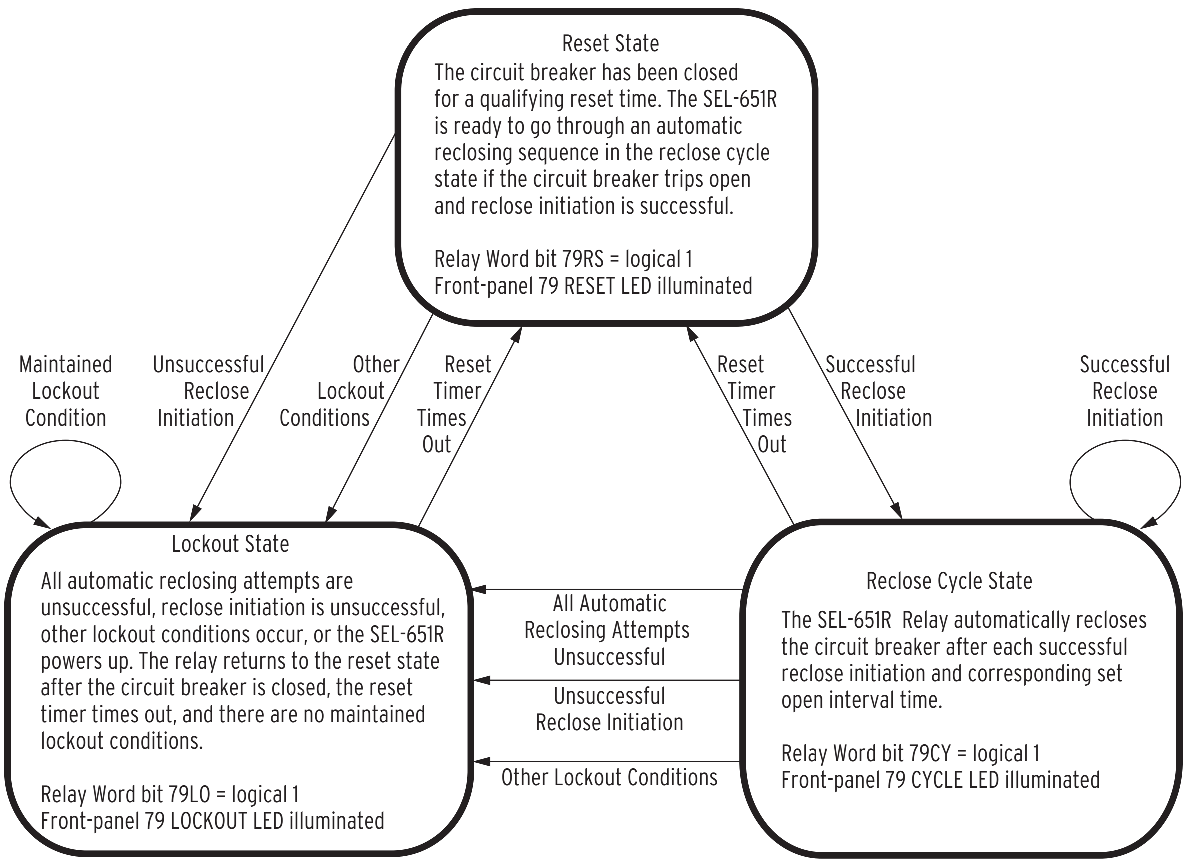


Figure 6.9 Reclosing Relay States and General Operation

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. For example, all automatic reclosing attempts are unsuccessful, see *Figure 6.10*.

- Reclose initiation is unsuccessful because SELOGIC setting 79RIS (reclose initiation supervision) is effectively equal to logical 0.
- The circuit breaker opens without reclose initiation, such as happens with an external trip.
- The shot counter is equal to or greater than last shot, and the circuit breaker is open; for example the shot counter is driven to last shot with SELOGIC control equation setting 79DLS while open-interval timing is in progress.
- The close failure timer (setting CFD) times out (see *Figure 6.3*).
- SELOGIC control equation setting 79DTL = logical 1.
- The Reclose Supervision Limit Timer (setting 79CLSD) times out (see *Figure 6.6* and top of *Figure 6.7*).
- A new reclose initiation occurs while the reclosing relay is timing on an open interval, for example flashover in the tank while breaker is open.

NOTE: Review Three-Phase (3P) vs. Single-Phase (A, B, and C) on page 6.2.

Reclosing Relay States and Settings/Setting Group Changes

If individual settings are changed for the active setting group **or** the active setting group is 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, with last shot corresponding to the new settings; see discussion on last shot that follows.
- The reset timer is loaded with reset time setting 79RSLD. 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, so 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 79RSLD 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 will immediately go to the Lockout State, because shot = last shot.

Defeat the Reclosing Relay

If **either** of the following reclosing relay settings is made:

- Reclose enable setting E79 := N.
- Open-interval 1 time setting 79OI1 := OFF.

then the reclosing relay is defeated, and no automatic reclosing can occur. These settings are explained later in this section.

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

- All three reclosing relay state Relay Word bits (79RS, 79CY, and 79LO) are forced to logical 0 (see *Table 6.5*).
- All shot-counter Relay Word bits (SH0, SH1, SH2, SH3, and SH4) are forced to logical 0 (see *Table 6.7*).
- The analog output 79SH is set to –1 (see *Table 6.7*)
- The front-panel LEDs 79 RESET, 79 CYCLE, and 79 LOCKOUT are all extinguished, a ready indication that the recloser is defeated.

Close Logic Can Still Operate When the Reclosing Relay is Defeated

If the reclosing relay is defeated, the close logic (see *Figure 6.3*) can still operate if SELOGIC control equation circuit breaker status setting 52A__ is set to something other than logical 0. Making the setting 52A__ := 0 defeats the close logic **and** also defeats the reclosing relay. See the discussion in *Defeat the Close Logic on page 6.9*.

Reclosing Relay Timer Settings

The open-interval and reset timer factory settings are shown in *Table 6.6*:

Table 6.6 Reclosing Relay Timer Settings and Setting Ranges

Timer Setting (range)	Factory Setting (in cycles)	Definition
79OI1 (OFF, 12.00–999999 cyc)	300.00	open-interval 1 time
79OI2 (OFF, 90.00–999999 cyc)	600.00	open-interval 2 time
79OI3 (OFF, 120.00–999999 cyc)	600.00	open-interval 3 time
79OI4 (OFF, 120.00–999999 cyc)	OFF	open-interval 4 time
79RSD (180.00–999999 cyc)	1800.00	reset time from reclose cycle state
79RSLD (0.00–999999 cyc)[a]	600.00	reset time from lockout state

[a] 180.00 cycles is the 79RSLD setting range lower limit for SEL-651R recloser controls with older firmware versions (see Table A.1, Manual Date Code entry 20120824).

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

Open-Interval Timers

The reclose enable setting, E79, determines the number of open-interval time settings that can be set. For example, if setting E79 := 3, the first three open-interval time settings in *Table 6.6*, 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 6.6*, the open-interval 4 time setting 79OI4 is the first open-interval time setting set to OFF:

79OI4 := **OFF**

Thus, open-interval time 79OI4 is not operable. But if the settings were:

79OI3 := **OFF**

79OI4 := **900.00 cycles** set to some value other than OFF

open-interval time 79OI4 would still be inoperative, because a preceding open-interval time is set to OFF (i.e., 79OI3 := OFF).

If open-interval 1 time setting, 79OI1, is set to OFF (79OI1 := OFF), 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. In the *Figure 6.10* example, open-interval 1 time setting, 79OI1 := 30, times first. If the subsequent first reclosure is not successful, then open-interval 2 time setting, 79OI2 := 600, starts timing. If the subsequent second reclosure is not successful, the relay goes to the Lockout State because 79OI3 := OFF (no third open interval and subsequently no third reclosure).

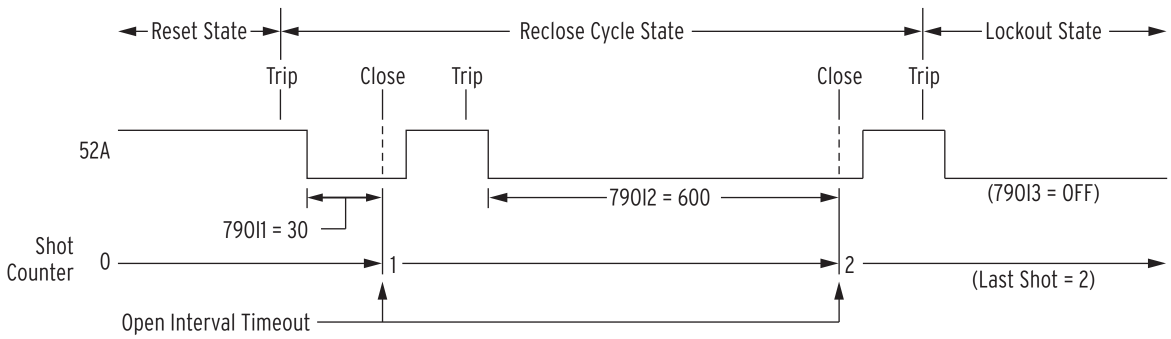


Figure 6.10 Example Reclosing Sequence From Reset to Lockout

SELOGIC control equation setting 79STL (stall open-interval timing) can be set to control open-interval timing.

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 to OFF. The "last shot" value is also equal to the number of reclosures.

In the *Figure 6.10* example, two set open-interval times precede open-interval 3 time, which is set to OFF (79OI3 := OFF):

79OI1 := **30.00**

79OI2 := **600.00**

79OI3 := **OFF**

For this example:

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

Observe Shot-Counter Operation

Observe the reclosing relay shot counter operation, especially during testing, with the front-panel reclose count display—see *Table 11.2*.

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 52A__.

Setting 79RSD:

Qualifies closures when the relay is in the Reclose Cycle State. These closures are usually automatic reclosures resulting from open-interval time-out.

Setting 79RSD is also the reset time used in sequence coordination schemes.

Setting 79RSLD:

Qualifies closures when the relay is in the Lockout State. These closures are usually manual closures. These manual closures can originate externally to the relay, or via the SELOGIC control equation setting CL (see *Figure 6.3*).

Setting 79RSLD is also the reset timer used when the relay powers up, when it has individual settings changed for the active setting group, or when the active setting group is changed.

See *Momentary Drive-to-Lockout While Breaker Closed on page 6.26* for a description of a scenario in which there is no reset timing via setting 79RSLD to go from the lockout state to the reset state. In this scenario, the drive-to-lockout setting, 79DTL, causes the relay to transition between the reset and lockout states while the breaker remains closed continuously.

Typically, setting 79RSLD is set less than setting 79RSD. Such setting of 79RSLD emulates reclosing relays with motor-driven timers that have a relatively short reset time from the lockout position to the reset position. The 79RSD and 79RSLD settings are set independently. Setting 79RSLD can even be set greater than setting 79RSD, if desired. SELOGIC control equation setting 79BRS (block reset timing) can be set to control reset timing.

Monitoring Open-Interval and Reset Timing

Monitor open-interval and reset timing with the following Relay Word bits:

Relay Word Bits	Definition
OPTMN	Indicates that the open-interval timer is **actively** timing
RSTMN	Indicates that the reset timer is **actively** timing

If the open-interval timer is actively timing, OPTMN 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), OPTMN 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 if no stall conditions are present.

If the reset timer is actively timing, RSTMN asserts to logical 1. If the reset timer is not timing, RSTMN deasserts to logical 0.

Reclosing Relay Shot Counter

Refer to *Figure 6.10*.

The shot counter increments for each reclose operation. For example, when the relay is timing on open-interval 1, 79OI1, 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. The shot counter resets back to shot = 0 when the reclosing relay returns to the Reset State.

Table 6.7 Shot Counter Correspondence to Relay Word Bits and Open-Interval Times

Shot	Corresponding Relay Word Bit	Corresponding Open-Interval	Analog Output
0	SH0	79OI1	79SH = 0
1	SH1	79OI2	79SH = 1
2	SH2	79OI3	79SH = 2
3	SH3	79OI4	79SH = 3
4	SH4		79SH = 4
reclosing relay defeated	N/A	N/A	79SH = –1

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., SH2 = logical 1).

The shot counter also increments for sequence coordination operation. The shot counter can increment beyond the last shot for sequence coordination, but no further than shot = 4.

The analog output 79SH can be used in SELOGIC compares. For example, for a recloser operating in a three-phase mode (group setting ESPB := N), the SELOGIC equation:

OUT202 := **79SH3P > 2**

would assert output contact OUT202 when the shot counter is at a value greater than 2.

Reclosing Relay SELOGIC Control Equation Settings Overview

NOTE: The SELOGIC settings in Table 6.8 have an appended "3P" (three-phase).

Table 6.8 Reclosing Relay SELOGIC Control Equation Settings (Sheet 1 of 2)

SELOGIC Control Equation Setting	Factory-Default Setting	Definition
79RI3P	TRIP3P	Reclose Initiate
79RIS3P	52A3P OR 79CY3P	Reclose Initiate Supervision
79DTL3P	(NOT LT02 OR NOT LT06) AND (TRIP3P OR NOT 52A3P) OR PB12_PUL OR OC3	Drive-to-Lockout
79DTL3X (G&W Viper-ST, Joslyn TriMod 600R, Siemens SDR Triple-Single, Kyle NOVA-TS or NOVA-STS Triple-Single)	R_TRIG SV02T	Drive-to-Lockout (extra)
79DTL3X (all others)	0	
79DLS3P	79LO3P	Drive-to-Last Shot
79SKP3P	(51PT OR 51G1T) AND NOT LT04 AND (79SH3P < MV01)	Skip Shot
79STL3P	TRIP3P	Stall Open-Interval Timing
79BRS3P	0	Block Reset Timing
79SEQ3P	0	Sequence Coordination

Table 6.8 Reclosing Relay SELogic Control Equation Settings (Sheet 2 of 2)

SELogic Control Equation Setting	Factory-Default Setting	Definition
79CLS3P (Traditional Retrofit)	PWR_SRC1 AND TCCAP AND NOT (BTFAIL)	Reclose Supervision
79CLS3P (all others)	TCCAP AND NOT (BTFAIL)	

The factory-default settings in *Table 6.8* are discussed in detail in the remainder of this section. They are for three-phase reclosing (factory-default setting ESPB := N).

Reclose Initiate and Reclose Initiate Supervision Settings (79RI and 79RIS, Respectively)

The reclose initiate setting 79RI is a rising-edge detect setting. The reclose initiate supervision setting 79RIS supervises setting 79RI. When setting 79RI detects a rising edge (logical 0 to logical 1 transition), setting 79RIS has to be at logical 1 (79RIS = logical 1) in order for open-interval timing to be initiated.

If 79RIS = logical 0 when setting 79RI detects a rising edge (logical 0 to logical 1 transition), the relay goes to the Lockout State.

Factory 79RI/79RIS Settings Example

With factory settings:

79RI3P := **TRIP3P**

79RIS3P := **52A3P OR 79CY3P**

the transition of the TRIP3P Relay Word bit from logical 0 to logical 1 initiates open-interval timing only if the 52A3P or 79CY3P Relay Word bit is at logical 1.

The circuit breaker has to be closed (circuit breaker status 52A3P = logical 1) at the instant of the first trip of the automatic reclose cycle in order for the SEL-651R to successfully initiate reclosing and start timing on the first open interval. The SEL-651R is not yet in the reclose cycle state (79CY3P = logical 0) at the instant of the first trip.

Then for any subsequent trip operations in the automatic reclose cycle, the SEL-651R is in the reclose cycle state (79CY3P = logical 1) and the SEL-651R successfully initiates reclosing for each trip. Because of factory setting 79RIS3P := 52A3P OR 79CY3P, successful reclose initiation in the reclose cycle state (79CY3P = logical 1) is not dependent on the circuit breaker status (52A3P). This allows successful reclose initiation in the case of an instantaneous trip, but the circuit breaker status indication is slow: the instantaneous trip (reclose initiation) occurs before the SEL-651R sees the circuit breaker close.

If a flashover occurs in a circuit breaker tank during an open interval (circuit breaker open) and the SEL-651R calls for a trip, the SEL-651R goes immediately to lockout.

Additional 79RI/79RIS Settings Example

The preceding settings example initiates open-interval timing on the rising edge of the TRIP3P Relay Word bit. The following is an example of reclose initiation on the opening of the circuit breaker.

With setting:

79RI3P := **NOT 52A3P**

the transition of the 52A3P Relay Word bit from logical 1 to logical 0 (breaker opening) initiates open-interval timing. Setting 79RI3P looks for a logical 0 to logical 1 transition, thus Relay Word bit 52A3P is inverted in the 79RI3P setting.

The reclose-initiate supervision setting 79RIS3P supervises setting 79RI3P. With settings:

79RI3P := **NOT 52A3P**

79RIS3P := **TRIP3P**

the transition of the 52A3P Relay Word bit from logical 1 to logical 0 initiates open-interval timing only if the TRIP3P Relay Word bit is at logical 1 (TRIP3P = logical 1). Thus, the TRIP3P Relay Word bit has to be asserted when the circuit breaker opens in order to initiate open-interval timing. With a long enough setting of the Minimum Trip Duration Timer (TDURD), the TRIP Relay Word bit will still be asserted to logical 1 when the circuit breaker opens (see *Figure 5.1* and *Figure 5.3*).

If the TRIP3P Relay Word bit is at logical 0 (TRIP3P = 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.

Other 79RI/79RIS Settings Considerations

1. If no reclose initiate supervision is desired, make the following setting:

   79RIS := **1** set directly to logical 1

   Setting 79RIS = logical 1 at all times. Any time a logical 0 to logical 1 transition is detected by setting 79RI, open-interval timing will be initiated, unless prevented by other means.

2. If the following setting is made:

   79RI := **0** set directly to logical 0

   reclosing is never initiated. The reclosing relay is effectively inoperative.

3. If the following setting is made:

   79RIS := **0** set directly to logical 0

   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 (79DTL and 79DLS, Respectively)

When 79DTL = logical 1, the reclosing relay goes to the Lockout State (Relay Word bit 79LO = logical 1), and the front-panel LOCKOUT LED illuminates.

Setting 79DTL has a 60-cycle dropout time. This keeps the drive-to-lockout condition up 60 more cycles after 79DTL has reverted back to 79DTL = logical 0. This is useful for situations where both of the following are true:

- Any of the trip and drive-to-lockout conditions are pulsed conditions (e.g., the **OPEN** Command Relay Word bit, OC3, asserts for only 1/4 cycle; refer to *Figure 6.11*).
- Reclose initiation is by the breaker contact opening (e.g., 79RI3P := NOT 52A3P; refer to *Additional 79RI/79RIS Settings Example on page 6.24* in the preceding setting 79RI [reclose initiation] discussion).

Then the drive-to-lockout condition overlaps reclose initiation and the SEL-651R stays in lockout after the breaker trips open.

When 79DLS = 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.

Momentary Drive-to-Lockout While Breaker Closed

If the relay had previously been in the Reset State (Relay Word bit 79RS = logical 1) with the breaker closed and then a drive-to-lockout condition comes true (via setting 79DTL), the relay immediately goes to the Lockout State (Relay Word bit 79LO = logical 1). If the breaker continues to remain closed and then the drive-to-lockout condition (via setting 79DTL) goes away (after the previously discussed 60-cycle dropout time), the relay reverts immediately back to the Reset State.

No reset timing via setting 79RSLD is needed to return to the Reset State in this scenario because the breaker remains closed the entire time. The relay had previously timed on a reset time (setting 79RSD or 79RSLD) when it first went to the Reset State, before the drive-to-lockout logic (via setting 79DTL) started activating. Thus, there is no need to again reset–time–qualify a breaker that remained closed throughout such a transition (Reset State–Lockout State–Reset State), because of drive-to-lockout setting 79DTL.

Factory 79DTL/79DLS Settings Example

The drive-to-lockout factory settings are as follows:

79DTL3P := **(NOT LT02 OR NOT LT06) AND (TRIP3P OR NOT 52A3P) OR PB12_PUL OR OC3**

79DTL3X := **R_TRIG SV02T** (G&W Viper-ST, Siemens SDR Triple-Single, Joslyn TriMod 600R, Kyle NOVA-TS or NOVA-STS Triple-Single)

79DTL3X := **0** (all others)

Settings 79DTL3P and 79DTL3X are functionally equivalent, as evidenced in *Figure 6.1*. Setting 79DTL3X is for extra three-phase drive-to-lockout logic and is seen as a supplement to 79DTL3P. For the single-phase drive-to-lockout logic, settings 79DTL3P and 79DTL3X provide convenient locations to insert three-phase drive-to-lockout conditions (see *Figure 6.1*), rather than repetitively inserting them in each single-phase drive-to-lockout setting (79DTLA, 79DTLB, and 79DTLC).

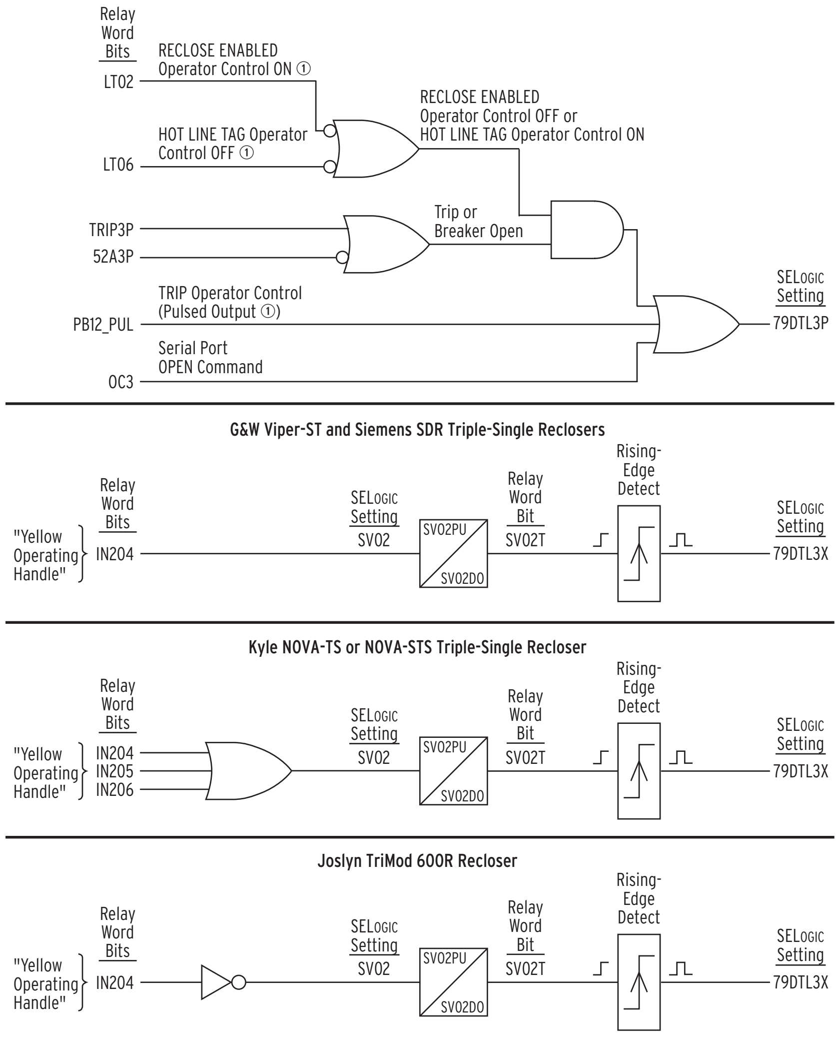
Figure 6.11 shows in more detail the programmed conditions that drive the reclosing relay to lockout:

- If either the {RECLOSE ENABLED} operator control is OFF or the {HOT LINE TAG} operator control is ON **and** a trip occurs or the breaker opens, the reclosing relay is driven to lockout.
- If the {TRIP} operator control is pressed or an **OPEN** command is sent to the serial port, the reclosing relay is driven to lockout. Both these operations are deemed manual operations, thus no automatic reclosing takes place.
- The explanation for the 79DTL3X factory-default setting is found in the side column notes adjacent to *Figure 5.2* and *Figure 6.11*.

"YELLOW OPERATING HANDLE" TRIP AND DRIVE-TO-LOCKOUT

The factory-default TR3X trip setting (Figure 5.2) and 79DTL3X drive-to-lockout setting (Figure 6.11) are set the same for G&W Viper®-ST, Siemens SDR Triple-Single, and Kyle NOVA-TS or NOVA-STS Triple-Single reclosers. These settings propagate the pulling of a single yellow operating handle (on a single phase) to trip and lockout all three phases.

The Joslyn TriMod 600R recloser doesn't need the TR3X "yellow operating handle" trip setting because the single yellow operating handle on the unit opens all three phases directly.



① See Table 11.9.

Figure 6.11 Factory-Default Drive-to-Lockout Logic Settings

The drive-to-last-shot factory setting is:

79DLS3P := **79LO3P**

Three open-intervals are also set in the factory settings, resulting in last shot = 3. Any time the relay is in the lockout state (Relay Word bit 79LO3P = 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 = 3:

79DLS3P := **79LO3P** = Logical 1

Additional 79DTL Settings Example

To drive the relay to the Lockout State for fault current above a certain level when tripping (e.g., level of phase instantaneous overcurrent element 50P3), make settings similar to the following:

79DTL3P := **TRIP3P AND 50P3 OR ...**

Additionally, if the reclosing relay should go to the Lockout State for an underfrequency trip, make settings similar to the following:

79DTL3X := **81D1T OR ...**

Other 79DTL/79DLS Settings Considerations

If no special drive-to-lockout or drive-to-last-shot conditions are desired, make the following settings:

79DTL := **0** set directly to logical 0

79DLS := **0** set directly to logical 0

With settings 79DTL and 79DLS inoperative, the relay still goes to the Lockout State, and to last shot, if an entire automatic reclose sequence is unsuccessful.

Overall, settings 79DTL or 79DLS are needed to take the relay to the Lockout State or to last shot for immediate circumstances.

Skip-Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively)

The skip-shot setting 79SKP causes a reclose shot to be skipped. Thus, an open-interval time is skipped, and the next open-interval time is used instead.

If 79SKP = logical 1 at the instant of successful reclose initiation (see preceding discussion on settings 79RI and 79RIS), the relay increments the shot counter to the next shot and then loads the open-interval time corresponding to the new shot (see *Table 6.7*). 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.

After successful reclose initiation, open-interval timing does not start until allowed by the stall open-interval timing setting 79STL. If 79STL = logical 1, open-interval timing is stalled. If 79STL = logical 0, open-interval timing can proceed.

If an open-interval time has not yet started timing (79STL = logical 1 still), the 79SKP setting is still processed. In such conditions (open-interval timing has not yet started timing), if 79SKP = 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 6.7*).

If the open interval still does not start timing (it is still fully loaded for the given shot) and 79SKP is still asserted (79SKP = logical 1), then each subsequent processing interval (¼ cycle), the shot counter will increment and the corresponding open-interval time will be loaded for that shot, superseding any previously loaded open intervals. With the preceding being true, the shot counter increments from shot = 0 to shot = 1 the first processing interval and from shot =1 to shot = 2 the second processing interval, and so forth until the last shot reached.

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 6.18*).

If the relay is in the middle of timing on an open interval and 79STL changes state to 79STL = logical 1, open-interval timing stops where it is. If 79STL changes state back to 79STL = logical 0, open-interval timing resumes where it left off. Use the OPTMN Relay Word bit to monitor open-interval timing (see *Monitoring Open-Interval and Reset Timing on page 6.22*).

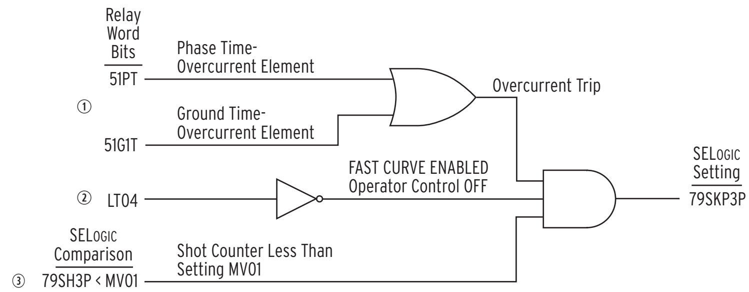
Factory 79SKP/79STL Settings Example

The skip-shot function factory setting is as follows:

79SKP3P := **(51PT OR 51G1T) AND NOT LT04 AND (79SH3P < MV01)**

MV01 := **2**

Refer to *Figure 6.12*. In a typical distribution protection scenario, there are two trips on fast curves, followed by two trips on delay curves. These operations can be phase (51PT) or ground (51G1T) time-overcurrent elements. How elements 51PT and 51G1T each convert between fast and delay curve operation is covered in *Time-Overcurrent Elements on page 4.13*.



① See Figure 4.16, and Figure 4.20; ② Table 11.9, ③ Table 7.2

Figure 6.12 Factory-Default Skip-Shot Logic

If the fast curves are disabled ({FAST CURVE ENABLED} operator control turned off; LT04 = logical 0), we do not want four delay-curve trips (two additional delay-curve trips replacing the two disabled fast-curve trips). We only want the two remaining delay-curve trips, with their standard open interval between them (open interval 3, setting 79OI3). The logic in *Figure 6.12* (dramatized in *Figure 6.13*) accelerates the sequencing of the shot counter so that the third open interval is loaded after the first trip on a delay curve.

As shown in the *Figure 6.10* example of a standard reclose sequence:

- The first trip occurs and shot = 0 (and first open-interval time is then loaded)
- and the second trip occurs and shot = 1 (and the second open-interval time is loaded)

And it follows that the third open-interval (setting 79OI3) is loaded at the third trip, when shot = 2. So, to get the third open-interval loaded at the first trip rather than at the third trip, the shot counter has to be accelerated instantly from shot = 0 to shot = 2 (and then stop at shot = 2) at the time of the first trip. The comparison (79SH3P < MV01) at the bottom of *Figure 6.12* accomplishes this.

For *Figure 6.12*, math-variable setting MV01 is set to MV01 := 2, equal to the number of fast-curve trips. MV01 is compared to the reclosing relay shot counter, via analog output 79SH3P. Thus, if:

79SH3P < MV01 (= 2)

and the rest of the logic in *Figure 6.12* is true, then SELOGIC setting 79SKP3P effectively equals logical 1 (79SKP3P = logical 1). With 79SKP3P = logical 1, for the instant of the first trip, the shot counter increments from 79SH3P = 0 to 79SH3P = 1. The next processing interval (next quarter cycle), the overcurrent trip will still be on and the shot counter increments from 79SH3P = 1 to 79SH3P = 2. Now, the shot counter stops incrementing, because

79SH3P ≥ MV01 (= 2)

With the shot = 2, the third open-interval (setting 79OI3) is then loaded and timed, as shown in *Figure 6.13*. If the number of fast-curve trips is changed, math-variable setting MV01 is likewise changed.

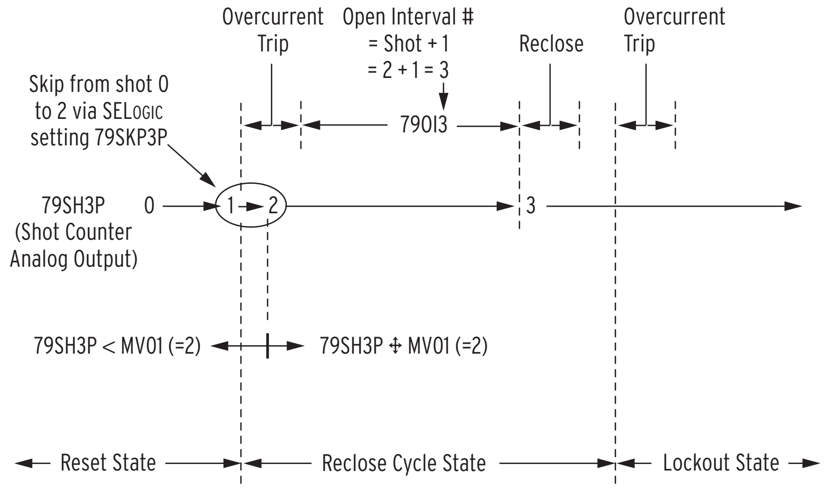


Figure 6.13 Skip-Shot Sequence

OPEN INTERVAL TIMING STALLED TOO LONG?

If open interval timing is stalled too long by factory setting 79STL3P"= TRIP3P, change the controlling minimum trip duration time setting TDURD. See Minimum Trip Duration Timer on page 5.5 for more detail.

The stall open-interval timing factory setting is as follows:

79STL3P := **TRIP3P**

After successful reclose initiation, open-interval timing does not start as long as the trip condition is present (Relay Word bit TRIP3P = logical 1). As discussed previously, if an open-interval time has not yet started timing (79STL3P = logical 1 still), the 79SKP3P setting is still processed. Once the trip condition goes away (Relay Word bit TRIP3P = logical 0), open-interval timing can proceed.

Additional 79SKP Settings Example

With skip-shot factory set as follows,

79SKP3P := **50P2 AND SH03P**

if shot = 0 (Relay Word bit SH03P = logical 1) **and** phase current is above the phase instantaneous overcurrent element 50P2 threshold (Relay Word bit 50P2 = 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 79OI1) is skipped, and the relay times on the open-interval 2 time (setting 79OI2) instead.

Table 6.9 Example Open-Interval Time Settings

Shot	Corresponding Relay Word Bit	Corresponding Open Interval	Open-Interval Time Setting
0	SH03P	79OI1	30 cycles
1	SH13P	79OI2	600 cycles

In *Table 6.9*, note that the open-interval 1 time (setting 79OI1) is a short time, while the following open-interval 2 time (setting 79OI2) is significantly longer. For a high-magnitude fault (greater than the phase instantaneous overcurrent element 50P2 threshold), open-interval 1 time is skipped, and open-interval timing proceeds on the following open-interval 2 time. The longer open-interval time provides more time for the fault to dissipate (or the debris causing the fault to fall away from the line) and more equipment cooling time. Also, the skipped open interval reduces the number of potential reclosures back into the fault, thus reducing equipment stress.

Once the shot is incremented to shot = 1, Relay Word bit SH0 = logical 0 and then setting 79SKP3P = logical 0, regardless of Relay Word bit 50P2.

Additional 79STL Settings Example 1

If the SEL-651R is used on a feeder with a line-side independent power producer (cogenerator), the utility should not reclose into a line still energized by an islanded generator. To monitor line voltage and block reclosing, connect a line-side single-phase potential transformer to a voltage channel on the SEL-651R as shown in *Figure 6.14*.

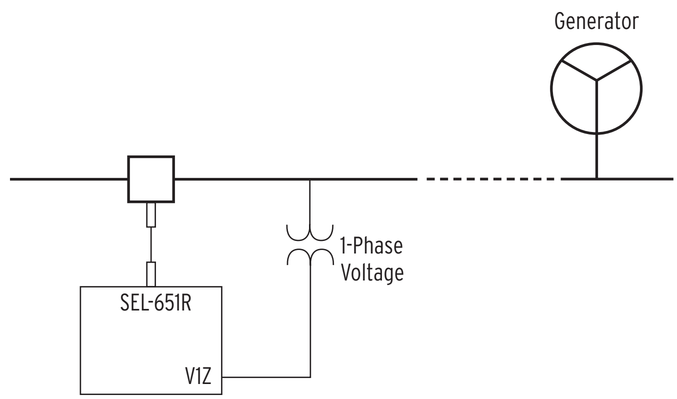


Figure 6.14 Reclose Blocking for Islanded Generator

If the line is energized, an overvoltage element can be set to assert. Make a setting like the following:

79STL3P := **59ZA1 OR ...**

If line voltage is present, Relay Word bit 59ZA1 asserts, stalling open-interval timing (reclose block). If line voltage is not present, Relay Word bit 59ZA1 deasserts, allowing open-interval timing to proceed unless some other set condition stalls open-interval timing.

Additional 79STL Settings Example 2

Refer to *Figure 6.8* and the accompanying setting example, showing an application for setting 79STL.

Other 79SKP/79STL Settings Considerations

If no special skip-shot or stall open-interval timing conditions are desired, make the following settings:

79SKP := **0** set directly to logical 0

79STL := **0** set directly to logical 0

Block-Reset Timing Setting (79BRS)

The block-reset timing setting 79BRS keeps the reset timer from timing. Depending on the reclosing relay state, the reset timer can be loaded with either reset time:

79RSD (Reset Time from Reclose Cycle)

or

79RSLD (Reset Time from Lockout)

Depending on how setting 79BRS is set, none, one, or both of these reset times can be controlled. If the reset timer is timing and then 79BRS asserts to:

79BRS = logical 1

reset timing is stopped and does not begin timing again until 79BRS deasserts to:

79BRS = logical 0

When reset timing starts again, the reset timer is fully loaded. Thus, successful reset timing has to be continuous. Use the RSTMN Relay Word bit to monitor reset timing (see *Monitoring Open-Interval and Reset Timing on page 6.22*).

Factory 79BRS Settings Example

The block reset function is not enabled in the factory settings:

79BRS3P := **0** set directly to logical 0

Additional 79BRS Settings Example 1

The block reset timing setting is:

79BRS3P := **(51P OR 51G1) AND 79CY3P**

Relay Word bit 79CY3P corresponds to the Reclose Cycle State. The reclosing relay is in one of the three reclosing relay states at any one time (see *Figure 6.9* and *Table 6.5*).

When the relay is in the Reset or Lockout States, Relay Word bit 79CY3P is deasserted to logical 0. Thus, the 79BRS3P 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 51PT pickup (51P) asserts momentarily]. But, this assertion of pickup 51P has no effect on reset timing because the relay is in the Lockout State (79CY3P = logical 0). The relay will time immediately on reset time 79RSLD and take the relay from the Lockout State to the Reset State with no additional delay because 79BRS3P is deasserted to logical 0.

When the relay is in the Reclose Cycle State, Relay Word bit 79CY3P is asserted to logical 1. Thus, the factory 79BRS3P setting can function to block reset timing if time-overcurrent pickup 51P or 51G1 is picked up while the relay is in the Reclose Cycle State. This helps prevent repetitive “trip-reclose” cycling.

Additional 79BRS Settings Example 2

If the block-reset timing setting is:

79BRS3P := **51P OR 51G1**

then reset timing is blocked if time-overcurrent pickup 51P or 51G1 is picked up, regardless of the reclosing relay state.

Sequence-Coordination Setting (79SEQ)

The sequence-coordination setting 79SEQ keeps the SEL-651R in step with a downstream recloser in a sequence-coordination scheme. Sequence coordination prevents overreaching SEL-651R overcurrent elements from tripping for faults beyond the downstream recloser. This is accomplished by incrementing the shot counter and supervising overcurrent elements with resultant shot-counter elements.

In order for sequence-coordination setting 79SEQ to increment the shot counter, both the following conditions must be true:

- No trip present (Relay Word bit TRIP = logical 0)
- Circuit breaker closed (SELOGIC control equation setting 52A = logical 1, effectively)

Sequence-coordination setting 79SEQ is usually set with some overcurrent element pickups. If the above 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., downstream recloser—see *Figure 6.15*) has operated to clear a fault. Incrementing the shot counter keeps the SEL-651R in step with the downstream device, as is shown in the following *Additional 79SEQ Settings Example 1* and *Additional 79SEQ Settings Example 2*.

Every time a sequence-coordination operation occurs, the shot counter is incremented, and the reset timer is loaded up with reset time 79RSD. 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 previously discussed SELOGIC control equation setting 79BRS.

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.

Factory 79SEQ Settings Example

Sequence coordination is not enabled in the factory settings:

79SEQ3P := **0**

Additional 79SEQ Settings Example 1

With sequence-coordination setting:

79SEQ3P := **79RS3P AND 51P**

sequence coordination is operable only when the SEL-651R is in the Reset State (79RS3P = logical 1). Refer to *Figure 6.15* and *Figure 6.16*.

NOTE: This example portrayed in Figure 6.15 and Figure 6.16 only shows operation with phase overcurrent elements. Sequence coordination can also work with ground overcurrent elements (e.g., add a ground time-overcurrent element pickup to the sequence-coordination setting:
79SEQ3P := 79RS3P AND
(51P OR 51G1).

Assume that the downstream recloser is set to operate twice on the fast curve and then twice on the delay curve. The delay curve is allowed to operate after two fast-curve operations because the fast curves are then inoperative for tripping. The SEL-651R fast curve is coordinated with the downstream recloser fast curve. The SEL-651R delay curve is coordinated with the downstream recloser delay curve. How phase time-overcurrent element 51PT converts between fast and delay curve operation is covered in *Time-Overcurrent Elements on page 4.13*.

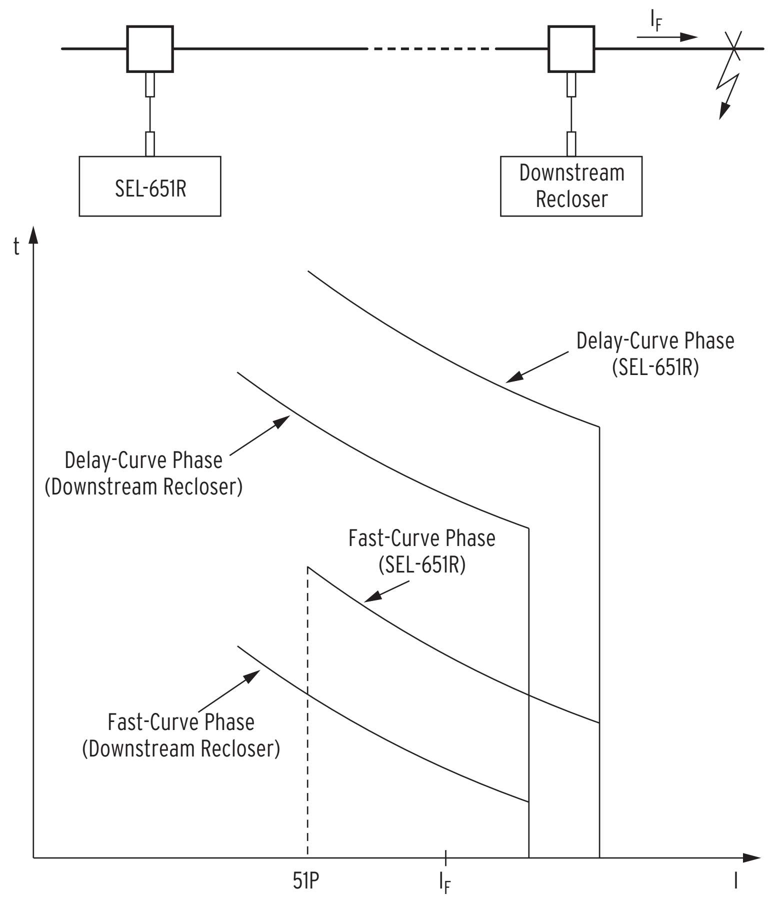


Figure 6.15 Sequence Coordination Between the SEL-651R Recloser Control and a Downstream Recloser

① Fault occurs beyond downstream recloser.
② Fault cleared by downstream recloser fast curve.
③ Downstream recloser recloses into fault.
④ Fault cleared by downstream recloser delay curve.

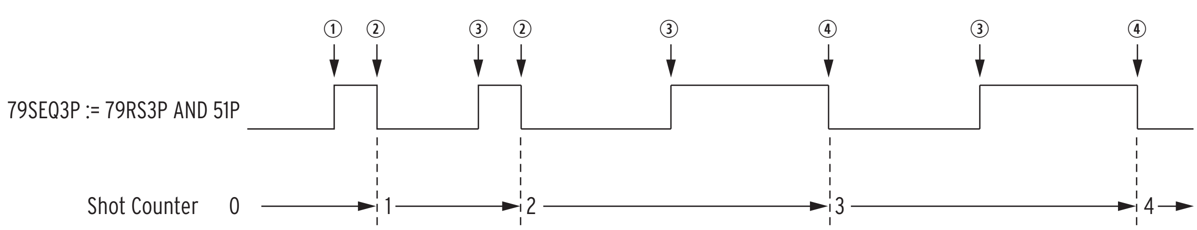


Figure 6.16 Operation of SEL-651R Shot Counter for Sequence Coordination With Downstream Recloser (Additional 79SEQ Settings Example 1)

If the SEL-651R is in the Reset State (79RS3P = logical 1) and then a permanent fault beyond the downstream recloser occurs (fault current IF in *Figure 6.15*), the downstream recloser fast curve operates to clear the fault. The SEL-651R also sees the fault. The phase time-overcurrent pickup 51P asserts and then deasserts without tripping, incrementing the SEL-651R shot counter from:

shot = 0 to shot = 1

When the downstream recloser recloses, its fast curve operates again to clear the fault. The SEL-651R also sees the fault again. The phase time-overcurrent pickup 51P asserts and then deasserts without tripping, incrementing the SEL-651R shot counter from:

shot = 1 to shot = 2

At shot = 2, the SEL-651R now operates on its delay curve, instead of its fast curve. This keeps the SEL-651R in step with the downstream recloser, which now also operates on its delay curve, after two operations on its fast curve. If the fast curve was still active in the SEL-651R for shot ≥ 2, it would overtrip for the fault beyond the downstream recloser (the SEL-651R fast curve would operate before the downstream recloser delay curve).

Figure 6.16 shows the continuing operation of the sequence-coordination logic and subsequent incrementing of the shot counter to shot = 3 and shot = 4. The shot counter returns to shot = 0 after the reset timer (loaded with reset time 79RSD) times out.

Additional 79SEQ Settings Example 2

Review preceding Example 1.

The following example limits sequence-coordination shot-counter incrementing. Assume that the downstream recloser in *Figure 6.15* is set to operate twice on its fast curve and then twice on its delay curve for faults beyond it. Assume that the SEL-651R is set to operate only once on its fast curve and then twice on its delay curve for faults between the SEL-651R and the downstream recloser.

If the SEL-651R sequence-coordination setting is:

79SEQ3P := **79RS3P AND 51P**

and there is a permanent fault beyond the downstream recloser, the shot counter of the SEL-651R will increment all the way to shot = 4 (see *Figure 6.16*). If there is then a coincident fault between the SEL-651R and the downstream recloser, the SEL-651R will trip and go to the Lockout State. Any time the shot counter is at a value equal to or greater than last shot (last shot = 2, in this case) and the SEL-651R trips, it goes to the Lockout State.

To avoid this problem, make the following sequence-coordination setting:

79SEQ3P := **79RS3P AND 51P AND SH03P**

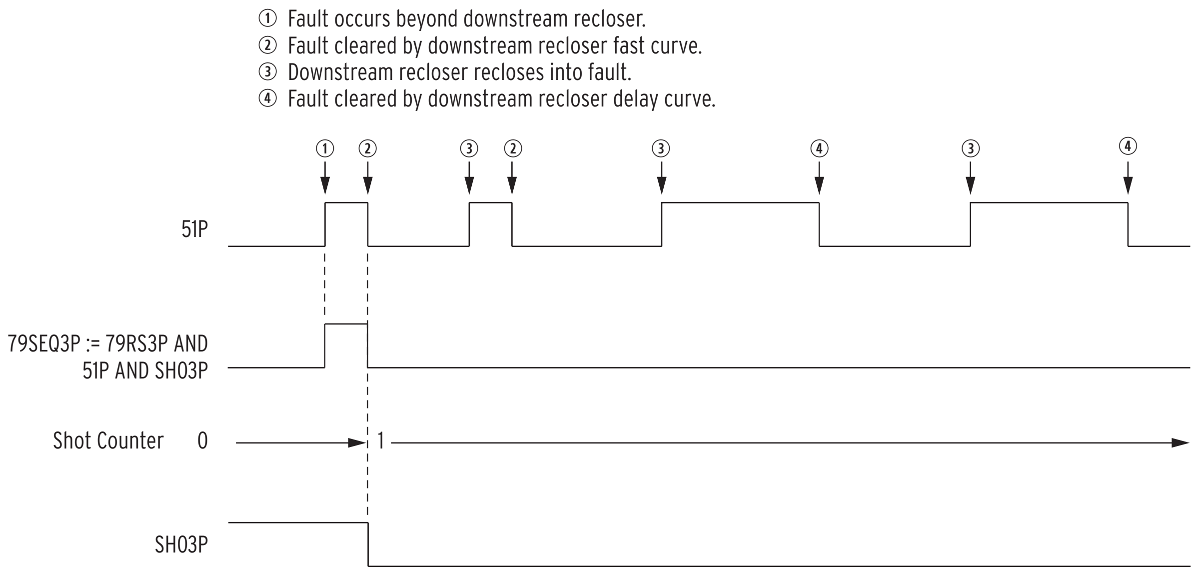


Figure 6.17 Operation of SEL-651R Shot Counter for Sequence Coordination With Downstream Recloser (Additional 79SEQ Settings Example 2)

Refer to *Figure 6.17*.

If the SEL-651R is in the Reset State (79RS3P = logical 1) with the shot counter reset (shot = 0; SH03P = logical 1) and then a permanent fault beyond the downstream recloser occurs (fault current IF in *Figure 6.15*), the downstream recloser fast curve operates to clear the fault. The SEL-651R also sees the fault. The phase time-overcurrent pickup 51P asserts and then deasserts without tripping, incrementing the relay shot counter from:

shot = 0 to shot = 1

Now the SEL-651R cannot operate on its fast curve because the shot counter is at shot = 1; it is now operating on its delay curve.

The downstream recloser continues to operate for the permanent fault beyond it, but the SEL-651R shot counter does not continue to increment. Sequence-coordination setting 79SEQ3P is effectively disabled by the shot counter incrementing from shot = 0 (SH03P = logical 1) to shot = 1 (SH03P = logical 0).

79SEQ3P := **79RS3P AND 51P AND SH03P**

The shot counter stays at shot = 1.

Thus, if there is a coincident fault between the SEL-651R and the downstream recloser, the SEL-651R will operate on delay curve and then reclose once, instead of going straight to the Lockout State (shot = 1 < last shot = 2).

As stated earlier, the reset-time setting 79RSD takes the shot counter back to shot = 0 after a sequence-coordination operation increments the shot counter. Make sure that reset-time setting 79RSD is set long enough to maintain the shot counter at shot = 1 as shown in *Figure 6.17*.

Reclose Supervision Setting (79CLS)

See *Reclose Supervision Logic on page 6.10*.

Section 7

SELOGIC Control Equation Programming

Functions use operands (inputs) and operators to generate outputs. Complex functions are created by using the outputs of several functions as operands in the new function.

Embedded relay functions such as protection elements, tripping and closing logic, and event report triggering use logic built into the SEL-651R. In some cases, these embedded functions can be customized because they include SELOGIC® control equations as inputs. The outputs of these functions and equations are generally made available as Relay Word bits. Each function and equation is discussed in the appropriate protection, control, and monitoring section.

Custom functions may be constructed with SELOGIC control equations using operands such as SELOGIC variables and embedded relay functions.

NOTE: All SELOGIC control equations must be set to NA, 0, 1, a single Relay Word bit, or a combination of Relay Word bits.

This section describes use of SELOGIC control equation programming to customize relay operation and automate substations. This section covers the following topics:

- SELOGIC control equation operands
- SELOGIC control equation operators
- SELOGIC control equation functions

SELOGIC Control Equation Capacity

SELOGIC control equation available capacity is a measure of remaining execution capacity and settings storage capacity. For maximum efficiency, use parentheses only when necessary and set unused equations to NA rather then 0 or 1.

Each SELOGIC control equation has a 15-operand maximum. Use a SELOGIC control equation variable (SV01–SV48) as an intermediate setting step if more operands are required.

Because the relay executes the logic at a deterministic interval, there is a limit to the amount of SELOGIC control equation programming that the relay can execute. Rather than limit parameters to guarantee that an application does not exceed the maximum processing requirements, the relay measures and calculates the available capacity when SELOGIC control equations are entered. The relay will not allow entry of programming that will cause the relay to be unable to complete all SELOGIC control equations each processing interval. The relay calculates capacities based on the total amount of SELOGIC control equation programming executed in Global, Group, Logic, and several other settings areas.

Use the **STATUS S** command to view available execution capacity and settings storage.

SELOGIC Control Equation Operands

Outputs from embedded relay functions are generally available for use as operands in SELOGIC control equations. Some analog values are available as operands as well. Use these operands to customize the operation of your SEL-651R and use the SEL-651R to automate substation operation. The operands available for use in SELOGIC control equations are summarized in *Table 7.1*.

Table 7.1 Summary of SELOGIC Control Equation Operands

Operand Type	Relay Word Bit Operands
Constants	0, 1
Inputs	Status Inputs, Optoisolated Inputs
Inputs	Local Bits (see *Section 11: Front-Panel Operations*)
Inputs	Remote Bits (see *Section 10: Communications*)
Inputs	Receive MIRRORED BITS® (see *Appendix D: MIRRORED BITS Communications*)
Elements	Protection and Control Elements (see *Section 4: Protection Functions*)
Functions	Variables/Timers, Latch Bits, Counters
Outputs	Trip and Close Outputs, Contact Outputs
Outputs	Transmit MIRRORED BITS (See *Appendix D: MIRRORED BITS Communications*)
Analog	Received, Measured, or Calculated Analog Values

Relay Word Bits

Data within the relay are available for use in SELOGIC control equations. Relay Word bits include received digital values including optoisolated inputs, control bits, and remote bits. They also include calculated digital values such as SELOGIC control equation variables, SELOGIC control equation functions, and protection and control elements. *Appendix F: Relay Word Bits* contains a list of Relay Word bits available within the SEL-651R.

Analog Quantities

Analog quantities are analog values within the relay, including set, measured, and calculated values. *Table 7.2* contains a list of analog quantities available for SELOGIC expressions within the SEL-651R.

NOTE: The analog quantities available for use in SELOGIC equations, as shown in Table 7.2, are a subset of the complete list of analog quantities shown in Table G.1.

Table 7.2 Analog Quantities (Sheet 1 of 2)

Quantities	Description
PFA, PFB, PFC	Power factor magnitude; A-, B-, C-phase
PF3	Power factor, magnitude three-phase
LDPFA, LDPFB, LDPFC	Power factor leading = 1; A-, B-, C-phase
LDPF3	Power factor leading = 1; three-phase
IAHT, IBHT, ICHT	THD, Current, A-, B-, C-phase, magnitude
INHT	THD Current, neutral, magnitude
VAYHT, VBYHT, VCYHT	THD Voltage, A-, B-, C-phase-to-neutral, Y-terminals, magnitude
VAZHT, VBZHT, VCZHT	THD Voltage, A-, B-, C-phase-to-neutral, Z-terminals, magnitude
YEAR	Year number (0000–9999)

Table 7.2 Analog Quantities (Sheet 2 of 2)

Quantities	Description
DAYY	Day of Year number (1–366)
WEEK	Week number (1–52)
DAYW	Day of Week number (1–7)
MINSM	Minutes since Midnight
SC01–SC16	SELOGIC counter 01 to 16 present value (see *Analog Comparators and Checks on page 7.6* for more information)
MV01–MV32	Math Variable 01 to 32
79SHA, 79SHB, 79SHC	Shot counter—A-, B-, C-phase
79SH3P	Shot counter—three-phase

SELOGIC Control Equation Operators

Use the analog comparators to create a Boolean result from an analog value, and Boolean operators to combine values with a resulting Boolean value. Edge-trigger operators provide a pulse output. Combine the operators and operands to form statements that evaluate complex logic. *Table 7.3* contains a summary of operators available in the SEL-651R.

Operator Precedence

When you combine several operators and operands within a single expression, the SEL-651R evaluates the operators from left to right starting with the highest precedence operators working down to the lowest precedence. This means that if you write an equation with three AND operators, for example SV01 AND SV02 AND SV03, each AND will be evaluated from the left to the right. If you substitute NOT SV04 for SV03 to make SV01 AND SV02 AND NOT SV04, the relay evaluates the NOT operation of SV04 first and uses the result in subsequent evaluation of the expression. Operator precedence is shown in *Table 7.3*.

Table 7.3 Operator Precedence

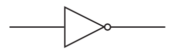
Operator	Description
( )	Parenthesis
NOT	Boolean Complement
R_TRIG	Rising Edge Trigger
F_TRIG	Falling Edge Trigger
<, >, <=, >=	Analog Comparison
=	Analog Equality Check
<>	Analog Inequality Check
AND	Boolean AND
OR	Boolean OR

Parentheses Operators

Use paired parentheses to control the execution order of operations in a SELOGIC control equation. Use as many as 14 nested sets of parentheses in each SELOGIC control equation. The relay calculates the result of the operation on the innermost pair of parentheses first and then uses this result with the remaining operations.

NOT Operator

Use the NOT operator to invert a Boolean value. Create a NOT function using the NOT operator. This function would be described mathematically by the equation f(A) = NOT A and graphically by the following IEEE symbol:



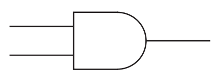
AND Operator

Use AND to combine two Boolean values according to the truth table shown in *Table 7.4*.

Table 7.4 AND Operator Truth Table

Value A	Value B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

Create an AND function using the AND operator. This function would be described mathematically by the equation f(A,B) = A AND B and graphically by the following IEEE symbol:



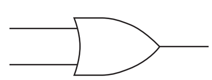
OR Operator

Use OR to combine two Boolean values according to the truth table shown in *Table 7.5*.

Table 7.5 OR Operator Truth Table

Value A	Value B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

Create an OR function using the OR operator. This function would be described mathematically by the equation f(A,B) = A OR B and graphically by the following IEEE symbol:



R_TRIG Operator

R_TRIG is a time-based function that creates a pulse when a rising edge is detected, as shown in *Figure 7.1*. Use R_TRIG to sense when a value changes from logical 0 to logical 1 and take action only after the value changes state.

R_TRIG applies to individual Relay Word bits only, not to groups of elements within parentheses. For example, the SELOGIC control equation event report generation setting uses several rising-edge operators:

ER := **R_TRIG 51P OR R_TRIG 51G1 OR R_TRIG OUT103**

When a logical 0 to logical 1 transition of ER is detected, the SEL-651R generates an event report (if the relay is not already generating a report that encompasses the new transition). The rising-edge operators in the ER equation enable detection of each individual transition.

Suppose a ground fault occurs and a breaker failure condition finally results. *Figure 7.1* demonstrates the action of the rising-edge operator R_TRIG on the individual elements in setting ER.

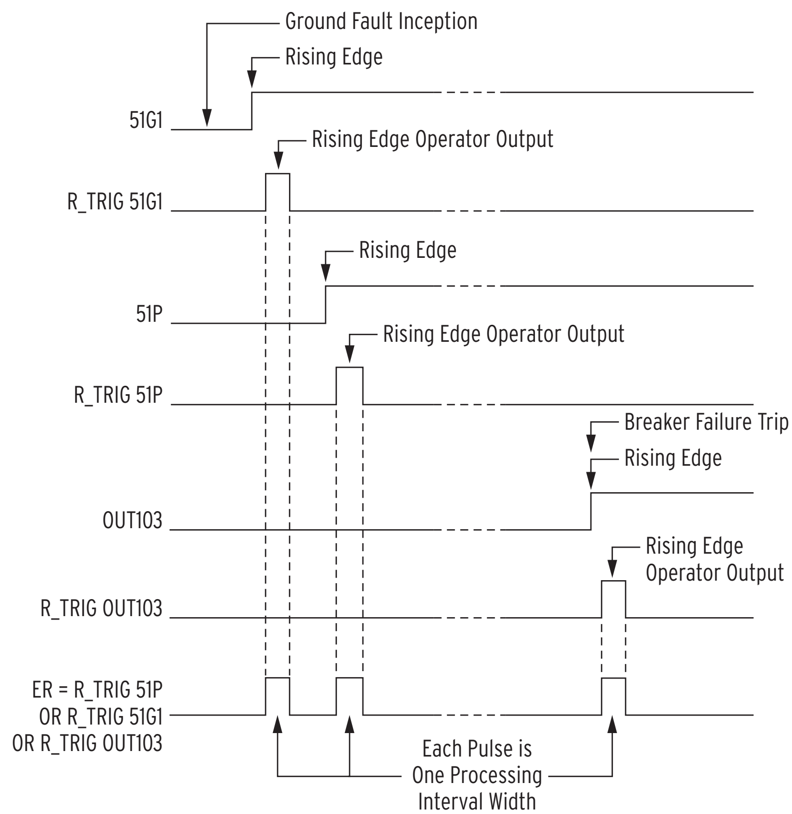


Figure 7.1 Rising Edge Operator Example

Note in *Figure 7.1* that setting ER detects three separate rising edges, because of the application of rising-edge operators R_TRIG. The rising edge operator R_TRIG in front of a Relay Word bit detects this logical 0 to logical 1 transition as a rising edge and as a result asserts to logical 1 for one processing interval. The assertions of 51G1 and 51P are close enough that they will be on the same event report (generated by 51G1 asserting first). The assertion of OUT103 for a breaker failure condition is some appreciable time later and will generate another event report, if the first event report capture has ended when OUT103 asserts.

If the rising-edge operators R_TRIG were not applied and setting ER was:

ER := **51P OR 51G1 OR OUT103**

the ER setting would not detect the assertion of OUT103, because 51G1 and 51P would continue to be asserted at logical 1.

F_TRIG Operator

F_TRIG is a time-based function that creates a pulse when a falling edge is detected, as shown in *Figure 7.2*. Use F_TRIG to sense when a value changes from logical 1 to logical 0 and take action only after the value changes state.

The argument of an F_TRIG statement must be a single Relay Word bit within the SEL-651R. An example of the relay detecting a falling edge of a calculated quantity is shown in *Figure 7.2*.

For example, suppose the SELOGIC control equation event report generation setting is set with the detection of the falling edge of an underfrequency element:

ER := **... OR F_TRIG 81D1T**

When frequency goes above the corresponding pickup level 81D1P, Relay Word bit 81D1T deasserts and an event report is generated (if the relay is not already generating a report that encompasses the new transition). This allows a recovery from an underfrequency condition to be observed. *Figure 7.2* demonstrates the action of the falling edge operator F_TRIG on the underfrequency element in setting ER.

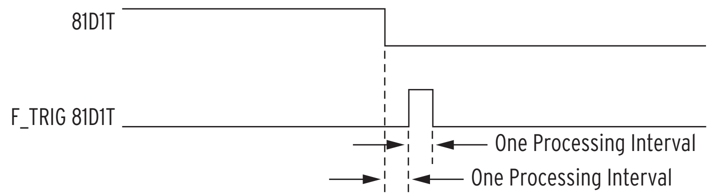


Figure 7.2 Falling Edge Operator Example

Analog Comparators and Checks

The <, >, <=, => comparator operators are generally used to determine states to drive a sequence of actions. Use the = check operator to check whether an integer value is equal to another integer value. Do not use the = check operator for noninteger values, because it is unlikely that they will ever be equal.

Math variables (MV01–MV32) provide storage locations for constants that may be used in analog comparisons. The values in these storage locations may be changed but the SEL-651R does not support mathematical operands and functions on these or any other analog value. See *Figure 6.12* for an example of how a mathematical variable can be used.

Use the analog comparators to create your own schemes. For example, monitor the current (IA, IB, IC) harmonics on your system by creating a THD (total harmonic distortion) SCADA system alarm that you may use to initiate the retrieval of harmonic meter data. The following equation is an example of how to implement this alarm.

SV33 : = **(IAHT >= 5) OR (IBHT >= 5) OR (ICHT >= 5)**

Comments

NOTE: Comments may be entered in upper- or lowercase letters. The comments will always be displayed in uppercase letters.

The pound symbol (#) is used as a comment operator. All characters entered after the # will be treated as text instead of logic.

SELOGIC control equation comments are very powerful tools for documenting and clarifying programming. Even programming that is well understood during installation and commissioning should have comments to help with any modifications needed later. These comments are stored in the SEL-651R.

SELOGIC Control Equation Functions

Variables/Timers

The SEL-651R has forty-eight (48) SELOGIC control equation variables/ timers (the SEL-651R-1 has 64). Each SELOGIC control equation variable/ timer has a SELOGIC control equation setting input and variable/timer outputs as shown in *Figure 7.3*.

These timers have pickup and dropout time settings (SV*n*PU and SV*n*DO, *n* = 01 through 48; *n* = 01 through 64 for SEL-651R-1).

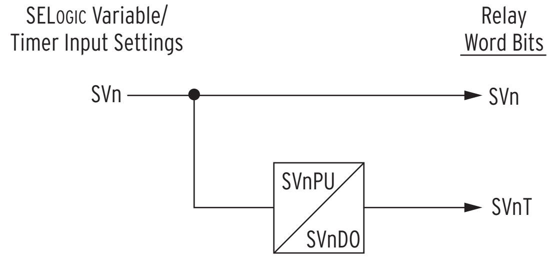


Figure 7.3 SELOGIC Control Equation Variables/Timers

If power to the SEL-651R is lost, settings are changed for the active setting group, or the active setting group is changed, the SELOGIC control equation variables/timers are reset. Relay Word bits SV*n* and SV*n*T (*n* = 01 through 48; *n* = 01 through 64 for SEL-651R-1) are reset to logical 0 and corresponding timer settings SV*n*PU and SV*n*DO are reloaded after power restoration, settings change, or active setting group switch.

Example 1

In the SELOGIC control equation settings, a SELOGIC control equation timer can be used for a simple breaker failure scheme:

SV02 := **TRIP3P**

The TRIP3P Relay Word bit is run through a timer for breaker failure timing. Timer pickup setting SV02PU is set to the breaker failure time (SV02PU := 12.00 cycles). Timer dropout setting SV02DO is set for a 2-cycle dropout (SV02DO := 2.00 cycles). The output of the timer (Relay Word bit SV02T) operates output contact OUT103.

OUT103 := **SV02T**

Example 2

Another application idea is dedicated breaker failure protection (see *Figure 7.4*):

SV06 := **IN101** # breaker failure initiate

SV07 := **(SV07 OR IN101) AND (50P1 OR 50G1)**

OUT101 := **SV06T** # retrip

OUT102 := **SV07T** # breaker failure trip

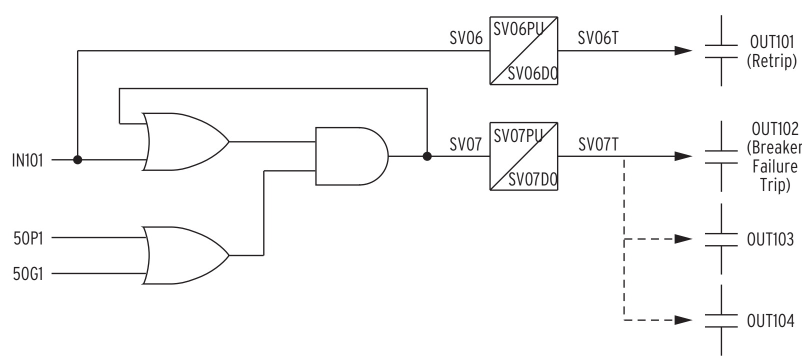


Figure 7.4 Dedicated Breaker Failure Scheme Created With SELOGIC Control Equation Variables/Timers

Note that the above SELOGIC control equation setting SV07 creates a seal-in logic circuit (as shown in *Figure 7.4*) by virtue of SELOGIC control equation setting SV07 being set equal to Relay Word bit SV07 (SELOGIC control equation variable SV07):

SV07 := **(SV07 OR IN101) AND (50P1 OR 50G1)**

Optoisolated input IN101 functions as a breaker failure initiate input. Phase instantaneous overcurrent element 50P1 and ground instantaneous overcurrent element 50G1 function as fault detectors.

Timer pickup setting SV06PU provides retrip delay, if desired, but can also be set to zero. Timer dropout setting SV06DO holds the retrip output (output contact OUT101) closed for extra time, if needed, after the breaker failure initiate signal (IN101) deasserts.

Timer pickup setting SV07PU provides breaker failure timing. Timer dropout setting SV07DO holds the breaker failure trip output (output contact OUT102) closed for extra time, if needed, after the breaker failure logic unlatches (fault detectors 50P1 and 50G1 dropout).

Note that *Figure 7.4* suggests the option of having output contacts OUT103 and OUT104 operate as additional breaker failure trip outputs. To do this make the following SELOGIC control equation settings:

OUT103 := **SV07T** # breaker failure trip

OUT104 := **SV07T** # breaker failure trip

Example 3

The seal-in logic circuit in the dedicated breaker failure scheme in *Figure 7.4* can be removed by changing the SELOGIC control equation setting SV07 to:

SV07 := **IN101 AND (50P1 OR 50G1)**

If the seal-in logic circuit is removed, optoisolated input IN101 (breaker failure initiate) has to be continually asserted for a breaker failure time-out.

Timer Reset Conditions

If power to the relay is lost, settings are changed for the active setting group, or the active setting group is changed, the SELOGIC control equation variables/timers are reset. Relay Word bits SV*n* and SV*n*T (*n* = 01 through 48; *n* = 01 through 64 for SEL-651R-1) are reset to logical 0 and corresponding timer settings SV*n*PU and SV*n*DO load up again.

Preceding *Figure 7.4* shows an effective seal-in logic circuit, created by use of Relay Word bit SV07 (SELOGIC control equation variable SV07) in SELOGIC control equation SV07:

SV07 := **(SV07 OR IN101) AND (50P1 OR 50G1)**

If power to the relay is lost, settings are changed for the active setting group, or the active setting group is changed, the seal-in logic circuit is broken by virtue of Relay Word bit SV07 being reset to logical 0 (assuming input IN101 is not asserted). Relay Word bit SV07T is also reset to logical 0, and timer settings SV07PU and SV07DO load up again.

Latch Bits

Latch control switches (Latch Bits are the outputs of these switches) replace traditional latching relays. Traditional latching relays maintain their output contact state. The SEL-651R latch control switches retain their state even when power to the relay is lost. If the latch control switch is set to a programmable output contact and power to the relay is lost, the state of the latch control switch is stored in nonvolatile memory, but the output contact will go to its de-energized state. When power to the relay is restored, the programmable output contact will go back to the state of the latch control switch after relay initialization.

Traditional latching relay output contact states are changed by pulsing the latching relay inputs (see *Figure 7.5*). Pulse the set input to close (set) the latching relay output contact. Pulse the reset input to open (reset) the latching relay output contact. Often the external contacts wired to the latching relay inputs are from remote control equipment (e.g., SCADA, RTU).

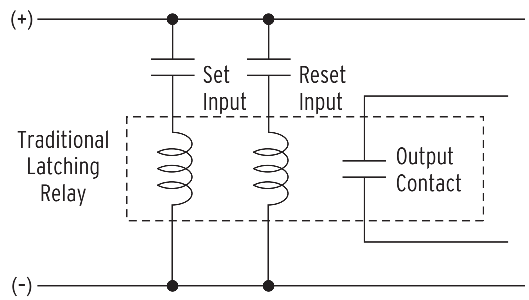


Figure 7.5 Traditional Latching Relay

Thirty-two latch control switches in the SEL-651R provide latching relay functionality. See *Latch Bits Set/Reset SELOGIC Equations on page SET.31*.

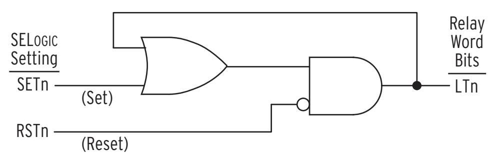


Figure 7.6 Latch Control Switches Drive Latch Bits LT01 Through LT032

The output of the latch control switch in *Figure 7.6* is a Relay Word bit LT*n* (*n* = 01 through 32), called a latch bit. The latch control switch logic in *Figure 7.6* repeats for each latch bit LT01 through LT32. Use these latch bits in SELOGIC control equations.

These latch control switches each have the following SELOGIC control equation settings:

SET*n* (set latch bit LT*n* to logical 1)

RST*n* (reset latch bit LT*n* to logical 0)

If setting SET*n* asserts to logical 1, latch bit LT*n* asserts to logical 1. If setting RST*n* asserts to logical 1, latch bit LT*n* deasserts to logical 0. If both settings SET*n* and RST*n* assert to logical 1, setting RST*n* has priority and latch bit LT*n* deasserts to logical 0.

Latch Bits: Application Ideas

Latch control switches can be used for such applications as:

- Reclosing relay enable/disable
- Ground relay enable/disable
- Sequence coordination enable/disable

Latch control switches can be applied to almost any control scheme. The following is an example of using a latch control switch to enable/disable the reclosing relay in the SEL-651R.

Example: Reclosing Relay Enable/Disable Setting

Use a latch control switch to enable/disable the reclosing relay in the SEL-651R. In this example, a SCADA contact is connected to optoisolated input IN104 as shown in *Figure 7.7*. Use a Remote Bit or Local Bit instead of an input if your application warrants it.

If the reclosing relay is enabled and the SCADA contact is pulsed, the reclosing relay is then disabled. If the SCADA contact is pulsed again, the reclosing relay is enabled again. Each pulse of the SCADA contact changes the state of the reclosing relay. The control operates in a cyclic manner. The SCADA contact is not maintained, just pulsed to enable/disable the reclosing relay.

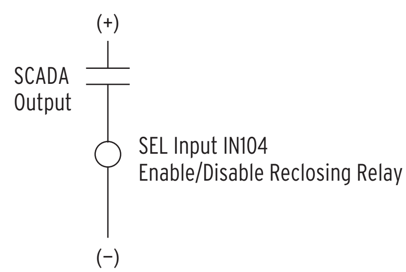


Figure 7.7 SCADA Contact Pulses Input IN104 to Enable/Disable Reclosing Relay

This reclosing relay logic is implemented in the following SELOGIC control equation settings and is displayed in *Figure 7.8*. Note that the figure includes an extra timer that is not included in the settings. This timer will be used in the next example. *Figure 7.9* shows the timing for this example.

SET01 := **(R_TRIG IN104) AND (NOT LT01)**

RST01 := **(R_TRIG IN104) AND LT01**

79DTL3P := **NOT LT01**

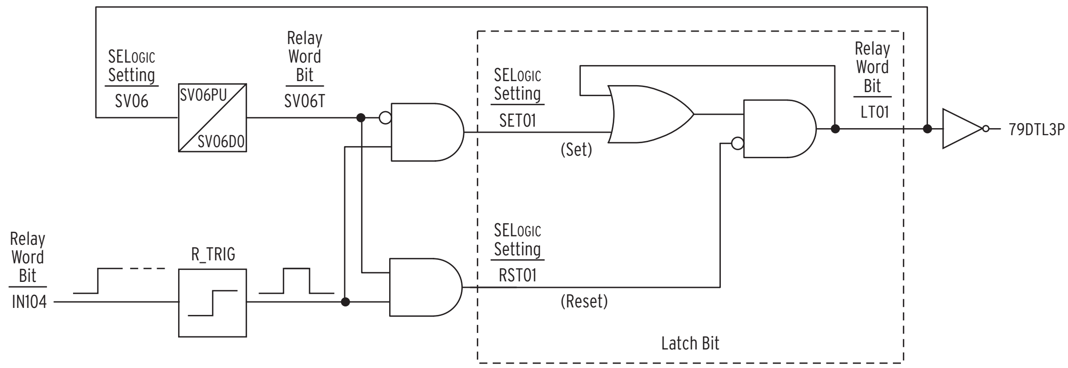


Figure 7.8 Single Input to Enable/Disable Reclosing

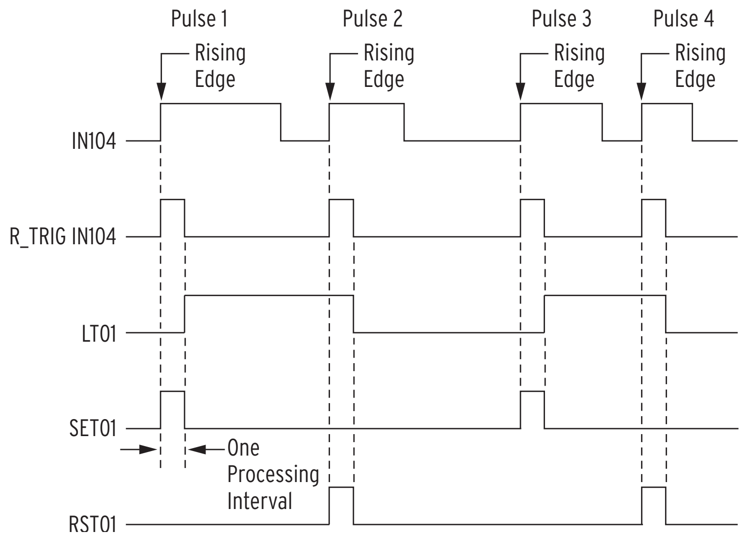


Figure 7.9 Latch Control Switch Operation Time Line

A variation of the previous example adds more security by adding a timer with equal pickup/dropout times as shown in *Figure 7.8*. Suppose that SV06PU and SV06DO are both set to 300 cycles. Then the SV06T timer keeps the state of latch bit LT01 from being able to be changed at a rate faster than once every 300 cycles (5 seconds). *Figure 7.10* shows the timing for this example.

SV06 := **LT01**

SET01 := **(R_TRIG IN104) AND (NOT SV06T)**

RST01 := **(R_TRIG IN104) AND SV06T**

79DTL3P := **NOT LT01**

Note that in *Figure 7.8* the latch control switch output (latch bit LT01) uses feedback for SELOGIC control equation settings SET01 and RST01. The feedback of latch bit LT01 determines whether input IN104 operates the SET01 or RST01 input. If latch bit LT01 = logical 0, input IN104 operates SET01 (set latch bit LT01). If latch bit LT0 = logical 1, input IN104 operates RST01 (reset latch bit LT01).

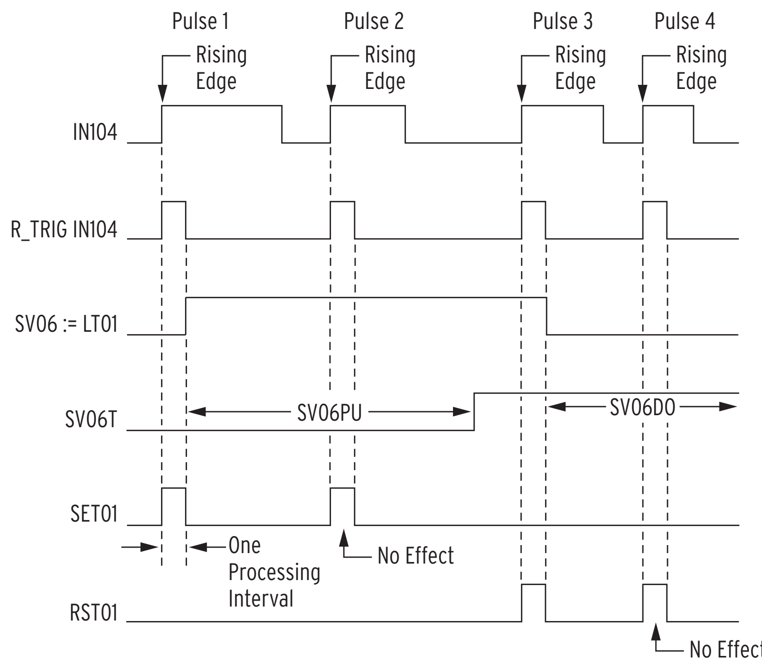


Figure 7.10 Latch Control Switch (With Time-Delay Feedback) Operation Time Line

Latch Bits: Nonvolatile State

Power Loss

The states of the latch bits (LT01–LT32) are retained if power to the relay is lost and then restored. If a latch bit is asserted (e.g., LT02 = logical 1) when power is lost, it is asserted (LT02 = logical 1) when power is restored. If a latch bit is deasserted (e.g., LT03 = logical 0) when power is lost, it is deasserted (LT03 = logical 0) when power is restored. This feature makes the latch bit feature behave the same as traditional latching relays. In a traditional installation, if power is lost to the panel, the latching relay output contact position remains unchanged.

Note: If a latch bit is set to a programmable output contact, such as OUT103 := LT02, and power to the relay is lost, the state of the latch bit is stored in nonvolatile memory but the output contact will go to its de-energized state. When power to the relay is restored, the programmable output contact will go back to the state of the latch bit after relay initialization.

Settings Change or Active Setting Group Change

If individual settings are changed (for the active setting group or one of the other settings groups) or the active setting group is changed, the states of the latch bits (Relay Word bits LT01 through LT32) are retained, much like in the preceding *Power Loss* explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the latch bits (the relay is not momentarily disabled).

If the individual settings change or active setting group change causes a change in SELOGIC control equation settings SET*n* or RST*n* (*n* = 01 through 32), the retained states of the latch bits can be changed, subject to the newly enabled settings SET*n* or RST*n*.

Make Latch Control Switch Settings With Care

The latch bit states are stored in nonvolatile memory so they can be retained during power loss, settings change, or active setting group change. The nonvolatile memory is rated for a finite number of writes for all cumulative latch bit state changes. Exceeding the limit can result in a FLASH self-test failure. **An average of 70 cumulative latch bit state changes per day can be made for a 25-year relay service life**.

This requires that SELOGIC control equation settings SET*n* and RST*n* for any given latch bit LT*n* (*n* = 01 through 32) be set with care. Settings SET*n* and RST*n* must not result in continuous cyclical operation of latch bit LT*n*. Use timers to qualify conditions set in settings SET*n* and RST*n*. If any optoisolated inputs IN101 through IN106 are used in settings SET*n* and RST*n*, the inputs have their own debounce timer that can help in providing the necessary time qualification.

In the preceding reclosing relay enable/disable example application (*Figure 7.7*), the SCADA contact cannot be asserted/deasserted continuously, which would causing latch bit LT01 to change state continuously. Note that the rising-edge operators in the SET01 and RST01 settings keep latch bit LT01 from cyclically operating for any single assertion of the SCADA contact.

Counters

SELOGIC control equation counters are up- or down-counting elements. These counters conform to the standard counter function block in IEC 1131-3 First Edition 1993-03 International Standard for Programmable Controllers - Part 3: Programming Languages, as shown by the symbol in *Figure 7.11*.

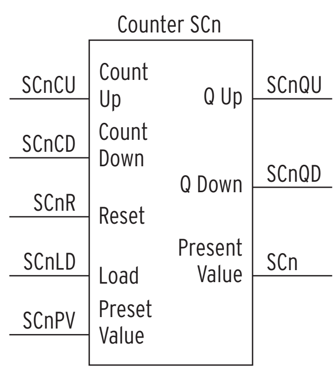


Figure 7.11 Up/Down Counters

Table 7.6 describes the Boolean input settings, counter value setting, and Boolean outputs of the counters. Sixteen counters are available, *n* = 01 through 16. See *SELOGIC Counter Settings on page SET.40*.

Table 7.6 Counter Inputs and Outputs (Sheet 1 of 2)

Name	Type	Description
SC*n*LD	Active High Input	Load counter with the preset value (follows SELOGIC setting)
SC*n*PV	Input Value	This Preset Value is loaded when SC*n*LD pulsed. This Preset Value is used as a maximum count in the SC*n*QU comparison (follows SELOGIC setting)
SC*n*CU	Rising-Edge Input	Count Up increments the counter (follows SELOGIC setting)

Table 7.6 Counter Inputs and Outputs (Sheet 2 of 2)

Name	Type	Description
SC*n*CD	Rising-Edge Input	Count Down decrements the counter (follows SELOGIC setting). The counter freezes if set to NA. See NOTE under *SELOGIC Counter Settings on page SET.40*.
SC*n*R	Active High Input	Reset counter to zero (follows SELOGIC setting).
SC*n*QU	Active High Output	This Q Up output asserts when the Preset Value (maximum count) is reached (SC*n* = SC*n*PV, *n* = 01 to 16).
SC*n*QD	Active High Output	This Q Down output asserts when the counter is equal to zero (SC*n* = 0, *n* = 01 to 16).
SC*n*	Output Value	This counter output is an analog value that may be used with analog comparison operators in a SELOGIC control equation, or viewed with the **COUNTER** command.

Viewing Counters

The serial port command **COUNTER** displays the present value of SC01 through SC16. See *COUNTER Command (View SELOGIC Counters) on page 10.20*.

Counters: Application Ideas

Counters can be used for such applications as:

- Keeping track of a tap-changer position
- Switching and cycling of a capacitor bank
- Peak shaving with control of on-site generation

Examples

Example 7.1 illustrates how to use the SELOGIC control equation counters to limit the demand by starting an on-site 60 Hz diesel generator.

EXAMPLE 7.1

When the three-phase demand is greater than 100 kW for greater than 10 minutes, the diesel generator should start to pick up load. The generator should be started in 5 minutes when demand is greater than 125 kW. Also, if the demand is greater than 150 kW, the diesel generator should start immediately.

Figure 7.12 shows the logic required to create the 10-second periodic waveforms R_TRIG SV10 and F_TRIG SV10 shown in Figure 7.13. One periodic waveform is used to increment a counter when the three-phase power is above the 3PWR1 power element pickup (3PWR1P set equivalent to 100 kW primary) and both periodic waveforms are used when the three-phase power is above the 3PWR2 power element pickup (3PWR2P set equivalent to 125 kW primary). The R_TRIG SV10 waveform is used to decrement the counter when the three-phase power is below both thresholds.

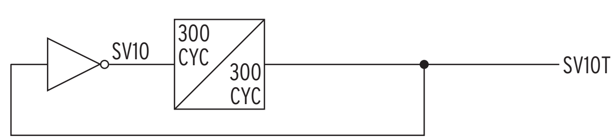


Figure 7.12 SELOGIC Variable SV10 Timing Logic Used in Example 7.1

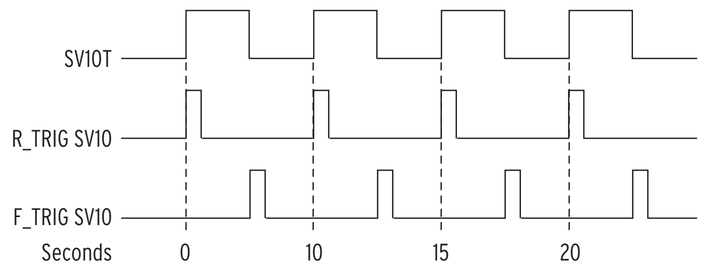


Figure 7.13 SELOGIC Variable SV10 Timer Output

Make the following settings to implement this function:

SV10PU :=**300.00**

SV10DO :=**300.00**

SV10 := **NOT SV10T** 10 second period

ESC := **1** enable one counter

ESV := **10** enable ten (or more) timers

SC01PV := **60** maximum counter value

SC01R := **IN101** disable the starting of the generator if desired (reset counter to zero)

SC01LD := **IN102 OR 3PWR3** start the generator immediately (set counter to maximum value; 3PWR3 asserts at the equivalent of 150 kW primary)

SC01CU := **R_TRIG SV01 AND 3PWR1 OR F_TRIG SV01 AND 3PWR2** increment counter SC01, faster when the demand is higher than 125 kW (3PWR1 asserts at the equivalent of 100 kW primary; 3PWR2 asserts at the equivalent of 125 kW primary)

SC01CD := **R_TRIG SV01 AND NOT 3PWR1** decrement counter SC01 when the demand is below 100 kW

OUT102 := **(SC01 > 48)** warning that diesel generator is about to start

OUT101 := **SC01QU** start generator signal

Settings for three-phase power elements 3PWR1, 3PWR2, and 3PWR3 are found in Table 4.15.

Because demands are slow-changing values, it does not make sense to check them continuously. The ten-second period makes the SV10T preset value setting easier to determine.

$$\text{Preset Value} = \frac{10 \text{ minutes} \bullet 60 \text{ s/minute}}{10 \text{ s/count}} = 60 \text{ counts}$$

Figure 7.14 is provided as a reference to this example.

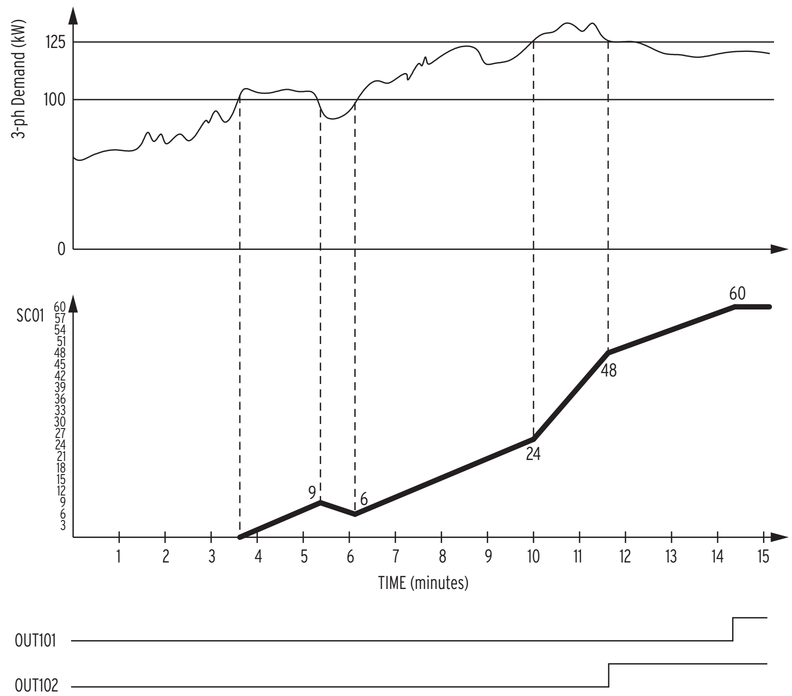


Figure 7.14 SELOGIC Control Equation Counter Example

Figure 7.2 illustrates how to use SELOGIC timers and counters to pulse LEDs and lock pushbuttons.

EXAMPLE 7.2

Figure 7.15 shows the logic required to pulse the LED and lock the pushbuttons. Timing is shown in Figure 7.16. Pushbutton 6, labeled **PUSHBUTTONS LOCKED**, is used to lock the enable/disable selection state of pushbuttons 1, 2, 3, 5, 7, 8, 9, and 10. If pushbutton 6 is pressed and held, pushbutton 6 LED will flash two (2) times and remain illuminated on the third flash. The designated pushbuttons are now locked in the last state selected. If pushbutton 6 is pressed and held a second time, the pushbutton LED will flash on two (2) times, then remain off. The designated pushbuttons are now unlocked, and each can be toggled between enable/disable.

Timer SV01 is used to generate an output pulse of 30 cycles on and 30 cycles off. The on-pulse illuminates the pushbutton 6 LED and increments the counter by one. The counter has a maximum range of three. The counter limits LED illumination to two flashes and a third illumination remaining on for lock conditions and two flashes, then remaining off for unlock conditions.

See partial logic and settings from relay default settings to clarify the example.

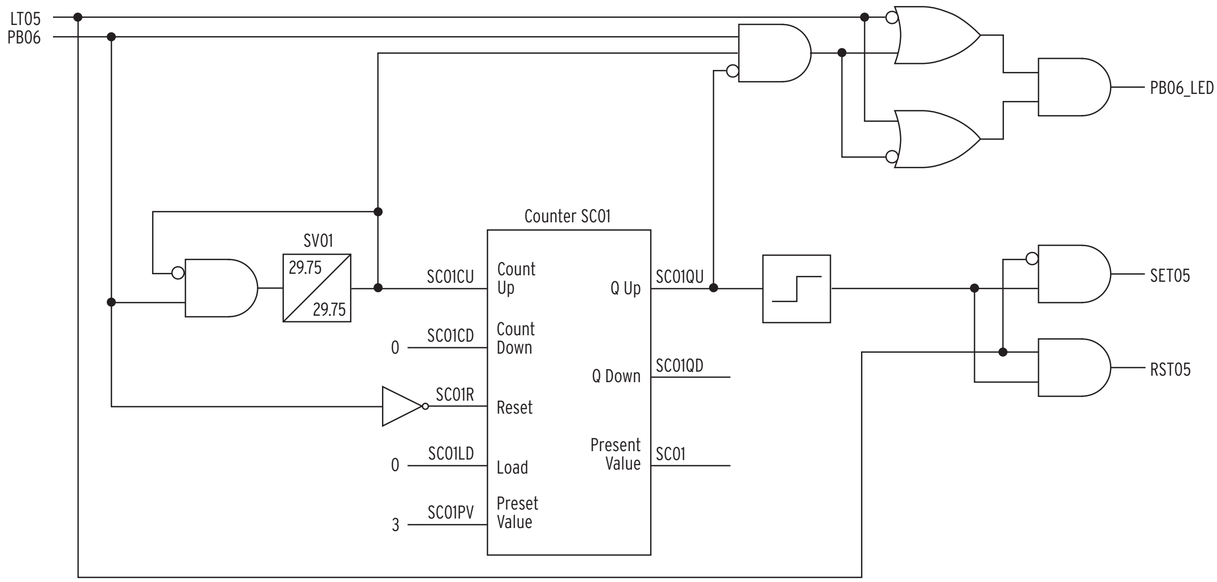


Figure 7.15 Pulse LED and Lock Pushbuttons Example

Make the following settings to implement these functions:

SET05 := **R_TRIG SC01QU AND NOT (LT05)** lock pushbuttons, must press for three seconds (locked when LT05 deasserted)

RST05 := **R_TRIG SC01QU AND LT05**

SV01PU := **29.75** with processing time ≈ 30 cycles

SV01DU := **29.75** with processing time ≈ 30 cycles

SV01 := **NOT SV01T AND PB06** 1 Hz blink generator for lock pushbutton

SC01PV := **3** maximum count

SC01R := **NOT PB06** reset counter

SC01LD := **0** set to 1 to defeat blink delay

SC01CU := **SV01T** count the blinks for lock pushbuttons control

SC01CD := **0** count down, not used

PB06_LED := **NOT (LT05 AND NOT (SV01T AND PB06 AND NOT (SC01QU)) OR NOT (LT05) AND SV01T AND PB06 AND NOT (SC01QU))** pushbuttons locked

[= NOT LT05 OR (PB06 AND SV01T AND NOT SC01QU)
AND
LT05 OR NOT(PB06 AND SV01T AND NOT SC01QU), as shown in *Figure 7.15*]

See latch bit equations for pushbutton use of LT05.

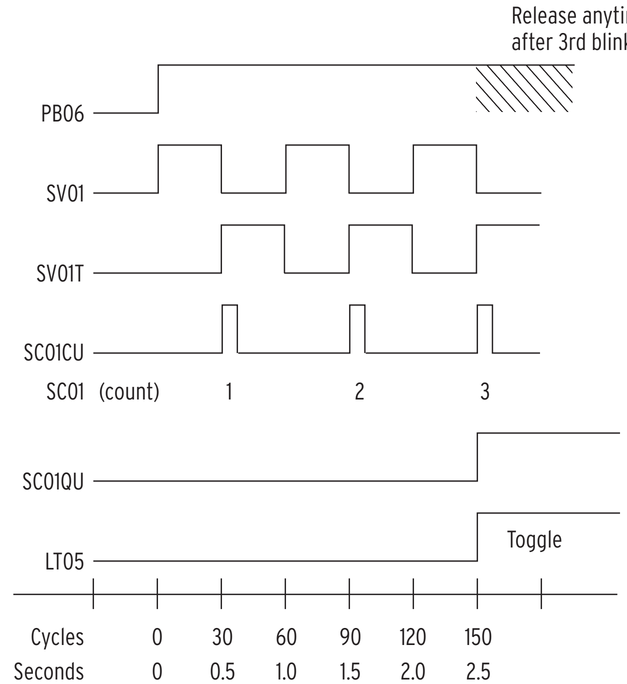


Figure 7.16 SELOGIC Control Equation Time and Counter

Counters: Volatile State and Disabled Behavior

Power Loss

SELOGIC counters SC01–SC16 are reset to a count value of zero after power to the SEL-651R relay module is lost and then restored. The counter output Relay Word bits behave as explained below for enabled and disabled counters.

Settings Change or Active Group Change

SELOGIC counters SC01–SC16 are retained through settings changes and active group changes.

Enabled and Disabled Counters

If a settings change or group change results in a different number of enabled counters (logic enable setting ESC changes), the counters behave as follows:

- ➤ newly enabled counters (or enabled counters after power is restored) start at a count value of zero, with output SC*nn*QD = logical 1, and SC*nn*QU = logical 0
- ➤ disabled counters are set to zero, with both outputs SC*mm*QD and SC*mm*QU forced to logical 0

Recloser Status Inputs

Six recloser status inputs are provided for recloser control operations (see *Figure 2.46*, *Figure 2.49*, and *Figure 2.69*). These status inputs are rated for nominal 12 Vdc and are not optically isolated. Make use of these inputs by using their Relay Word bits IN201–IN206 in SELOGIC control equations. See ratings in *Specifications on page 1.8*.

Figure 7.17 is used for following discussion/examples and shows the resultant Relay Word bits (Relay Word bits IN201–IN206) that follow corresponding timers. The figure shows examples of energized and de-energized inputs and corresponding Relay Word bit states. Assert an input by applying rated control voltage to the appropriate connector pin.

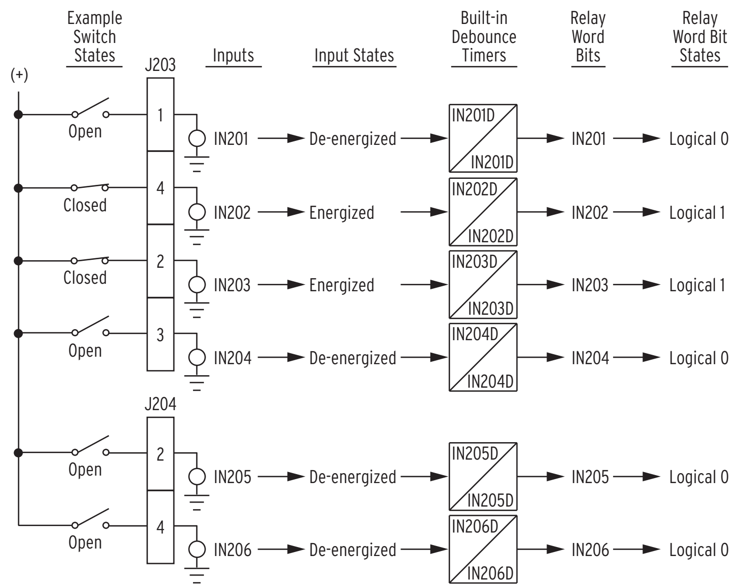


Figure 7.17 Example Operation of Recloser Status Inputs

Input Debounce Timers

Each input has a dedicated pickup/dropout timer (IN201D–IN206D) that is used to help eliminate unnecessary transitions caused by bouncing contacts. In global settings, set EICIS := Y to enable modification of these settings, default time is 0.75 cycles, except for G&W Viper-ST, Tavrida OSM, and Siemens SDR (1.5 cycles). The pickup/dropout timers IN201D–IN206D have a setting range of 0.00–2.00 cycles.

The relay takes the entered timer setting and internally runs the timer at the nearest 1/16-cycle. For example, if setting IN205D = 0.80, internally the timer runs at the nearest 1/16-cycle: 13/16-cycles (13/16 = 0.8125). The relay processing interval is 1/4-cycle, so Relay Word bits IN201 through IN206 are updated every 1/4-cycle.

For most applications, the input pickup/dropout debounce timers should be set in 1/4-cycle increments. For example, in the factory default settings, all the optoisolated input pickup/dropout debounce timers are set at 0.75-cycle, such as IN204D := 0.75.

If more than 2-cycles of debounce is needed, run Relay Word bit IN20*n* (*n* = 1 through 6) through a SELOGIC variable timer (see *Figure 7.3*) and use the output of the timer for input functions.

Optoisolated Inputs

You may order optoisolated inputs IN101–IN107 as an option. These inputs are located on the main board of the SEL-651R (see *Figure 7.2*). These inputs have debounce timers similar to those described in Recloser Status Inputs; the default time is 0.5 cycles.

Figure 7.18 shows the resultant Relay Word bits (Relay Word bits IN101–IN107) that follow corresponding timers.

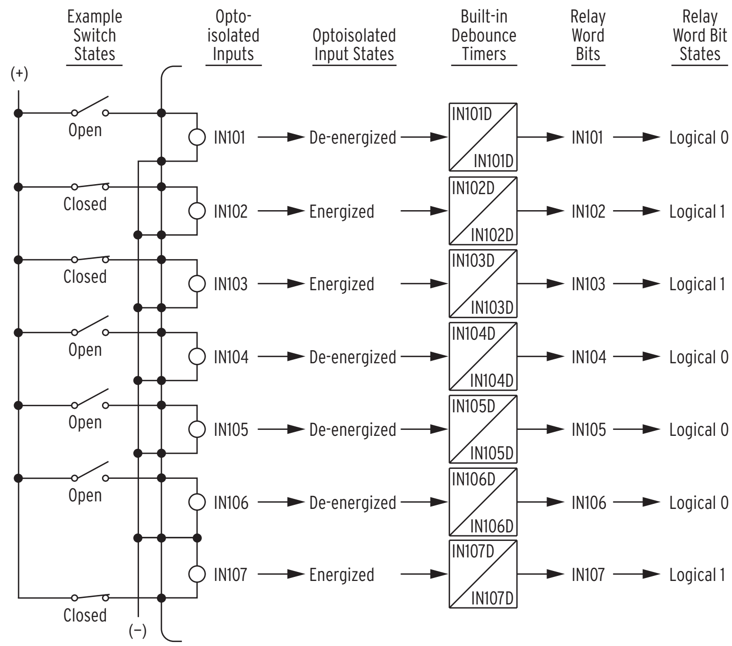


Figure 7.18 Example Operation of Optoisolated Inputs

Screw and torque information for optoisolated inputs IN101–IN107 is found in *Extra Connections on page 2.45*.

Remote Bits

Up to 32 remote control switches are operated via the serial communications port only. They may be operated using any of the following:

- ➤ SEL ASCII command CONTROL as described in *Section 10: Communications*.
- ➤ Fast Operate commands as described in *Appendix C: SEL Communications Processors*.
- ➤ DNP3 Objects 10 and 12 as described in *Appendix E: DNP3 Communications*.

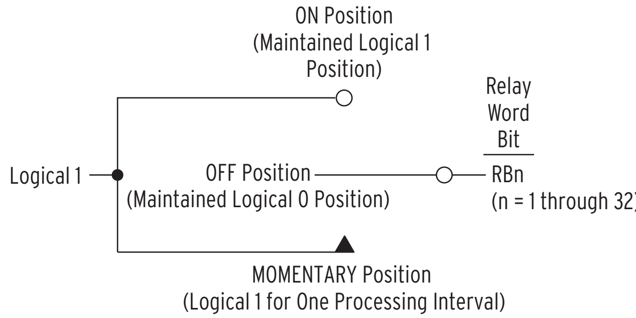


Figure 7.19 ON/OFF/MOMENTARY Remote Control Switch

The output of the switch in *Figure 7.19* is a Relay Word bit (RB01–RB32) called a Remote Bit and repeats for each Remote Bit. Use these Remote Bits in SELOGIC control equations.

Remote Bit RB*n* may be in the ON (RB*n* = logical 1) position, in the OFF (RB*n* = logical 0) position, or maintained in the OFF (RB*n* = logical 0) position and pulsed to the MOMENTARY (RB*n* = logical 1) position for one processing interval (1/4 cycle).

The state of each remote bit (Relay Word bits RB01 through RB32) is retained if relay settings are changed (for the active setting group or one of the other settings groups) or the active setting group is changed.

Remote Bits: Application Ideas

With SELOGIC control equations, the remote bits can be used in applications similar to those that use local bits.

Also, remote bits can be used much as optoisolated inputs are used in operating latch control switches. Pulse (momentarily operate) the remote bits for this application.

Remote Bits: Momentary Position

This subsection describes how the momentary position of the remote control switch operates using the SEL ASCII command CONTROL. It operates in the same manner when used with a Fast Operate or DNP3 pulse command.

Use the **CON *n*** command and **PRB *n*** subcommand to put the remote control switch in the momentary ON position for one processing interval, regardless of its initial state. The remote control switch is then placed in the OFF position.

If RB*n* is initially at logical 0, pulsing it with the **CON *n*** command and **PRB *n*** subcommand will change RB*n* to a logical 1 for one processing interval, and then return it to a logical 0. If RB*n* is initially at logical 1 instead, pulsing it with the **CON *x*** command and **PRB *x*** subcommand will change RB*n* to a logical 0.

Remote Bit: Volatile State

The states of the remote bits (Relay Word bits RB01 through RB32) are not retained if power to the relay is lost and then restored. The remote control switches always come back in the OFF position (corresponding remote bit is deasserted to logical 0) when power is restored to the relay.

Multiple Settings Groups

The SEL-651R has six (6) independent settings groups (the SEL-651R-1 has eight [8]). Each setting group has complete relay (overcurrent, reclosing, frequency, etc.) and SELOGIC control equation settings. The active setting group can be:

- Shown or selected with the SEL ASCII serial port **GROUP** command as described in *Section 10: Communications*.
- Shown or selected with the `MAIN` menu `Set/Show` menu item and the `Active Group` submenu item as described in *Section 11: Front-Panel Operations*.
- Selected with SELOGIC control equation settings SS1 through SS6 (SS1 through SS8 for SEL-651R-1). Settings SS1 through SS6 (SS1 through SS8 for SEL-651R-1) have priority over all other selection methods. Use remote bits in these equations to select settings groups with Fast Operate commands as described in *Appendix C: SEL Communications Processors*.
- Shown with DNP3 Objects 20 and 22 as described in *Appendix E: DNP3 Communications* and selected with Objects 40 and 41.

Settings Groups: Application Ideas

Settings Groups can be used for such applications as:

- Sectionalizing, midpoint, and tie reclosers in energized and de-energized states
- Environmental conditions such as winter storms, periods of high summer heat, etc.
- Hot-line tag that disables closing and sensitizes protection
- Commissioning and operation

Active Setting Group Indication

Only one setting group can be active at a time. Relay Word bits SG1 through SG6 (SG1 through SG8 for SEL-651R-1) indicate the active setting group, as shown in *Table 7.7*.

Table 7.7 Definitions for Active Setting Group Indication Relay Word Bits SG1 Through SG8

Relay Word Bit	Definition
SG1	Indication that setting Group 1 is the active setting group
SG2	Indication that setting Group 2 is the active setting group
SG3	Indication that setting Group 3 is the active setting group
SG4	Indication that setting Group 4 is the active setting group
SG5	Indication that setting Group 5 is the active setting group
SG6	Indication that setting Group 6 is the active setting group
SG7	Indication that setting Group 7 is the active setting group (SEL-651R-1 only)
SG8	Indication that setting Group 8 is the active setting group (SEL-651R-1 only)

For example, if setting Group 4 is the active setting group, Relay Word bit SG4 asserts to logical 1, and the other Relay Word bits SG1, SG2, SG3, SG5, and SG6 are all deasserted to logical 0.

Active Setting Group Selection

The Global settings class contains the SELOGIC control equation settings SS1 through SS6 (SS1 through SS8 for SEL-651R-1), as shown in *Table 7.8*.

Table 7.8 Definitions for Active Setting Group Switching SELOGIC Control Equation Settings SS1 Through SS8

Setting	Definition
SS1	go to (or remain in) setting Group 1
SS2	go to (or remain in) setting Group 2
SS3	go to (or remain in) setting Group 3
SS4	go to (or remain in) setting Group 4
SS5	go to (or remain in) setting Group 5
SS6	go to (or remain in) setting Group 6
SS7	go to (or remain in) setting Group 7 (SEL-651R-1 only)
SS8	go to (or remain in) setting Group 8 (SEL-651R-1 only)

The operation of these settings is explained with the following example:

Assume the active setting group starts out as setting Group 3. Corresponding Relay Word bit SG3 is asserted to logical 1 as an indication that setting Group 3 is the active setting group.

With setting Group 3 as the active setting group, setting SS3 has priority. If setting SS3 is asserted to logical 1, setting Group 3 remains the active setting group, regardless of the activity of settings SS1, SS2, SS4, SS5, and SS6 (and additional settings SS7 and SS8 for SEL-651R-1). With settings SS1 through SS6 (SS1 through SS8 for SEL-651R-1) all deasserted to logical 0, setting Group 3 still remains the active setting group.

With setting Group 3 as the active setting group, if setting SS3 is deasserted to logical 0 and one of the other settings (e.g., setting SS5) asserts to logical 1, the relay switches from setting Group 3 as the active setting group to another setting group (e.g., setting Group 5) as the active setting group, after qualifying time setting TGR:

TGR	Group Change Delay Setting	(settable from 0.00 to 16000.00 cycles)

In this example, TGR qualifies the assertion of setting SS5 before it can change the active setting group.

Active Setting Group Changes

The recloser control is disabled for less than 1 second while in the process of changing active settings groups. Relay elements, timers, and logic are reset, unless indicated otherwise in the specific logic description. For example, local bit (LB01 through LB16), remote bit (RB01 through RB32), and latch bit (LT01 through LT32) states are retained during an active setting group change. The output contacts do not change state until the relay enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group. For instance, if setting OUT105 := 1 (logical 1) in Group 2, and setting OUT105 := 1 (logical 1) in Group 3, and the relay is switched from Group 2 to Group 3, OUT105 stays energized before, during, and after the group change. However, if the Group 3 setting was OUT105 := 0 (logical 0) instead, then OUT105 remains energized until the relay enables in Group 3, solves the SELOGIC equations, and causes OUT105 to de-energize. See *Figure 7.28* for examples of output contacts in the de-energized state (i.e., corresponding output contact coils de-energized).

Example 1: Active Setting Group Switching

Use a single optoisolated input to switch between two settings groups in the SEL-651R. In this example, optoisolated input IN105 on the relay is connected to a SCADA contact in *Figure 7.20*. Each pulse of the SCADA contact changes the active setting group from one setting group, such as setting Group 1, to another, such as setting Group 4. The SCADA contact is not maintained, just pulsed to switch from one active setting group to another.

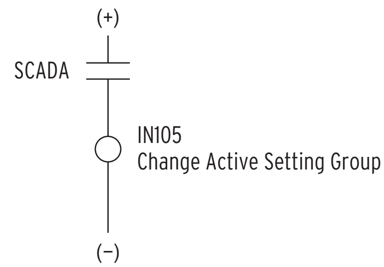


Figure 7.20 SCADA Contact Pulses Input IN105 to Switch Active Setting Group Between Settings Groups 1 and 4

If setting Group 1 is the active setting group and the SCADA contact is pulsed, setting Group 4 becomes the active setting group. If the SCADA contact is pulsed again, setting Group 1 becomes the active setting group again. The setting group control operates in a cyclical manner.

This logic is implemented in the SELOGIC control equation settings in *Table 7.9*.

Table 7.9 SELOGIC Control Equation Settings for Switching Active Setting Group Between Setting Groups 1 and 4

Setting Group 1	Setting Group 4
SV08PU := 60.00	SV08PU := 60.00
SV08DO := 0.00	SV08DO := 0.00
SV08 := SG1	SV08 := SG4
Global Settings	
SS1 := IN105 AND SV08T AND NOT SG1	
SS2 := 0	
SS3 := 0	
SS4 := IN105 AND SV08T AND NOT SG4	
SS5 := 0	
SS6 := 0	
SS7 := 0 (SEL-651R-1 only)	
SS8 := 0 (SEL-651R-1 only)	

SELOGIC control equation timer input setting SV08 in *Table 7.9* has logic output SV08T, shown in operation in *Figure 7.21* for both settings groups 1 and 4. The settings for SS1 and SS4 include expressions that steer the IN105 assertion to the appropriate setting. SS1 is only allowed to operate when the recloser control is not in Group 1, and SS4 is only allowed to operate when the recloser control is not in Group 4. These details are explained below.

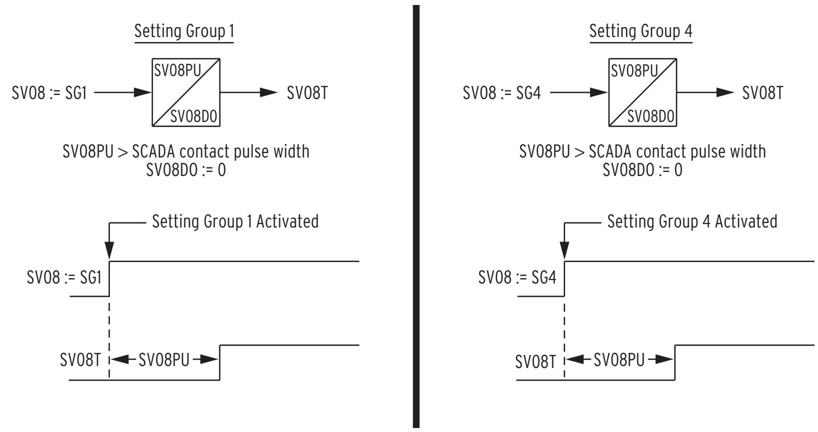


Figure 7.21 SELOGIC Control Equation Variable Timer SV08T Used in Setting Group Switching

In this example, timer SV08T is used in both settings groups: different timers could have been used with the same operational result. The timers reset during the setting group change, allowing the same timer to be used in both settings groups.

Timer pickup setting SV08PU is set greater than the pulse width of the SCADA contact (*Figure 7.20*). This allows only one active setting group change, such as from setting Group 1 to 4, for each pulse of the SCADA contact, and subsequent assertion of input IN105. The function of the SELOGIC control equations in *Table 7.9* becomes more apparent in the following example scenario.

Start Out in Setting Group 1

The recloser control has been in setting Group 1 for some time, with timer logic output SV08T asserted to logical 1, thus enabling SELOGIC control equation setting SS4 for the assertion of input IN105. The inclusion of AND NOT SG1 in the setting for SS1 prevents SS1 from detecting the next IN105 assertion. See *Figure 7.22*.

Switch to Setting Group 4

The SCADA contact pulses input IN105, and the active setting group changes to setting Group 4 after qualifying time setting TGR (perhaps set at a cycle or so to qualify the assertion of setting SS4). Optoisolated input IN105 also has its own built-in debounce timer (IN105D) available.

Note that *Figure 7.22* shows both setting Group 1 and setting Group 4 settings. The setting Group 1 settings (near the top of *Figure 7.22*) are enabled only when setting Group 1 is the active setting group and likewise for the setting Group 4 settings near the bottom of the figure. The group selection settings, SS1 and SS4, are global settings, and are enabled in every setting group.

Setting Group 4 is now the active setting group, and Relay Word bit SG4 asserts to logical 1. After the relay has been in setting Group 4 for a time period equal to SV08PU, the timer logic output SV08T asserts to logical 1, thus enabling SELOGIC control equation setting SS1 for a new assertion of input IN105. The inclusion of AND NOT SG4 in the setting for SS4 prevents SS4 from detecting the next IN105 assertion.

Note that input IN105 is still asserted because setting Group 4 is activated. Pickup time SV08PU keeps the continued assertion of input IN105 from causing the active setting group to revert back again to setting Group 1 for a single assertion of input IN105. This keeps the active setting group from being changed at a time interval less than time SV08PU.

Switch Back to Setting Group 1

The SCADA contact pulses input IN105 a second time, and the active setting group changes back to setting Group 1 after qualifying time setting TGR, perhaps set at a cycle or so to qualify the assertion of setting SS1. Optoisolated input IN105 also has its own built-in debounce timer IN105D available. The timing is shown in *Figure 7.22*.

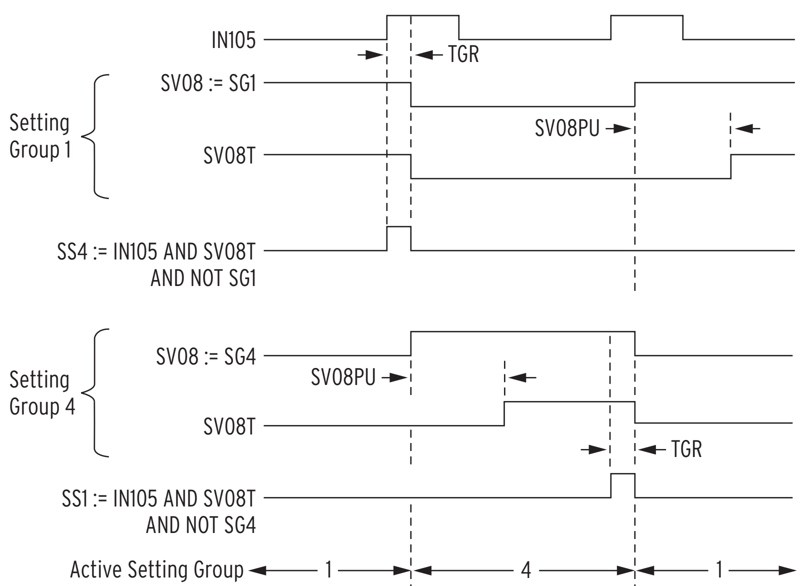


Figure 7.22 Active Setting Group Switching (With Single Input) Timing

Example 2: Active Setting Group Switching

Use three optoisolated inputs to switch between the six settings groups in the SEL-651R. In this example, optoisolated inputs IN101, IN102, and IN103 on the recloser control are connected to a rotating selector switch as shown in *Figure 7.23*.

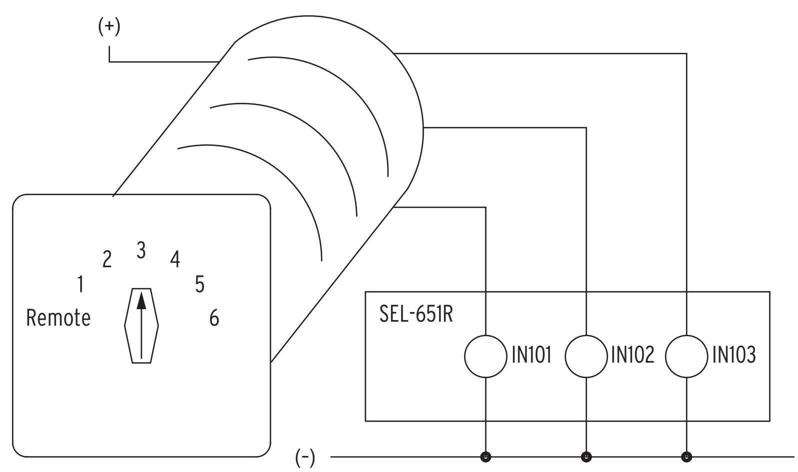


Figure 7.23 Rotating Selector Switch Connected to Inputs IN101, IN102, and IN103 for Active Setting Group Switching

The selector switch has multiple internal contacts arranged to assert inputs IN101, IN102, and IN103, dependent on the switch position. As shown in *Table 7.10*, when the selector switch is moved from one position to another, a different setting group is activated. The logic is implemented in the SELOGIC control equation settings in *Table 7.10*.

Table 7.10 Active Setting Group Switching Input Logic

Input States			Active Setting Group	SELOGIC Settings
IN103	IN102	IN101		
0	0	0	Remote	
0	0	1	Group 1	SS1 := NOT IN103 AND NOT IN102 AND IN101
0	1	0	Group 2	SS2 := NOT IN103 AND IN102 AND NOT IN101
0	1	1	Group 3	SS3 := NOT IN103 AND IN102 AND IN101
1	0	0	Group 4	SS4 := IN103 AND NOT IN102 AND NOT IN101
1	0	1	Group 5	SS5 := IN103 AND NOT IN102 AND IN101
1	1	0	Group 6	SS6 := IN103 AND IN102 AND NOT IN101

The settings in *Table 7.10* are made in global settings.

Selector Switch Starts Out in Position 3

If the selector switch is in position 3 in *Figure 7.23*, setting Group 3 is the active setting group (Relay Word bit SG3 = logical 1). Inputs IN101 and IN102 are energized and IN103 is de-energized:

SS3 := **NOT IN103 AND IN102 AND IN101**
:= **NOT (logical 0) AND (logical 1) AND (logical 1) = logical 1**

To get from the position 3 to position 5 on the selector switch, the switch passes through the position 4. The switch is only briefly in position 4:

SS4 := **IN103 AND NOT IN102 AND NOT IN101**
:= **(logical 1) AND NOT (logical 0) AND NOT (logical 0) = logical 1**

but not long enough to be qualified by time setting TGR to change the active setting group to setting Group 4, see *Figure 7.24*. For such a rotating selector switch application, qualifying time setting TGR is typically set at 180 to 300 cycles. Set TGR long enough to allow the selector switch to pass through intermediate positions, without changing the active setting group, until the switch rests on the desired setting group position.

Selector Switch Switched to Position 5

If the selector switch rests on position 5 in *Figure 7.23*, setting Group 5 becomes the active setting group (after qualifying time setting TGR; Relay Word bit SG5 = logical 1). Inputs IN101 and IN103 are energized and IN102 is de-energized:

SS5 := **IN103 AND NOT IN102 AND IN101**
:= **NOT(logical 1) AND NOT (logical 0) AND (logical 1) = logical 1**

To get from position 5 to position REMOTE on the selector switch, the switch passes through the positions 4, 3, 2, and 1. The switch is only briefly in these positions, but not long enough to be qualified by time setting TGR to change the active setting group to any one of these settings groups, see *Figure 7.24*.

Selector Switch Now Rests on Position REMOTE

If the selector switch rests on position REMOTE in *Figure 7.23,* all inputs IN101, IN102, and IN103 are de-energized and all settings SS1 through SS6 in *Table 7.10* are at logical 0. The last active setting group (Group 5 in this example) remains the active setting group (Relay Word bit SG5 = logical 1).

With settings SS1 through SS6 all at logical 0, use the serial port **GROUP** command or the front panel GROUP menu to switch the active setting group from Group 5, in this example, to another desired setting group. The timing is shown in *Figure 7.24*.

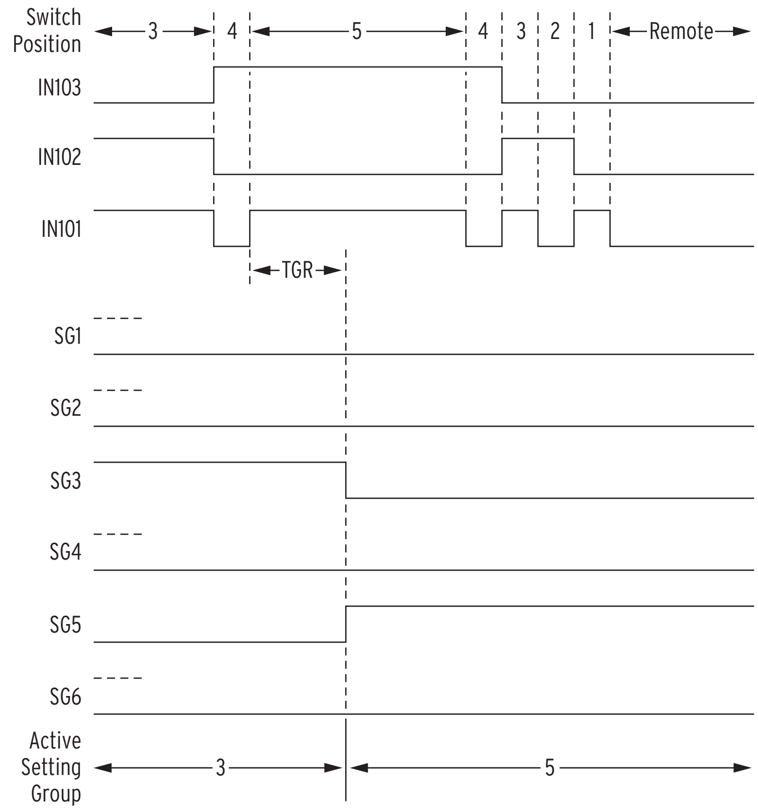


Figure 7.24 Active Setting Group Switching (With Rotating Selector Switch) Time Line

Active Setting: Nonvolatile State

Power Loss

The active setting group is retained if power to the relay is lost and then restored. If a particular setting group is active (e.g., setting Group 5) when power is lost, the same setting group is active when power is restored.

Settings Change

If individual settings are changed for the active setting group or one of the other settings groups, the active setting group is retained, much like in the preceding explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the active setting group, so the relay is not momentarily disabled.

If the individual settings change causes a change in one or more SELOGIC control equation settings SS1 through SS6 (SS1 through SS8 for SEL-651R-1), the active setting group can be changed, subject to the newly enabled SS1 through SS6 settings.

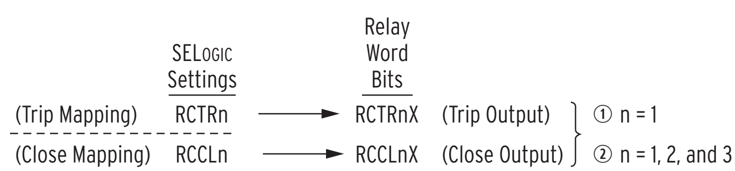
Make Active Setting Group Switching Settings with Care

The active setting group is stored in nonvolatile memory so it can be retained during power loss or settings change. The nonvolatile memory is rated for a finite number of writes for all setting group changes. Exceeding the limit can result in a FLASH self-test failure. **An average of four (4) setting group changes per day can be made for a 25-year relay service life**.

This requires that SELOGIC control equation settings SS1 through SS6 (SS1 through SS8 for SEL-651R-1; see *Table 7.8*) be set with care. Settings SS1 through SS6 must not result in continuous cyclical changing of the active setting group. Time setting TGR qualifies settings SS1 through SS6 before changing the active setting group. If optoisolated inputs IN101 through IN106 are used in settings SS1 through SS6, the inputs have their own built-in debounce timer that can help in providing the necessary time qualification.

Trip and Close Mapping and Output Logic

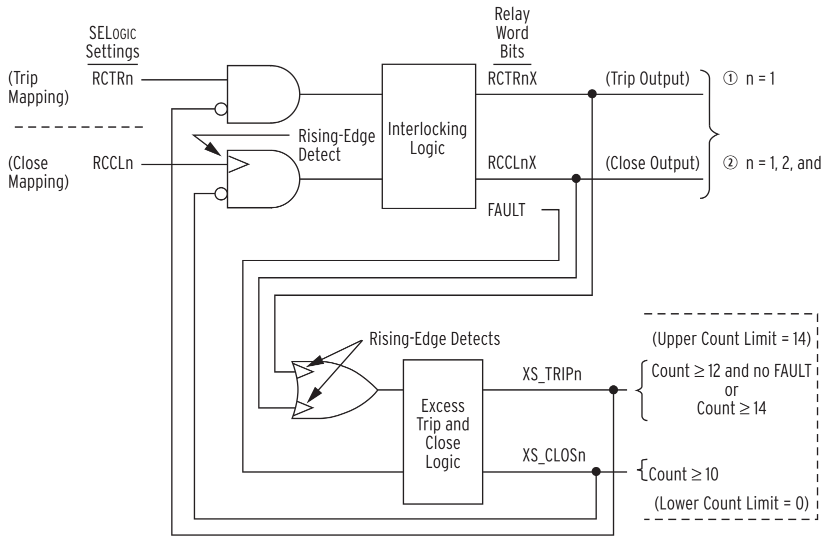
Figure 7.25 and *Figure 7.26* contain the trip and close mapping and output logic that the SEL-651R uses when connected to various reclosers (see *Section 2* figure references within *Figure 7.25* and *Figure 7.26* for the corresponding reclosers).



① See Figure 2.46 and Figure 2.54
② See Figure 2.59

Figure 7.25 Trip and Close Mapping and Output Logic

Note that in *Figure 7.26* there is a rising-edge detect on the RCCL*n* input into gate AND 2. This prevents standing close conditions.



① See Figure 2.66.
② See Figure 2.48, Figure 2.51, Figure 2.56, Figure 2.62, and Figure 2.65.

Figure 7.26 Trip and Close Mapping and Output Logic With Interlocking Logic and Excess Trip and Close Logic

The term mapping in the preceding discussion refers to providing a transition between the A-B-C power system world outside the SEL-651R and the A-B-C algorithm world inside the SEL-651R, as detailed in *Figure 9.23* through *Figure 9.25* and the accompanying text.

Factory Trip- and Close-Mapping Settings

The factory settings for the trip-mapping and close-mapping settings are as follows (see *Figure 5.1* and *Figure 6.1*):

RCTR1:= **TRIP3P OR TRIPA OR TRIPB OR TRIPC**

RCTR2:= **TRIP3P OR TRIPA OR TRIPB OR TRIPC**

RCTR3:= **TRIP3P OR TRIPA OR TRIPB OR TRIPC**

RCCL1:= **CLOSE3P**

RCCL2:= **CLOSE3P**

RCCL3:= **CLOSE3P**

As a conservative approach, all the trip logic outputs from *Figure 5.1* are entered in all preceding factory trip-mapping settings, ensuring three-phase tripping for all reclosers.

Making Three-Phase Recloser Trip- and Close-Mapping Settings

For three-phase reclosers (reclosers that can only trip and close all three phases in unison), the *Figure 5.1* Relay Word Bit outputs TRIPA, TRIPB, and TRIPC in the preceding factory trip-mapping setting RCTR1 are inoperative (Group Setting ESPB := N). Thus, the recloser trip settings can be minimized to RCTRn := TRIP3P. The corresponding recloser close settings are already minimized to RCCLn := CLOSE3P.

Making Single-Phase Recloser Trip- and Close-Mapping Settings

For single-phase reclosers (reclosers that can trip and close all three phases in unison or each phase individually), change the factory trip-mapping settings so that each setting is set to TRIPA, TRIPB, or TRIPC (refer to *Table 9.21*). For example:

RCTR1:= **TRIPA OR TRIP3P**.

RCTR2:= **TRIPB OR TRIP3P**.

RCTR3:= **TRIPC OR TRIP3P**.

Such settings depend on correspondence with the power system, as detailed in *Figure 9.23* through *Figure 9.25* and accompanying text. Note that in *Figure 5.1* three-phase tripping (SELOGIC settings TR3P and TR3X) also flows through Relay Word Bit outputs TRIPA, TRIPB, and TRIPC.

In the preceding suggested trip settings example and in *Table 9.21*, the TRIP3P value is included in each trip-mapping setting, in case Group Setting ESPB is changed between Y and N. As shown in *Figure 5.1*, changing Group Setting ESPB changes the enabled Relay Word Bit outputs (switches between TRIP3P and TRIPA, TRIPB, TRIPC). If single-phase tripping is never used (Group Setting ESPB:=N), the preceding suggested trip settings can all be minimized to TRIP3P only.

For single-phase reclosers, change the factory close-mapping settings so that each setting is set to CLOSEA, CLOSEB, or CLOSEC (refer to *Table 9.22*). For example:

RCCL1:= **CLOSEA OR CLOSE3P**

RCCL2:= **CLOSEB OR CLOSE3P**

RCCL3:= **CLOSEC OR CLOSE3P**

Such settings depend on correspondence with the power system, as detailed in *Figure 9.23* through *Figure 9.25* and accompanying text. Note that in *Figure 6.1* three-phase close conditions other than auto reclose (SELOGIC setting CL3P) do not flow through CLOSEA, CLOSEB, and CLOSEC. Three-phase close conditions other than auto reclose have to be programmed in each SELOGIC setting CLA, CLB, and CLC if single-phase tripping and closing is enabled for the recloser (group setting ESPB:= Y).

In the preceding suggested close settings example and in *Table 9.22*, the CLOSE3P value is included in each close-mapping setting, in case Group Setting ESPB is changed between Y and N. As shown in *Figure 6.1*, changing Group Setting ESPB changes the enabled Relay Word Bit outputs (switches between CLOSE3P and CLOSEA, CLOSEB, CLOSEC). If single-phase closing is never used (Group Setting ESPB:=N), the preceding suggested close settings can all be minimized to CLOSE3P only.

Interlocking Logic

The interlocking logic in *Figure 7.26* prevents Relay Word Bit outputs RCTR*n*X and RCCL*n*X from being asserted at the same time. This is critical in situations such as that shown in *Figure 2.48*, where only one of the stacked trip or close FETs can be on at one time; otherwise, a short-circuit between 155 Vdc power and ground would result.

Excess Trip and Close Logic

Relay Word Bit outputs XSTRIP*n* and XSCLOS*n* from the excess trip and close logic in *Figure 7.26* operate as feedback to the trip and close mapping logic, respectively, in the same figure. This excess trip and close logic feedback prevents Relay Word Bit outputs RCTR*n*X and RCCL*n*X from asserting too many times within a time period. This restriction prevents overheating of the recloser coils.

Realistically, such a restriction would most likely take effect during testing or any other time the front-panel {TRIP} and {CLOSE} operator controls are pushed an excessive number of times. Each assertion of trip output RCTR*n*X or close output RCCL*n*X is detected by the rising-edge detect inputs of the excess trip and close logic and is considered a count. These counts accumulate in the excess trip and close logic.

Any time the cumulative count increments (for a new trip or close), a 360-cycle timer in the excess trip and close logic starts timing. When the 360-cycle timer times out, the cumulative count decrements one (1) count. If the cumulative count is still greater than zero (0), the 360-cycle timer loads up again and times. When the 360-cycle timer times out, again, the cumulative count decrements one (1) count, again. This process repeats until the cumulative count eventually decrements down to zero (0).

The 360-cycle timer period makes room for one more count (one more trip or close operation) to be added to the cumulative counter every 360 cycles. Any time a new trip or close occurs, the cumulative counter increments and the 360-cycle timer is interrupted, if timing, and loaded up again. Conceivably, if the time period between trip or close operations is less than 360 cycles, the cumulative counter just continues incrementing, with no decrementing, until the cumulative count runs up to the set limits shown in *Figure 7.26*.

Note that the assertion of XS_CLOS*n* (excess close for pole *n*) is at a lesser count (cumulative count = 10) than XS_TRIP*n* (excess trip for pole *n*). More trips are allowed, because tripping is a more critical function than closing. If a fault is present (Relay Word bit FAULT asserted), then two additional trip attempts (cumulative count up to 14, instead of just to 12) are allowed before XS_TRIP is asserted. The 360-cycle timer works at bringing the cumulative count back down.

Output Contacts

The SEL-651R comes standard with two Form-C output contacts (OUT201 and OUT202). An ordering option adds 8 extra output contacts: six Form-A (OUT101–OUT106), and two Form-C (OUT107 and OUT108). See *Figure 7.27* for a definition of the output contact Forms.

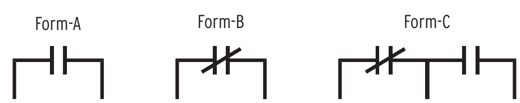


Figure 7.27 Output Contact Forms

Figure 2.11 shows the output contact terminal locations on the SEL-651R relay module rear panel. Refer to *Extra Connections on page 2.45* for connector and tightening torque information.

SEL-651R output contacts are normally operated using SELOGIC control equation OUT*n* (*n* = 101–108, 201–202) or one of several other methods.

These two methods are ordinarily only used in testing:

- SEL ASCII command **PULSE** as described in *Section 10: Communications*.
- Front-panel HMI Control menu and Output Contacts submenu as described in *Section 11: Front-Panel Operations*.

Figure 7.28 shows the example operation of Relay Word bits that in turn control corresponding output contacts. Output contacts OUT103 through OUT106 are not shown in *Figure 7.28*, but are Form-A type output contacts that operate similarly to output contacts OUT101 and OUT102.

SELOGIC control equation settings OUT*n* and serial port ASCII commands PULSE OUT*n* are shown as inputs into the logic in *Figure 7.28*. Front-Panel HMI, not shown in *Figure 7.28*, has the same logical effect as the serial port ASCII commands PULSE OUT*n* in *Figure 7.28*—it is just a different means to the same result (assertion of Relay Word bit OUT*n*).

SCADA Operation

To operate output contacts via SCADA, use one of the following methods of operation.

- ➤ Fast Operate commands as described in *Appendix C: SEL Communications Processors*.
- ➤ DNP3 Objects 10 and 12 as described in *Appendix E: DNP3 Communications*.

Both methods must first be programmed using SELOGIC control equation OUT*n* (*n* = 101–108, 201–202). For example, remote bit RB01 may be used to control output OUT202 with the setting OUT202 := RB01. See *Remote Bits on page 7.20*.

Output Contact Operation

The assertion of a Relay Word bit causes the energization of the corresponding output contact coil. Depending on the contact type (Form-A or Form-B), the output contact closes or opens. A Form-A output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. A Form-B output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized.

Notice that *Figure 7.28* shows all four possible combinations of output contact coil states (energized or de-energized) and output contact types (Form-A or Form-B).

Only OUT201 is used in the SEL-651R factory default settings, and it functions as an alarm contact.

The default settings are

OUT101 through OUT108 := **0**

OUT201 := **NOT (SALARM OR HALARM)**

OUT202 := **0**

The output SELOGIC equations are located in the logic settings class, see *Output Contact SELOGIC Equations on page SET.45* Output.

In most applications, monitor the normally closed side of the Form-C contact (OUT201) for fail-safe alarm operation. When the SEL-651R is not enabled (for example, if ac power and the battery are not connected), the normally closed contact would be in the closed position, indicating the alarm condition. When the SEL-651R is powered-up and operational, the normally closed contact would be open, indicating a non-alarm condition.

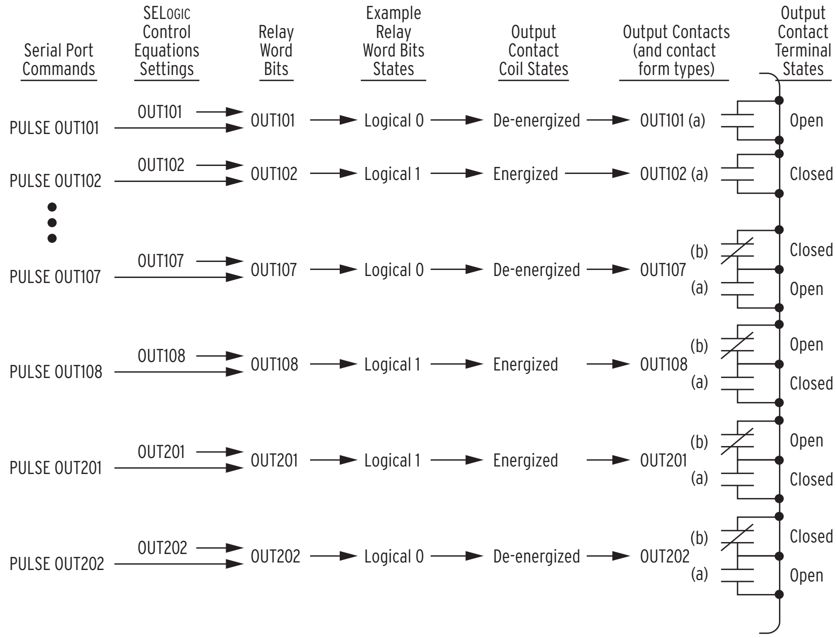


Figure 7.28 Logic Flow for Example Output Contact Operation

If an ac transfer switch is installed, the Form-B side of output contact OUT202 is wired to its control circuit (see *Figure 2.44*). This is done in case any future transfer switch control is needed. From the factory, no control is set for output contact OUT202 (see preceding factory default output contact settings).

SELOGIC Control Equations: Examples

Example: Tripping

If tripping does not involve single-pole or switch-onto-fault trip logic, the SELOGIC control equation trip setting TR3P is the only trip setting needed (see *Trip Logic on page 5.1*).

Note that *Figure 5.1* appears quite complex. But because tripping does not involve single-pole or switch-onto-fault trip logic in this example, the only effective inputs in *Figure 5.1* are SELOGIC control equation trip settings TR3P and TR3X.

TRSOTF := **0** not used-set directly to logical 0

TR3P := **51PT OR 51G1T OR 50P1 AND SH03P** fuse saving example

ULTR3P := **NOT (51P OR 51G1)**

TR3X := **0**

TRA := **0**

TRB := **0**

TRC := **0**

Analysis of Trip Setting TR3P

Again, the example trip equation is as follows:

TR3P := **51PT OR 51G1T OR 50P1 AND SH03P**

The Relay Word bit definitions are as follows:

51PT	phase time-overcurrent element timed out
51G1T	residual ground time-overcurrent element timed out
50P1	phase instantaneous overcurrent element asserted
SH03P	reclosing relay shot counter at shot = 0

In the trip equation, the AND operator is executed before the OR operators:

50P1 AND SH03P

Element 50P1 can only cause a trip if the three-phase reclosing relay shot counter is at shot = 0. When the reclosing relay shot counter is at shot = 0, Relay Word bit SH03P is in the following state:

SH03P = 1

If maximum phase current is above the phase instantaneous overcurrent element pickup setting 50P1P, Relay Word bit 50P1 is in the following state:

50P1 = 1

With SH03P = 1 and 50P1 = 1, the logical AND operation results in

(50P1 AND SH0) = (1 AND 1) = 1

and an instantaneous trip results. This logic is commonly used in fuse-saving schemes for distribution feeders.

If the reclosing relay shot counter advances to shot = 1 for the reclose that follows the trip, Relay Word bit SH03P is in the following state:

SH03P = 0

If maximum phase current is above the phase instantaneous overcurrent element pickup setting 50P1P for the reoccurring fault, Relay Word bit 50P1 is in the following state:

50P1 = 1

With SH03P = 0 and 50P1 = 1, the logical AND operation results in

(50P1 AND SH03P) = (1 AND 0) = 0

and no trip results from phase instantaneous overcurrent element 50P1.

A trip will eventually result if time-overcurrent element 51PT or 51G1T times out. If residual ground time-overcurrent element 51G1T times out, Relay Word bit 51G1T is in the following state:

51G1T = 1

When shot = 1, SH03P = 0 and the result is:

```
TR3P  = (51PT OR 51G1T OR 50P1 AND SH03P)
      = (0 OR 1 OR 1 AND 0)
      = (0 OR 1 OR 0)
      = 1
```

and a time-delayed trip results from residual ground time-overcurrent element 51G1T.

Trip Output Contact

To assert output contact OUT101 to trip a circuit breaker, make the following SELOGIC control equation output contact setting:

OUT101 := **TRIP3P**

Note that this simple output contact setting example is different from the standard recloser control trip/close output settings discussed in *Trip and Close Mapping and Output Logic on page 7.29*.

Example: Phase Time-Overcurrent Element 51PT

Examine a phase time-overcurrent element as an example of protection element operation via the logic output of Relay Word bits. The following Relay Word bits are the logic outputs of the phase time-overcurrent element:

51P	indication that the maximum phase-current magnitude is above the level of the phase time-overcurrent pickup setting 51PJP or 51PKP
51PT	indication that the phase time-overcurrent element has timed out on its curve
51PR	indication that the phase time-overcurrent element is fully reset

Pickup Indication

If the maximum phase current is at or below the level of the phase time-overcurrent pickup setting 51PJP or 51PKP, Relay Word bit 51P is in state 0.

If the maximum phase current is above the level of the phase time-overcurrent pickup setting 51PJP or 51PKP, Relay Word bit 51P is in state 1.

The 51PT element is either timing on its curve or is already timed out.

Time–Out Indication

If phase time-overcurrent element 51PT is not timed out on its curve, Relay Word bit 51PT is in state 0.

If phase time-overcurrent element 51PT is timed out on its curve, Relay Word bit 51PT is in state 1.

Reset Indication

If phase time-overcurrent element 51PT is not fully reset, Relay Word bit 51PR is in state 0. The 51PT element is either:

- Timing on its curve
- Already timed out
- Timing to reset (one-cycle reset or electromechanical emulation—see setting 51PRS)

If phase time-overcurrent element is fully reset, Relay Word bit 51PR is in state 1.

Relay Word Bit Applications

Common uses for Relay Word bits 51P, 51PT, and 51PR:

51P	Testing, such as assigning to an output contact for pickup testing, trip unlatch logic.
51PT	Trip logic.
51PR	Testing, such as assigning to an output contact for reset indication.

Section 8
Metering and Monitoring

Introduction

The SEL-651R Recloser Control includes extensive metering features and monitoring functions. The metering functions facilitate power system planning and operation, while the monitoring functions aid in maintenance planning and electrical load forecasting.

The metering functions include:

- Fundamental (Instantaneous) Metering
- Demand Metering
- Energy Metering
- Maximum/Minimum Metering
- Harmonic and RMS Metering

The monitoring functions include:

- Breaker/Recloser Contact Wear Monitor
- Battery Monitor
- Load Profile Recorder

This section explains each of these features.

Dependence on Y and Z Voltage Inputs, Phase Connection Settings, and Scaling

The SEL-651R is configured with six voltage inputs, labeled V1Y, V2Y, V3Y (called the "Y-side"); and V1Z, V2Z, V3Z (called the "Z-side"). Global settings determine which voltage(s) are used for the metered quantities that involve a voltage signal. Additionally, global current and voltage connection settings allow phase rolling of the current and voltage inputs—see *Current and Voltage Connection Settings on page 9.28*.

All metering and monitoring functions use the rolled voltages and currents, and the voltage signal names become VAY, VBY, VCY, VAZ, VBZ, and VCZ.

All metering functions are calculated in primary quantities, as determined by the CTR, CTRN, PTRY, and PTRZ group settings. See *Settings Explanations on page 9.27* for details on these ratio settings.

Table 8.1 lists the metering quantities and which of the global settings affect them.

Table 8.1 Metering Quantities Affected by Global Settings CTPOL, EPHANT, VSELECT, or FSELECT

Quantity	Affected by Global settings:	Effect
Fundamental Current:		
Instantaneous	CTPOL (CT polarity)	Phase angle—180-degree shift.
Demand	None	Not affected
Peak demand	None	Not affected
RMS Current	None	Not affected
Fundamental Voltage:		
Instantaneous	EPHANT (Phantom voltage enable)	Generate balanced three-phase phantom voltages from one voltage terminal.
RMS Voltage	None	Not affected
Sequence Components:		
Voltage	EPHANT	Shutdown calculations for terminals that have EPHANT enabled.
Frequency:		
System Frequency	FSELECT (Frequency source selection)	Voltage channel (V1Y or V1Z) for frequency measurement
Power:		
Instantaneous	CTPOL, EPHANT or VSELECT	Power direction and voltage source
Power Factor	CTPOL, EPHANT or VSELECT	Power direction and voltage source
Demand	CTPOL, EPHANT or VSELECT	Power direction and voltage source
Peak Demand	CTPOL, EPHANT or VSELECT	Power direction and voltage source
Average Power:		
Real	CTPOL, VSELECT	Power direction and voltage source
Energy:		
Real	CTPOL, EPHANT or VSELECT	Power direction and voltage source
Reactive	CTPOL, EPHANT or VSELECT	Power direction and voltage source
Total Harmonic Distortion:		
Currents	None	Not affected
Voltages	None	Not affected
Harmonics:		
Currents	None	Not affected
Voltages	None	Not affected

Fundamental (Instantaneous) Metering

Description

The SEL-651R performs current, voltage, symmetrical component, and power metering using the fundamental (filtered) signals obtained from the same cosine filter that is used in the protective relay algorithms. These values respond to the fundamental signal at the measured system frequency, which is usually near 50 Hz or 60 Hz. Frequency tracking ensures that frequency variations do not adversely affect metering accuracy.

The fundamental metering function updates the metering values approximately twice per second.

The SEL-651R converts the metered values to primary units using the current transformer ratio settings (CTR and CTRN) and potential transformer ratio settings (PTRY and PTRZ). The PTRY setting is entered in an adjusted fashion when Low-Energy Analog (LEA) inputs are present, as described in

Potential Transformer (PT) Ratios on page 9.40. If LEA inputs are in use, the actual primary to secondary ratio of the voltage divider must be scaled down before entry as the PTRY setting.

The metered values are available in several forms:

- Serial port ASCII communications; see *METER Command (Metering Data) on page 10.26*
- Serial port Fast Meter communications; see *Appendix C: SEL Communications Processors*
- Serial port DNP; see *Default Data Map on page E.20*
- Front-panel LCD; see *Front-Panel Menus and Screens on page 11.4*

Appendix G: Analog Quantities lists certain meter values that are available for:

- Display points; see *Rotating Display on page 11.12*
- Load Profile Recorder; see *Load Profile Report on page 8.38*

Table 7.2 lists certain meter values that are available for:

- SELOGIC® Analog Comparisons; see *Analog Quantities on page 7.2*.

See *Specifications on page 1.8* for a listing of the fundamental metering accuracy in the SEL-651R.

These fundamental quantities are used in the Instantaneous Metering quantities, as well as the Demand, Energy, and Maximum/Minimum Metering functions, described later in this section.

Because the fundamental quantities are filtered to the power system frequency, they are immune to signal energy at dc and harmonic frequencies.

Harmonics and True RMS Metering on page 8.18, use the full signal spectrum (except dc) in the calculations. RMS metering quantities may differ from fundamental metering quantities if the system contains harmonic energy.

Effect of Global Settings EGNDSW, EPHANT, VSELECT, and FSELECT on Fundamental Metering Functions

Ground Switch Option

Global setting EGNDSW is normally set to Y in the SEL-651R. This enables the ground switch logic for protection functions and fundamental current metering functions.

NOTE: Harmonics and rms metering functions are not affected by the EGNDSW setting.

In fundamental metering, setting ENGDSW affects how the IG quantity is derived, and how it relates to the IN and 3I0 quantities. These quantities (IN, 3I0, IG) are available in the various metering output formats, such as the serial port **MET** command.

The ground switch logic is fully described in *Section 4: Protection Functions*.

Fundamental Metering when EGNDSW := Y

Use this selection when the neutral current input channel IN is wired residually (see *Figure 2.46* and *Figure 2.48*) and measures the zero-sequence current of the power system. The IA, IB, and IC current inputs are also capable of measuring the zero-sequence current, 3I0 = IA + IB + IC.

Because the IN channel is more sensitive to small currents, it is more accurate for metering measurements. When currents are higher than the range of the IN channel, the 3I0 quantity is more accurate, because the IN channel will saturate.

Therefore, in the SEL-651R fundamental metering subsystem, quantity IG is automatically switched between IN and 3I0, depending on the present size of the signal being measured. This is similar to the behavior of the IG quantity used in the overcurrent elements 50G1, 51G2, etc., when EGNDSW := Y.

If the current transformer ratio setting for the IN channel (CTRN) is different than the phase channels IA, IB, and IC (CTR), the proper ratio is used for each signal, and the IG quantity is truly representing primary amps.

Thus, when EGNDSW := Y, fundamental metering quantity IG will exactly match IN for small signals, and 3I0 for large signals.

Fundamental Metering when EGNDSW := N

Use this selection when the neutral current input channel IN is not connected, or is not connected to a current source related to the phase channels IA, IB, IC.

In this mode, current input channel IN is not coupled with the fundamental metering quantity IG. Thus, when EGNDSW := N, fundamental metering quantity IG matches 3I0 at all times.

Phantom Voltage Function

A phantom setting allows three-phase voltages to be generated from a single metered quantity, and the power quantities to be calculated from the generated voltages. The single-phase voltage must be connected to terminal V1Y or V1Z.

Global setting VYCONN or VZCONN is set as shown in *Table 8.2*, depending on the connected voltage signals. The magnitude adjustment factor is 1 for phase-to-neutral signals, and $1/(\sqrt{3})$ to convert phase-to-phase signals to phase-to-neutral signals.

Table 8.2 Phantom Voltage Adjustments (Sheet 1 of 2)

Voltage Connected V1Y-N or V1Z-N (Becomes "Reference" Voltage)	Setting VYCONN or VZCONN	Magnitude and Phase Displacement Adjustment, Multiplied By Reference Voltage to Create V_{phnt}	
		Systems With ABC Rotation	Systems With ACB Rotation
V_A	A	$1\angle 0°$	$1\angle 0°$
V_B	B	$1\angle 120°$	$1\angle(-120)°$
V_C	C	$1\angle(-120)°$	$1\angle 120°$
V_{AB}	AB	$\frac{1}{\sqrt{3}}\angle -30°$	$\frac{1}{\sqrt{3}}\angle 30°$

Table 8.2 Phantom Voltage Adjustments (Sheet 2 of 2)

Voltage Connected V1Y-N or V1Z-N (Becomes "Reference" Voltage)	Setting VYCONN or VZCONN	Magnitude and Phase Displacement Adjustment, Multiplied By Reference Voltage to Create V_{phnt}	
		Systems With ABC Rotation	Systems With ACB Rotation
V_{BC}	BC	$\frac{1}{\sqrt{3}}\angle 90°$	$\frac{1}{\sqrt{3}}\angle -90°$
V_{CA}	CA	$\frac{1}{\sqrt{3}}\angle -150°$	$\frac{1}{\sqrt{3}}\angle 150°$

The phantom voltage V_{phnt} signal created using *Table 8.2* is labeled as VAY or VAZ, depending on the EPHANT setting. The recloser control derives B- and C-phase signals by rotating V_{phnt} by either 120 or –120, depending on the phase rotation setting PHROT.

NOTE: Phantom voltages can only be enabled on one set of terminals at a time.

Figure 8.1 shows an example of the phantom voltage function with ABC phase rotation.

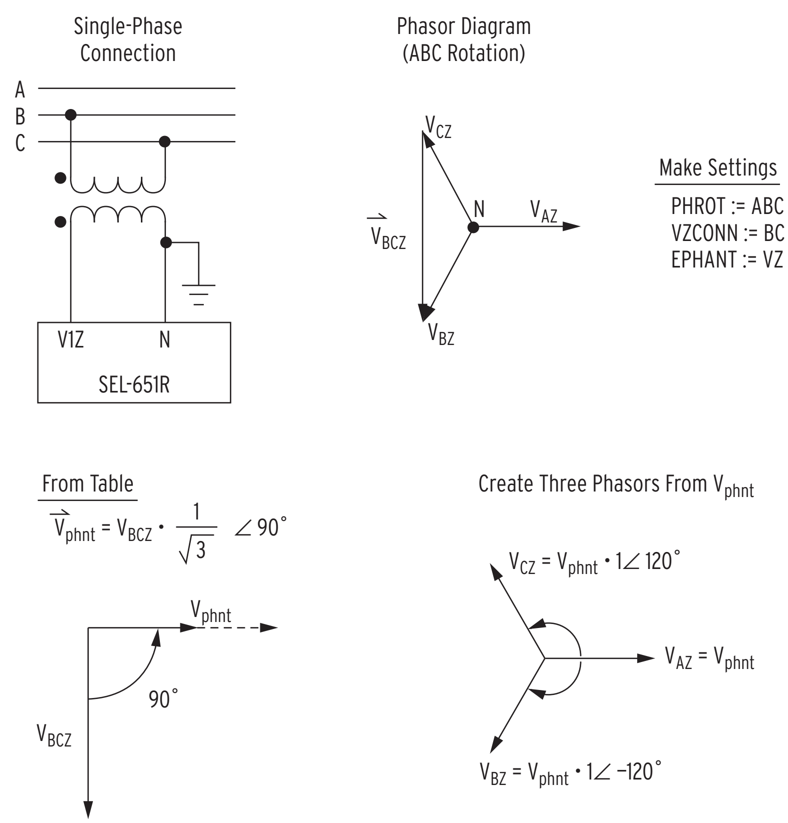


Figure 8.1 Example Phasor Diagram of Phantom Voltage Adjustment

When the phantom voltage option is being used (i.e., EPHANT is set to VY or VZ), the fundamental power and energy quantities are based on the derived phantom voltages.

NOTE: The phantom voltage settings have no effect on the protection elements in the SEL-651R. See Voltage Elements on page 4.26.

When the phantom voltage option is being used (i.e., EPHANT is set to VY or VZ), symmetrical components (positive-, negative-, and zero-sequence voltages) are not calculated. In the example shown in *Figure 8.1*, EPHANT := VZ, thus V1Z, V2Z, and 3V0Z are set to zero internally, and they are not displayed in the **MET** command. These values are hidden because they would look like a perfectly balanced three-phase system, which may be misleading.

Phantom Voltage Option Not in Service

If phantom voltage generation is not enabled (i.e., EPHANT := OFF), and three-phase voltages are connected, global setting VSELECT selects the voltage input terminals (VY or VZ) that are used to calculate power and energy quantities.

If Global setting VSELECT := OFF when EPHANT := OFF, power and energy metering is disabled.

Frequency Measurement Selection

Global setting FSELECT determines the voltage input terminal (V1Y or V1Z) that is used to measure frequency. This setting is unaffected by the phantom voltage setting. See *Frequency Source Selection Setting (FSELECT) on page 9.33*.

Demand Metering

The SEL-651R offers the choice between two types of demand metering, settable with the Group setting:

EDEM := **THM** Thermal Demand Meter

or

EDEM := **ROL** Rolling Demand Meter

The demand metering settings (in *Table 8.3*) are available via the **SET** command (see *Table 9.1* and also *Settings Sheet page SET.7* at the end of *Section 9*). Also refer to *METER Command (Metering Data) on page 10.26*, and *MET D Demand Metering on page 10.28*).

The SEL-651R provides demand and peak demand metering for the following values:

Currents	
$I_{A,B,C,N}$	Input currents (A primary)
I_G	Ground Current (A primary; IG = IN or 3I0, see *Ground Switch Option on page 8.3*)
$3I_2$	Negative-sequence current (A primary)

If three-phase voltage signals are connected and the global settings VYCONN, VZCONN, EPHANT, and VSELECT are properly made, the SEL-651R provides demand metering for the following values:

Power

$MVA_{A,B,C,3P}$		Single-phase and three-phase megavolt-amperes, primary
$MW_{A,B,C,3P}$	IN	Single-phase and three-phase megawatts, primary
$MW_{A,B,C,3P}$	OUT	Single-phase and three-phase megawatts, primary
$MVAR_{A,B,C,3P}$	IN	Single-phase and three-phase megavars, primary
$MVAR_{A,B,C,3P}$	OUT	Single-phase and three-phase megavars, primary

where IN and OUT correspond to the standard relay convention of OUT for positive power, and IN for negative power. Global setting CTPOL can change the direction of power (and energy) metering. See *Table 8.1*.

If a single-phase voltage is connected, and the settings VYCONN, VZCONN, and EPHANT are properly made, the same demand values are available by using the phantom voltage feature (see *Fundamental (Instantaneous) Metering on page 8.2*). Power demand metering accuracy degrades when the phantom feature is used. The accuracy error is proportional to the amount of system load imbalance, and the zero-sequence source impedance.

Depending on enable setting EDEM, these demand and peak demand values are thermal demand or rolling demand values. The differences between thermal and rolling demand metering are explained in the following subsection.

Comparison of Thermal and Rolling Demand Meters

The example in *Figure 8.2* 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”).

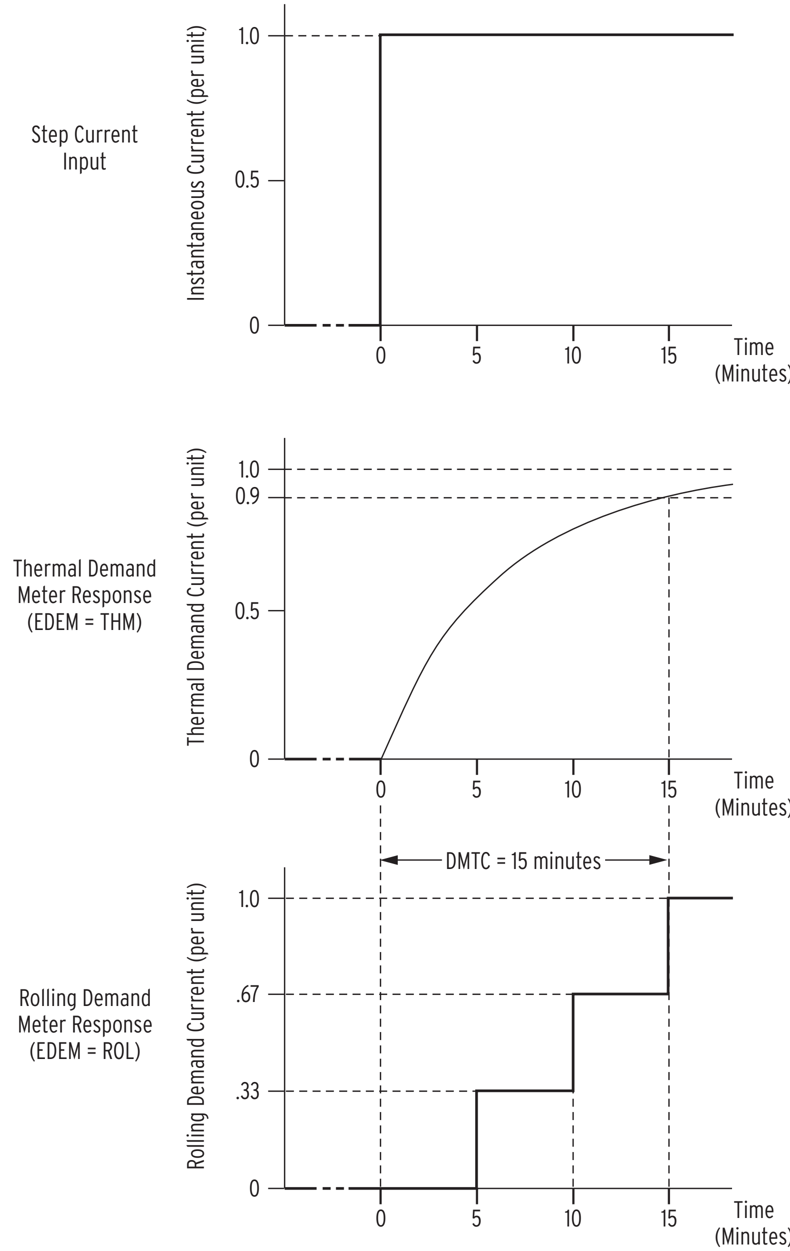


Figure 8.2 Response of Thermal and Rolling Demand Meters to a Step Input (Setting DMTC = 15 Minutes)

Thermal Demand Meter Response (EDEM := THM)

The response of the thermal demand meter in *Figure 8.2* (middle) to the step current input (top) is analogous to the series RC circuit in *Figure 8.3*.

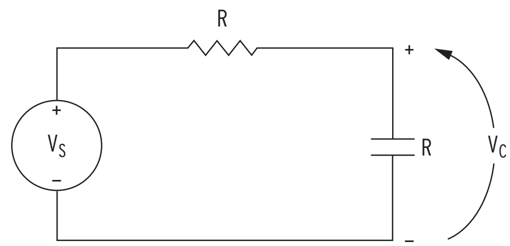


Figure 8.3 Voltage V_S Applied to Series RC Circuit

In the analogy:

Voltage V_S in *Figure 8.3* corresponds to the step current input in *Figure 8.2* (top).

Voltage V_C across the capacitor in *Figure 8.3* corresponds to the response of the thermal demand meter in *Figure 8.2* (middle).

If voltage V_S in *Figure 8.3* has been at zero (V_S = 0.0 per unit) for some time, voltage V_C across the capacitor in *Figure 8.3* is also at zero (V_C = 0.0 per unit). If voltage V_S is suddenly stepped up to some constant value (V_S = 1.0 per unit), voltage V_C across the capacitor starts to rise toward the 1.0 per unit value. This voltage rise across the capacitor is analogous to the response of the thermal demand meter in *Figure 8.2* (middle) to the step current input (top).

NOTE: The examples in this section discuss demand current, but MVA, MW, and MVAR demand values are also available, as stated at the beginning of this subsection.

In general, because voltage V_C across the capacitor in *Figure 8.3* 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 DMTC (see *Table 8.3*). Note in *Figure 8.2*, the thermal demand meter response (middle) is at 90 percent (0.9 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC := 15 minutes, referenced to when the step current input is first applied.

The SEL-651R updates thermal demand values approximately every 2 seconds.

Rolling Demand Meter Response (EDEM := ROL)

The response of the rolling demand meter in *Figure 8.2* (bottom) to the step current input (top) is calculated with a sliding time-window arithmetic average calculation. The width of the sliding time window is equal to the demand meter time constant setting DMTC (see *Table 8.3*). Note in *Figure 8.2*, the rolling demand meter response (bottom) is at 100 percent (1.0 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC := 15 minutes, referenced to when the step current input is first applied.

The rolling demand meter integrates the applied signal, such as step current, input in 5-minute intervals. The integration is performed approximately every 2 seconds. The average value for an integrated 5-minute interval is derived and stored as a 5-minute total. The rolling demand meter then averages a number of the 5-minute totals to produce the rolling demand meter response. In the *Figure 8.2* example, the rolling demand meter averages the three latest 5-minute totals because setting DMTC = 15 (15/5 = 3). The rolling demand meter response is updated every 5 minutes, after a new 5-minute total is calculated.

The following is a step-by-step calculation of the rolling demand response example in *Figure 8.2* (bottom).

Time = 0 Minutes

Presume that the instantaneous current has been at zero for quite some time before "Time = 0 minutes" or that the demand meters were recently reset. The three 5-minute intervals in the sliding time-window at "Time = 0 minutes" each integrate into the following 5-minute totals:

5-Minute Totals	Corresponding 5-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 5-minute intervals in the sliding time-window at "Time = 5 minutes" each integrate into the following 5-minute totals:

5-Minute Totals	Corresponding 5-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 5-minute intervals in the sliding time-window at "Time = 10 minutes" each integrate into the following 5-minute totals:

5-Minute Totals	Corresponding 5-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 5-minute intervals in the sliding time-window at "Time = 15 minutes" each integrate into the following 5-minute totals:

5-Minute Totals	Corresponding 5-Minute Interval
1.0 per unit	0 to 5 minutes
1.0 per unit	5 to 10 minutes
1.0 per unit	10 to 15 minutes
3.0 per unit	

Rolling demand meter response at "Time = 15 minutes" = 3.0/3 = 1.0 per unit.

Demand Meter Settings

Table 8.3 Demand Meter Settings and Settings Range

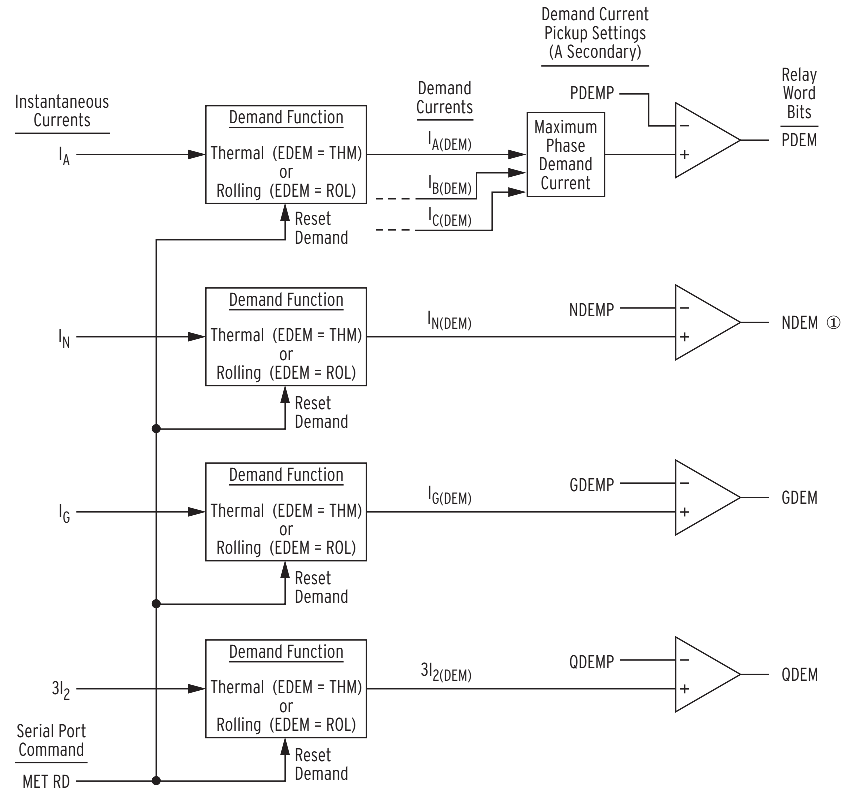
Setting	Definition	Range
EDEM	Demand meter type	THM = thermal ROL = rolling
DMTC	Demand meter time constant	5, 10, 15, 30, or 60 minutes
PDEMP	Phase demand current pickup	0.10–3.20 A secondary
NDEMP	Neutral ground demand current pickup[a]	0.005–0.640 A secondary
GDEMP	Ground demand current pickup[b]	0.005–3.200 A secondary
QDEMP	Negative-sequence demand current pickup	0.10–3.20 A secondary

[a] NDEMP is only available when Global setting EGNDSW := N

[b] GDEMP setting range shown is for factory settings, with EGNDSW := Y, and CTR = CTRN := 1000. See Settings Sheet page *SET.27* at the end of Section 9 for details.

NOTE: Changing setting EDEM or DMTC resets the demand meter values to zero. This also applies to changing the active setting group, and setting EDEM or DMTC is different in the new active setting group. Demand current pickup settings PDEMP, NDEMP, GDEMP, and QDEMP can be changed without affecting the demand meters.

The demand current pickup settings in *Table 8.3* are applied to demand current meter outputs as shown in *Figure 8.4*. For example, when residual ground demand current $I_{G(DEM)}$ goes above corresponding demand pickup GDEMP, Relay Word bit GDEM asserts to logical 1. Use these demand current logic outputs (PDEM, NDEM, GDEM, and QDEM) to alarm for high loading or unbalance conditions. Use them in other schemes such as the following example.



① NDEM is only functional when Global Setting EGNDSW := N.

Figure 8.4 Demand Current Logic Outputs

Demand Current Logic Output Application: Raise Pickup for Unbalance Current

During times of high loading, the residual ground overcurrent elements can see relatively high unbalance current I_G ($I_G = 3I_0$). To avoid tripping on unbalance current I_G, use Relay Word bit GDEM to detect the residual ground (unbalance) demand current $I_{G(DEM)}$ and effectively raise the pickup of the residual ground time-overcurrent element 51G1T. This is accomplished with the following settings from *Table 8.3*, pertinent residual ground overcurrent element settings, and SELOGIC control equation torque control setting 51G1TC:

EDEM := **THM**

DMTC := **5**

GDEMP := **1.000**

51G1JP := **1.50**

50G5P := **2.30**

51G1TC := **NOT(GDEM) OR GDEM AND 50G5**

51G1SW := **0**

Refer to *Figure 8.4*, *Figure 8.5*, and *Figure 4.20*.

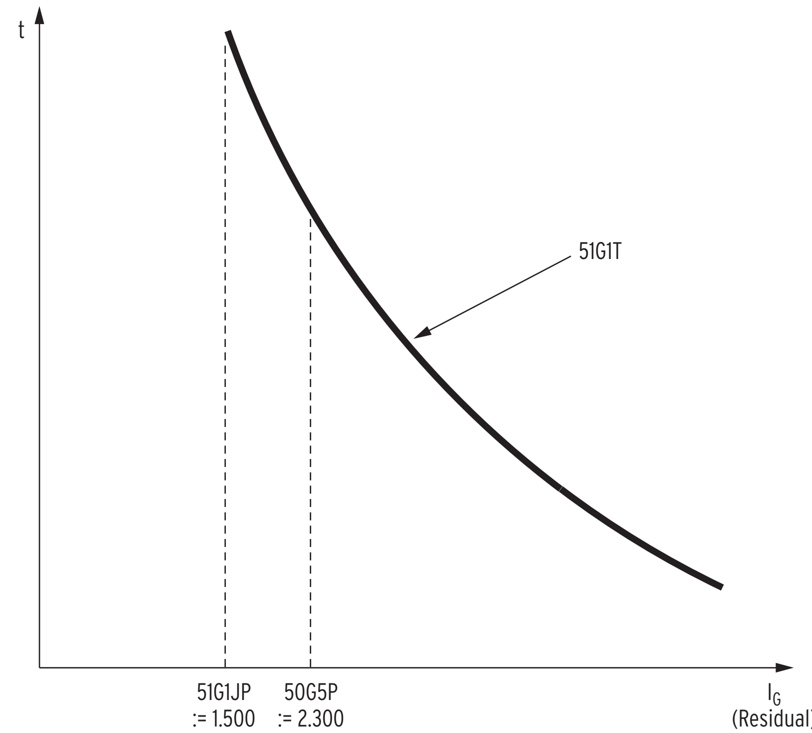


Figure 8.5 Raise Pickup of Residual Ground Time-Overcurrent Element for Unbalance Current

Residual Ground Demand Current Below Pickup GDEMP

When unbalance current I_G is low, unbalance demand current $I_{G(DEM)}$ is below corresponding demand pickup GDEMP = 1.000 A secondary, and Relay Word bit GDEM is deasserted to logical 0. This results in SELOGIC control equation torque control setting 51G1TC being in the state:

$$\begin{aligned} \text{51G1TC} :=\ & \text{NOT(GDEM) OR GDEM AND 50G5} \\ =\ & \text{NOT (logical 0) OR (logical 0) AND 50G5} \\ =\ & \text{logical 1} \end{aligned}$$

Equation 8.1

Thus, the residual ground time-overcurrent element 51G1T operates on its standard pickup:

$$\text{51G1JP} := 1.500 \text{ A Secondary}$$

Equation 8.2

If a ground fault occurs, the residual ground time-overcurrent element 51G1T operates with the sensitivity provided by pickup 51G1JP := 1.500 A secondary. The thermal demand meter, even with setting DMTC = 5 minutes, does not respond fast enough to the ground fault to make a change to the effective residual ground time-overcurrent element pickup—it remains at 1.500 A secondary. Demand meters respond to more slow-moving general trends.

Residual Ground Demand Current Goes Above Pickup GDEMP

When unbalance current I_G increases, unbalance demand current $I_{G(DEM)}$ follows, going above corresponding demand pickup GDEMP = 1.000 A secondary, and Relay Word bit GDEM asserts to logical 1. This results in SELOGIC control equation torque control setting 51GTC being in the state:

$$51G1TC := NOT(GDEM) OR GDEM AND 50G5$$

$$= NOT (logical 1) OR (logical 1) AND 50G5$$
$$= logical 0 OR 50G5$$
$$= 50G5$$ **Equation 8.3**

Thus, the residual ground time-overcurrent element 51G1T operates with an effective, less-sensitive pickup:

$$50G5P := 2.300 \text{ A Secondary}$$ **Equation 8.4**

The reduced sensitivity keeps the residual ground time-overcurrent element 51G1T from tripping on higher unbalance current I_G.

Residual Ground Demand Current Goes Below Pickup GDEMP Again

When unbalance current I_G decreases again, unbalance demand current $I_{G(DEM)}$ follows, going below corresponding demand pickup GDEMP = 1.000 A secondary, and Relay Word bit GDEM deasserts to logical 0. This results in SELOGIC control equation torque control setting 51G1TC being in the state:

$$51G1TC := NOT(GDEM) OR GDEM AND 50G5$$

$$= NOT (logical 0) OR (logical 0) AND 50G5$$
$$= logical 1$$ **Equation 8.5**

Thus, the residual ground time-overcurrent element 51G1T operates on its standard pickup again:

$$51G1JP := 1.500 \text{ A Secondary}$$ **Equation 8.6**

View or Reset Demand Metering Information

Via Serial Port

See *METER Command (Metering Data), MET D Demand Metering on page 10.28*. The **MET D** command displays demand and peak demand metering.

The **MET RD** command resets the demand metering values. The **MET RP** command resets the peak demand metering values.

After demand values are reset, if setting EDEM := ROL, there may be a delay of up to two times the DMTC setting before the demand values are updated.

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **MET D**, **MET RD**, and **MET RP** are also available via the front-panel menu. See *Human-Machine Interface on page 11.2*.

Demand Metering Updating and Storage

The SEL-651R updates demand values approximately every two seconds.

The SEL-651R stores peak demand values to nonvolatile storage once per day and overwrites the previous stored value if it is exceeded. Should the recloser control lose control power, it will restore the peak demand values saved by the relay at 23:50 hours on the previous day.

Demand metering peak recording is momentarily suspended when SELOGIC control equation setting FAULT is asserted (= logical 1). See the explanation for the FAULT setting in the following subsection *Maximum/Minimum Metering Update and Storage on page 8.17*.

Energy Metering

If three-phase voltages signals are connected and the global settings VYCONN, VZCONN, EPHANT, and VSELECT are properly made, the SEL-651R provides energy metering for the following values:

$MW.h_{A,B,C,3P}$	IN	Single-phase and three-phase megawatt-hours, primary
$MW.h_{A,B,C,3P}$	OUT	Single-phase and three-phase megawatt-hours, primary
$MVAR.h_{A,B,C,3P}$	IN	Single-phase and three-phase megavar-hours, primary
$MVAR.h_{A,B,C,3P}$	OUT	Single-phase and three-phase megavar-hours, primary

where IN and OUT correspond to the standard relay convention of OUT for positive power, and IN for negative power. Global setting CTPOL can change the direction of energy (and power) metering. See *Table 8.1*.

If a single-phase voltage is connected, and the settings VYCONN, VZCONN, and EPHANT are properly made, the same energy values are available by using the phantom voltage feature (see *Fundamental (Instantaneous) Metering on page 8.2*). Energy metering accuracy degrades when the phantom feature is used. The accuracy error is proportional to the amount of system load imbalance, and the zero-sequence source impedance.

View or Reset Energy Metering Information

Via Serial Port

See *METER Command (Metering Data) on page 10.26*, *MET E Energy Metering on page 10.29*. The **MET E** command displays accumulated single- and three-phase megawatt and megavar hours. The **MET RE** command resets the accumulated single- and three-phase megawatt and megavar hours.

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **MET E** and **MET RE** are also available via the front-panel menu. See *Human-Machine Interface on page 11.2*.

Energy Metering Updating and Storage

The SEL-651R updates energy values approximately every two seconds.

The SEL-651R stores energy values to nonvolatile storage once per day and overwrites the previous stored value. Should the recloser control lose control power, it will restore the energy values saved by the relay at 23:50 hours on the previous day.

Accumulated energy metering values function like those in an electromechanical energy meter. When the energy meter reaches 99999.999 MWh or 99999.999 MVARh, the SEL-651R starts over at zero.

Maximum/Minimum Metering

The SEL-651R includes a maximum/minimum metering function that records the excursions of certain fundamental metering quantities (see below). The date and time stamps at which each quantity reached its maximum and minimum value are also reported.

View or Reset Maximum/Minimum Metering Information

Via Serial Port

See *MET M Maximum/Minimum Metering on page 10.31*. The **MET M** command displays maximum/minimum metering for the following values:

Currents	
$I_{A,B,C,N}$	Input currents (A primary)
I_G	Ground Current (A primary; IG = IN or 3I0, see *Ground Switch Option on page 8.3*)
$3I_2$	Negative-sequence current (A primary)
Voltages	
V_AY, V_BY, V_CY	Input voltages, Y-terminals (kV primary)[a]
V_AZ, V_BZ, V_CZ	Input voltages, Z-terminals (kV primary)[a]
Power	
MW_{3P}	Three-phase megawatts
$MVAR_{3P}$	Three-phase megavars
MVA_{3P}	Three-phase megavolt-amperes

[a] if Global setting EPHANT := VY, the Y-terminal voltages are replaced by the calculated phantom voltages. Similarly, if EPHANT := VZ, the Z-terminal voltages are replaced by the calculated phantom voltages. See Phantom Voltage Function on page 8.4.

The **MET RM** command resets the maximum/minimum metering values.

The MW and MVAR maximum and minimum values can be negative or positive, indicating the range of power flow that has occurred since the last **MET RM** reset command. These functions simulate analog meter drag-hands, with the maximum value representing the upper drag-hand and the minimum value representing the lower drag-hand.

Table 8.4 shows the values that the recloser control would record for various power flow directions (either MW3P or MVAR3P).

Table 8.4 Operation of Maximum/Minimum Metering With Directional Power Quantities

If Power Varies		Recorded MAX	Recorded MIN
From:	To:		
9.7	16.2	16.2	9.7
–4.2	1.4	1.4	–4.2
–25.3	–17.4	–17.4	–25.3
–6.2	27.4	27.4	–6.2

(For simplicity, the date and time stamps are not shown here.)

Via Front Panel

The metering and reset functions available via serial port commands **MET M** and **MET RM** are also available via the front-panel menu. See *Human-Machine Interface on page 11.2*.

Maximum/Minimum Metering Update and Storage

The maximum/minimum metering function is intended to reflect normal load variations rather than fault conditions or outages. Therefore, the SEL-651R updates maximum/minimum values only if Global SELOGIC setting FAULT is deasserted (= logical 0) and has been deasserted for at least 3600 cycles.

The factory default setting is set with time-overcurrent element pickups:

FAULT := **51P OR 51G1**

If there is a fault, 51P or 51G1 asserts and blocks updating of maximum/minimum metering values.

NOTE: SELOGIC control equation setting FAULT also controls other recloser control functions; see SELOGIC Control Equation Setting FAULT on page 5.13.

In addition to FAULT being deasserted for at least 3600 cycles, the following conditions must also be met:

➤ For voltage values V_AY, V_BY, V_CY, V_AZ, V_BZ, and V_CZ, the voltage is above the threshold: 25.0 V secondary (300 V base).

➤ For phase current values I_A, I_B, and I_C, the current is above the threshold: 0.01 A secondary.

➤ For neutral current value I_N, the current is above the threshold: 2 mA secondary.

➤ For ground current value I_G:

All three-phase currents I_A, I_B, and I_C are above threshold.

➤ For power values MW_{3P}, $MVAR_{3P}$, and MVA_{3P}:

All three-phase currents I_A, I_B, and I_C are above threshold, and the required voltages V_AY, V_BY, V_CY, or V_AZ, V_BZ, and V_CZ (depending on the EPHANT or VSELECT Global settings) are above threshold. See *Phantom Voltage Function on page 8.4*.

➤ The metering value is above the previous maximum or below the previous minimum for approximately one second.

The SEL-651R stores maximum/minimum values to nonvolatile storage once per day and overwrites the previous stored value if that is exceeded. If the recloser control loses control power, it will restore the maximum/minimum values saved at 23:50 hours on the previous day.

Note: The values used by the maximum/minimum metering are the same fundamental metering values as used in the instantaneous metering function. The maximum/minimum metering function updates approximately twice per second. These values should be relatively immune to transient conditions.

Harmonics and True RMS Metering

The SEL-651R is capable of measuring signal distortions up to the 15th harmonic on the ten analog input channels.

The signals connected to the SEL-651R terminals I1, I2, I3, IN, V1Y, V2Y, V3Y, V1Z, V2Z, and V3Z are first conditioned by analog low-pass filters, and then sampled at 32 times per power system cycle and placed into internal quantities with the names:

IA, IB, IC, IN

VAY, VBY, VCY

VAZ, VBZ, VCZ

according to the global settings IPCONN, VYCONN, and VZCONN. See *Current and Voltage Connection Settings on page 9.28* for more details.

Every two seconds, a 256-sample data set from each channel is processed to calculate:

- Fundamental Root Mean Squared (rms) magnitude (1st harmonic, in primary units)
- Harmonic content *n*, where *n* = 2 through 15 (in percent of fundamental)
- Total Harmonic Distortion (THD),
- True rms magnitude (in primary units).

Additionally, if global setting VSELECT ≠ OFF:

- Average real power (in primary MW)

is calculated.

Harmonic Metering

The harmonic calculations are visible in the serial port **MET H** command and through the front panel METER menu. See *Section 10: Communications* for a sample **MET H** command response, and *Section 11: Front-Panel Operations*. This command includes the fundamental rms, true rms, and THD values for each quantity, along with the individual harmonics.

The fundamental rms magnitude value is expressed in A primary for the current channels (IA, IB, IC, and IN), and kV primary for the voltage channels.

The individual harmonics (2nd through 15th) are expressed as a percentage of the fundamental, with an upper limit of 100 percent.

There is no dc component calculated.

To avoid calculating meaningless harmonics during outages, if the fundamental magnitude of a channel is less than shown in *Table 8.5*, the harmonics and the THD calculations are set to zero for that channel.

Table 8.5 Harmonic and THD Calculation Thresholds

Channel	Threshold
IA, IB, IC	Setting CTR • 1 A • 0.02
IN	Setting CTRN • 0.2 A • 0.02
VAY, VBY, VCY	Setting PTRY • 300 V • 0.02
VAZ, VBZ, VCZ	Setting PTRZ • 300 V • 0.02

The THD quantities are available for control functions by using them in SELOGIC control equations as part of an analog comparison. See *Table 7.2* for details.

True RMS Metering

The true rms calculations are visible in the serial port **MET RMS** command and through the front-panel METER menu. The true rms value is expressed in A primary for the current channels (IA, IB, IC, and IN), and kV primary for the voltage channels. See *Section 10: Communications* for a sample **MET RMS** command response, and *Section 11: Front-Panel Operations*.

The rms meter calculations include the average per-phase and three-phase real power in primary MW based on currents IA, IB, and IC, and voltages VAY, VBY, and VCY if global setting VSELECT := VY; and voltages VAZ, VBZ, and VCZ if global setting VSELECT := VZ. The phantom voltage setting, EPHANT, has no effect on the average power calculations.

The true rms calculations are based on the same 256-sample data set that is used in the harmonics calculations. The true rms values are scalar quantities, therefore no phase angle or polarity sign is included.

The true rms current and voltage readings will differ from the fundamental rms magnitude calculated in the harmonics metering function if there is any harmonic energy content in the signal.

NOTE: When testing the SEL-651R, remember that the SEL-651R protection functions (overcurrent elements, undervoltage elements, etc.) are based on fundamental rms values, not true rms values.

Similarly, the average power quantities will differ from the fundamental power quantities when there is harmonic energy in voltage or current signals. The average power quantities are directional, so they are affected by the global CT Polarity setting CTPOL (see *Table 8.1*).

Breaker/Recloser Contact Wear Monitor

The breaker/recloser contact wear monitor in the SEL-651R provides information that helps in scheduling circuit breaker or recloser maintenance. This monitoring function accumulates the number of internal and external trip operations and integrates the number of close-open operations and the per-phase current during each opening operation. The SEL-651R compares the integrated close-open information to a predefined breaker or recloser maintenance curve to calculate the percent contact wear on a per-phase basis. The SEL-651R updates and stores the contact wear information, and the number of trip operations, in nonvolatile memory. You can view this information through the front-panel display and by communicating with the SEL-651R through any serial communications port with a computer.

Individual phase Breaker Contact Wear bits, BCWA, BCWB, and BCWC, assert when the contact wear percentage on their respective phases reaches 100 percent. You can use these individual phase elements or the combined result of these elements, BCW (which asserts when BCWA or BCWB or BCWC assert), in a SELOGIC control equation to alarm or control other functions, such as block reclosing.

Involved phase and ground/earth fault information is also tabulated for each breaker or recloser operation.

This feature will be called "breaker monitor" for the remainder of this section, and elsewhere in this Instruction Manual, except where a distinction must be made between breakers and reclosers.

The breaker monitor is enabled with the Global setting:

EBMON := **Y**

The breaker monitor settings in *Table 8.6* are available via the **SET G** command (see *Table 9.1* and also Settings Sheet at the end of *Section 9*). Also refer to *BREAKER Command on page 10.12* and *BRE W (Preload Breaker Wear) on page 10.13*.

When setting EBMON := N, the breaker monitor is disabled from accumulating any new data, although any data already recorded is unaffected, and can still be accessed.

The breaker monitor is set with breaker or recloser maintenance information provided by the switchgear manufacturer. This breaker maintenance information lists the number of close/open operations that are permitted for a given current interruption level.

Table 8.6 Breaker Monitor Settings and Settings Ranges

Setting	Definition	Range
COSP1	Close/Open set point 1—maximum	0–65000 close/open operations
COSP2	Close/Open set point 2—middle	0–65000 close/open operations
COSP3	Close/Open set point 3—minimum	0–65000 close/open operations
KASP1	kA Interrupted set point 1—minimum	0.00–999.00 kA in 0.01 kA steps
KASP2	kA Interrupted set point 2—middle	0.00–999.00 kA in 0.01 kA steps
KASP3	kA Interrupted set point 3—maximum	0.00–999.00 kA in 0.01 kA steps
BKMON3P BKMONA BKMONB BKMONC	SELOGIC control equation breaker monitor initiation settings	Relay Word bits referenced in *Appendix F: Relay Word Bits*

Setting notes:

- ➤ COSP1 must be set greater than COSP2.
- ➤ COSP2 must be set greater than or equal to COSP3.
- ➤ KASP1 must be set less than KASP2.
- ➤ If COSP2 is set the same as COSP3, then KASP2 must be set the same as KASP3.
- ➤ KASP3 must be set at least 5 times (but no more than 100 times) the KASP1 setting value.
- ➤ KASP2 must be set less than or equal to KASP3.

Table 8.7 lists the breaker monitor setting values for several common three-phase recloser types. Make the six settings (COSP1, COSP2, COSP3, KASP1, KASP2, and KASP3) in the Global Settings after setting EBMON := Y.

Table 8.7 Recommended Breaker Monitor Settings for Various Reclosers

Recloser Model	Recloser Type	Interrupt Rating (Amps primary)	Settings			
			COSP1	COSP2 COSP3	KASP1	KASP2 KASP3
RXE	OIL	6000	10000	20	0.10	6.00
RVE	OIL	6000	10000	20	0.10	6.00
WE	OIL	12000 (@ 4.8 kV)	10000	20	0.19	12.00
WE	OIL	10000 (@ 14.4 kV)	10000	20	0.16	10.00
VWE	VACUUM	12000	10000	80	0.48	12.00
VWVE27	VACUUM	12000	10000	80	0.48	12.00
VWVE38X	VACUUM	12000	10000	80	0.48	12.00
WVE27	OIL	8000	10000	20	0.13	8.00
WVE38X	OIL	8000	10000	20	0.13	8.00
VSA12	VACUUM	12000	10000	80	0.48	12.00
VSA16	VACUUM	16000	10000	80	0.64	16.00
VSA20	VACUUM	20000	10000	80	0.80	20.00
VSA20A	VACUUM	20000	10000	80	0.80	20.00
VSA20B	VACUUM	20000	10000	80	0.80	20.00
VSO12	VACUUM	12000	10000	80	0.48	12.00
VSO16	VACUUM	16000	10000	80	0.64	16.00
G&W Viper®-S or Viper®-ST 15.5 or 27 kV	VACUUM	12500	10000	2510 64	1.25	2.00 12.50
G&W Viper-S or Viper-ST 38 kV	VACUUM	12000	10000	100	1.25	12.00

The parameters in *Table 8.7* are derived from ANSI C37.61-1973/IEEE Standard 321-1973, IEEE Standard Guide for the Application, Operation, and Maintenance of Automatic Circuit Reclosers.

For example, if the SEL-651R is connected to a type WVE27 Recloser, use the **SET G** command to enter and save the following global settings for the breaker wear monitor:

EBMON := **Y**

COSP1 := **10000**

COSP2 := **20**

COSP3 := **20**

KASP1 := **0.10**

KASP2 := **8.00**

KASP3 := **8.00**

If single-phase reclosers or breakers are connected to the SEL-651R, make global setting BKTYP := 1. The same breaker monitor settings (COSP1, COSP2, COSP3, KASP1, KASP2, and KASP3) are used for all three phases.

The remaining breaker monitor settings are the SELOGIC equations that control when the breaker monitor function accumulates data. These settings are BKMON3P for three-phase breakers, and BKMONA, BKMONB, and BKMONC for single-phase breakers. See *Operation of SELOGIC Control Equation Breaker Monitor Initiation Settings on page 8.25*.

Breaker Monitor Setting Example

If your recloser is not included in *Table 8.7*, or you adapt the SEL-651R to operate a breaker, you can create a contact wear monitor curve for your specific breaker or recloser. The breaker/recloser contact wear monitor is set with breaker or recloser maintenance information provided by the switchgear manufacturer. This maintenance information lists the number of close/open operations that are permitted for a given current interruption level. The following is an example of breaker maintenance information for a 25 kV circuit breaker.

Table 8.8 Breaker Maintenance Information for a 25 kV Circuit Breaker

Current Interruption Level (kA)	Permissible Number of Close/Open Operations[a]
0.00–1.20	10,000
2.00	3,700
3.00	1,500
5.00	400
8.00	150
10.00	85
20.00	12

[a] The action of a circuit breaker closing and then later opening is counted as one close/open operation.

The breaker maintenance information in *Table 8.8* is plotted in *Figure 8.6*.

Connect the plotted points in *Figure 8.6* for a breaker maintenance curve. To estimate this breaker maintenance curve in the SEL-651R breaker monitor, enter three set points:

Set Point 1 — *maximum* number of close/open operations with corresponding current interruption level.

Set Point 2 — number of close/open operations that correspond to some *midpoint* current interruption level.

Set Point 3 — number of close/open operations that correspond to the *maximum* current interruption level.

Enter these three points with the settings in *Table 8.6*.

The following settings are made from the breaker maintenance information in *Table 8.8* and *Figure 8.6*:

COSP1 := **10000**

COSP2 := **150**

COSP3 := **12**

KASP1 := **1.20**

KASP2 := **8.00**

KASP3 := **20.00**

Figure 8.7 shows the resultant breaker maintenance curve.

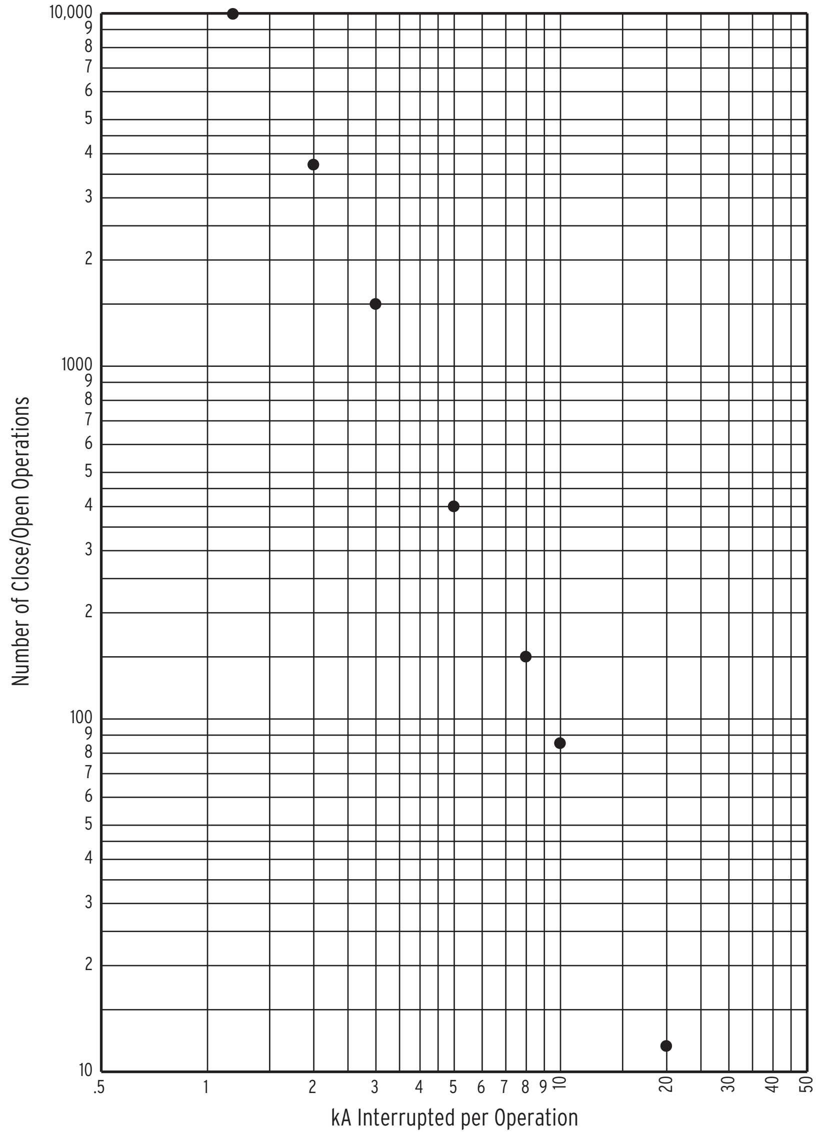


Figure 8.6 Plotted Breaker Maintenance Points for a 25 kV Circuit Breaker

Breaker Maintenance Curve Details

In *Figure 8.7*, note that set points KASP1, COSP1 and KASP3, COSP3 are set with breaker maintenance information from the two extremes in *Table 8.8* and *Figure 8.6*.

In this example, set point KASP2, COSP2 happens to be from an in-between breaker maintenance point in the breaker maintenance information in *Table 8.8* and *Figure 8.6*, but it does not have to be. Set point KASP2, COSP2 should be set to provide the best curve-fit with the plotted breaker maintenance points in *Figure 8.6*.

Regardless of the type of circuit breaker or recloser connected to the SEL-651R (single-phase or three-phase), each phase (A, B, and C) has its own breaker maintenance curve (like that in *Figure 8.7*), because the separate circuit breaker interrupting contacts for phases A, B, and C do not necessarily interrupt the same magnitude current, depending on fault type and loading.

Also, in the case of single-phase breakers or reclosers, one or two phases may not even operate for certain faults, and the contacts and mechanisms are not being subjected to any wear.

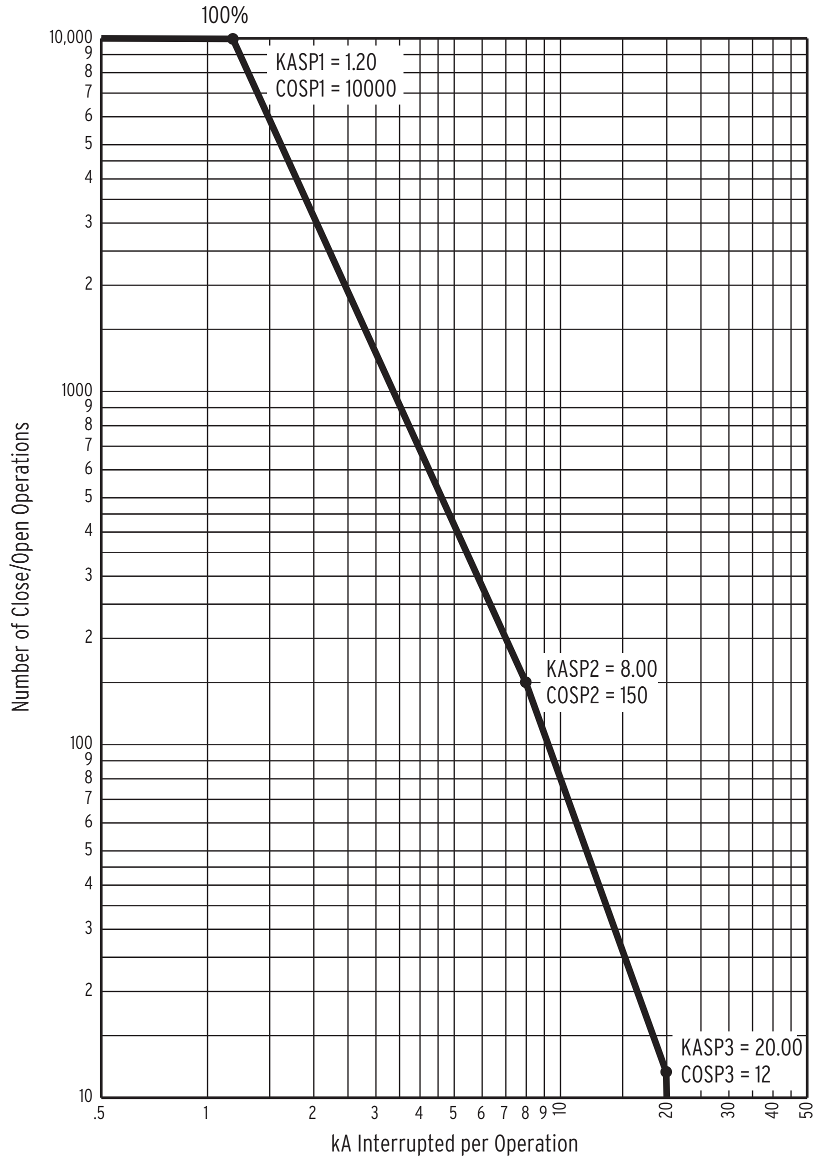


Figure 8.7 SEL-651R Breaker Maintenance Curve for a 25 kV Circuit Breaker

In *Figure 8.7*, note that the breaker maintenance curve levels off horizontally below set point KASP1, COSP1. This is the close/open operation limit of the circuit breaker (COSP1 = 10000), regardless of interrupted current value.

Also, note that the breaker maintenance curve falls vertically above set point KASP3, COSP3. This is the maximum interrupted current limit of the circuit breaker (KASP3 = 20.00 kA). If the interrupted current is greater than setting KASP3, the interrupted current is accumulated as a current value equal to setting KASP3.

Operation of SELOGIC Control Equation Breaker Monitor Initiation Settings

The SELOGIC control equation breaker monitor initiation settings BKMON3P, BKMONA, BKMONB, and BKMONC in *Table 8.6* determine when the breaker monitor reads in current values (Phases A, B, and C) for the breaker maintenance curve (see *Figure 8.7*) and the breaker monitor accumulated currents/trips and involved phase/ground counters (see *BREAKER Command on page 10.12*).

As previously described, separate breaker wear models are maintained for each of the three power system phases. These models are independently triggered when single-phase breakers are connected, and are triggered together when three-phase breakers are connected.

When a **three-phase recloser or breaker is connected**, global setting BKTYP must be set to 3 (see *Section 9: Settings*). When BKTYP :=3, global setting BKMON3P is the only breaker monitor initiation setting that can be made. BKMON3P controls the breaker monitor logic for all three phases.

When **single-phase capable reclosers or breakers are connected**, global setting BKTYP must be set to 1. When BKTYP :=1, global breaker monitor initiation settings BKMONA, BKMONB, and BKMONC can be accessed. These settings control the breaker monitor logic for each phase separately. These three settings are present even if single-phase tripping is not employed. In this case, they should be set to operate together, as shown in a later subsection. Setting BKMON3P is not available when BKTYP := 1.

Regardless of which type of breaker is in use, the three breaker monitor models act similarly, and will be described once using "BKMON*p*" in place of BKMON3P, BKMONA, BKMONB, and BKMONC to avoid repeating the same information (*p* = 3P, A, B, or C).

The BKMON*p* setting looks for a rising edge (logical 0 to logical 1 transition) as the indication to read in current values. The acquired current values are then applied to the breaker maintenance curve and the breaker monitor accumulated currents/trips.

In the factory default settings, the SELOGIC control equation breaker monitor initiation setting is set:

BKMONA := **RCTR1X** (RCTR1X is the logic output of *Figure 7.26*)

BKMONB := **RCTR2X** (RCTR2X is the logic output of *Figure 7.26*)

BKMONC := **RCTR3X** (RCTR3X is the logic output of *Figure 7.26*)

These settings must be modified in certain installations. The recommended settings for BKMON*p* are covered in *Breaker Monitor Initiate Settings (BKMONp, Where p = 3P, A, B, or C) on page 9.38*.

Refer to *Figure 8.8*. When BKMON*p* asserts (Relay Word bit RCTR_X goes from logical 0 to logical 1), the breaker monitor reads in the current values and applies them to the breaker monitor maintenance curve and the breaker monitor accumulated currents/trips.

As detailed in *Figure 8.8*, the breaker monitor actually reads in the current values one cycle after the assertion of BKMON*p*. This helps especially if an instantaneous trip occurs. The instantaneous element trips when the fault current reaches its pickup setting level. The fault current may still be climbing to its full value, at which it levels off. The one-cycle delay on reading in the current values allows time for the fault current to level off.

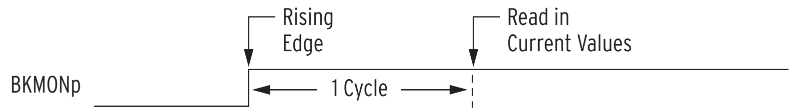


Figure 8.8 Operation of SELogic Control Equation Breaker Monitor Initiation Setting

See *Figure 8.13* and accompanying text for more information on setting BKMON*p*. The operation of the breaker monitor maintenance curve, when new current values are read in, is explained in the following example.

Breaker Monitor Operation Example

As stated earlier, each phase (A, B, and C) has its own breaker maintenance curve. For this example, presume that the interrupted current values occur on a single phase in *Figure 8.9* through *Figure 8.12*. Also, presume that the circuit breaker interrupting contacts have no wear at first (brand new or recent maintenance performed).

Note in the following four figures (*Figure 8.9* through *Figure 8.12*) that the interrupted current in a given figure is the same magnitude for all the interruptions. For example, in *Figure 8.10*, 2.5 kA is interrupted 290 times. This is not realistic, but helps in demonstrating the operation of the breaker maintenance curve and how it integrates for varying current levels.

0–10 Percent Breaker Wear

Refer to *Figure 8.9*. Current value 7.0 kA is interrupted 20 times (20 close/open operations = 20 – 0), pushing the breaker maintenance curve from the 0 percent wear level to the 10 percent wear level.

Compare the 100 percent and 10 percent curves and note that for a given current value, the 10 percent curve has only 1/10 of the close/open operations of the 100 percent curve.

10–25 Percent Breaker Wear

Refer to *Figure 8.10*. The current value changes from 7.0 kA to 2.5 kA, and 2.5 kA is interrupted 290 times (290 close/open operations = 480 –190), pushing the breaker maintenance curve from the 10 percent wear level to the 25 percent wear level.

Compare the 100 percent and 25 percent curves and note that for a given current value, the 25 percent curve has only 1/4 of the close/open operations of the 100 percent curve.

25–50 Percent Breaker Wear

Refer to *Figure 8.11*. The current value changes from 2.5 kA to 12.0 kA, and 12.0 kA is interrupted 11 times (11 close/open operations = 24 – 13), pushing the breaker maintenance curve from the 25 percent wear level to the 50 percent wear level.

Compare the 100 percent and 50 percent curves and note that for a given current value, the 50 percent curve has only 1/2 of the close/open operations of the 100 percent curve.

50–100 Percent Breaker Wear

Refer to *Figure 8.12*. The current value changes from 12.0 kA to 1.5 kA, and 1.5 kA is interrupted 3000 times (3000 close/open operations = 6000 – 3000), pushing the breaker maintenance curve from the 50 percent wear level to the 100 percent wear level.

When the breaker maintenance curve reaches 100 percent for a particular phase, the percentage wear remains at 100 percent (even if additional current is interrupted), until reset by the **BRE R** command (see *View or Reset Breaker Monitor Information on page 8.31*). But the current and trip counts continue to be accumulated, until reset by the **BRE R** command.

Additionally, logic outputs assert for alarm or other control applications; see the following discussion.

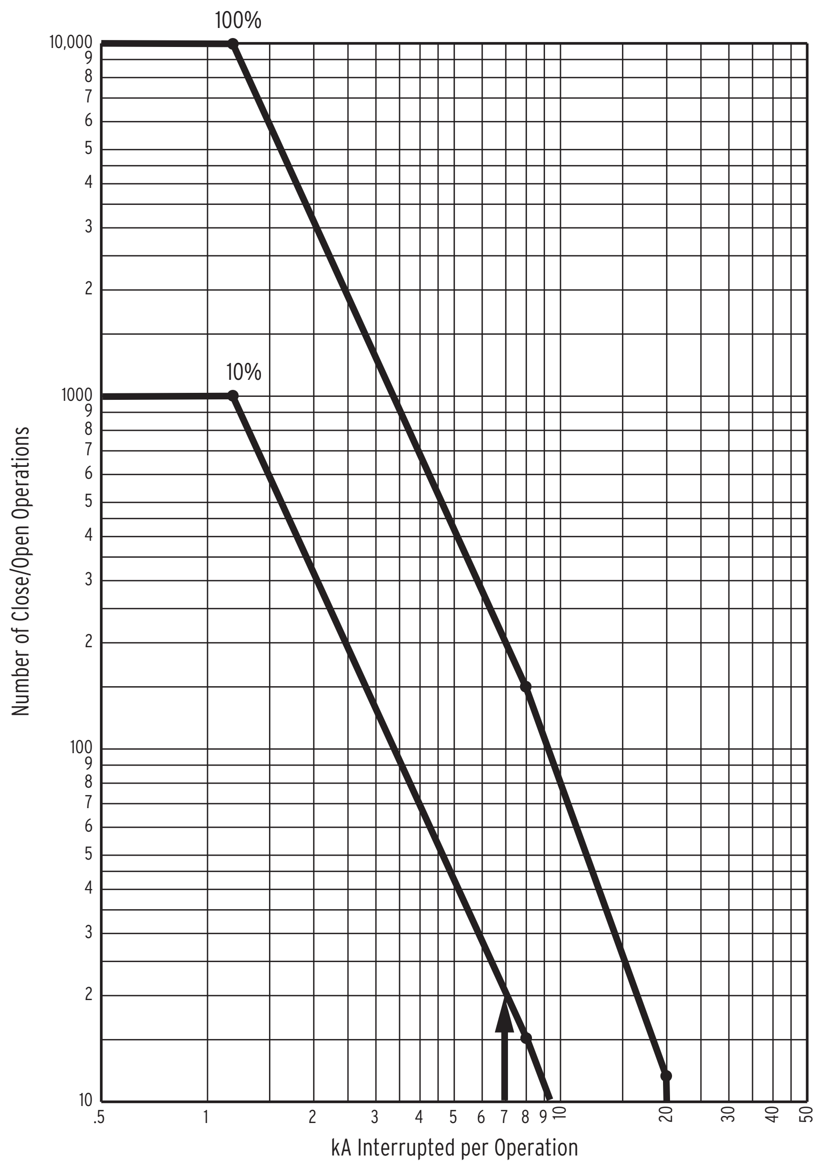


Figure 8.9 Breaker Monitor Accumulates 10 Percent Wear

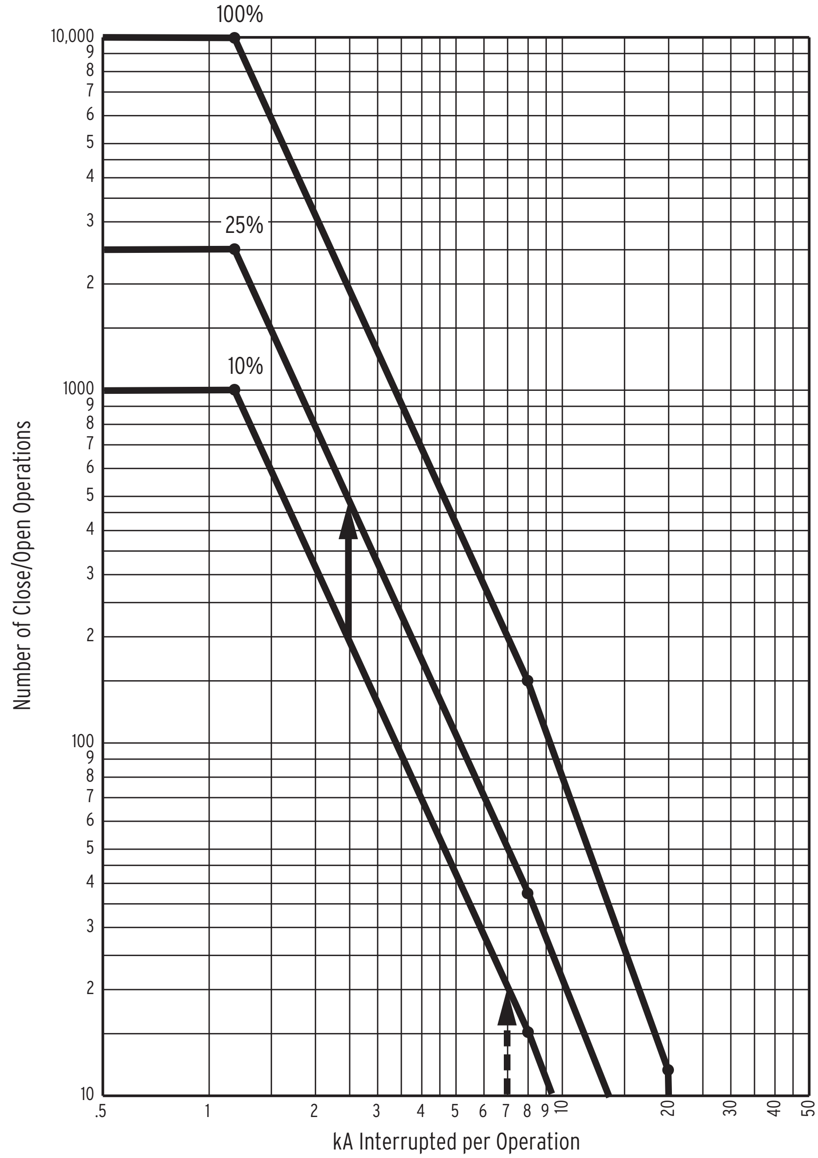


Figure 8.10 Breaker Monitor Accumulates 25 Percent Wear

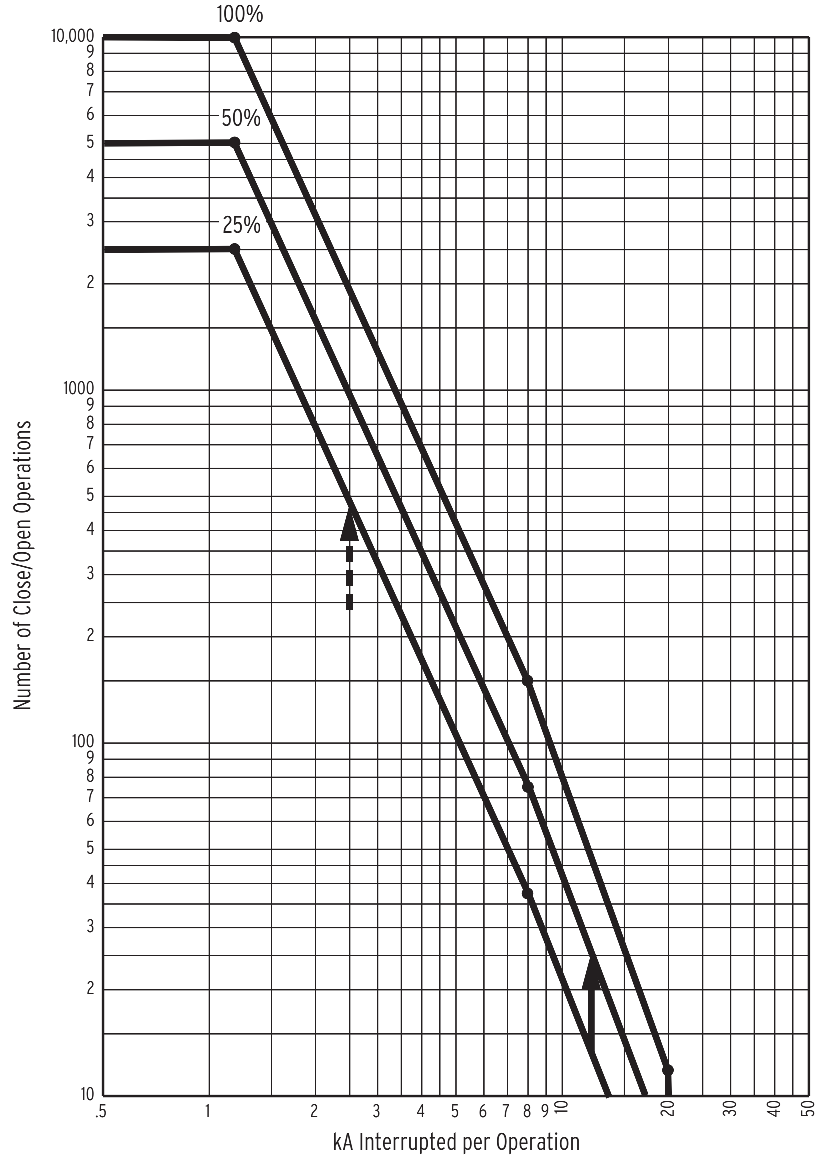


Figure 8.11 Breaker Monitor Accumulates 50 Percent Wear

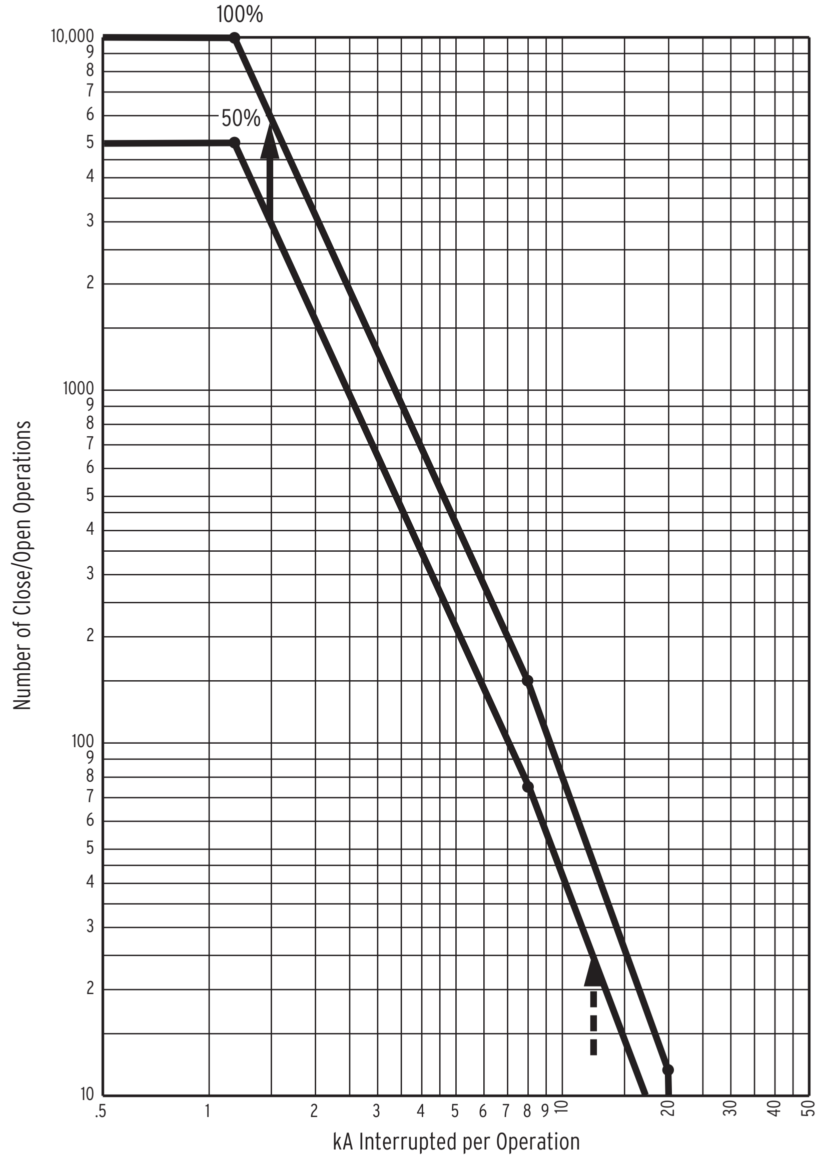


Figure 8.12 Breaker Monitor Accumulates 100 Percent Wear

Breaker Monitor Output

When the breaker maintenance curve for a particular phase (A, B, or C) reaches the 100 percent wear level (see *Figure 8.12*), a corresponding Relay Word bit (BCWA, BCWB, or BCWC) asserts.

Relay Word Bits	Definition
BCWA	Phase A breaker contact wear has reached the 100 percent wear level
BCWB	Phase B breaker contact wear has reached the 100 percent wear level
BCWC	Phase C breaker contact wear has reached the 100 percent wear level
BCW	BCWA OR BCWB OR BCWC

Example Applications

These logic outputs can be used to alarm:

OUT105 := **BCW**.

or to drive the recloser control to lockout the next time the recloser control trips:

79DTL3X := **TRIP3P AND BCW**. three-phase application

View or Reset Breaker Monitor Information

Accumulated breaker wear/operations data are retained if the recloser control loses power or the breaker monitor is disabled (setting EBMON := N). The accumulated data can only be reset if the **BRE R** command is executed; see the following discussion on the **BRE R** command.

Via Serial Port

See *BREAKER Command on page 10.12*. The **BRE** command displays the following information:

- ➤ Accumulated number of internal (recloser control) initiated trips
- ➤ Accumulated interrupted current from internal (recloser control) initiated trips
- ➤ Accumulated number of externally initiated trips
- ➤ Accumulated interrupted current from externally initiated trips
- ➤ Percent circuit breaker contact wear for each phase
- ➤ Accumulated number of trips involving A-phase, B-phase, and C-phase
- ➤ Accumulated number of trips involving ground (G)
- ➤ Date when the preceding items were last reset (via the **BRE R** command)

See *BREAKER Command on page 10.12*. The **BRE W** command allows the trip counters, accumulated values, percent breaker wear, and involved phase/ ground counters to be preloaded for each individual phase.

The **BRE R** command resets the accumulated values and the percent wear for all three phases. For example, if breaker contact wear has reached the 100 percent wear level for A-phase, the corresponding Relay Word bit BCWA asserts (BCWA = logical 1). Execution of the **BRE R** command resets the wear levels for all three phases back to 0 percent and consequently causes Relay Word bit BCWA to deassert (BCWA = logical 0).

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **BRE** and **BRE R** are also available via the front-panel menu entry Monitor. See *SEL-651R Menu Card on page 11.4*.

Determination of Internally Initiated Trips and Externally Initiated Trips

See *BREAKER Command on page 10.12*. Note in the **BRE** command response that the accumulated number of trips and accumulated interrupted current are separated into two groups of data: that generated by *internally initiated trips* (Internal Trips) and that generated by *externally initiated trips* (External Trips). The categorization of this data is determined by the status of the TRIP*p* Relay Word bit when the SELOGIC control equation breaker monitor initiation setting BKMON*p* operates.

Refer to *Figure 8.8* and accompanying explanation. If BKMON*p* newly asserts (logical 0 to logical 1 transition), the recloser control reads in the current values (Phases A, B, and C). Now the decision has to be made: is this current and trip count information accumulated under *internally initiated trips* or *externally initiated trips*?

To make this determination, the status of the TRIP*p* Relay Word bit is checked at the instant BKMON*p* newly asserts (TRIP*p* is the logic output of *Figure 5.1*). If TRIP*p* is asserted (TRIP*p* = logical 1), the current and trip count information is accumulated under *internally initiated trips* (Int Trips). If TRIP*p* is deasserted (TRIP*p* = logical 0), the current and trip count information is accumulated under *externally initiated trips* (Ext Trips).

Regardless of whether the current and trip count information is accumulated under internally initiated trips or externally initiated trips, this same information is routed to the breaker maintenance curve for continued breaker wear integration (see *Figure 8.8* through *Figure 8.12*).

Internally initiated trips (Internal Trips) are also referred to as *Relay Initiated Trips* or *Control Initiated Trips*, and any of these names are used throughout this or other SEL Instruction Manuals.

Internal and External Trip Counters

Each time one of the BKMON*p* settings is newly asserted, the corresponding internal or external count is incremented, using the method shown in the previous subsection to determine internal versus external trips.

To avoid multiple counting in single-phase trip applications, a new count is only recorded when a breaker is closed at the instant that the associated BKMON*p* setting asserts. For example, if the breaker on phase-B is already open, and BKMONB asserts, the internal or external trip counter will not increment because the breaker was already open when BKMONB asserted. The Relay Word bits SPOA, SPOB, and SPOC are used to provide the breaker open status information.

Involved Phase and Ground Counters

The involved phase and ground counters are incremented whenever a current exceeds one of the time-overcurrent element settings one cycle after BKMON*p* asserts:

The A-phase counter is incremented if |IA| is greater than: 51PJP, 51PKP, 51AJP, or 51AKP.

The B-phase counter is incremented if |IB| is greater than: 51PJP, 51PKP, 51BJP, or 51BKP.

The C-phase counter is incremented if |IC| is greater than: 51PJP, 51PKP, 51CJP, or 51CKP.

The ground counter is incremented if |IG| is greater than: 51G1JP, 51G1KP, 51G2JP, or 51G2KP, and Relay Word bit SPO (single pole open) was deasserted at the rising edge of BKMON*p*.

If no time-overcurrent element pickup settings are enabled, this feature will not operate. To ensure that it operates, time-overcurrent element pickup values must be set, even if they are not used for tripping.

In single-phase tripping applications, if more than one of the BKMON*p* settings asserts, the phase involvement counters are updated one cycle after the first BKMON*p* setting asserts.

Factory Default Setting Example

As discussed previously, the SELOGIC control equation breaker monitor initiation factory default setting is:

BKMON3P := **RCTR1X** when BKTYP := 3

BKMONA := **RCTR1X** when BKTYP := 1

BKMONB := **RCTR2X** when BKTYP := 1

BKMONC := **RCTR3X** when BKTYP := 1

Thus, any new assertion of BKMON*p* will be deemed an internal trip, and the current and trip count information is accumulated under *internally initiated trips*.

Additional Example

Refer to *Figure 8.13*. Output contact OUT101 is set to provide tripping:

OUT101 := **TRIP3P**

Note that optoisolated input IN106 monitors the trip bus. If the trip bus is energized by output contact OUT101, an external control switch, or some other external trip, then IN106 is asserted.

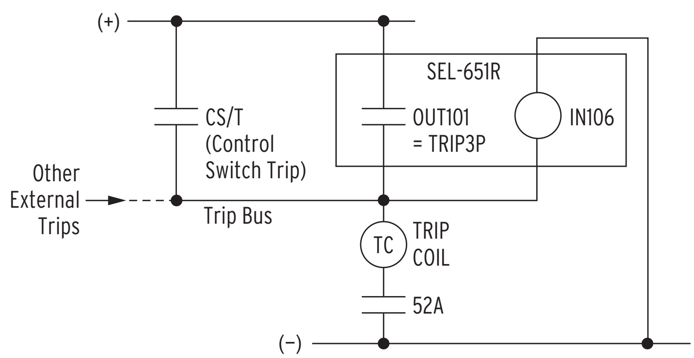


Figure 8.13 Input IN106 Connected to Trip Bus for Breaker Monitor Initiation

If the SELOGIC control equation breaker monitor initiation setting is set:

BKMON3P := **IN106**

then the SEL-651R breaker monitor detects all trips.

If output contact OUT101 asserts, energizing the trip bus, the breaker monitor will deem it an *internally initiated trip*. This is because when BKMON3P is newly asserted (input IN106 energized), the TRIP3P Relay Word bit is asserted. Thus, the current and trip count information is accumulated under *internally initiated trips*.

If the control switch trip, or some other external trip, asserts, energizing the trip bus, the breaker monitor will deem it an *externally initiated trip*. This is because when BKMON3P is newly asserted (input IN106 energized), the TRIP3P Relay Word bit is deasserted. Thus, the current and trip count information is accumulated under *externally initiated trips*.

Battery System Monitor

NOTE: Units ordered with 125 Vdc power supplies do not contain batteries or the battery charging circuitry. These units will continuously assert the BTFAIL Relay Word bit, and some settings must be modified accordingly.

NOTE: If global setting PWRDN_AC is changed while ac power is removed (SEL-651R is operating off battery power), the new PWRDN_AC setting does not become active until the next loss of ac power. Likewise, if global setting PWRDN_WU is changed while ac power is removed (SEL-651R is operating off battery power), the new PWRDN_WU setting does not become active until the next press of the {WAKE UP} pushbutton.

The SEL-651R monitors the internal battery system, which includes the battery charger and battery. This subsection describes how the battery system operates, how the battery system is automatically and manually checked, and what the SEL-651R does when it detects a problem with the battery system.

The following settings are discussed in this subsection:

➤ Power-off Delay After AC Loss (OFF, 1–1440 min.)
PWRDN_AC := 180

➤ Power-off Delay After Wake Up (OFF, 1–1440 min.)
PWRDN_WU := 20

➤ Request Battery Test SELOGIC Equation
TESTBATT := NA

These global settings are available via the **SET G** command, described in *Section 10: Communications*. The example setting values listed above will be used in the description that follows.

Battery System Operation

The 12 V lead-acid battery powers the SEL-651R and provides trip and close power to the capacitors when the ac source is de-energized. The SEL-651R includes a temperature-compensated 12 V battery charger powered from an external ac source. See *Section 1: Introduction and Specifications* for battery specifications.

When the ac source is energized, the SEL-651R built-in battery monitor/charger controls charging current to the battery system. When ac power is present, the SEL-651R will charge the battery in one of three modes:

➤ Constant current charge,

➤ Fast charge, or

➤ Float charge.

The transition between the charge modes is determined by measured battery current, voltage, temperature, and time spent in each mode.

The CHRGG Relay Word bit asserts when the batteries are charging (when the ac source is energized). The DISCHG Relay Word bit asserts when the batteries are discharging (when the ac source is de-energized and the SEL-651R is operating from battery power).

The SEL-651R also periodically tests the batteries by subjecting them to a load test for 10 seconds. If the battery voltage falls below this threshold during the test, the discharge test failure Relay Word bit DTFAIL asserts, and the **BATTERY PROBLEM** LED illuminates on the front panel, with factory default front-panel settings. DTFAIL remains asserted until the next successful battery load test.

If the batteries fail, or when you remove them temporarily during replacement, the ac source provides sufficient energy to trip and close most reclosers. However, the ac source voltage may dip significantly during a fault, reducing or eliminating the source voltage needed to power the SEL-651R and trip the recloser. To counteract this, the SEL-651R can ride through 0.5 seconds of ac source (and battery) loss. During this 0.5 seconds ride-through time, the SEL-651R can still issue a trip—such a trip would likely be a high-current instantaneous or fast curve operation.

SEL-651R Puts Itself To Sleep

If the ac source is de-energized, the SEL-651R operates off battery power and initiates a countdown timer that starts with the global settings value PWRDN_AC, in minutes. If the ac source does not re-energize before the countdown timer reaches zero, the SEL-651R will shut itself off. The final action before the control shuts down is to make a Going to Sleep entry in the Sequential Events Recorder (SER). The example setting value of PWRDN_AC := 180 minutes gives a three-hour standby time before the unit shuts off.

The 12-volt dc auxiliary power source is also shut-off whenever the SEL-651R is off. See *+12 Vdc Auxiliary Power Supply on page 2.47* for details on the 12 Vdc power supply output.

This sleep feature allows the battery to be left in a partially charged state, rather than completely discharged, and allows power to be available for subsequent front-panel operator activities (see *Wake Up the SEL-651R*).

When the countdown reaches one minute, the TOSLP (to sleep) Relay Word bit asserts and stays asserted, to allow some final control action to be taken before protection is disabled. See *Possible Application of TOSLP Relay Word Bit on page 8.36*.

During the ac outage, if the countdown timer has not reached 0 and the battery voltage drops too low, the control will be disabled and will shut off immediately to protect the battery. In this case, the TOSLP bit will not be asserted.

If ac power comes back after the TOSLP bit has asserted, but before the SEL-651R shuts down, the TOSLP bit will be deasserted and the control will abort the countdown. If ac power fails again, the countdown timer will load with the PWRDN_AC setting and start over again.

Wake Up the SEL-651R

When the SEL-651R is in the sleep mode, it wakes up when either of the following occurs:

- The ac source is re-energized
- The front-panel **{WAKE UP}** pushbutton is operated

After the SEL-651R is awakened via the front-panel **{WAKE UP}** pushbutton, the SEL-651R initiates a countdown timer that starts with the global settings value PWRDN_WU, in minutes. If the ac source does not re-energize before the count down timer reaches zero, the SEL-651R will shut itself off.

The SEL-651R will continue to operate on battery power until the countdown reaches zero. See the previous subsection for a description of the TOSLP Relay Word bit, which operates identically for the countdown timing after a wake-up operation. The example setting value of PWRDN_WU := 20 minutes gives a 20 minute standby time before the unit shuts off, unless the front panel is being used.

While ac is off, if a front-panel button is pressed, and the present countdown is less than 15 minutes, the countdown timer is loaded with 15 minutes. This ensures that the control stays energized as long as an operator is using the front panel. If an operator is using a laptop computer to access data during an ac outage, a front-panel button (e.g., **{ESC}**) should be pressed periodically to ensure that the unit does not shut off before the data retrieval is completed.

If the SEL-651R wakes up because the ac power source was energized and then de-energized before the SEL-651R control completes the initialization routine, upon detecting that ac power is not present, it will function as if the {WAKE UP} pushbutton was pressed, described above.

If there is insufficient battery voltage when the {WAKE UP} pushbutton is pressed, the SEL-651R will not wake up.

Possible Application of TOSLP Relay Word Bit

If allowed by system operating procedures, a possible application of the TOSLP Relay Word bit is to use it in a trip equation to open the recloser or circuit breaker. This action can improve the coordination on radial systems after the system is re-energized, because the line section beyond the SEL-651R would be isolated while the recloser control is powering up.

Before tripping the breaker or recloser, a nonvolatile latch could be set to indicate that the recloser control performed the trip based on a loss of source power. When the power comes back on, and the SEL-651R initializes, it could reclose the breaker/recloser when it determines that the nonvolatile latch is in the asserted position. This function could be supervised by any Hot Line Tag or Reclose Block conditions.

Without this approach, the breaker or recloser is left in the closed position when the recloser control shuts down. The recloser control is then unable to protect the line for a few seconds after power is restored, while it performs the diagnostic checks that are part of its start-up sequence, which could lead to coordination difficulties if there is a fault on the load side of the recloser.

Battery System Diagnostics

The SEL-651R monitors the 12 V battery system, including charge/discharge current, battery voltage, and temperature. The SEL-651R automatically applies a battery load test approximately once per day and includes provisions to perform a battery load test via the serial communications ports or SELOGIC. You can obtain vital battery system information from the SEL-651R status report via the front-panel and serial communications ports.

Automatic Battery Load Test

ISSUE **STA C** COMMAND AFTER REPLACING BATTERY

If the battery is replaced after a battery test failure, issue the **STA C** command to clear the battery test failure status.

The SEL-651R automatically load tests the 12 V battery about every 24 hours. An internal 24-hour timer cumulatively times whenever the SEL-651R is in the float-charge mode, such as when ac voltage is powering the SEL-651R and charging the battery. Even if the battery is fully charged, the SEL-651R maintains a low-rate charging current, so it is still in the float-charge mode.

If the 24-hour timer runs out and the SEL-651R is still in the float-charge mode, the battery charger is shut off for ten seconds, which simulates an ac outage and tests the battery. If the battery voltage drops too quickly, the test is aborted, and the DTFAIL Relay Word bit asserts. If the battery voltage is okay throughout the test period, the battery charger is turned back on.

Once the battery fails an automatic load test, automatic testing is no longer performed unless the battery tests successfully via one of the following described means (SELOGIC or serial port), or the battery is replaced.

SELOGIC Battery Load Test

The Request Battery Test (TESTBATT) SELOGIC Equation is provided for entry of user-defined battery load test conditions. this function is useful for initiating a battery test from the front panel, at a set time of day, or remotely. This SELOGIC equation is rising-edge qualified, meaning that it will only initiate a battery test when its state changes from 0 to 1. This prevents an asserted condition from continually initiating battery tests. Following a valid rising edge of the TESTBATT equation, the SEL-651R will initiate a battery test if the following conditions are met.

NOTE: If the TESTBATT equation is held in a continually asserted state, this will not impede initiation of the automatic battery load test nor the battery load test via serial port.

- ➤ There is no battery test currently in progress.
- ➤ Battery charger is NOT in Discharge (AC off) or Startup (relay is starting up) mode.
- ➤ There have not been more than four battery tests in the last hour.

Battery Load Test via Serial Port

View the results of a battery test or request a new battery test by using the **BTT** or **BTT NOW** commands at the serial port.

See *BTT Command on page 10.14* for required serial port access levels and sample screen captures.

Battery Status

Check the battery status in several ways. On the front panel (with factory default front-panel settings), the **BATTERY PROBLEM** LED (see *Figure 11.13*) illuminates for any of the following battery problems:

- ➤ Load test failure (Relay Word bits DTFAIL = logical 1 and BTFAIL = logical 1)
- ➤ Cannot charge or is otherwise internally damaged; Relay Word bit BTFAIL = logical 1)

Use the STATUS menu on the front panel of the SEL-651R to access more battery status information. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to move to different status screens. Those status elements of interest for the battery are the following.

INPBV =	Input Power Bus Voltage (Vdc)
12VAUX =	12V Auxiliary Bus Voltage (Vdc)
MODE =	Battery Charger Mode
	STARTUP = Startup
	CUR_CHG = Constant Current Charge
	FST_CHG = Fast Charge
	FLT_CHG = Float Charge
	DISCHRG = Discharge
	BAT_FLR = Battery Failure
	BAT_TST = Battery Discharge Test
VBAT =	Battery Voltage (Vdc)
IBAT =	Battery Current (A dc, discharge if negative)
TCCAPV =	Trip/Close Capacitor Voltage (Vdc)

The same battery status information as described above is also available via serial port communications using the **STATUS** command.

The battery voltage “VBAT” is also available as an analog quantity for use in the Load Profile Recorder (see *Table G.1*).

Include VBAT in the LDLIST setting (using the **SET R** command; see *Section 9: Settings*) to record the battery performance during source outages (see *Load Profile Report on page 8.38*).

Use the Sequential Events Recorder (See *Sequential Events Recorder (SER) on page 12.2*) to determine the moment that the power source outage began and ended, and the Load Profile Report to check the battery performance during the source outage.

Modifying Reclosing Logic

In addition to alarming, the recloser control elements associated with the battery and charging system can provide control functions, such as disabling or blocking reclosing. For example, the factory default logic settings include one of these following automatic reclose supervision settings:

Traditional Retrofit reclosers:	79CLS3P := PWR_SRC1 AND TCCAP AND NOT(BTFAIL)
Other reclosers:	79CLS3P := TCCAP AND NOT(BTFAIL)

This is for three-phase trip applications (Group setting ESPB := N).

This SELOGIC control equation permits automatic reclosing to proceed after a reclose interval time out only if *all* the following conditions are present:

- (Traditional Retrofit reclosers only.) The AC voltage source is present; PWR_SRC1 = logical 1. This assumes the traditional installation where the low-voltage ac close power is wired to the same phase as the SEL-651R power supply input. See *Figure 2.35*.
- The Trip and Close Capacitors are fully charged; TCCAP = logical 1.
- The Battery is healthy; BTFAIL = logical 0.

This is a factory default setting because recloser tripping and closing requires dc battery energy. Therefore, if the batteries or charging system are not functioning properly, the control should not reclose after a trip because there might not be enough dc battery energy to trip again after a reclose.

Load Profile Report

The SEL-651R Load Profile Recorder is capable of recording up to 15 selectable analog quantities at a periodic rate and storing the data in a report in nonvolatile memory.

The load profile report is available via serial port communications by using the LDP command. See *LDP Command (Load Profile Report) on page 10.25*.

At the interval given by load profile acquisition rate setting LDAR, the recloser control adds a record to the load profile buffer. This record contains the time stamp, the present value of each of the analog quantities listed in the load profile list setting LDLIST, and a checksum. These settings are made and reviewed with the **SET R** and **SHO R** serial port commands, respectively. Setting LDAR can be set to any of the following values: 5, 10, 15, 30, and 60 minutes. Setting LDLIST may contain any of the quantities that are marked in the Load Profile column of *Table G.1* (see *Report Settings on page SET.58*).

Labels are entered into the setting as either comma or space delimited, but are displayed as comma delimited. Load profiling is disabled if the LDLIST setting is empty (i.e., set to NA or 0), which is displayed as LDLIST := 0. The load buffer is stored in nonvolatile memory and the acquisition is synchronized to the time of day, with a resolution of ± 5 seconds. Changing the LDAR setting may result in up to two acquisition intervals before resynchronization occurs. If LDAR setting is increased, the next acquisition time does not have a complete interval; therefore, no record is saved until the second acquisition time, which is a complete cycle. When the buffer fills up, newer records overwrite older records. The recloser control is able to store at least 26 days of data at a LDAR of 5 minutes, if all 15 values are used. If less than 15 values are specified, the recloser control will be able to store more days of data before data overwrite occurs. Likewise, if the interval is set longer, the recloser control will be able to store more days of data before data overwrite occurs.

Section 9
Settings

Introduction

The SEL-651R Recloser Control stores customer-entered settings in nonvolatile memory. Settings are divided into the following six setting classes:

1. Global
2. Group *n* (where *n* = Group 1–6; *n* = Group 1–8 for SEL-651R-1)
3. Logic *n* (where *n* = Group 1–6; *n* = Group 1–8 for SEL-651R-1)
4. Front Panel
5. Report
6. Port *p* (where *p* = 1, 2, 3, or F)

Some setting classes have multiple instances. In the above list, there are six "settings groups" for group and logic settings and four port setting instances, one for each serial port.

Settings may be viewed or set in several ways, as shown in *Table 9.1*.

Table 9.1 Methods of Accessing Settings

	Serial Port Commands	Front Panel HMI Set/Show Menu	ACSELERATOR QuickSet SEL-5030 (PC software)
Display Settings	All settings (**SHO** command)	Some settings[a, b]	All settings
Change Settings	All settings (**SET** command)	Some settings[a, b]	All settings

[a] Only global, group, front panel, and port setting classes can be accessed.
[b] SELOGIC® control equations can only be viewed on the HMI.

See *Factory Default Settings on page 9.56* for examples of the **SHO** command, including the factory default settings.

The **SET** command is described in the next subsection. *Table 9.2* lists the settings classes with a brief description, and the page numbers for the *Settings Sheets* included at the end of this section. The order of the setting sheets matches the numbered list, above.

See *SET/SHOW Menu on page 11.12* for details on accessing settings via the front-panel HMI. See *Section 3: PC Software* for ACSELERATOR QuickSet® SEL-5030 Software information.

Table 9.2 Serial Port SET Commands

Command	Settings Type	Description	Settings Sheets[a]
SET G	Global	System configuration, current and voltage connection settings, input debounce timers, breaker monitor, etc.	*SET.1–SET.5*
SET *n*	Group	Overcurrent and voltage elements, reclosing relay, tripping, closing, etc., for settings Group *n* (*n* = 1, 2, 3, 4, 5, 6; *n* = 1, 2, 3, 4, 5, 6, 7, 8 for SEL-651R-1).	*SET.5–SET.30*
SET L *n*	Logic	General logic settings for settings Group *n* (*n* = 1, 2, 3, 4, 5, 6; *n* = 1, 2, 3, 4, 5, 6, 7, 8 for SEL-651R-1).	*SET.31–SET.47*
SET F	Front Panel	Front-panel default display, pushbutton and target LED settings, display points, and local control bits.	*SET.48–SET.57*
SET R	Report	Sequential Events Recorder (SER) trigger conditions, event report settings, and Load Profile Recorder (LDP) settings.	*SET.58*
SET P *n*	Port	Serial port settings for Serial Port *n* (*n* = 1, 2, 3, or F).	*SET.59–SET.62*

[a] Located at the end of this section.

View settings with the respective serial port **SHOW** commands (**SHO G**, **SHO**, **SHO L**, **SHO F**, **SHO R**, **SHO P**). See *SHOW Command (Show/View Settings) on page 10.36*.

Make Global Settings (SET G) First

For most applications, make global settings (*Global Settings on page SET.1*) before making the group settings. Changing some of the global settings can cause certain group settings to be hidden from view or forced to default values. The global settings, in general, define the overall physical connections and equipment type, while the group settings define the application-specific details.

The SEL-651R will display a specific warning message before allowing a global setting to be changed that would affect group settings. These warnings are shown in *Settings Explanations on page 9.27*.

Settings Changes Via the Serial Port

NOTE: In this manual, commands you type appear in bold/uppercase: **SET**. Computer keys you press appear in bold/brackets: **<Enter>**.

See *Section 10: Communications* for information on serial port communications and recloser control access levels. The **SET** commands in *Table 9.2* operate at Access Level 2 (screen prompt: =>>). To change a specific setting, enter the command:

SET *n m s* TE[RSE]

where:

n = L, G, R, F, or P (parameter ***n*** is not entered for the group settings).

m = group (1 . . . 6; *m* = 1 . . . 8 for SEL-651R-1) or port (1, 2, 3, or F). The SEL-651R selects the active group or port if ***m*** is not specified.

where:

s =	the name of the specific setting you wish to jump to and begin setting. If ***s*** is not entered, the recloser control starts at the first setting.
TERSE (or **TE**) =	instructs the SEL-651R to skip the `SHOW` display after the last setting. Use this parameter to speed up the **SET** command. If you wish to review the settings before saving, do not use the **TERSE** option.

When you issue the **SET** command, the SEL-651R 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 9.3*.

Table 9.3 Set Command Editing Keystrokes

Press Key(s)	Results
<Enter>	Retains setting and moves to the next setting.
^ <Enter>	Returns to previous setting.
< <Enter>	Returns to previous setting section.
> <Enter>	Moves to next setting section.
END <Enter>	Exits editing session, then prompts you to save the settings.
<Ctrl + X>	Aborts editing session without saving changes.

The recloser control checks each entry to ensure that it is within the setting range. If it is not, an `Out of Range` message is generated, and the recloser control prompts for the setting again.

If a given setting is beyond 80 characters (like an SER trigger list setting, set with **SET R** command), then a backslash (\) and carriage return have to be made to complete the setting on the next line. The backslash does not have to be entered right at character position 81—it can be entered earlier and then the setting continued on the next line.

When all the settings are entered, the recloser control displays the new settings and prompts for approval to enable them. Answer **Y <Enter>** to enable the new settings.

The SEL-651R handles settings changes as shown in *Table 9.4*.

Table 9.4 Settings Changes Effects (SALARM Relay Word Bit, ENABLED LED, SER) (Sheet 1 of 2)

Settings Change	SALARM Relay Word Bit Pulsed for 1 Second?	ENABLED LED Extinguished for a Few Seconds?	Sequential Events Recorder (SER) "Settings Changed" Entry?
Global	Yes	Yes	Yes
Active Group	Yes	Yes	Yes
Inactive Group	Yes	No	Yes
Active Logic	Yes	Yes	Yes
Inactive Logic	Yes	No	Yes
Front Panel	Yes	Yes	Yes
Report	Yes	Yes	Yes
Port (any)	No	No	No

Table 9.4 Settings Changes Effects (SALARM Relay Word Bit, ENABLED LED, SER) (Sheet 2 of 2)

Settings Change	SALARM Relay Word Bit Pulsed for 1 Second?	ENABLED LED Extinguished for a Few Seconds?	Sequential Events Recorder (SER) "Settings Changed" Entry?
Refer to *Section 7*			
Copy from active to inactive group	No	No	Yes
Copy from inactive to active group	Yes	Yes	Yes
Group Change	Yes	Yes (less than 1 second)	Yes

In *Table 9.4*, an inactive group is one of the five settings groups (one of the seven settings groups for the SEL-651R-1) that is not the currently active group. For example, if Setting Group 2 is currently active, Settings Groups 1, 3, 4, 5, and 6 (and additional Settings Groups 7 and 8 for the SEL-651R-1) are inactive. A **SET L 4** command represents a change to logic settings in inactive Settings Group 4.

The SALARM Relay Word bit is in the factory default setting for OUT201.

If the ENABLED LED is extinguished, then SEL-651R protection functions are disabled.

The SER is described in *Section 12: Analyzing Events*.

Time-Overcurrent Curves

Standard Inverse-Time Characteristic Curves

The information in *Table 9.5* and *Table 9.6* describes the curve timing for the curve and time dial settings made for the time-overcurrent elements (see *Figure 4.16* through *Figure 4.22*). The time-overcurrent curves in *Figure 9.1* through *Figure 9.10* conform to IEEE C37.112-1996 IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays.

where:

T_p = Operating time in seconds
T_R = Electromechanical induction-disk emulation reset time in seconds (if you select electromechanical reset setting)
TD = Time-dial setting
M = Applied multiples of pickup current [for operating time (T_p), M > 1; for reset time (T_R), M ≤ 1]

Table 9.5 Equations Associated With U.S. Curves (Sheet 1 of 2)

Curve Type	Operating Time	Reset Time	Figure
U1 (Moderately Inverse)	$T_p = TD \cdot \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$T_R = TD \cdot \left(\frac{1.08}{1 - M^2}\right)$	*Figure 9.1*
U2 (Inverse)	$T_p = TD \cdot \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$T_R = TD \cdot \left(\frac{5.95}{1 - M^2}\right)$	*Figure 9.2*

Table 9.5 Equations Associated With U.S. Curves (Sheet 2 of 2)

Curve Type	Operating Time	Reset Time	Figure
U3 (Very Inverse)	$T_p = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$	*Figure 9.3*
U4 (Extremely Inverse)[a]	$T_p = TD \bullet \left(0.02434 + \frac{5.64}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.64}{1 - M^2}\right)$	*Figure 9.4*
U5 (Short-Time Inverse)	$T_p = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$	*Figure 9.5*

[a] U.S. Curve U4 differs slightly from the SEL-351R Recloser Control and SEL-351 Relay family U4 curves.

Table 9.6 Equations Associated With IEC Curves

Curve Type	Operating Time	Reset Time	Figure
C1 (Standard Inverse)[a]	$T_p = TD \bullet \frac{0.14}{M^{0.02} - 1}$	$T_R = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$	*Figure 9.6*
C2 (Very Inverse)[a]	$T_p = TD \bullet \frac{13.5}{M - 1}$	$T_R = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$	*Figure 9.7*
C3 (Extremely Inverse)[a]	$T_p = TD \bullet \frac{80}{M^2 - 1}$	$T_R = TD \bullet \left(\frac{80}{1 - M^2}\right)$	*Figure 9.8*
C4 (Long-Time Inverse)	$T_p = TD \bullet \frac{120}{M - 1}$	$T_R = TD \bullet \left(\frac{120}{1 - M}\right)$	*Figure 9.9*
C5 (Short-Time Inverse)	$T_p = TD \bullet \frac{0.05}{M^{0.04} - 1}$	$T_R = TD \bullet \left(\frac{4.85}{1 - M^2}\right)$	*Figure 9.10*

[a] Recloser curves 200–202 are equivalent to IEC curves as follows: 200 = IEC Standard Inverse (C1), 201 = IEC Very Inverse (C2), 202 = IEC Extremely Inverse (C3).

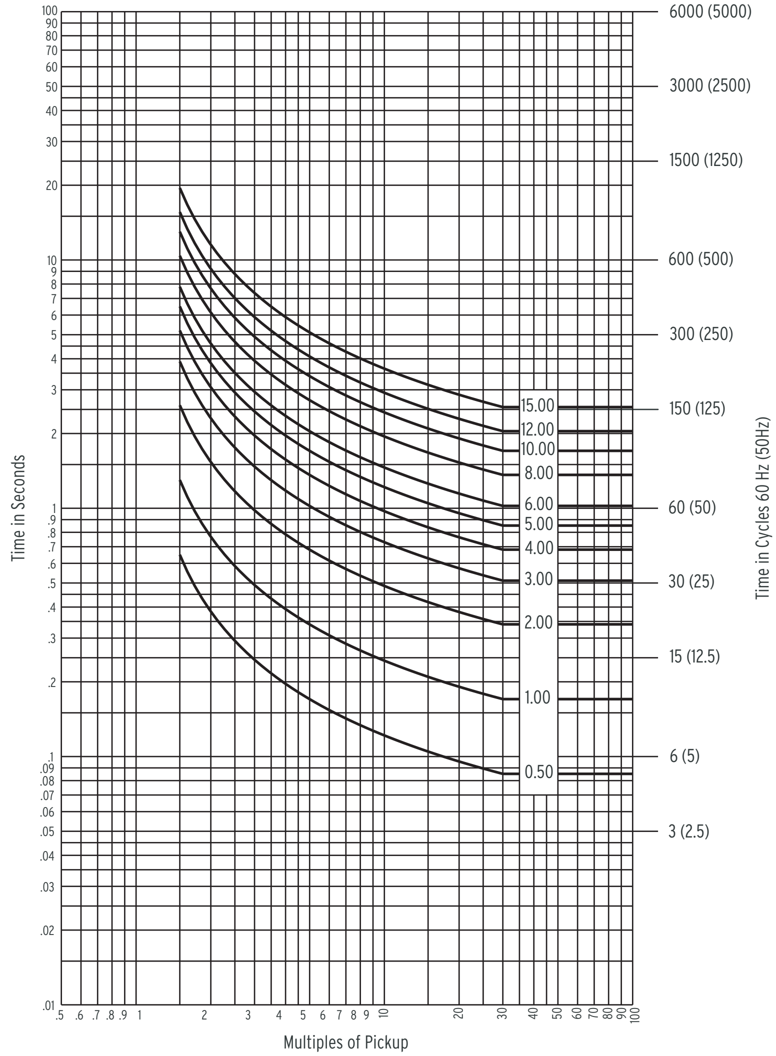


Figure 9.1 U.S. Moderately Inverse Curve: U1

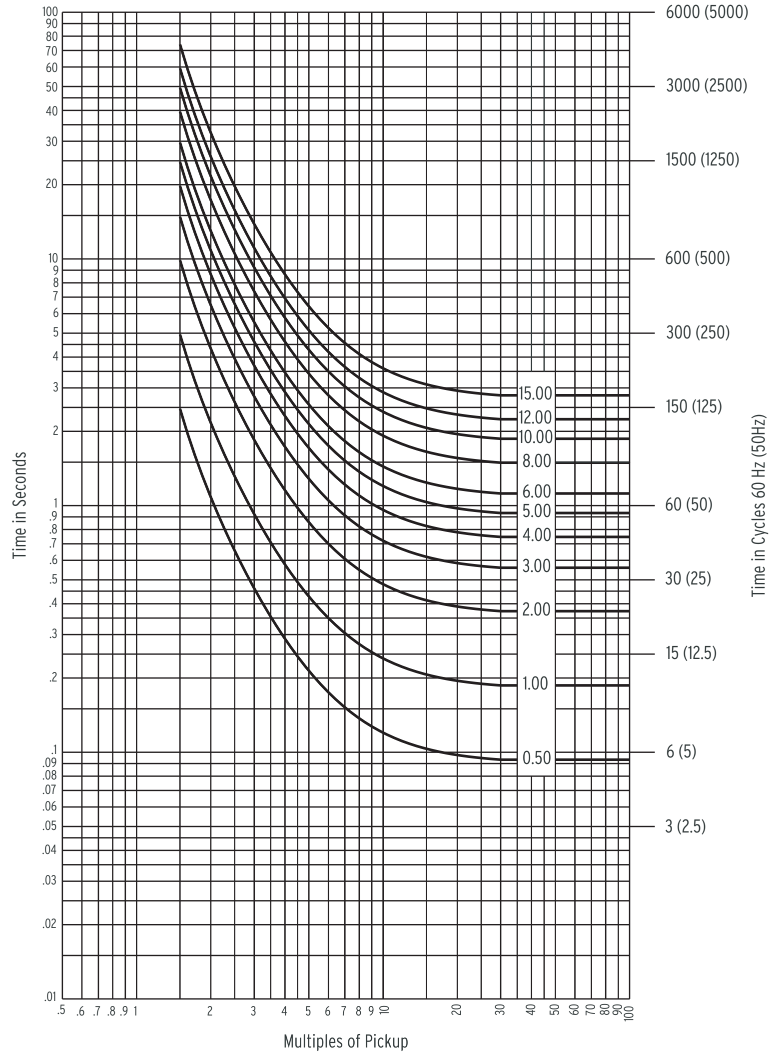


Figure 9.2 U.S. Inverse Curve: U2

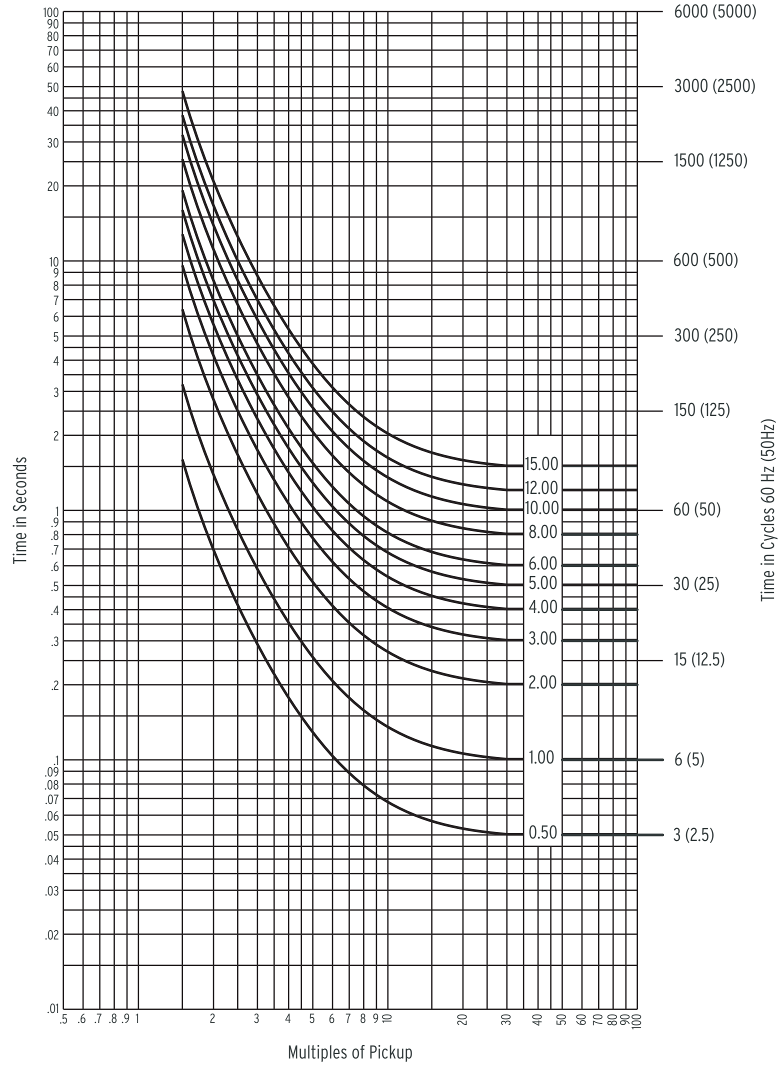


Figure 9.3 U.S. Very Inverse Curve: U3

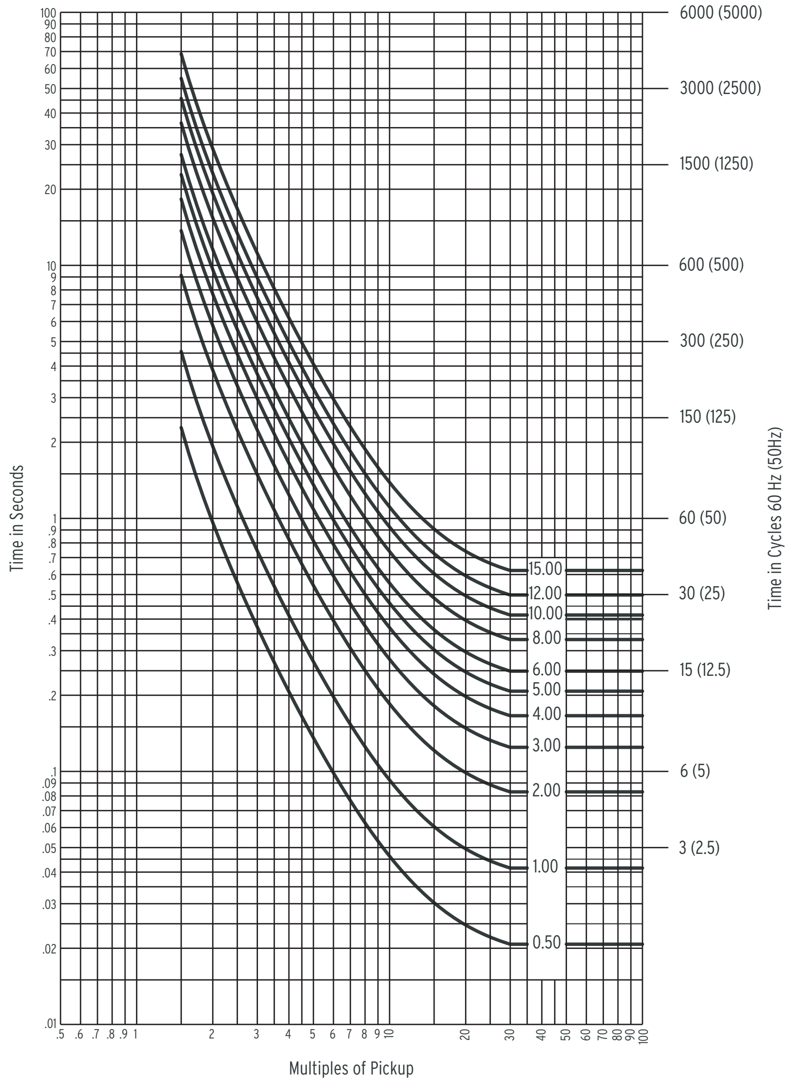


Figure 9.4 U.S. Extremely Inverse Curve: U4

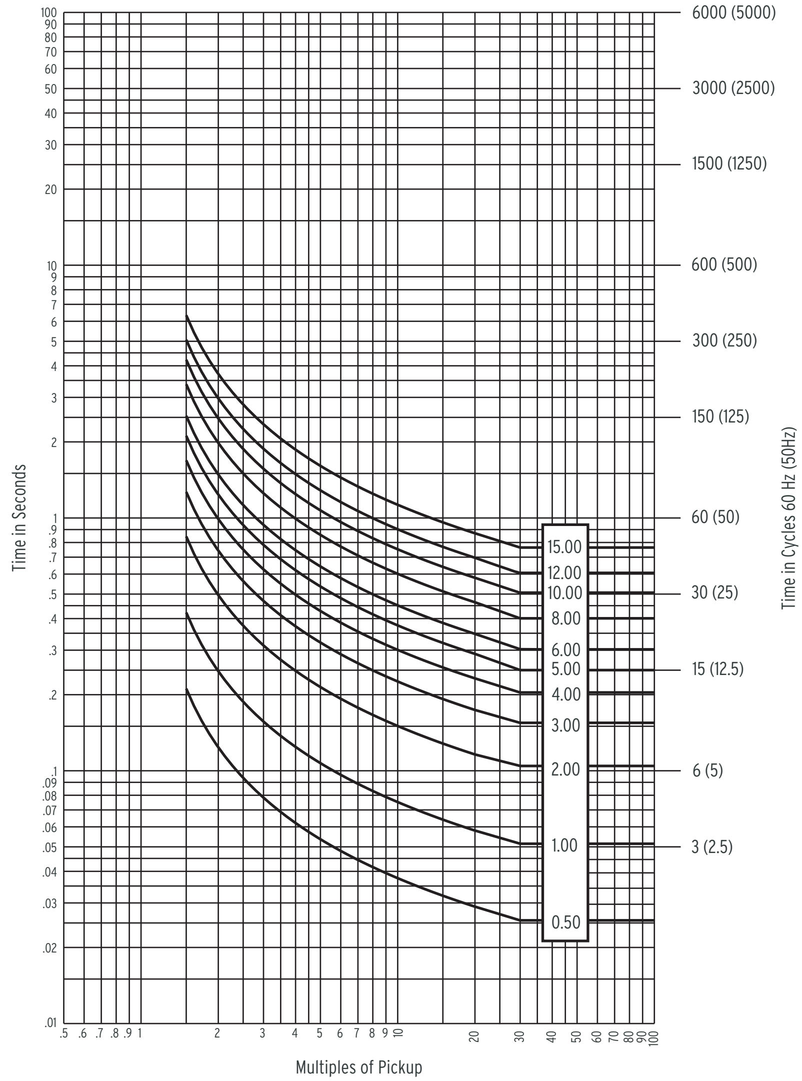


Figure 9.5 U.S. Short-Time Inverse Curve: U5

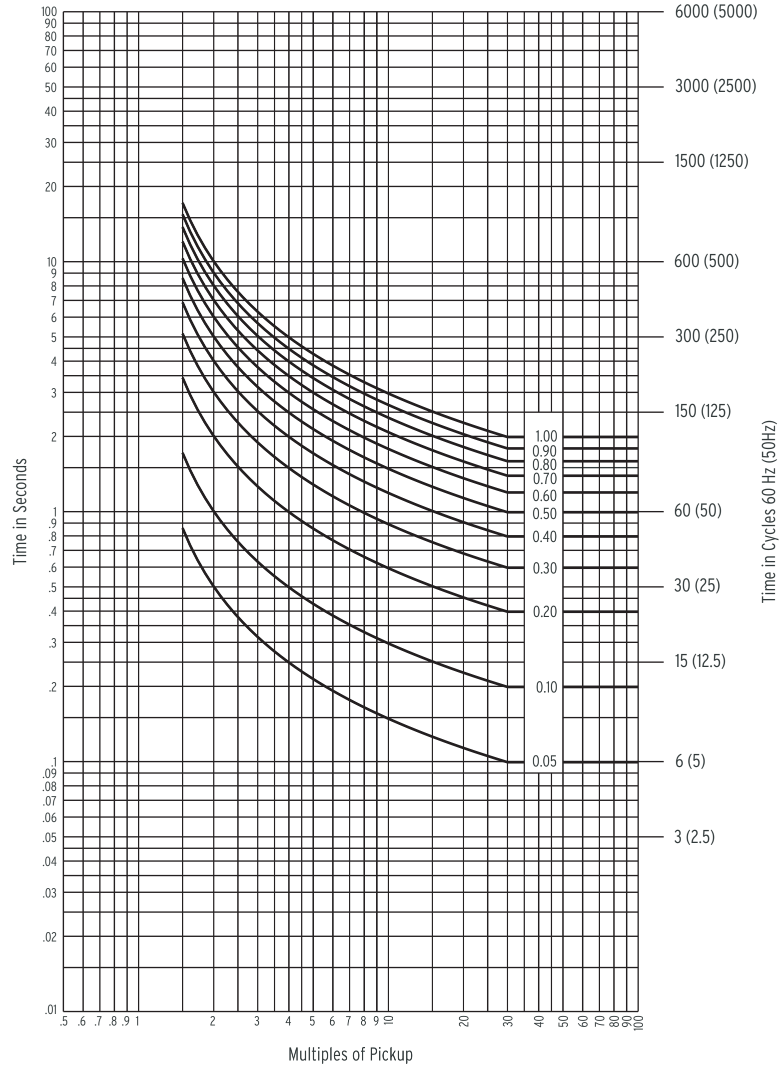


Figure 9.6 IEC Class A Curve (Standard Inverse): C1

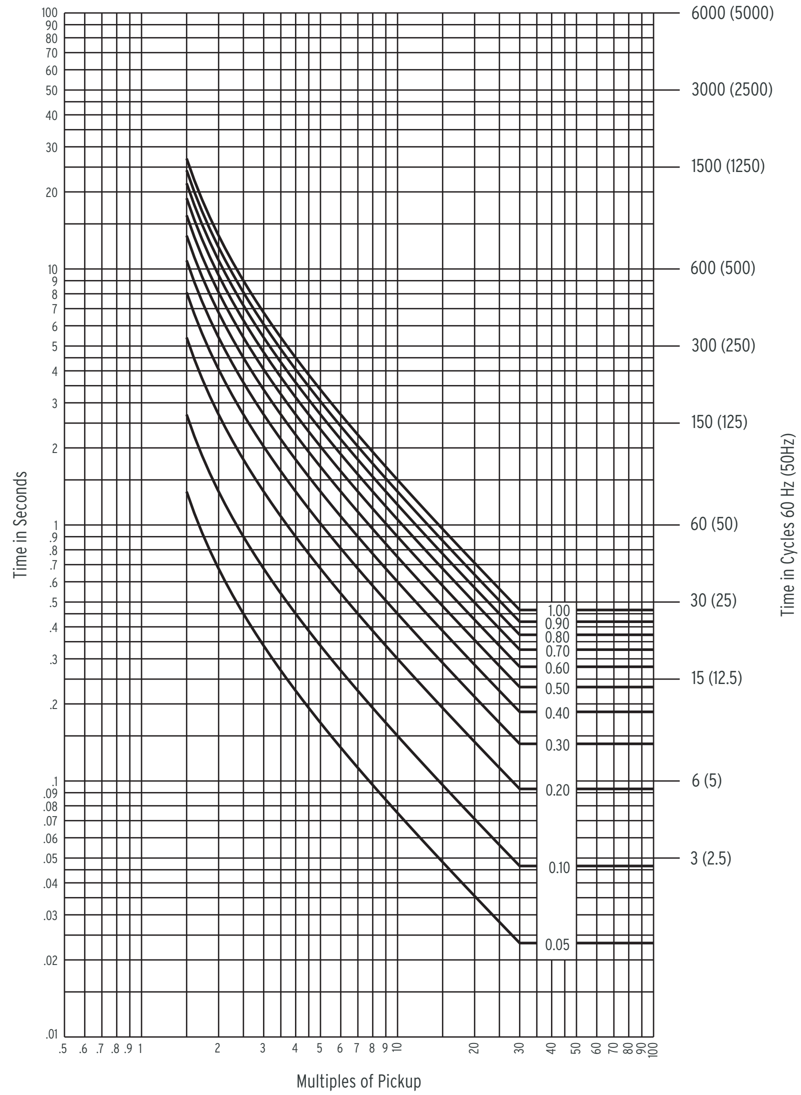


Figure 9.7 IEC Class B Curve (Very Inverse): C2

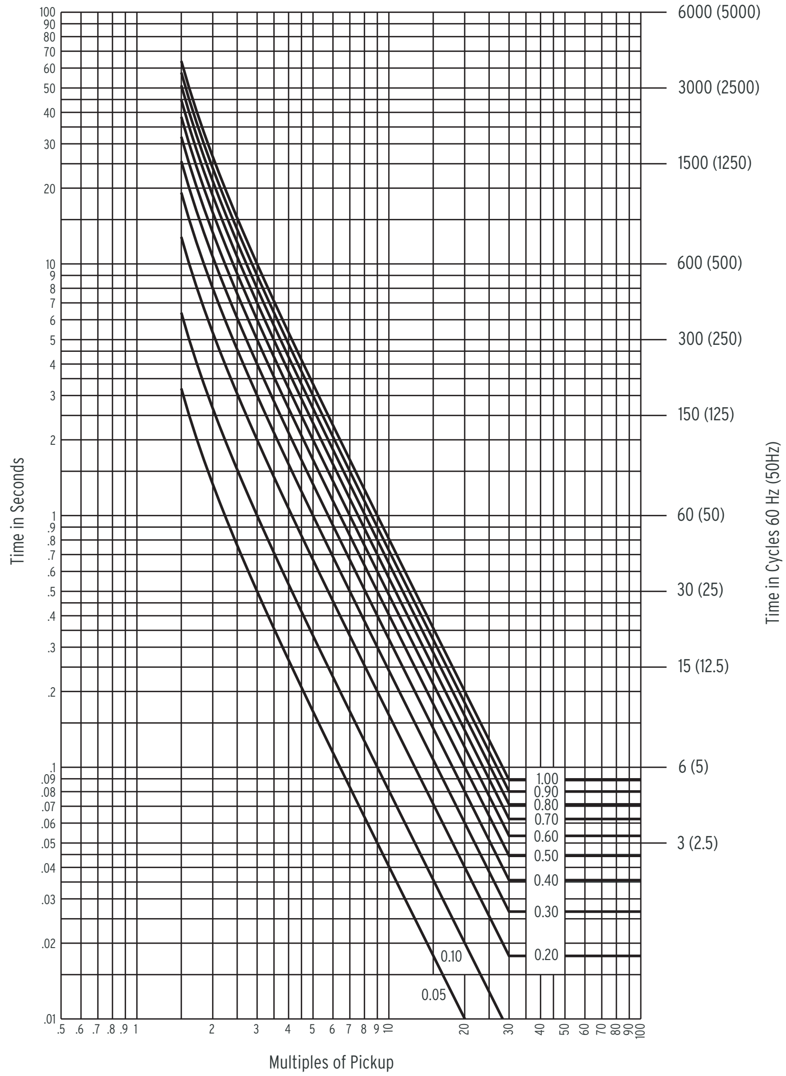


Figure 9.8 IEC Class C Curve (Extremely Inverse): C3

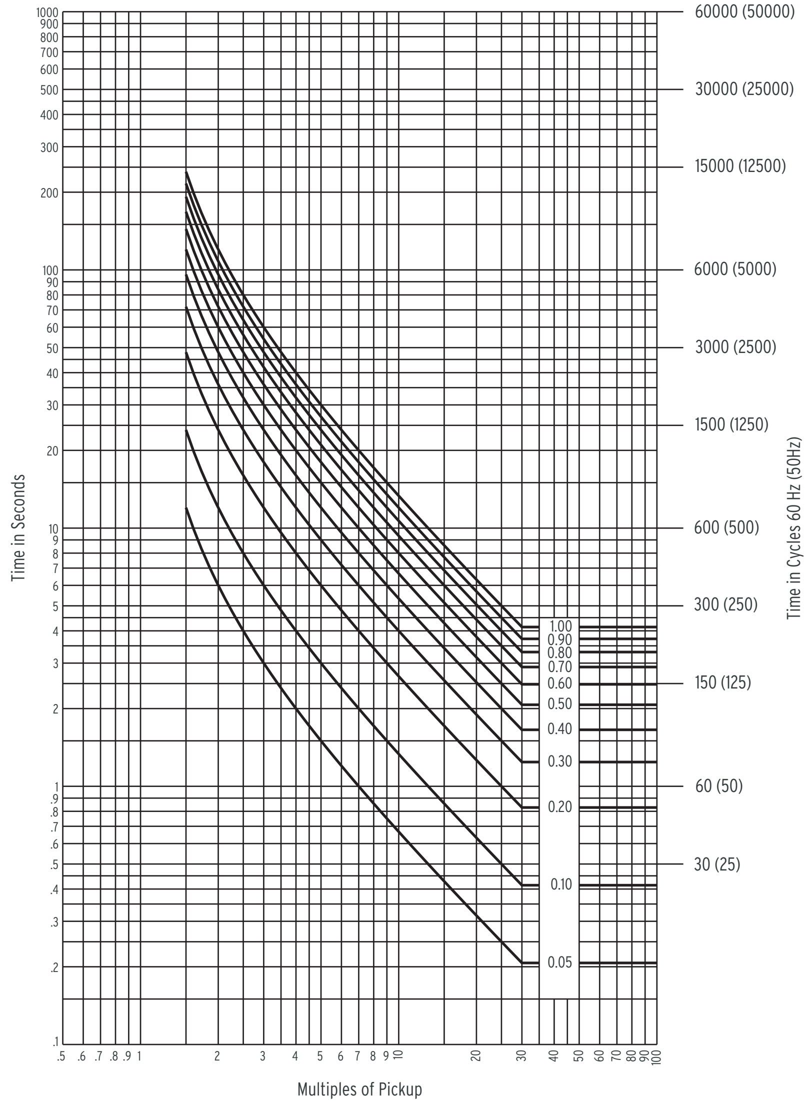


Figure 9.9 IEC Long-Time Inverse Curve: C4

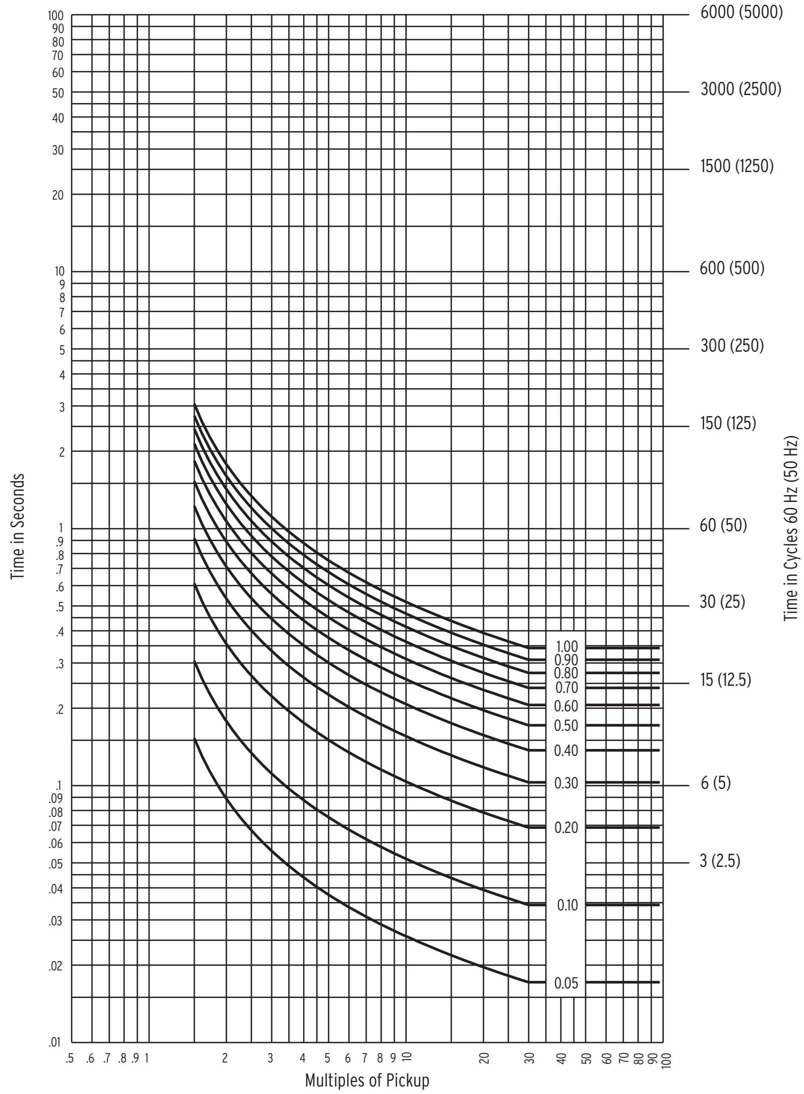


Figure 9.10 IEC Short-Time Inverse Curve: C5

Recloser Curves

Traditional recloser curves are available for the time-overcurrent elements (see *Figure 4.16* through *Figure 4.22*). The recloser curves in *Figure 9.11* through *Figure 9.20* can be specified with either the older electronic recloser control designation or the newer micro-processor-based recloser control designation (see *Table 9.7*). For example, a given recloser curve has the following two designations:

Older electronic recloser control designation: A

Newer microprocessor-based recloser control designation: 101

Recloser curve A and curve 101 are the same curve—use either designation in making curve settings in the SEL-651R.

The recloser curves have a time-dial setting range of 0.10 to 2.00, as is available in traditional microprocessor-based recloser controls. In traditional microprocessor-based recloser controls, the time-dial setting is often referred to as a “vertical multiplier” setting instead.

The recloser curves in *Figure 9.11* through *Figure 9.20* are shown with an effective time-dial setting of 1.00.

NOTE: The electromechanical reset setting is not available with recloser curves. It is only available with traditional electromechanical time-overcurrent relay curves (U1–U5 and C1–C5). See Table 4.3, and Table 4.5 through Table 4.7 for further information.

Table 9.7 Recloser Curve Designations

Recloser Curve Cross Reference—Old to New					
Old	**New**	**Reference**	**Old**	**New**	**Reference**
A	101	*Figure 9.11*	Z	134	*Figure 9.17*
B	117	*Figure 9.12*	1	102	*Figure 9.14*
C	133	*Figure 9.11*	2	135	*Figure 9.12*
D	116	*Figure 9.13*	3	140	*Figure 9.12*
E	132	*Figure 9.16*	4	106	*Figure 9.19*
F	163	*Figure 9.14*	5	114	*Figure 9.17*
G	121	*Figure 9.15*	6	136	*Figure 9.15*
H	122	*Figure 9.14*	7	152	*Figure 9.20*
J	164	*Figure 9.14*	8	113	*Figure 9.20*
KP	162	*Figure 9.18*	8PLUS	111	*Figure 9.13*
L	107	*Figure 9.20*	9	131	*Figure 9.19*
M	118	*Figure 9.18*	KG	165	*Figure 9.17*
N	104	*Figure 9.11*	11	141	*Figure 9.19*
P	115	*Figure 9.16*	13	142	*Figure 9.15*
R	105	*Figure 9.12*	14	119	*Figure 9.19*
T	161	*Figure 9.18*	15	112	*Figure 9.20*
V	137	*Figure 9.15*	16	139	*Figure 9.13*
W	138	*Figure 9.11*	17	103	*Figure 9.18*
Y	120	*Figure 9.17*	18	151	*Figure 9.16*

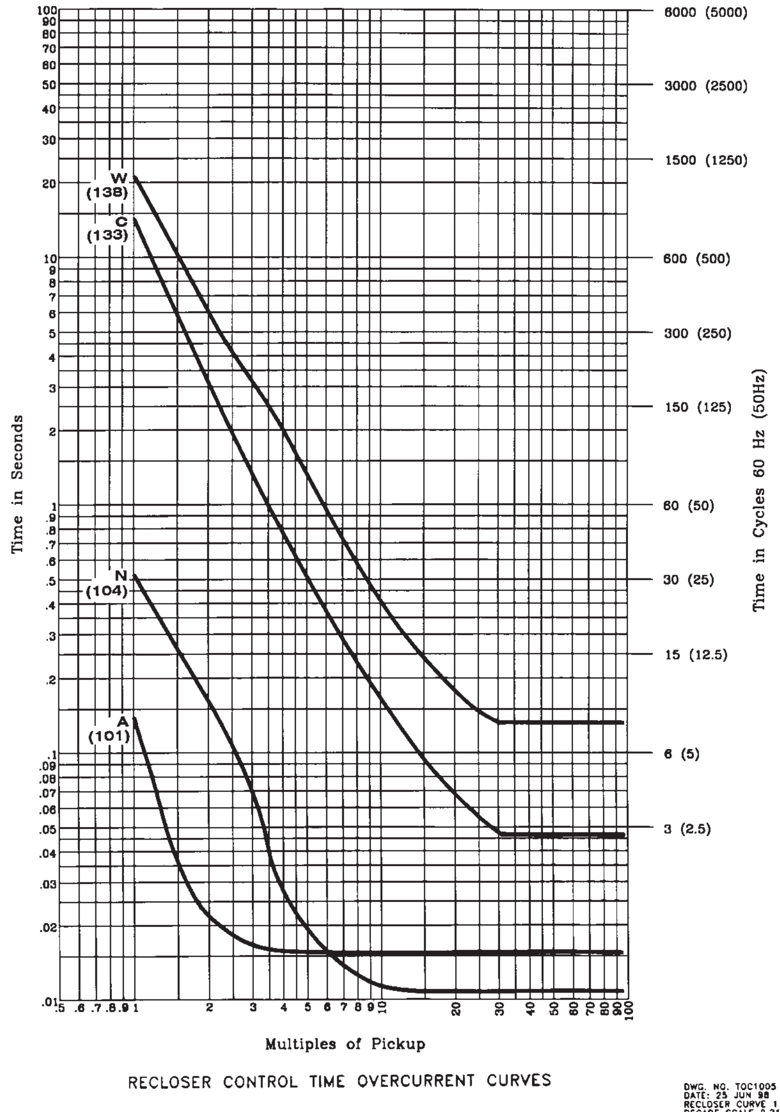


Figure 9.11 Recloser Control Response Curves A, C, N, and W

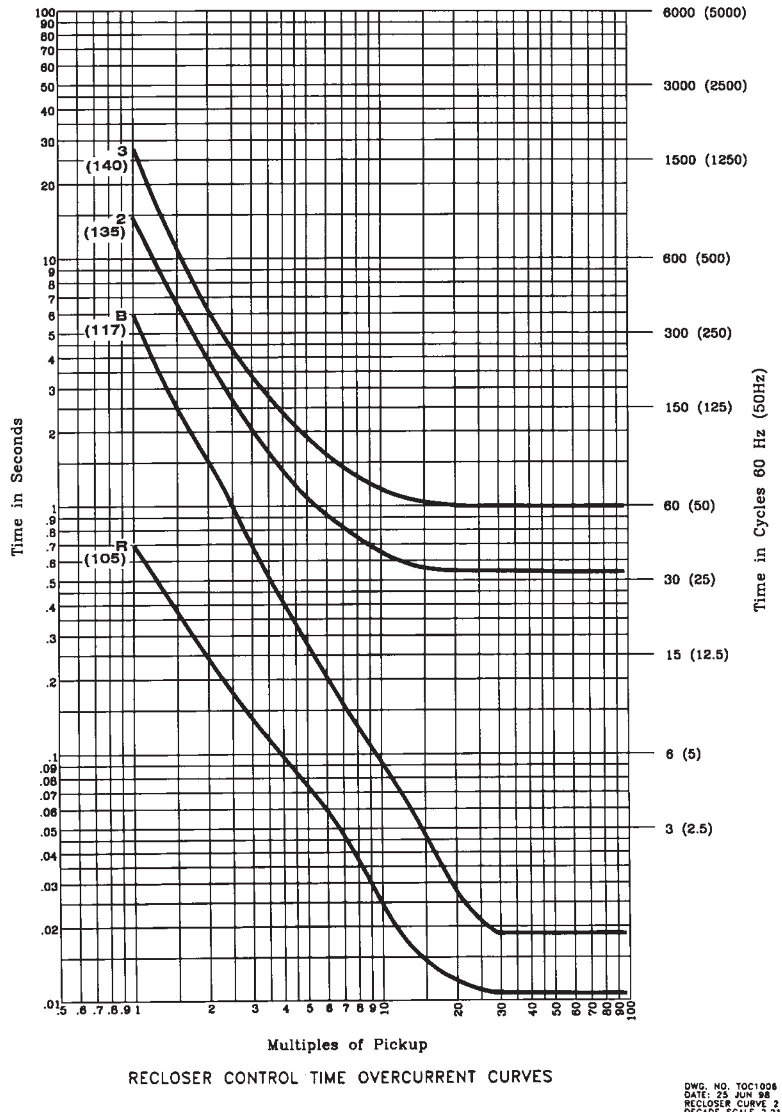


Figure 9.12 Recloser Control Response Curves B, R, 2, and 3

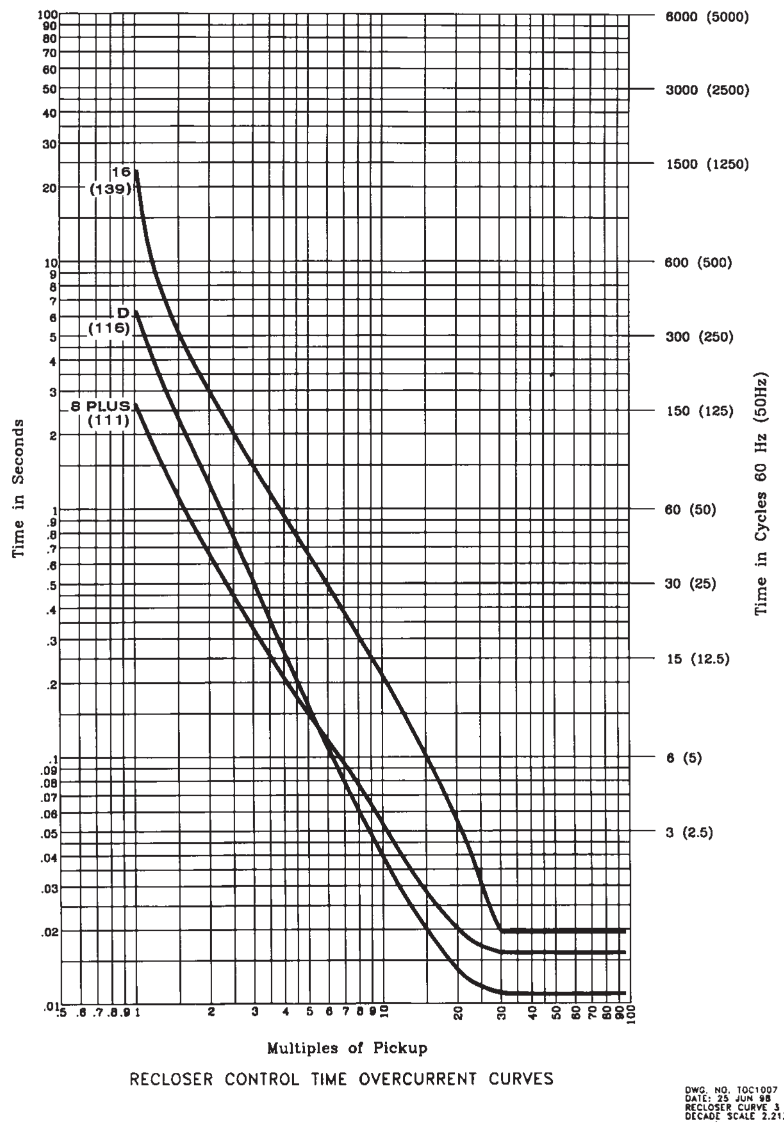


Figure 9.13 Recloser Control Response Curves D, 8PLUS, and 16

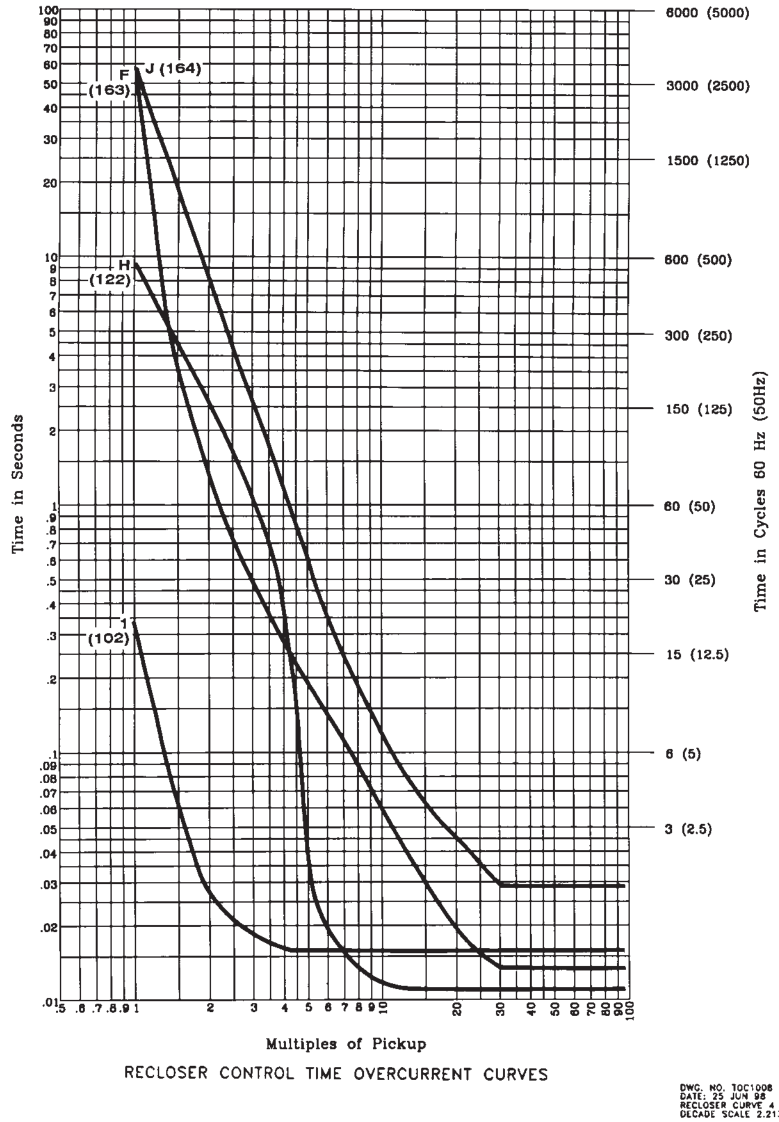


Figure 9.14 Recloser Control Response Curves F, H, J, and 1

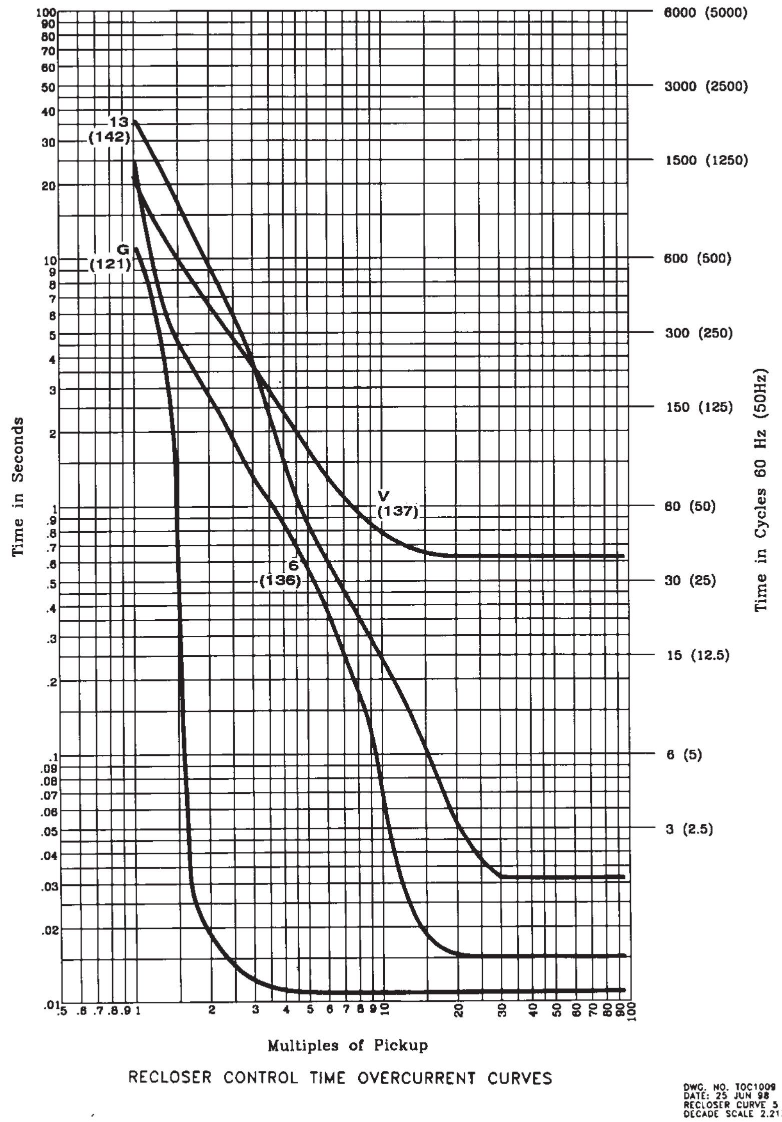


Figure 9.15 Recloser Control Response Curves G, V, 6, and 13

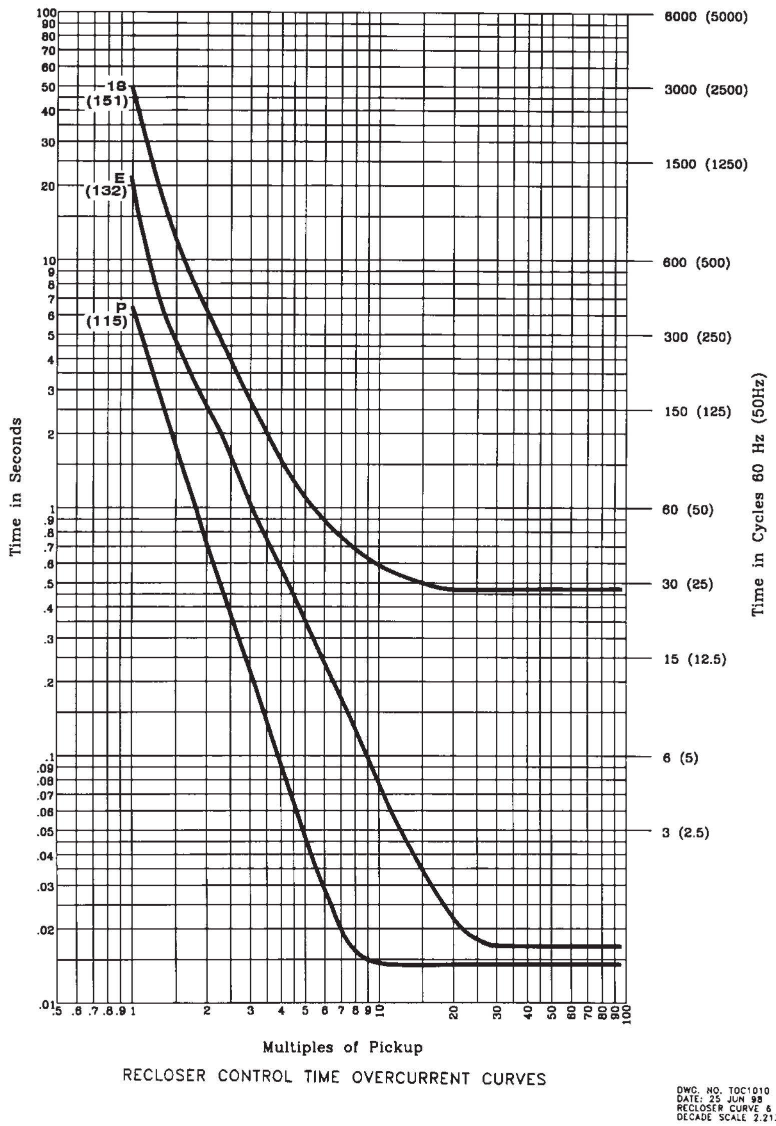


Figure 9.16 Recloser Control Response Curves E, P, and 18

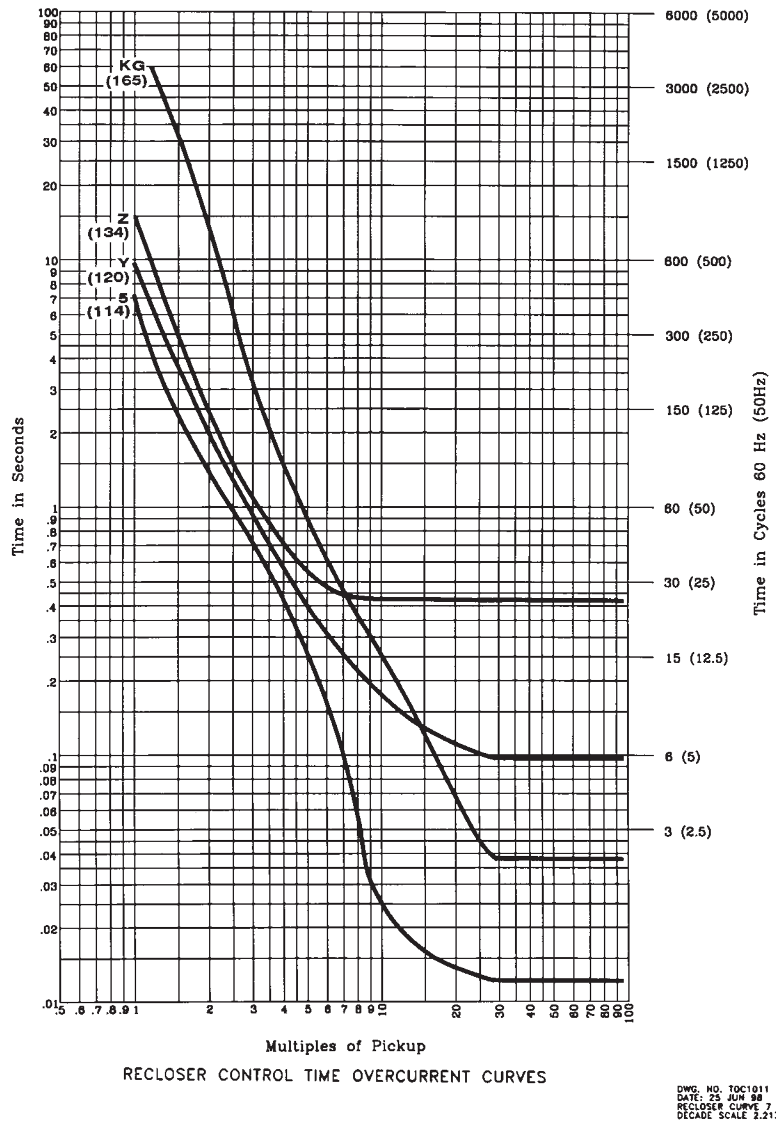


Figure 9.17 Recloser Control Response Curves KG, Y, Z, and 5

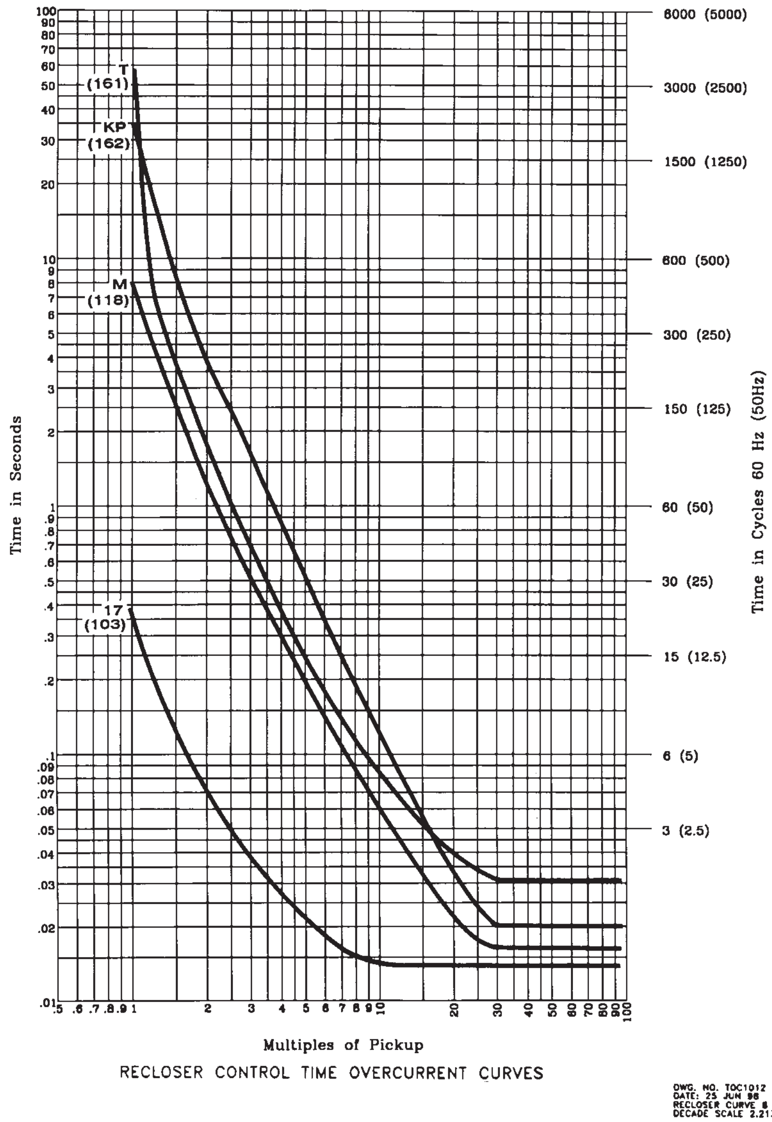


Figure 9.18 Recloser Control Response Curves KP, M, T, and 17

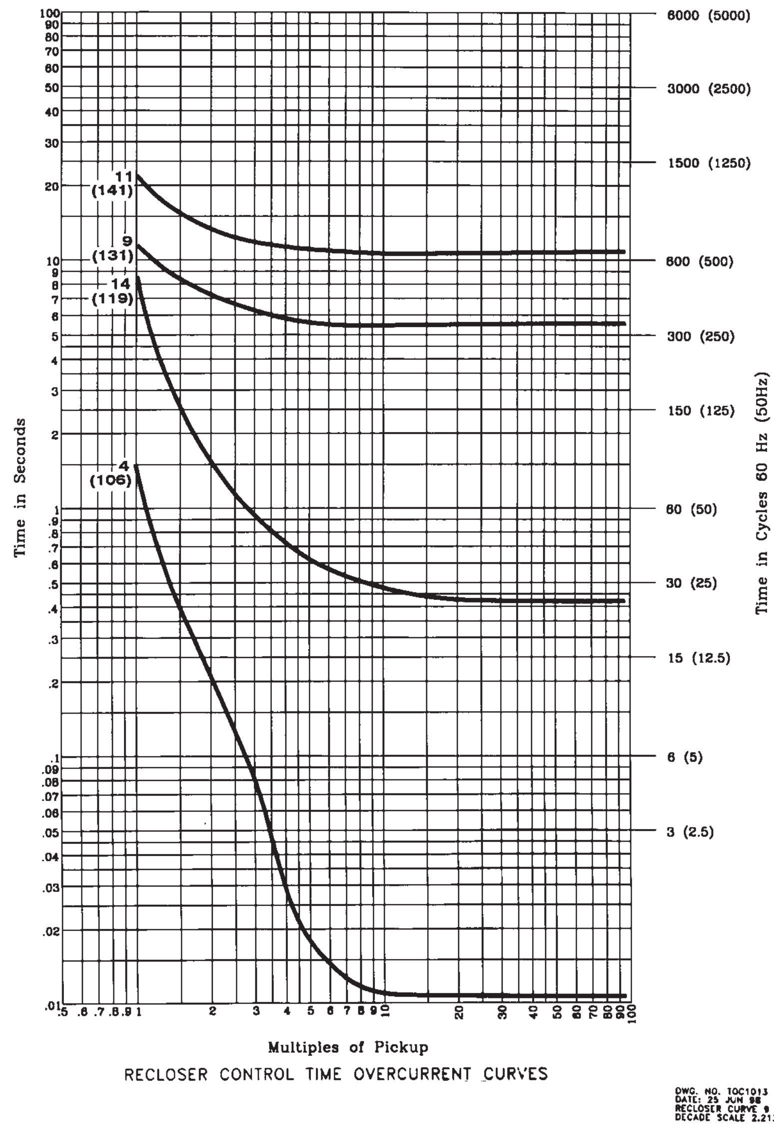


Figure 9.19 Recloser Control Response Curves 4, 9, 11, and 14

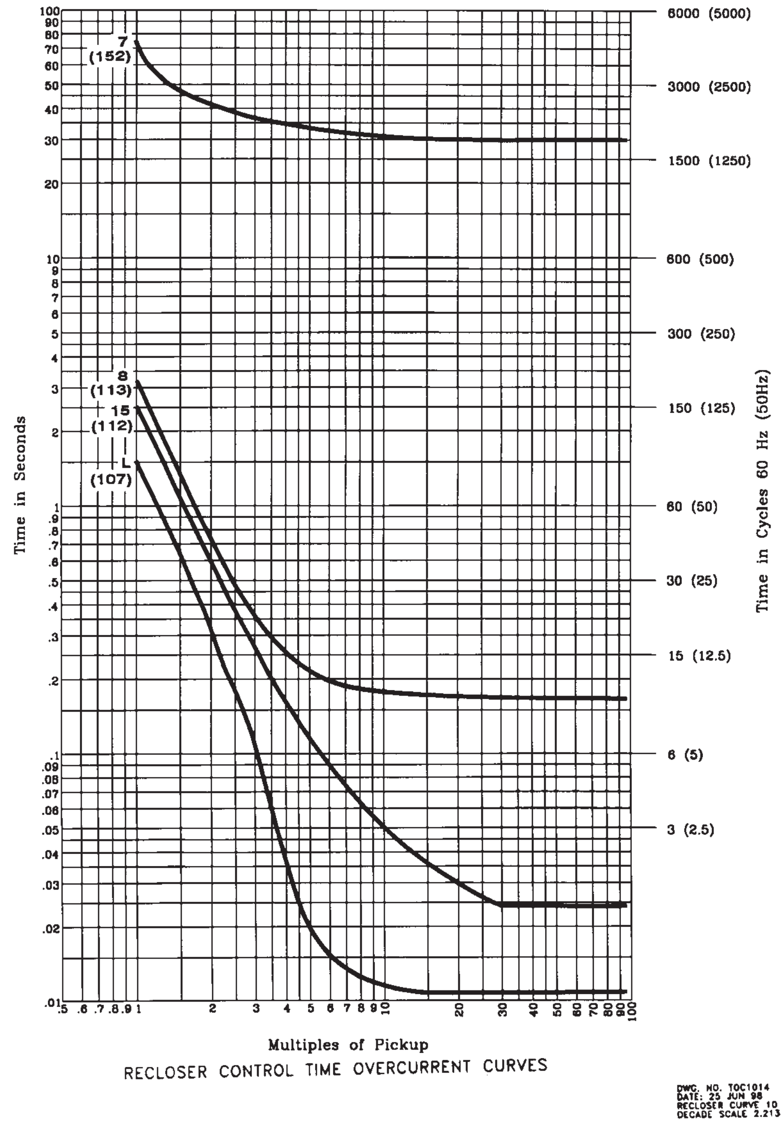


Figure 9.20 Recloser Control Response Curves L, 7, 8, and 15

SELOGIC Control Equation Settings

SELOGIC® control equations appear in the global, group, logic, and front-panel settings classes of the SEL-651R. This is different than the SEL-351R Recloser Control, which contains all of the SELOGIC control equation settings in one settings class.

The SEL-651R offers enhanced SELOGIC control equation setting capabilities such as nested parentheses, analog comparisons, and the NA setting. The SELOGIC control equation setting syntax is fully described in *Section 7: SELOGIC Control Equation Programming*.

Relay Word Bits

Relay Word bits can be used in SELOGIC control equation settings. Numerous SELOGIC control equation settings examples are given in *Section 4: Protection Functions* through *Section 7: SELOGIC Control Equation Programming*. With a few exceptions, SELOGIC control equation settings can also be set directly to 1 (logical 1), 0 (logical 0), or NA (not applicable).

See *Table F.1* and *Table F.2* for a listing and description of the SEL-651R Relay Word bits.

NA Setting

From a logic standpoint, setting a SELOGIC control equation to NA acts similarly to setting the equation to 0 (logical 0). The difference between 0 and NA is that the 0 setting consumes a small amount of microprocessor time every processing interval, while the NA setting consumes no microprocessor time. Thus, several SELOGIC control equation settings have factory default values of NA, which allows more microprocessor time for other functions.

For example, setting TMB1A := NA (Channel A, Transmit Bit 1) will result in Relay Word bit TMB1A being “permanently deasserted.”

See *SELOGIC Control Equation Capacity on page 7.1* for more information.

Analog Comparisons

Analog Quantities on page 7.2 describes the use of Analog Quantities in SELOGIC control equations.

Settings Explanations

Note that most of the settings in the settings sheets that follow include references for additional information. The following explanations are for settings that do not have reference information anywhere else in the instruction manual.

General Global Settings

NOTE: The PHROT setting describes the electrical rotation of the power system phases, as opposed to the IPCONN, VYCONN, and VZCONN settings, which describe the connections to the SEL-651R current and voltage terminals.

Refer to *Global Settings*: *General Settings on page SET.1*.

The Global Settings NFREQ and PHROT allow you to configure the SEL-651R to your specific system.

Set NFREQ equal to your nominal power system frequency, either 50 Hz or 60 Hz.

Set PHROT equal to your power system phase rotation, either ABC or ACB.

Set DATE_F to format the date displayed in recloser control reports and the front-panel display. Set DATE_F to MDY to display dates in Month/Day/Year format; set DATE_F to YMD to display dates in Year/Month/Day format; set DATE_F to DMY to display dates in Day/Month/Year format.

Current and Voltage Connection Settings

See *Global Settings*: *Current and Voltage Connection Settings on page SET.1*.

The SEL-651R rear-panel terminals are shown in *Figure 2.11*. The rear panel terminal markings are designated with numeric labels and terminal labels. For the purpose of explaining the current and voltage connection settings, a simplified list of the SEL-651R current and voltage input terminals is used:

- For currents: I1, I2, I3, IN
- For voltages: V1Y, V2Y, V3Y, V1Z, V2Z, V3Z

This simplified list does not include the polarity marks on the current inputs. For example, the current channel I1 is comprised of the physical terminals numbered Z01 (I1 polarity, indicated with a dot above the terminal) and Z02 (I1 non-polarity), but will be referred to as only the I1 channel.

See *Figure 2.46* and *Figure 2.48* for current connections, and *Figure 2.36* through *Figure 2.40* for voltage connections.

Current Connection Setting (IPCONN)

NOTE: The IPCONN setting serves a different function than the PHROT setting. See the note in General Global Settings on page 9.27.

NOTE: Other SEL-651R settings handle the phase rolling of voltages, trip signals, close signals, and breaker status readings (see the following subsections).

The current signals are normally brought into the SEL-651R cabinet via a prewired control cable. The factory connection includes a residual connection to the channel IN terminals, and the I1, I2, and I3 phase current terminals, as shown in *Figure 2.46* and *Figure 2.48*.

The electrical phase orientation of the power system overhead line is usually not easy to change, so the resulting CT secondary signals coming from the recloser are not the same in every installation. To eliminate the need to make wiring changes at the back-panel, a global setting, IPCONN, can be used to designate which phases are connected to each of the terminals I1, I2, and I3. *Table 9.8* shows the required setting for IPCONN for the various CT signal connections.

Table 9.8 Current Connection Setting IPCONN

Phase CT Signal Connections			Required Global Setting
I1 Terminals	I2 Terminals	I3 Terminals	IPCONN
I_A	I_B	I_C	ABC
I_A	I_C	I_B	ACB
I_B	I_A	I_C	BAC
I_B	I_C	I_A	BCA
I_C	I_A	I_B	CAB
I_C	I_B	I_A	CBA

Note that setting IPCONN is deemed a “reference setting” in following *Table 9.14*, *Table 9.20*, *Table 9.21*, and *Table 9.22*. The following subsection *Pole Status (52a), Trip, and Close Mapping Variations for Single-Phase Reclosers (BKTYP := 1) on page 9.48* explains this in greater detail.

Enable Ground Switch Setting (EGNDSW)

The SEL-651R can operate with or without the **IN** channel connected to a current source. The factory wiring configuration employs a wired-residual connection to the **IN** terminals, allowing the measurement of zero-sequence current via the more sensitive **IN** channel. The effect of the EGNDSW setting is shown in *Table 9.15*, *Table 4.17*, and *Ground Switch Option on page 8.3*.

When setting EGNDSW is changed via the serial port **SET G** command, several functions in the group settings class are disabled or changed.

The following warning is displayed when EGNDSW is changed from Y to N:

```
WARNING! The global setting EGNDSW was changed to “N”,
which will cause the E50G, E51G1, E51G2, 51G1JP,
51G1KP, E32, and GDEMP settings to be set to factory
default values in all six settings groups.
```

The following warning is displayed when EGNDSW is changed from N to Y:

```
WARNING! The global setting EGNDSW was changed to “Y”,
which will cause the CTRN setting to be set to the same
value as CTR in all six settings groups.
```

Both warnings are followed by a confirmation prompt, which allows the technician to approve or cancel the changes.

CT Polarity Setting (CTPOL)

The SEL-651R uses directional information contained in current and voltage signals in these functions:

- Power measurement (see *Table 8.1*)
- Power elements
- Load encroachment
- Fault locator
- Directional control

The direction of the calculated power or impedance depends on the relative phase of the current measurements as compared to the voltage signals, which is normally a function of switchgear orientation. The CTPOL := (POS or NEG) setting provides an easy way to change the polarity of the measured current signals, and thus the resulting power direction and impedances.

Figure 2.45, *Figure 2.47*, *Figure 2.50*, *Figure 2.53*, *Figure 2.55*, and *Figure 2.58* show the SEL-651R factory CT circuit wiring for supported reclosers. The directional arrows shown in the primary bus inside the switchgear identifies the forward or OUT direction, when Global Setting CTPOL := POS.

The CTPOL setting functions by negating (or multiplying by –1) the current signals being read on the **I1**, **I2**, and **I3** current inputs (and the channel **IN** current if setting EGNDSW := Y) if setting CTPOL := NEG. The event report will show the polarity after the CTPOL adjustment is made, so any analysis tools, such as the SEL-5601 Analytic Assistant software, will extract the same phase information that the SEL-651R is using.

Breaker/Recloser Type Setting (BKTYP) and Enable Single-Phase Breaker Setting (ESPB)

Global setting BKTYP indicates the type of recloser the SEL-651R interfaces with:

- BKTYP := 3 (three-phase)—interface with recloser that is capable of only tripping and closing all three phases in unison
- BKTYP := 1 (single-phase)—interface with recloser that is capable of tripping and closing all three phases in unison or each phase individually

Figure 6.2, *Figure 7.25*, and *Figure 7.26* use the BKTYP setting to set up the processing structure of breaker/pole status inputs and trip/close outputs. If BKTYP := 1, then group setting ESPB (see *Table 9.19*) can be set:

- ESPB := Y—enable single-phase tripping and closing
- ESPB := N—enable three-phase tripping and closing

Even with setting ESPB := Y, three-phase tripping can still occur (note three-phase trip settings TR3P and TR3X in *Figure 5.1* are always enabled).

If BKTYP := 3, then ESPB := N always.

Figure 5.1 and *Figure 6.1* use the ESPB setting to set up the internal trip/close logic. *Figure 6.2* uses the ESPB setting to further refine breaker/pole status for single-phase or three-phase closing/reclosing.

Voltage Connection Settings (VYCONN and VZCONN)

The SEL-651R has six analog voltage inputs, broken into two sets of three-phase connections, called the VY- and VZ-terminals. *Figure 2.36* through *Figure 2.40* cover the actual wiring for these inputs. This section deals with the settings that determine how the SEL-651R processes the signals measured on these terminals.

The SEL-651R can be used with all six voltage inputs connected, or with reduced functionality, less than six voltages.

Like the current inputs, the voltage input terminals are labeled numerically (1, 2, 3) instead of by phase letter (A, B, C). This allows settings to be used that assign the measured signal to the correct phase quantity inside the SEL-651R. This reassignment is sometimes called phase rolling. It is much easier to change a setting than to change wiring, so the settings VYCONN and VZCONN have been provided in the SEL-651R.

Voltage Terminal Designations (simplified):

- VY-terminals: V1Y, V2Y, V3Y
- VZ-terminals: V1Z, V2Z, V3Z

Unlike the CT connections shown in *Table 9.8*, it is possible to operate the recloser control with less than three voltages on a set of terminals. *Table 9.9* shows the six combinations of three-phase voltage connections on the VY-terminals, plus six more single phase voltage connection variations.

The VZ-terminal voltages have a similar choice of settings as *Table 9.9*, except a “VZ” is used instead of a “VY.” Thus, the VZCONN setting is independent of the VYCONN setting.

NOTE: In Table 9.9, the phase-to-phase connections shown (AB, BC, CA) are single-phase measurements, which mean that only the V1Y terminal is "seeing" the voltage. The SEL-651R does not support open-delta connected potential transformers.

Table 9.9 Voltage Connection Setting VYCONN and Affected Settings

VY-Terminal Signal Connections			Required Global Setting	"VY" Available as Setting Choice for:		
V1Y	V2Y	V3Y	VYCONN :=	EPHANT	VSELECT	FSELECT
V_A	V_B	V_C	ABC	no	yes	yes
V_A	V_C	V_B	ACB	no	yes	yes
V_B	V_A	V_C	BAC	no	yes	yes
V_B	V_C	V_A	BCA	no	yes	yes
V_C	V_A	V_B	CAB	no	yes	yes
V_C	V_B	V_A	CBA	no	yes	yes
V_A	-	-	A	yes	no	yes
V_B	-	-	B	yes	no	yes
V_C	-	-	C	yes	no	yes
V_{AB}	-	-	AB	yes	no	yes
V_{BC}	-	-	BC	yes	no	yes
V_{CA}	-	-	CA	yes	no	yes
-	-	-	OFF	no	no	no

Single-Phase and Phase-to-Phase Voltage Connections

The bottom half of *Table 9.9* lists single-phase and phase-to-phase connection options for voltage input V1Y. These voltage input V1Y connections are actually between terminals V1Y-NY (see *Figure 2.11*). Even though terminal NY is the "neutral" connection, there is no internal ground connection on terminal NY, so phase-to-phase voltage connections can be made between voltage terminals V1Y-NY.

Figure 9.21 shows the voltage terminal assignments for these single-phase and phase-to-phase voltage connections. Even voltage terminals V2Y and V3Y are assigned, with the aid of the system rotation setting PHROT.

The internal voltages in *Figure 9.21* are used in the voltage elements (see *Voltage Elements on page 4.26*, *Figure 4.23*, and *Figure 4.24*) and in the event report columns (see *Figure 12.4*). Even though single-phase and phase-to-phase connections to V1Y-NY are shown in *Figure 9.21* (and "no connections" are shown at bottom of *Figure 9.21*), all the voltage terminals and subsequent internal voltages are active for the aforementioned voltage elements and event report columns.

Again, the VZ-terminal voltages have the same choices as the VY-terminal voltages portrayed in *Figure 9.21*—just substitute "VZ" for "VY". *Transition Between A-B-C Worlds on page 9.49* goes into greater detail and example on terminal assignments.

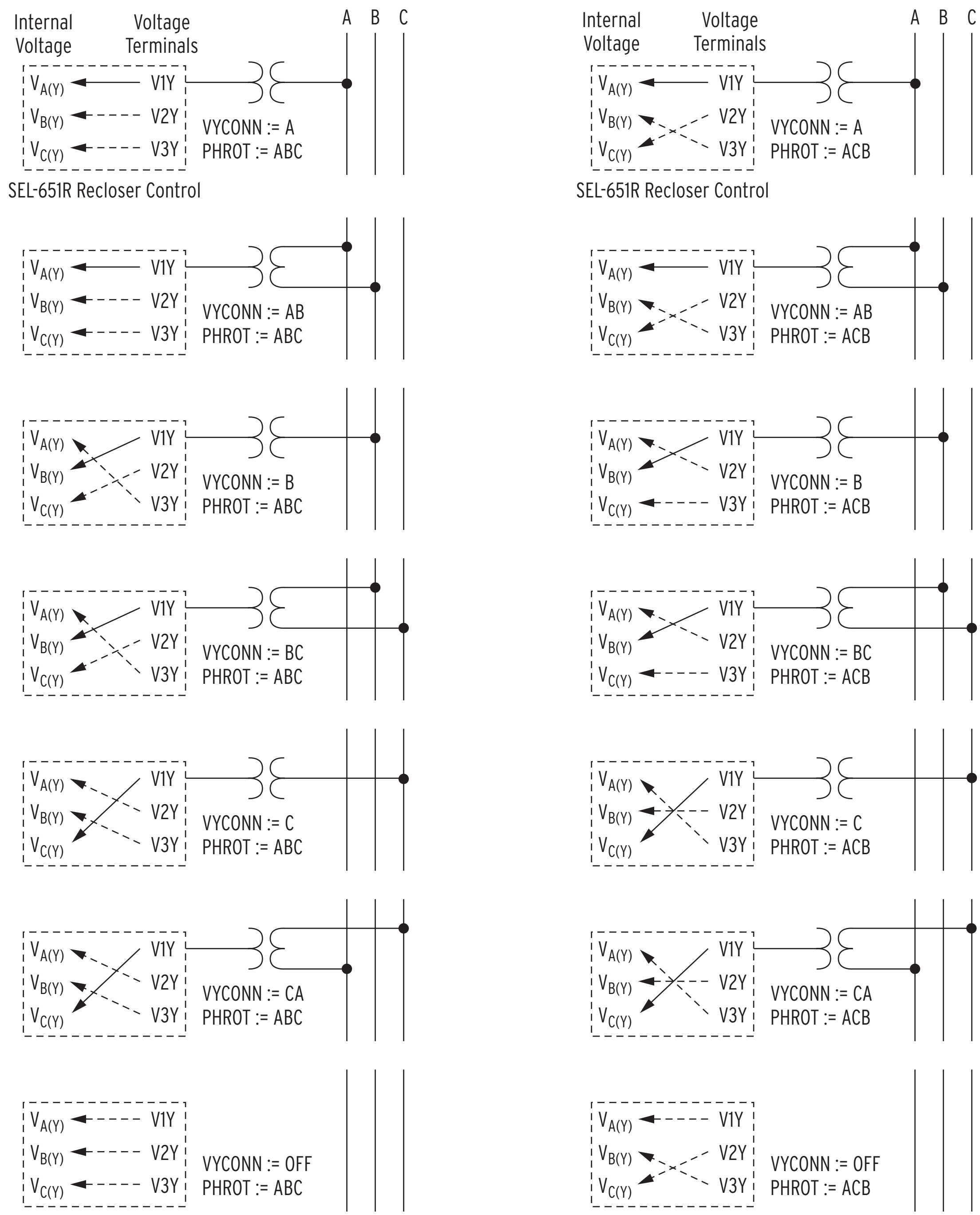


Figure 9.21 Terminal Assignments for Single-Phase and Phase-to-Phase Voltage Connections

Troubleshooting Voltage and Current Connections

The ability to make setting changes instead of wiring changes is very convenient. However, some tools are required to help troubleshoot problems that may arise if mistakes are made in either the wiring or the setting of the SEL-651R current and voltage inputs.

The serial port **MET** command is a convenient troubleshooting tool to use because it is possible to quickly see how the SEL-651R is interpreting the signals. *Section 10: Communications* contains a sample **MET** command capture. *Metering Check on page 2.44* gives a quick troubleshooting routine.

Event Reports are also powerful diagnostic tools (see *Section 12: Analyzing Events*). SEL-5601 Analytic Assistant software allows graphical representation of compressed event report data, including oscillography and phasor display.

The ACSELERATOR QuickSet SEL-5030 software contains a phasor display function that operates directly from a serial port connection to the SEL-651R. It is found under the HMI menu.

Enable Phantom Voltage Setting (EPHANT)

The SEL-651R can be configured to create phantom three-phase voltage signals from an applied single-phase voltage, on either the VY-terminals or the VZ-terminals, (but not both). *Table 9.9* shows the setting choices for VYCONN and VZCONN that allow the EPHANT setting to be made. See *Phantom Voltage Option Not in Service on page 8.6*.

The phantom voltage signals created are used only in fundamental metering functions (voltages, power, power factor, energy). The protection functions, including the under- and overvoltage elements, power elements, and event reports, are unaffected by the EPHANT setting.

Voltage Source Selection Setting (VSELECT)

The VSELECT setting is used to select which voltage terminals are used for the protection functions that require three-phase voltage:

- Power elements
- Load encroachment
- Fault locator
- Voltage Sag/Swell/Interruption elements
- Loss-of-potential
- Directional control

VSELECT also defines the voltage signals used in the power and energy metering functions, unless phantom voltages are selected (setting EPHANT ≠ OFF).

If VSELECT is changed to OFF, the following message is displayed.

```
WARNING! The global setting VSELECT was changed to
“OFF”. Settings ELOAD, E32, EFLOC, ELOP, EPWR, and ESSI
will be set to “N” in all six settings groups.
```

The voltage elements are not affected by the VSELECT setting (see *Voltage Elements on page 4.26*).

The Relay Word bits VSELY and VSELZ are controlled by the VSELECT setting (see *Figure 9.22*).

Frequency Source Selection Setting (FSELECT)

The FSELECT setting is used to select which voltage terminals are used for the frequency tracking and frequency measurement functions:

- Frequency elements, including undervoltage block (see *Frequency Elements on page 4.43*)
- Synchronism-check elements (defines **VP** terminal; see *Synchronism-Check Elements on page 4.33*)

If FSELECT is changed to OFF, the following message is displayed.

```
WARNING! The global setting FSELECT was changed to
"OFF". Settings E81 and E25 will be set to "N" in all
six settings groups.
```

Frequency measurement uses a zero-crossing detector on input terminals **V1Y** and **V1Z**.

Frequency tracking will default to the **V1Y** terminal when FSELECT := OFF.

Other Global Settings

Refer to *Global Enable Settings on page SET.2*.

Enable Independent Control Input Settings (EICIS)

For most applications, leave setting EICIS := N. This selection causes the debounce timers for the recloser status inputs (IN201–IN206, *Figure 7.17*) and optional optoisolated inputs (IN101–IN107, *Figure 7.18*) to be hidden from view, and set to factory default values. If different debounce time settings are required, then set EICIS := Y and make the appropriate debounce timer settings.

Voltage Ratio Correction Factors for VY- and VZ-Terminal Voltage Inputs

Make the V1YRCF, V2YRCF, and V3YRCF ratio correction factor global settings for the VY-terminal voltage inputs (V1Y, V2Y, and V3Y, respectively) when the SEL-651R is ordered with 8 V Low-Energy Analog (LEA) or Kyle/Cooper NOVA LEA voltage inputs (see *Figure 2.38* and *Figure 2.39* respectively). Make the V1ZRCF, V2ZRCF, and V3ZRCF ratio correction factor global settings for VZ-terminal voltage inputs (V1Z, V2Z, and V3Z respectively), when the SEL-651R is ordered with Lindsey SVMI LEA inputs (see *Figure 2.40*), 8 V Low-Energy Analog (LEA) voltage inputs (see *Figure 2.38* side bar note), or Siemens LEA inputs (see *Figure 2.63* and *Figure 2.64*). Ratio correction factor (RCF) settings compensate for irregularities (on a per-phase basis) of voltage dividers connected between the primary voltage system and the LEA inputs. The derivation of the RCF value for a voltage divider for a particular phase is defined as follows:

NOTE: Ratio Correction Factors serve a different purpose than Potential Transformer Ratio settings—see also following subsection Potential Transformer (PT) Ratios on page 9.40.

$$\begin{aligned}\mathrm{RCF} &= \frac{\text{true ratio}}{\text{marked ratio}}\\ &= \frac{(\mathrm{Vpri.}/\mathrm{Vsec.})}{\mathrm{PTR_{LEA}}}\\ &= \frac{\mathrm{Vpri.}}{\mathrm{Vsec.}\bullet\mathrm{PTR_{LEA}}}\end{aligned}$$

Equation 9.1

where:

Vpri. = test voltage applied to the primary side of the voltage divider

Vsec. = resultant voltage measured on the secondary side of the voltage divider

true ratio = Vpri./Vsec.

marked ratio = PTR_{LEA}

= effective nominal potential transformer (PT) ratio of the voltage divider connected between the primary voltage system and the LEA input (e.g., PTR_{LEA} = 10000 for G&W Viper-ST).

The marked ratio of the voltage divider (PTR_{LEA}) is always provided by the manufacturer and often the per-phase RCF values are also provided.

If the voltage divider is perfect, then:

$$\frac{\text{Vpri.}}{\text{Vsec.}} = \text{PTR}_{\text{LEA}} \text{ and RCF} = 1.000$$

Equation 9.2

Thus, the measured voltage divider performance equals the marked ratio of the voltage divider, as given by the manufacturer. But such perfect conditions are usually not the case.

If the voltage divider is putting out more voltage (Vsec.) than nominally expected for an applied voltage input (Vpri.), then:

$$\frac{\text{Vpri.}}{\text{Vsec.}} < \text{PTR}_{\text{LEA}} \text{ and RCF} < 1.000$$

Equation 9.3

An example of an RCF value less than 1.000 is found in *Example 9.1*. In this example, setting V2YRCF := 0.883 brings down the too high voltage on voltage input V2Y (0.82 V is brought down to nominal 0.72 V).

If the voltage divider is putting out less voltage (Vsec.) than nominally expected for an applied voltage input (Vpri.), then:

$$\frac{\text{Vpri.}}{\text{Vsec.}} > \text{PTR}_{\text{LEA}} \text{ and RCF} > 1.000$$

Equation 9.4

An example of an RCF value greater than 1.000 is also found in following *Example 9.1*. In this example, setting V3YRCF := 1.112 brings up the too low voltage on voltage input V3Y (0.65 V is brought up to nominal 0.72 V).

In the SEL-651R with LEA voltage inputs, RCF values for VY terminals (settings V1YRCF, V2YRCF, and V2YRCF) are applied to respective voltage inputs V1Y, V2Y, and V3Y, and the RCF values for VZ terminals (settings V1ZRCF, V2ZRCF, and V2ZRCF) are applied to respective voltage inputs V1Z, V2Z, and V3Z. The resultant secondary voltages from these voltage inputs are normalized by the RCF values. These normalized secondary voltages are used throughout the SEL-651R.

NOTE: At the end of the following subsection Voltage-Related Settings and LEA Inputs on page 9.43 is a discussion concerning RCF values that are less than unity (1.000) and their possible effect on voltage-related settings.

NOTE: 8 VAC LEA OPTION FOR BOTH VY-TERMINAL AND VZ-TERMINAL VOLTAGE INPUTS

The SEL-651R-1 has an option for both the VY-terminal and VZ-terminal voltage inputs to be ordered as 8 Vac LEA inputs. Thus, any discussions and/or examples concerning 8 Vac LEA inputs for the VY-terminal voltage inputs also apply, in like manner, to 8 Vac LEA inputs for the VZ-terminal voltage inputs (with corresponding VZ-terminal voltage input related settings).

EXAMPLE 9.1 Normalizing Voltages With Ratio Correction Factors

A voltage divider is connected to the LEA (8V) voltage inputs. The RCF values per phase for the voltage divider are given as:

V1YRCF:= 1.078 (voltage input V1Y; like Equation 9.4)
V2YRCF:= 0.883 (voltage input V2Y; like Equation 9.3)
V3YRCF:= 1.112 (voltage input V3Y; like Equation 9.4)

The marked ratio of the voltage divider is given as:

$$\text{PTR}_{\text{LEA}} = 10000$$

What are the true ratios of each phase of the voltage divider?

$$\text{true ratio (for a given phase)} = \frac{\text{Vpri.}}{\text{Vsec.}}$$

Vpri. and Vsec. are measured in manufacturer tests, to derive RCF values as shown in Equation 9.1 and accompanying explanation. From Equation 9.1:

$$\mathrm{RCF} \cdot \mathrm{PTR}_{\mathrm{LEA}} = \frac{\mathrm{Vpri.}}{\mathrm{Vsec.}} = \text{true ratio}$$

1.078 • 10000 = 10780 (true ratio for voltage input V1Y)
0.883 • 10000 = 8830 (true ratio for voltage input V2Y)
1.112 • 10000 = 11120 (true ratio for voltage input V3Y)

Note these true ratios vary from 8830 to 11120, while the marked ratio of the voltage divider is given as 10000.

Consider what is happening in this example. First, assume the primary voltage (Vpri.) is the same magnitude for each phase. When this primary voltage is run through the respective true ratios, the secondary voltage outputs vary widely. Presuming primary voltage of 12.47 kV (7.2 kV line-to-neutral), the resultant secondary voltages are:

7200 V/10780 = 0.67 V
(true secondary voltage to voltage input V1Y)
7200 V/8830 = 0.82 V
(true secondary voltage to voltage input V2Y)
7200 V/11120 = 0.65 V
(true secondary voltage to voltage input V3Y)

Note that the true secondary voltages to voltage inputs V1Y and V3Y are running low (below normalized secondary voltage 0.72 V = 7200 V/10000), while the voltage to voltage input V2Y is running high (above normalized secondary voltage 0.72 V). But, the RCF values adjust these true secondary voltages to normalized secondary voltage:

0.67 V · 1.078 = 0.72 V
(normalized voltage from voltage input V1Y)
0.82 V · 0.883 = 0.72 V
(normalized voltage from voltage input V2Y)
0.65 V · 1.112 = 0.72 V
(normalized voltage from voltage input V3Y)

Again, the normalized secondary voltage (0.72 V) is the same for all three phases in this example, because the primary voltage is assumed the same magnitude for each phase (7200 V). These normalized secondary voltages are used throughout the SEL-651R. The true secondary voltages cannot be seen (via the SEL-651R), unless the RCF values are set to unity (RCF = 1.000).

Voltage Phase Angle Correction Settings for VY-Terminal Voltage Inputs

Make the V1YPAC, V2YPAC, and V3YPAC voltage phase angle correction Global settings for the VY-terminal inputs (V1Y, V2Y, and V3Y, respectively) when the SEL-651R is ordered with Kyle/Cooper NOVA LEA inputs. These settings compensate for the lagging phase shift caused by the Internal Voltage Sensors of NOVA reclosers and the shielded cable from the recloser to the SEL-651R.

Refer to *Table 9.10* through *Table 9.12* to make voltage phase angle correction settings.

For example, if the SEL-651R is used to control a NOVA TS-27 with a 30 ft, 26-pin control cable and a 20 ft., 14-pin junction box cable, then calculate the phase angle correction setting from *Table 9.11* as follows.

$$\text{V1YPAC} = \text{V2YPAC} = \text{V3YPAC} = -3.3° + -0.8°\left(\frac{(30-10)\text{ ft}}{10\text{ ft}}\right) + -1.4°\left(\frac{(20-10)\text{ ft}}{10\text{ ft}}\right) = -6.3°$$

Table 9.10 Voltage Phase Angle Correction Settings for Cooper NOVA Three-Phase Reclosers

Model	Global Settings V1YPAC–V3YPAC for Various Control Cable Lengths				
	3.05 m (10 ft)	6.10 m (20 ft)	9.15 m (30 ft)	12.2 m (40 ft)	15.25 m (50 ft)
NOVA15	–1.9°	–3.0°	–4.1°	–5.2°	–6.3°
NOVA27 (and NOVA15 with extended BIL)	–3.4°	–4.5°	–5.6°	–6.7°	–7.8°
NOVA38 (and NOVA27 with extended BIL)	–5.7°	–6.8°	–7.9°	–9.0°	–10.0°

Table 9.11 Voltage Phase Angle Correction Settings for Cooper NOVA-TS Triple-Single Reclosers

Model	Global Settings V1YPAC–V3YPAC for 3.05 m (10 ft.) 26-pin Control Cable and 3.05 m (10 ft.) 14-pin Junction Box Cable
NOVA-TS-15	–2.1°[a]
NOVA-TS-27	–3.3°[b]
NOVA-TS-38	–5.5°[c]

[a] For each additional 3.05 m (10 ft.) of control cable, add a correction of –0.7°.
For each additional 3.05 m (10 ft.) of junction box cable, add a correction of –1.4°.
[b] For each additional 3.05 m (10 ft.) of control cable, add a correction of –0.8°.
For each additional 3.05 m (10 ft.) of junction box cable, add a correction of –1.4°.
[c] For each additional 3.05 m (10 ft.) of control cable, add a correction of –0.5°.
For each additional 3.05 m (10 ft.) of junction box cable, add a correction of –0.8°.

Table 9.12 Voltage Phase Angle Correction Settings for Cooper NOVA-STS Single-Tank, Triple-Single Reclosers

Model	Global Settings V1YPAC–V3YPAC for 3.05 m (10 ft.) 26-pin Control Cable
NOVA-STS-15	–0.8°[a]
NOVA-STS-27	–2.0°[b]
NOVA-STS-38	–4.2°[c]

[a] For each additional 3.05 m (10 ft.) of control cable, add a correction of –0.7°.
[b] For each additional 3.05 m (10 ft.) of control cable, add a correction of –0.8°.
[c] For each additional 3.05 m (10 ft.) of control cable, add a correction of –0.5°.

Voltage Phase Angle Correction Settings for VZ-Terminal Voltage Inputs

Make the V1ZPAC, V2ZPAC, and V3ZPAC phase angle correction Global settings for the VZ-terminal inputs (V1Z, V2Z, and V3Z, respectively) when the SEL-651R is ordered with Lindsey SVMI LEA inputs or Siemens LEA inputs.

Phase angle correction settings compensate for the lagging phase shift caused by the Lindsey Standard Voltage Monitoring Insulators (SVMI) and the shielded cable brought down from the Lindsey SVMI to the SEL-651R.

Because the phase shift can vary depending on the type and length of shielded cable used for the application, phase angle correction settings for Lindsey SVMI can be made by using the phase angle values on VY terminals as a reference (if available).

Similarly, the phase angle correction settings compensate for the lagging phase shift caused by the combination of built-in resistive voltage sensors and shielded cable brought down from the Siemens SDR reclosers to the SEL-651R (see *Figure 2.63* and *Figure 2.64*). Refer to *Table 9.13* to make these settings for the Siemens SDR reclosers.

Table 9.13 Voltage Phase Angle Correction Settings for Siemens SDR Reclosers

Model	Global Settings V1ZPAC–V3ZPAC for Various Control Cable Lengths				
	3.05 m (10 ft)	**6.10 m (20 ft)**	**9.15 m (30 ft)**	**12.2 m (40 ft)**	**15.25 m (50 ft)**
Siemens SDR Triple-Single	–1.4°	–2.1°	–2.7°	–3.3°	–4.0°
Siemens SDR Three-Phase	–1.4°	–2.1°	–2.7°	–3.3°	–4.0°

Breaker Monitor Initiate Settings (BKMONp, Where p = 3P, A, B, or C)

See *Breaker Monitor Initiate SELOGIC Equations on page SET.5*.

The function of the Breaker Monitor initiate settings is fully explained in *Section 8: Metering and Monitoring*. The recommended settings depend on Global Setting BKTYP.

When BKTYP := 3, only make setting BKMON3P.

The factory default setting is:

BKMON3P := RCTR1X.

This setting should satisfy all regular recloser applications.

The RCTR1X Relay Word bit is the final trip output for three-phase reclosers (see *Figure 7.25*).

When BKTYP := 1, only make settings BKMONA, BKMONB, and BKMONC.

The factory default settings are:

BKMONA := RCTR1X

BKMONB := RCTR2X

BKMONC := RCTR3X

These settings may need to change, depending on setting IPCONN, as shown in *Table 9.14*. Following subsection *Pole Status (52a), Trip, and Close Mapping Variations for Single-Phase Reclosers (BKTYP := 1) on page 9.48* explains the use of setting IPCONN as a “reference setting” in greater detail.

NOTE: The system phase rotation (and Global Setting PHROT) have no impact on the recommended settings shown in Table 9.14.

Table 9.14 Breaker Monitor Mapping Settings for Single-Phase Recloser (BKTYP := 1)

Reference Setting	Recommended Settings		
IPCONN :=	BKMONA :=	BKMONB :=	BKMONC :=
ABC	RCTR1X	RCTR2X	RCTR3X
ACB	RCTR1X	RCTR3X	RCTR2X
BAC	RCTR2X	RCTR1X	RCTR3X
BCA	RCTR3X	RCTR1X	RCTR2X
CAB	RCTR2X	RCTR3X	RCTR1X
CBA	RCTR3X	RCTR2X	RCTR1X

Identifier Labels

Refer to *Identifier Labels on page SET.5*.

The SEL-651R has two identifier labels: the Relay Identifier (RID) and the Terminal Identifier (TID). The Relay Identifier is typically used to identify the recloser control or the type of protection scheme. Typical Terminal Identifiers include an abbreviation of the substation name and line terminal.

The SEL-651R tags each report (event report, meter report, etc.) with the Relay Identifier and Terminal Identifier. This allows you to distinguish the report as one generated for a specific breaker and substation.

RID and TID settings may include the following characters: 0–9, A–Z, -, /, ., space.

Current Transformer (CT) Ratios

Refer to *Current and Potential Transformer Ratios on page SET.5*.

Phase and neutral current transformer ratios are set independently. If neutral channel IN is connected residually with Terminals I1, I2, I3 (this matches the SEL-651R factory wiring) then set CTR and CTRN the same. Group settings CTR and CTRN are used in SEL-651R event reports and metering functions to scale secondary current quantities into primary values.

When channel IN is connected residually, make Global Setting EGNDSW := Y. For ground protection (e.g., elements 50G1–50G6, and 51G1 and 51G2), the channel IN signal will automatically be used for small signals, and the calculated zero-sequence current (from terminals I1, I2, I3) will be used for large signals. See *Ground Switch Logic on page 4.64*. Metering functions will follow a similar behavior for the IG-derived quantities. See *Ground Switch Option on page 8.3*.

For applications that require a high sensitivity to zero-sequence current, neutral channel IN is connected separately to a core-balance current transformer that encompasses the three phases. This type of current transformer typically has a lower ratio than the phase current transformers, which allows for more sensitivity in ground fault detection.

Make Global Setting EGNDSW := Y for this application. Settings CTR and CTRN will be different in this case, with CTR being greater than CTRN. The setting limit for the ratio is:

$$1 \le \frac{CTR}{CTRN} \le 500$$

Equation 9.5

If channel IN is not connected, or it is connected to an unrelated current source (that is not measuring the zero-sequence current on the same electrical location as the phase CTs connected to terminals I1, I2, and I3), then make Global Setting EGNDSW := N, and set CTRN independently of CTR. Separate channel IN overcurrent elements, 50N1T–50N6T, controlled by enable setting E50N := 1–6, are available when EGNDSW := N.

Table 9.15 summarizes the above information.

Table 9.15 CTR and CTRN Settings in Relation to EGNDSW Setting

IN Channel Connection	EGNDSW Setting	CTRN Setting Requirements	50N Element Availability
Wired residually with terminals I1, I2, I3[a]	Y[a]	CTRN = CTR[a]	No[a]
Wired to a core-balance CT, measuring zero-sequence current on same line as CTs on terminals I1, I2, I3	Y	$1 \le \frac{CTR}{CTRN} \le 500$	No
Wired to a CT, unrelated to phase CTs	N	CTRN set independent of CTR	Yes
Not connected	N	CTRN setting not used	NA

[a] This is the factory configuration.

CT Sizing

The SEL-651R is designed to work with switchgear-mounted CTs. If the SEL-651R is being installed in a substation application where CTs can be individually specified, see the guidelines in the technical paper “The Impact of High Fault Current and CT Rating Limits on Overcurrent Protection,” available at selinc.com under “SEL Literature–Technical Papers.”

Potential Transformer (PT) Ratios

Refer to *Current and Potential Transformer Ratios on page SET.5*.

Group setting PTRY is the potential transformer ratio from the primary system to the SEL-651R VY-terminal voltage inputs. Group setting PTRZ is the potential transformer ratio from the primary system to the SEL-651R VZ-terminal voltage inputs. See voltage input details in *Figure 2.36*.

For example, on a 12.47 kV phase-to-phase primary system with wye-connected 7200:120 V PTs, the correct PTRY or PTRZ setting is 7200/120 = 60.00.

PT Ratio Setting Adjustments

The SEL-651R can be ordered with different secondary input voltage configurations (see *Models and Options on page 1.4*). LEA inputs are suitable for high-impedance sensors, such as capacitive voltage dividers and resistive voltage dividers.

For 8 V LEA inputs and Kyle/Cooper NOVA LEA inputs, an adjustment is needed for the PTRY setting as the SEL-651R does not internally scale the LEA inputs any differently than the 300 V inputs, on a per-unit basis. (See the following sections *PTRY Setting for 8 Vac Max LEA Inputs* and *PTRY Setting for Kyle/Cooper NOVA LEA Inputs*).

Lindsey SVMI LEA inputs do not need PT ratio setting adjustment. Setting PTRZ is the actual voltage divider ratio of the Lindsey SVMI connected to the SEL-651R.

PTRY Setting for 8 Vac Max LEA Inputs

NOTE: 8 VAC LEA OPTION FOR BOTH VY-TERMINAL AND VZ-TERMINAL VOLTAGE INPUTS

The SEL-651R-1 has an option for both the VY-terminal and VZ-terminal voltage inputs to be ordered as 8 Vac LEA inputs. Thus, any discussions and/or examples concerning 8 Vac LEA inputs for the VY-terminal voltage inputs also apply, in like manner, to 8 Vac LEA inputs for the VZ-terminal voltage inputs (with corresponding VZ-terminal voltage input related settings).

The SEL-651R does not internally scale the LEA inputs any differently than the 300 V inputs, on a per-unit basis. Thus, an 8 V LEA input with 4 Vac applied will appear as 4 V / 8 V = 50% of full-scale, or 150 Vac on a 300 V base. Any VY-terminal voltage-related settings (e.g., undervoltage element pickup setting 27YP1P) have the same setting range, regardless of whether the VY-terminal voltage inputs are standard 300 V inputs or LEA 8 V inputs. When the VY-terminal voltage inputs are LEA 8 V inputs, the SEL-651R still thinks it is looking at a 300 V input, even though the LEA inputs actually have only an 8 V range.

One step in making the VY-terminal voltage-related settings work when the VY-terminal voltage inputs are LEA 8 V inputs is to properly make the VY-terminal PT ratio setting (PTRY), as follows:

$$\text{setting PTRY} = (\text{PTR}_{\text{LEA}}) \cdot \left(\frac{8}{300}\right)$$

Equation 9.6

where PTR_{LEA} is the effective nominal PT ratio of the voltage divider connected between the primary system and the LEA inputs (e.g., PTR_{LEA} = 10000). PTR_{LEA} is also referred to as the marked ratio. Again, the SEL-651R thinks it is looking at a 300 V range signal, when the LEA inputs actually have only an 8 V range. Thus, PTR_{LEA} is corrected by a scaling factor of 8/300 (8 V/300 V = 8/300) in *Equation 9.6*.

NOTE: VOLTAGE DIVIDER RATIO FOR TAVRIDA OSM RECLOSER CAPACITIVE VOLTAGE SENSORS

For this 8 Vac LEA input application, the voltage divider ratio (PTR_{LEA}) is 8793.75, and thus setting PTRY = setting PTRZ = 234.50 (= 8793.75 x 8/300). See Figure 2.61.

EXAMPLE 9.2 Setting PTRY for LEA Inputs

A voltage divider (10000 ratio) is connected between a 12.47 kV system (7.2 kV line-to-neutral) and the LEA inputs (similar to Example 9.1).

PTR_{LEA} = 10000 = marked ratio

Using Equation 9.6:

$$\begin{aligned}\text{setting PTRY} &= (\text{PTR}_{\text{LEA}}) \cdot \left(\frac{8}{300}\right) \\ &= 10000 \cdot \left(\frac{8}{300}\right) = 266.67\end{aligned}$$

Equation 9.7

$$\frac{7200\text{ V}}{10000} = 0.72\text{ V}$$ (actual voltage divider output to the LEA inputs; 8 V base)

$$\frac{0.72\text{ V}}{8\text{ V}} = 0.09\text{ per unit output}$$ (9% of full scale)

$$0.09 \cdot 300\text{ V} = 27\text{ V}$$ (the relay thinks it is looking at 27 V on a 300 V base, not 0.72 V on an 8 V base)

$$\frac{7200\text{ V}}{27\text{ V}} = 266.67$$ (same as setting PTRY in Equation 9.7)

Setting PTRY in *Equation 9.6* is used to take these 300 V base secondary voltage values (that the SEL-651R thinks it sees) and ratio them up to primary values for metering and event reports.

PTRY Setting for Kyle/Cooper NOVA LEA Inputs

Use the PTRY settings in *Table 9.16* when the VY-terminal voltage inputs are Kyle/Cooper NOVA LEA inputs. The following example calculations give background and show how to then make voltage element settings when Kyle/Cooper NOVA LEA inputs are used.

Similar to the 8/300 factor applied for 8 Vac LEA inputs (see *Equation 9.6* and *Example 9.2*), a 37.09/300 factor is applied for Kyle/Cooper NOVA LEA inputs. For example, the voltage sensors of a NOVA 27 recloser connected to an SEL-651R have an effective voltage divider ratio of PTR_{LEA} = 1213. Thus, setting PTRY is:

$$\begin{aligned}\text{Setting PTRY} &= (PTR_{LEA})*(37.09/300)\\ &= 1213 * (37.09/300) = 149.96 \text{ (round to 150.00)}\end{aligned}$$

Likewise, the voltage sensors of a NOVA 15 recloser connected to an SEL-651R have an effective voltage divider ratio of PTR_{LEA} = 607. Thus, setting PTRY is:

$$\begin{aligned}\text{Setting PTRY} &= (PTR_{LEA})*(37.09/300)\\ &= 607 * (37.09/300) = 75.04 \text{ (round to 75.00)}\end{aligned}$$

For either of these examples, if 10.28 V is applied to the Kyle/Cooper NOVA LEA inputs on the SEL-651R, the recloser thinks it sees:

10.28 V * (300/37.09) = 83.15 V secondary

To then extrapolate to primary voltage for the NOVA 27 recloser:

83.15 V * PTRY = 83.15 V * 150.00 = 12,473 V = 12.47 kV primary

Likewise, for the NOVA 15 recloser:

83.15 V * PTRY = 83.15 V * 75.00 = 6,236 V = 6.24 kV primary

Thus, an SEL-651R voltage element pickup setting of 83.15 V secondary is equivalent to:

- 12.47 kV on the primary system, for voltage connections made via a Kyle/Cooper NOVA 27 recloser (equipped with internal voltage sensors)
- 6.24 kV on the primary system, for voltage connections made via a Kyle/Cooper NOVA 15 recloser (equipped with internal voltage sensors)

The preceding voltage results for the Kyle/Cooper NOVA 27 recloser example also apply to the other Kyle/Cooper NOVA reclosers listed in *Table 9.16* with corresponding setting PTRY = 150.

Table 9.16 PTRY Setting for Kyle/Cooper NOVA LEA Inputs

Recloser Description	PTRY Setting
NOVA 15	75
NOVA 27 and NOVA 15 with extended BIL.	150
NOVA 38 and NOVA 27 with extended BIL	150

PTRZ Setting for Siemens LEA Inputs

Use the PTRZ settings in *Table 9.17* when the VZ-terminal voltage inputs are Siemens LEA inputs. The following example calculations give background and show how to then make voltage element settings when Siemens LEA inputs are used.

Similar to the 8/300 factor applied for 8 Vac LEA inputs (see *Equation 9.6* and *Example 9.2*), a 8.49/300 factor is applied for Siemens LEA inputs. For example, the voltage sensors of a Siemens SDR 27 kV recloser connected to an SEL-651R have an effective voltage divider ratio of PTR_{LEA} = 2231. Thus, setting PTRZ is:

$$\begin{aligned}\text{Setting PTRZ} &= (PTR_{LEA})*(8.49/300)\\ &= 2231 * (8.49/300) = 63.14\end{aligned}$$

Likewise, the voltage sensors of a Siemens SDR 15.5 kV recloser connected to an SEL-651R have an effective voltage divider ratio of PTR_{LEA} = 1281. Thus, setting PTRZ is:

$$\begin{aligned}\text{Setting PTRZ} &= (PTR_{LEA})*(8.49/300)\\ &= 1281 * (8.49/300) = 36.25\end{aligned}$$

For either of these examples, if 5.92 V is applied to the Siemens LEA inputs on the SEL-651R, the recloser thinks it sees:

5.92 V * (300/8.49) = 209.19 V secondary

To then extrapolate to primary voltage for the Siemens SDR 27 kV recloser:

209.19 V * PTRZ = 209.19 V * 63.14 = 13,208 V = 13.2 kV primary

Likewise, for the Siemens SDR 15.5 kV recloser:

209.19 V * PTRZ = 209.19 V * 36.25 = 7,583 V = 7.6 kV primary

Thus, an SEL-651R voltage element pickup setting of 209.19 V secondary is equivalent to:

- 13.2 kV on the primary system, for voltage connections made via a Siemens SDR 27 kV recloser (equipped with internal voltage sensors)
- 7.6 kV on the primary system, for voltage connections made via a Siemens SDR 15.5 kV recloser (equipped with internal voltage sensors)

Table 9.17 PTRZ Setting for Siemens LEA Inputs

Recloser Description	PTRZ Setting
Siemens SDR 15.5 kV	36.25
Siemens SDR 27 kV	63.14

Voltage-Related Settings and LEA Inputs

Read the preceding *PTRY Setting for 8 Vac Max LEA Inputs on page 9.41* subsection in preparation for the following example.

When the VY-terminal voltage inputs are LEA 8 V inputs, any voltage-related setting tied to the VY-terminal voltage inputs (see *Table 9.18*) is adjusted by a factor of 300/8.

EXAMPLE 9.3 Voltage Setting Conversion to 300 V Base

This example uses much of the same information in Example 9.2. A voltage divider (10000 ratio) is connected between a 12.47 kV system (7.2 kV line-to-neutral) and the LEA inputs.

NOTE: 8 VAC LEA OPTION FOR BOTH VY-TERMINAL AND VZ-TERMINAL VOLTAGE INPUTS

The SEL-651R-1 has an option for both the VY-terminal and VZ-terminal voltage inputs to be ordered as 8 Vac LEA inputs. Thus, any discussions and/or examples concerning 8 Vac LEA inputs for the VY-terminal voltage inputs also apply, in like manner, to 8 Vac LEA inputs for the VZ-terminal voltage inputs (with corresponding VZ-terminal voltage input related settings).

$$\frac{7200\text{ V}}{10000} = 0.72\text{ V}$$ (actual voltage divider output to the LEA inputs; 8 V base)

$$0.72\text{ V} \cdot \frac{300}{8} = 27\text{ V}$$ (the relay thinks it is looking at 27 V on a 300 V base, not 0.72 V on an 8 V base)

27 V is the nominal adjusted secondary voltage—adjusted by the 300/8 factor from an 8 V base to a 300 V base. For this same example, if a 0.8 V output of the LEA (8 V base) is deemed an overvoltage condition, then an overvoltage element pickup setting (e.g., 59YP1P) could be set at:

$$\text{59YP1P} := 0.8\text{ V} \cdot \frac{300}{8} = 30\text{ V} \qquad \text{(300 V base)}$$

This 300/8 adjustment factor also applies to power elements (see *Table 4.15* and accompanying text), if power element pickup settings (3PWR1P–3PWR4P) are initially computed using the actual voltage values connected to the LEA 8 V inputs.

Table 9.18 Adjust Voltage-Related Settings When the Voltage Inputs Are 8 Vac LEA Inputs (VY-Terminal Example)

Setting	Multiply 8 V Base Voltage Value by 300/8 Factor:	Setting Sheet
VNOM *(nominal voltage)*	When VSELECT := VY	*Page SET.5*
27YP1P, 27YP2P, 27YPP1P, 59YP1P, 59YP2P, 59YPP1P, 59YN1P, 59YN2P, 59YQ1P, 59YV1P *(for voltage elements)*	Always	*Page SET.21*
27B81P *(for blocking frequency elements)*	When FSELECT := VY	*Page SET.22*
3PWR1P, 3PWR2P, 3PWR3P, 3PWR4P *(for power elements)*	When VSELECT := VY	*Page SET.23*
25VPLO, 25VPHI 25VSLO, 25VSHI *(for supervising synchronism-check elements)*	When FSELECT := VY When FSELECT := VZ	*Page SET.23*

Table 9.18 is an example of modifying VY-terminal voltage-related settings for 8 Vac LEA inputs. Similar modifications can be made for other LEA inputs by applying like factors to the LEA base voltage value:

➤ Kyle/Cooper NOVA LEA:

multiply *37.09 Vac base* voltage value by 300/37.09 factor (see *PTRY Setting for Kyle/Cooper NOVA LEA Inputs on page 9.41*)

➤ Siemens LEA:

multiply *8.49 Vac base* voltage value by 300/8.49 factor (see *PTRZ Setting for Siemens LEA Inputs on page 9.42*)

➤ 120 Vac, 1M Lindsey SVMI LEA:

No adjustment needed

Voltage-Related Settings Possibly Limited by RCF Settings

Read the preceding *Voltage Ratio Correction Factors for VY- and VZ-Terminal Voltage Inputs on page 9.34* subsection.

If most of the voltage range for VY-terminal voltage inputs (ordered as LEA 8 V inputs) is used in a particular installation (i.e., the nominal applied secondary voltage is close to or equal to 8 V), then a ratio correction factor (RCF) set below unity (RCF < 1.000) can effectively limit the upper setting range of a voltage-related setting.

This subsection, together with *Example 9.3* and *Table 9.18*, discusses making voltage-related settings for LEA 8 V inputs by applying an adjustment factor of 300/8. This adjustment factor puts the setting on a 300 V base. Thus, an 8 V signal on an LEA 8 V input translates to a 300 V signal on a 300 V base. 300 V is the upper setting range for the phase-to-neutral voltage-related settings.

For example, if the RCF for voltage input V2Y is set:

$$\text{global setting V2YRCF} = 0.900 \qquad (< 1.000\text{; set below unity})$$

and 8 V is applied to voltage input V2Y, then this applied voltage is normalized to:

$$8\text{ V} \bullet 0.900 = 7.2\text{ V} \quad \text{(normalized voltage from voltage input V2Y)}$$

8 V is the upper limit for voltage that can be applied to the VY-terminal voltage inputs. Assuming the above 0.900 RCF is the lowest RCF for the VY-terminal voltage inputs and that the normalized voltages for all the voltage inputs should be the same (7.2 V in this example), then the maximum applied voltages for the other two channels (RCF's > 0.900) must be less than 8 V:

$$\frac{7.2\text{ V}}{\text{RCF}} < 8\text{ V} \qquad (\text{RCF} > 0.900)$$

The 7.2 V normalized voltage in this example translates to 270 V on a 300 V base:

$$7.2\text{ V} \bullet \frac{300}{8} = 270\text{ V} \quad \text{(300 V base)}$$

270 V is thus the effective upper setting range for the phase-to-neutral voltage-related settings in this example. A phase-to-neutral voltage-related setting can be set higher (e.g., 290 V), but for voltage input V2Y such a setting would be indistinguishable from a 270 V setting, in this example. The VY-terminal voltage inputs (ordered as LEA 8 V inputs) cannot distinguish voltages above 8 V.

$$8\text{ V} \bullet 0.900 \bullet \frac{300}{8} = 270\text{ V} \quad \text{(300 V base)}$$

Preceding *Example 9.3* is **not** an example of this possible effective limiting of the upper setting range of voltage-related settings. In *Example 9.3*, the nominal applied secondary voltage to the VY-terminal voltage inputs is 0.72 V, nowhere near the 8 V upper limit for VY-terminal voltage inputs (ordered as LEA 8 V inputs).

Enable Settings

Enable settings are available in global, group, logic, and front-panel settings. Enable settings can cause other settings to be available or hidden, which reduces the number of settings to be made in most applications. Settings that are controlled by enable settings are indicated on the settings sheets. Some of these enable settings directly affect the SEL-651R built-in logic.

Table 9.19 Use of Enable Settings

Enable Setting	Setting Sheet	Controls	Setting Sheet
EGNDSW	*SET.1*	Group setting E50N Group setting NDEMP	*SET.6* *SET.27*
BKTYP	*SET.1*	Group setting ESPB Group setting SPOD Settings 52A_3P, 52A_A, 52A_B, and 52A_C	*SET.6* *SET.27* *SET.29*
EICIS and EBMON	*SET.2*	Global Settings IN10xD, IN20xD; COSP1–BKMONC	*SET.2* and *SET.4*
ESPB–EMV	*SET.6* and *SET.7*	Various settings	*SET.6–SET.29*
ESPB	*SET.6*	Relay Word bit SPE	See *Figure 9.22*
ELAT, ESV, ESC	*SET.31*	Latch bit, SELOGIC variables/ timers, and SELOGIC counters	*SET.31–SET.47*
EDP, ELB	*SET.48*	Display Points and Local Bits	*SET.53–SET.57*

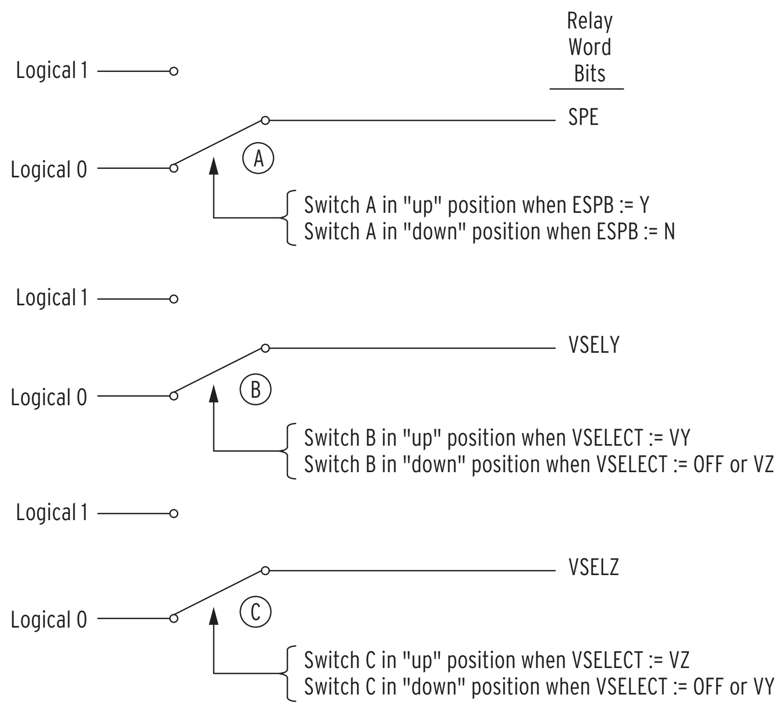


Figure 9.22 Operation of SPE, VSELY, and VSELZ Relay Word Bits

Line Length Setting

Refer to *Line Parameter Settings on page SET.7*.

Line length setting LL is used in the fault locator function (see *Fault Location on page 12.5*). The line length is associated with the line impedance settings (described in next subsection).

Line length setting LL is unitless and corresponds to the line impedance settings. For example, if a particular line length is 15 miles, enter the line impedance values (Ω secondary) and then enter the corresponding line length:

LL = 15.00 (miles)

If this length of line is measured in kilometers rather than miles, then enter:

LL = 24.14 (kilometers)

Impedance Settings Conversions

Refer to *Line Parameter Settings on page SET.7*, *Load-Encroachment Elements on page SET.20*, and *Directional Elements on page SET.20*.

The SEL-651R has eight settings that are in units of ohms, secondary (impedance). The settings are Z1MAG and Z0MAG (used in the Fault Locator), ZLF and ZLR (used in the Load Encroachment Logic), and Z2F, Z2R, Z0F, and Z0R (used in Directional Control).

Impedance values are converted from primary ohms to secondary ohms using either *Equation 9.8* or *Equation 9.9*.

NOTE: The derived Ω secondary values in Equation 9.8 and Equation 9.9 are on a 300 V base. This even holds true when the VY-terminal voltage inputs are LEA inputs, because the PTRY setting has already been adjusted to a 300 V base with Equation 9.6, for 8 V LEA inputs or with PTRY settings from Table 9.16 for Kayle/Cooper NOVA LEA inputs. Lindsey SVMI LEA inputs need no adjustment.

NOTE: 8 VAC LEA OPTION FOR BOTH VY-TERMINAL AND VZ-TERMINAL VOLTAGE INPUTS

The SEL-651R-1 has an option for both the VY-terminal and VZ-terminal voltage inputs to be ordered as 8 Vac LEA inputs. Thus, any discussions and/or examples concerning 8 Vac LEA inputs for the VY-terminal voltage inputs also apply, in like manner, to 8 Vac LEA inputs for the VZ-terminal voltage inputs (with corresponding VZ-terminal voltage input related settings).

When VSELECT := VY

$$\Omega \text{ primary} \bullet \left(\frac{\text{CTR}}{\text{PTRY}}\right) = \Omega \text{ secondary}$$

Equation 9.8

where:

CTR = phase (IA, IB, IC) current transformer ratio setting

PTRY = phase (V1Y, V2Y, V3Y) potential transformer ratio setting (see note)

When VSELECT := VZ

$$\Omega \text{ primary} \bullet \left(\frac{\text{CTR}}{\text{PTRZ}}\right) = \Omega \text{ secondary}$$

Equation 9.9

where:

CTR = phase (IA, IB, IC) current transformer ratio setting

PTRZ = phase (V1Z, V2Z, V3Z) potential transformer ratio setting

When VSELECT := OFF, the fault locator and load encroachment logic will not be available, and the associated settings cannot be accessed.

Math Variable Settings

NOTE: The context of a math variable is completely defined by its application. In the SEL-651R, math variables are not mathematical expressions. They are numeric constants. The SEL-651R does not offer mathematical operations in SELOGIC control equation expressions.

Refer to *Math Variable Settings on page SET.28*.

The math variable settings in the SEL-651R are controlled by enable setting EMV = 1–32. In the SEL-651R, these variables are numeric settings in the range –16000.00 to +16000.00. There are no units associated with the math variable settings. These settings create Analog Quantities (with the same name as the setting) that are available for use in analog comparisons in SELOGIC Control equations (see *Table 7.2*).

The math variable MV01 := 2.00 is the only one used in the SEL-651R factory settings. This setting selects the number of phase and ground time-overcurrent element operations on the fast curve, by virtue of being included in the factory setting for 51PSW, 51G1SW, and 79SKP3P. This default logic is described in *Figure 6.12* and related example in *Section 6: Close and Reclose Logic*.

Pole Status (52a), Trip, and Close Mapping Variations for Single-Phase Reclosers (BKTYP := 1)

Refer to *Close Logic Settings on page SET.29* and *Recloser Interface Trip and Close Settings on page SET.30*. Review *Breaker Status Logic on page 6.3* and *Trip and Close Mapping and Output Logic on page 7.29*.

In *Figure 9.24* and *Figure 9.25*, notice that the control cables bring in current, pole status (52a), and trip/close signals together for each single phase. For example, in *Figure 9.25*, current I3, pole status 52a3, and Trip 3/Close 3 are all associated with B-phase:

IPCONN := CA**B** (current channel I**3** connected to **B**-phase)

52A_**B** := IN20**3** (pole status 52a**3** connected to IN20**3**)

RCTR**3** := TRIP**B** OR … (drives output RCTR**3**X, connected to Coil **3**)

RCCL**3** := CLOSE**B** OR … (drives output RCCL**3**X, connected to Coil **3**)

Group setting IPCONN associates the current channels with the power system. For example, in *Figure 9.25*, IPCONN := CAB with current channels:

I1 connected to C-phase

I2 connected to A-phase

I3 connected to B-phase

This same IPCONN setting information can be used to make similar breaker monitor, pole status (52a), trip, and close mapping settings, as shown in *Table 9.14*, *Table 9.20*, *Table 9.21*, and *Table 9.22*, respectively

NOTE: If a single-phase recloser is ordered, and the application does not require single-phase tripping and closing, make setting ESPB := N. The remainder of this subsection could be skipped, although it is recommended that these settings be followed if possible at commissioning time. If a single-phase trip scheme is specified in the future (ESPB := Y), then the recloser control is properly configured.

NOTE: The ABB OVR-3/VR-3S (15 and 27 kV models) reclosers use 52B style contacts. 52A_x equation should use the inverse of the inputs (NOT IN20x).

NOTE: The system phase rotation (and Global Setting PHROT) have no impact on the recommended settings shown in Table 9.20, Table 9.21 and Table 9.22.

Table 9.20 Pole Status (52a) Mapping Settings for Single-Phase Reclosers (BKTYP := 1)

Reference Setting	Recommended Pole Status (52a) Mapping Settings		
IPCONN :=	52A_A :=	52A_B :=	52A_C :=
ABC	IN201	IN202	IN203
ACB	IN201	IN203	IN202
BAC	IN202	IN201	IN203
BCA	IN203	IN201	IN202
CAB	IN202	IN203	IN201
CBA	IN203	IN202	IN201

Table 9.21 Trip Mapping Settings for Single-Phase Reclosers (BKTYP := 1)

Reference Setting	Recommended Trip Mapping Settings		
IPCONN :=	RCTR1 :=	RCTR2 :=	RCTR3 :=
ABC	TRIPA OR TRIP3P	TRIPB OR TRIP3P	TRIPC OR TRIP3P
ACB	TRIPA OR TRIP3P	TRIPC OR TRIP3P	TRIPB OR TRIP3P
BAC	TRIPB OR TRIP3P	TRIPA OR TRIP3P	TRIPC OR TRIP3P
BCA	TRIPB OR TRIP3P	TRIPC OR TRIP3P	TRIPA OR TRIP3P
CAB	TRIPC OR TRIP3P	TRIPA OR TRIP3P	TRIPB OR TRIP3P
CBA	TRIPC OR TRIP3P	TRIPB OR TRIP3P	TRIPA OR TRIP3P

Table 9.22 Close Mapping Settings for Single-Phase Reclosers (BKTYP := 1)

Reference Setting	Recommended Close Mapping Settings		
IPCONN :=	RCCL1 :=	RCCL2 :=	RCCL3 :=
ABC	CLOSEA OR CLOSE3P	CLOSEB OR CLOSE3P	CLOSEC OR CLOSE3P
ACB	CLOSEA OR CLOSE3P	CLOSEC OR CLOSE3P	CLOSEB OR CLOSE3P
BAC	CLOSEB OR CLOSE3P	CLOSEA OR CLOSE3P	CLOSEC OR CLOSE3P
BCA	CLOSEB OR CLOSE3P	CLOSEC OR CLOSE3P	CLOSEA OR CLOSE3P
CAB	CLOSEC OR CLOSE3P	CLOSEA OR CLOSE3P	CLOSEB OR CLOSE3P
CBA	CLOSEC OR CLOSE3P	CLOSEB OR CLOSE3P	CLOSEA OR CLOSE3P

It is important to test that pole status (52a) and trip/close signals for a particular phase correspond to the proper current channel, before placing the unit into service. If the mapping settings shown in *Table 9.20*, *Table 9.21*, and *Table 9.22* are set incorrectly, tripping and closing may misoperate. *Table 9.20*, *Table 9.21*, and *Table 9.22* presume that the wiring from the control cable to the SEL-651R relay module is not changed (see *Figure 2.46*, *Figure 2.48*, and *Figure 2.49*).

The SEL-651R issues the following warning message when the IPCONN setting is changed (when setting BKTYP := 1):

```
WARNING! The IPCONN setting was changed. Recloser trip
(RCTR_), close (RCCL_), status (52A_), and breaker
monitor initiate (BKMON_) SELogic Equation settings may
also need to be changed.
```

Also, the SEL-651R issues the following warning message when the BKTYP setting is changed:

```
WARNING! The global setting BKTYP was changed. Certain
settings will be deactivated or activated in all six
settings groups. Settings related to trip, close, and
reclose logic, and the breaker status (52A_) and
breaker monitor initiate (BKMON_) settings may need to
be changed.
```

Transition Between A-B-C Worlds

In *Figure 9.23*, the SEL-651R “1-2-3” connections provide a transition between the:

“A-B-C” power system world, outside

and the

“A-B-C” algorithm world, inside the SEL-651R

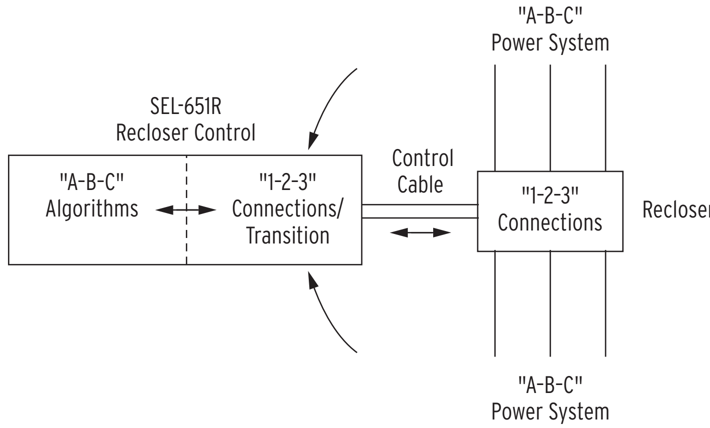


Figure 9.23 Overview of Transition Between A-B-C Worlds Inside and Outside the SEL-651R

NOTE: LEA Voltages: If the VY-terminal voltages are ordered as LEAs (low-energy analog inputs; rated up to 8 Vac), then the voltage signals brought to the VY terminals can come through the G&W Viper-ST control cable, as shown in Figure 2.38. This routing of voltage signals through the control cable is done if the capacitive screen voltage sensors in the recloser are used. In such a scenario, the voltage signals are grouped on a per phase basis with the corresponding current, trip/close signal, and pole status (52a).

Wiring to the power system (potential transformer connections and recloser primary bushing connections) can be rather random, but correct power system “A-B-C” designation is still needed within the SEL-651R algorithms. Preceding *Table 9.8* through *Table 9.14*, *Figure 9.21*, and *Table 9.20* through *Table 9.22* list the settings and all the possible settings combinations that realize the correct “A-B-C” designations within the SEL-651R for the numerous possible power system connections.

Figure 9.24 and *Figure 9.25* are a more in depth look at the transition idea given in *Figure 9.23*. The underlying assumption in *Figure 9.24* and *Figure 9.25* is that the wiring from the control cable is factory-standard in its connection to both the SEL-651R Recloser Control and the recloser (i.e., there is no rearrangement of the factory-standard cable wiring). Note that the currents, trip/close signals, and pole status (52a) come through the control cable, but the voltage connections are separate. Thus, for a given phase, the current, trip/close signal, and pole status (52a) remain grouped together.

Straight-Through Phase Connections

NOTE: What about traditional reclosers?: Figure 9.24 and Figure 9.25 use a G&W Viper-ST recloser as an example. A discussion concerning the substitution of a Traditional Retrofit recloser in these figures is given at the end of this subsection.

From inspection of the SEL-651R settings and connections in *Figure 9.24*, the correspondence between the power system world and the SEL-651R connections is:

A ←→ 1
B ←→ 2
C ←→ 3

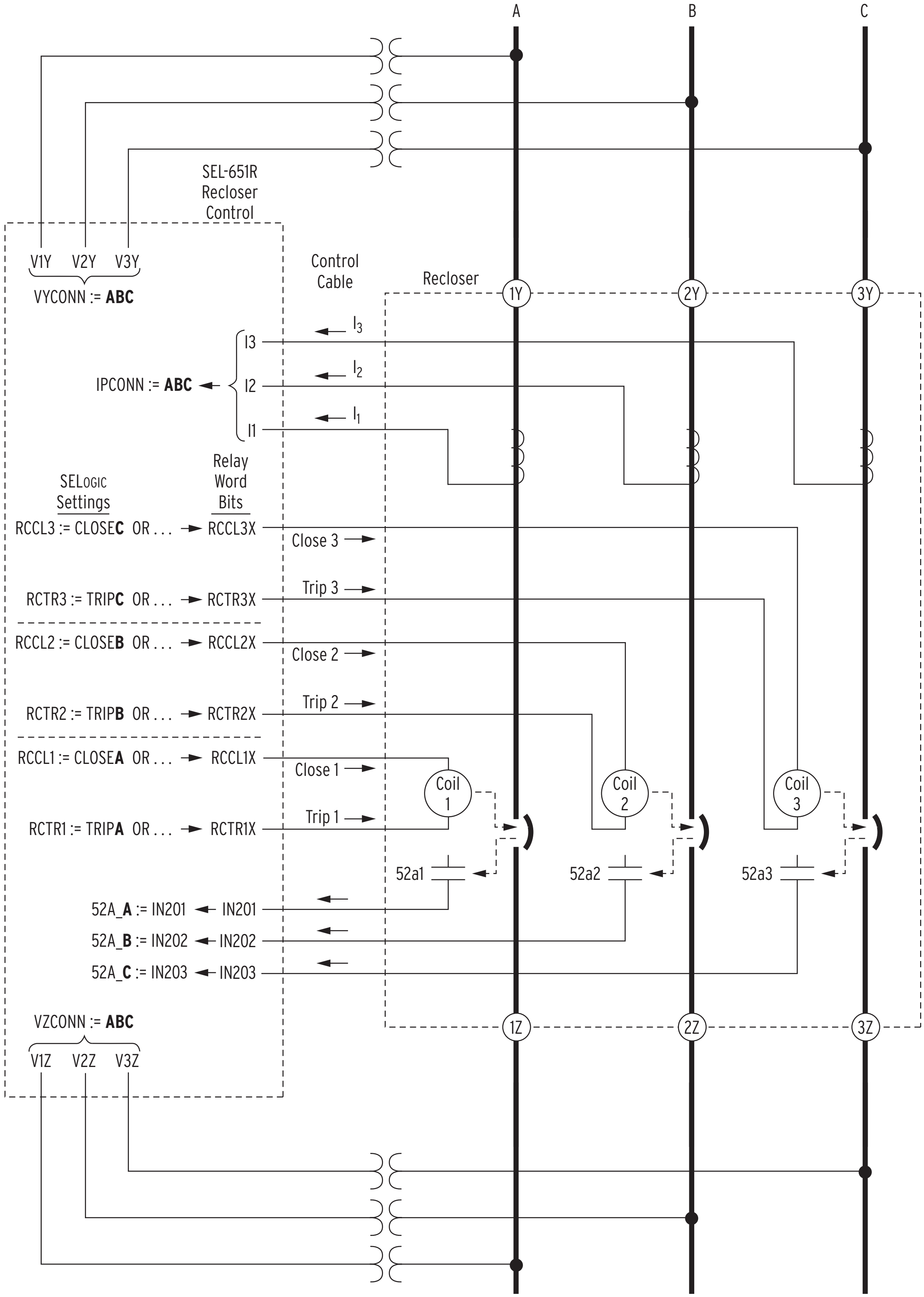


Figure 9.24 Single-Phase Recloser With Straight-Through Connections

Complex Phase Connections

Figure 9.25 is similar to *Figure 9.24*, but with the added complication of primary phase swapping. The correspondence between the power system world and the SEL-651R connections is first, at the top of *Figure 9.25*:

A ←→ 1
B ←→ 2
C ←→ 3

with VYCONN := ABC

(voltage terminals: V1Y ≈A-phase, V2Y ≈B-phase, V3Y ≈C-phase)

NOTE: VYCONN := CAB?: If the VY-terminal voltages are ordered as LEAs (low-energy analog inputs) and the voltage signals brought to the VY terminals come through the control cable, as shown in Figure 2.38, then VYCONN := CAB for the primary phase swapping scenario in Figure 9.25.

Then after the first primary phase swap at the top of the recloser, the correspondence between the power system world and the SEL-651R connections is (via the control cable in *Figure 9.25*):

C ←→ 1
A ←→ 2
B ←→ 3

with IPCONN := CAB

(current terminals: I1 ≈C-phase, I2 ≈A-phase, I3 ≈B-phase)

and:

Coil 1 ←→ C-phase
Coil 2 ←→ A-phase
Coil 3 ←→ B-phase

The following close circuit example traces “B ←→ 3” correspondence in *Figure 9.25*:

CLOSE**B** → RCCL**3** → RCCL**3**X (Close **3**) → Coil **3** → **B**-phase

“A-**B**-C” algorithms	“1-2-**3**” connections/transitions	“A-**B**-C” power system

The following trip circuit example traces “C ←→ 1” correspondence in *Figure 9.25*:

TRIP**C** → RCTR**1** → RCTR**1**X (Trip **1**) → Coil **1** → **C**-phase

“A-B-**C**” algorithms	“**1**-2-3” connections/transitions	“A-B-**C**” power system

The following pole status circuit example traces “A ←→ 2” correspondence in *Figure 9.25*:

52A_**A** ← IN202 ← 52a**2** ← Coil **2** ← **A**-phase

“**A**-B-C” algorithms	“1-**2**-3” connections/transitions	“**A**-B-C” power system

After the primary phase swap at the bottom of the recloser in *Figure 9.25*, the correspondence between the power system world and the SEL-651R connections is lastly:

B → 1
C → 2
A → 3

with VZCONN := BCA
(voltage terminals: V1Z ≈B-phase, V2Z ≈C-phase, V3Z ≈A-phase)

More detailed connections for each recloser can be found in the corresponding installation section in *Section 2: Installation*.

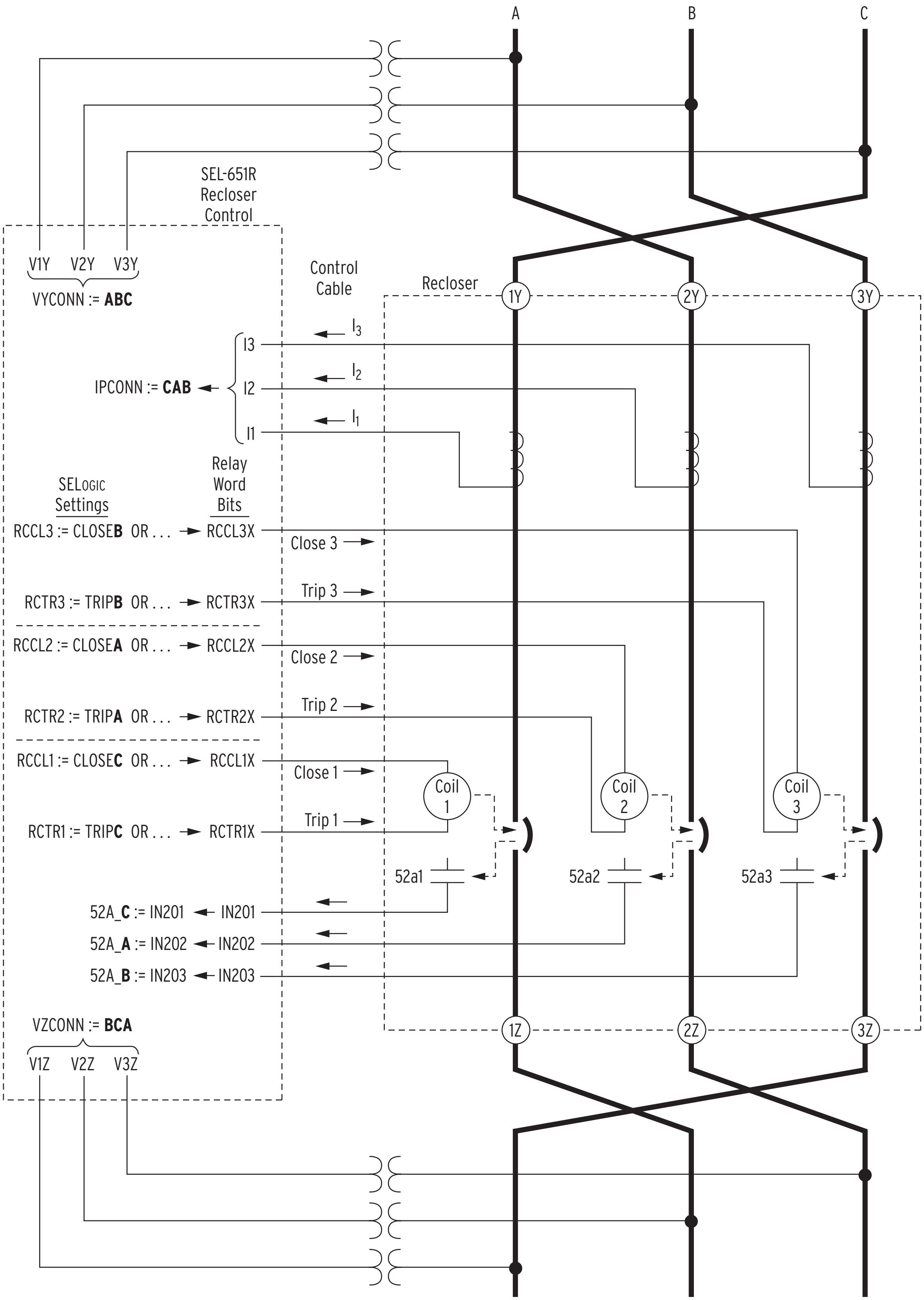


Figure 9.25 Single-Phase Recloser With Complex Connections

Three-Phase vs. Single-Phase Operation

The trip and close settings (RCTR*n* and RCCL*n*, respectively) in *Figure 9.24* and *Figure 9.25* imply single-phase operation. But, three-phase operation can be realized, too, as shown in the settings possibilities in *Table 9.21* and *Table 9.22* ("… OR TRIP3P" and "… OR CLOSE3P").

Three-Phase Recloser Considerations

If a three-phase recloser is substituted for a single-phase recloser in *Figure 9.24* and *Figure 9.25*, the voltage and current connections and associated settings are essentially the same (though there are some current polarity connection differences; compare *Figure 2.45* with *Figure 2.47*). The major differences are with the trip/close signals and pole status (52a) coming through the control cable; compare with *Figure 2.46* with *Figure 2.49*.

Traditional Retrofit and Control-Powered Kyle NOVA reclosers are three-phase reclosers only (global setting BKTYP := 3 and group setting ESPB:= N), where all three phases trip and close together. These reclosers have only one trip and close circuit and 52a status (see *Figure 2.46*). Three-phase operation in these reclosers is typically realized with settings:

RCTR1:= **TRIP3P** (see *Figure 5.1*)

RCCL1:= **CLOSE3P** (see *Figure 6.1*)

52A_3P:= **SW1 AND NOT RCCL1X** (see *Figure 6.2*)

Display Point Settings

Refer to *Settings Sheet page SET.48* and *SET.53*.

The factory default Front-Panel settings for DP01 and DP02 cause the message FACTORY DEFAULT SETTINGS to appear on the SEL-651R rotating display. This message is not automatically disabled when settings are changed. The message is intended to remind the technician that the SEL-651R needs to have settings applied before placing the recloser control into service. One of the first tasks performed by the technician should be to defeat the display of the FACTORY DEFAULT SETTINGS message.

The message can be defeated by making Front-Panel settings

DP01 := **NA**

DP02 := **NA**

More details and instructions on Display Points are available in *Rotating Display on page 11.12*.

Factory Default Settings

The SEL-651R factory default settings are presented in *Figure 9.26* through *Figure 9.32*.

```
=>SHO G <Enter>

Global Settings

General Settings:
NFREQ   := 60       PHROT   := ABC      DATE_F  := MDY
PWRDN_AC:= 180      PWRDN_WU:= 20
TESTBATT:= NA
FAULT   :=51P OR 51G1

Current and Voltage Connection Settings:
IPCONN  := ABC      EGNDSW  := Y        CTPOL   := POS      BKTYP   := 3
VYCONN  := ABC      VZCONN  := OFF
VSELECT := VY       FSELECT := VY

Global Enable Settings:
EICIS   := N        EBMON   := N

Setting Group Selection Settings:
TGR     := 0

Setting Group Selection SELogic Equations
SS1     :=PB04_PUL AND NOT SG1 AND LT05
SS2     :=PB04_PUL AND SG1 AND LT05
SS3     :=0
SS4     :=0
SS5     :=0
SS6     :=0
SS7     :=0
SS8     :=0

Voltage Ratio Correction Factors for Terminals V1Y, V2Y, V3Y:
V1YRCF  := 1.000    V2YRCF  := 1.000    V3YRCF  := 1.000

Voltage Ratio Correction Factors for Terminals V1Z, V2Z, V3Z:
V1ZRCF  := 1.000    V2ZRCF  := 1.000    V3ZRCF  := 1.000

Voltage Phase Angle Correction for Terminals V1Y, V2Y, V3Y:
V1YPAC  := 0.0      V2YPAC  := 0.0      V3YPAC  := 0.0

Voltage Phase Angle Correction for Terminals V1Z, V2Z, V3Z:
V1ZPAC  := 0.0      V2ZPAC  := 0.0      V3ZPAC  := 0.0


Breaker Monitor Initiate Selogic Equations:
BKMON3P :=RCTR1X

Data Reset Control:
RSTTRGT :=0

=>
```

BKTYP := 1 (single-phase models and Tavrida OSM)

SEL-651R-1 only

Voltage Ratio Correction Factor Settings for VY or VZ terminals are available only for SEL-651Rs ordered with LEA inputs on VY or VZ terminals.

Voltage Phase Angle Correction Factor settings on VY terminals and VZ terminals are only for SEL-651Rs ordered with “Kyle/Cooper NOVA” LEA inputs and “Lindsey SVMI” or “Siemens LEA” inputs, respectively.

Figure 9.26 Global Settings (SHO G) With Factory Default Values

```
=>SHO <Enter>
Group 1

Group Settings

Identifier and Instrument Transformer Settings:
RID     :=FEEDER 1
TID     :=STATION A
CTR     := 1000.0   CTRN    := 1000.0   PTRY    := 120.00   PTRZ    := 120.00
VNOM    := 120.00
```

PTRZ := 266.67 (G&W Viper-ST 8 V LEA models)
:= 234.50 (Tavrida OSM 8 V LEA models)

PTRY := 266.67 (G&W Viper-ST 8 V LEA models)
:= 150.00 (Kyle/Cooper NOVA LEA models)
:= 234.50 (Tavrida OSM 8 V LEA models)

```
Enable Settings:
ESPB    := N        E50P    := N        E50N    := N        E50G    := N
E50Q    := N        E51P    := 2        E51ABC  := N        E51G1   := 2
E51G2   := N        E51Q    := N        ELOAD   := N        E32     := N
EVOLT   := VY       E81     := N        EFLOC   := Y        ELOP    := N
EPWR    := N        E25     := N        E79     := 3        ESOTF   := N
EDEM    := THM      ESSI    := N        EMV     := 1

Line Parameter Settings:
Z1MAG   := 32.10    Z1ANG   := 68.86    Z0MAG   := 95.70    Z0ANG   := 72.47
LL      := 4.84

Maximum-phase Time-Overcurrent Element J Settings:
51PJP   := 0.40     51PJC   := A        51PJTD  := 1.00
51PJCT  := 0.00     51PJMR  := 0.00

Maximum-phase Time-Overcurrent Element K Settings:
51PKP   := 0.40     51PKC   := C        51PKTD  := 1.00
51PKCT  := 0.00     51PKMR  := 0.00

Maximum-phase Time-Overcurrent SELogic Settings:
51PTC   :=1
51PSW   :=NOT (LT04) OR (MV01 <= 79SH3P) # DELAY CURVE SELECTED WHEN SHOT COUNT MEETS
    OR EXCEEDS NUMBER OF FAST TRIPS (MV01)

Ground Time-Overcurrent Element #1-J Settings:
51G1JP  := 0.100    51G1JC  := 1        51G1JTD := 1.00
51G1JCT := 0.00     51G1JMR := 0.00

Ground Time-Overcurrent Element #1-K Settings:
51G1KP  := 0.100    51G1KC  := 13       51G1KTD := 1.00
51G1KCT := 0.00     51G1KMR := 0.00

Ground Time-Overcurrent #1 SELogic Settings:
51G1TC  :=LT01
51G1SW  :=NOT (LT04) OR (MV01 <= 79SH3P) # DELAY CURVE SELECTED WHEN SHOT COUNT MEETS
    OR EXCEEDS NUMBER OF FAST TRIPS (MV01)
```

59YP1P := 46.80 (G&W Viper-ST 8 V LEA models)
:= 83.20 (Kyle/Cooper NOVA LEA models)
:= 53.22 (Tavrida OSM 8 V LEA models)

```
Voltage Element Pickup Settings, Y-terminals:
27YP1P  := OFF      27YP2P  := OFF      27YPP1P := OFF      59YP1P  := 104.00
59YP2P  := OFF      59YPP1P := OFF      59YN1P  := OFF      59YN2P  := OFF
59YQ1P  := OFF      59YV1P  := OFF

Reclosing Relay Settings:
79OI1   := 300.00   79OI2   := 600.00   79OI3   := 600.00
79RSD   := 1800.00  79RSLD  := 600.00
79CLSD  := 900.00

Reclosing Relay SELogic Equations:
79RI3P  :=TRIP3P
79RIS3P :=52A3P OR 79CY3P
79DTL3P :=(NOT LT02 OR NOT LT06) AND (TRIP3P OR NOT 52A3P) OR PB12_PUL OR OC3
79DTL3X := 0
```

79DTL3X :=R_TRIG SV02T # QUALIFIED YELLOW HANDLE OPERATION
(G&W Viper-ST, Joslyn TriMod 600R, Kyle NOVA-TS or NOVA-STS Triple-Single, and Siemens SDR Triple-Single)

```
79DLS3P :=79LO3P
79SKP3P :=(51PT OR 51G1T) AND NOT LT04 AND (79SH3P < MV01) # SKIP TO DELAYED SHOTS
    WHEN FAST CURVES DISABLED
79STL3P :=TRIP3P
79BRS3P :=0
79SEQ3P :=0
79CLS3P :=PWR_SRC1 AND TCCAP AND NOT (BTFAIL) # RECLOSE ONLY WHEN AC PRESENT, TRIP/
    CLOSE CAPACITORS CHARGED, AND BATTERY HEALTHY
```

79CLS3P :=TCCAP AND NOT(BTFAIL) # RECLOSE ONLY WHEN TRIP/CLOSE CAPACITORS CHARGED AND BATTERY HEALTHY (all but Traditional Retrofit reclosers)

```
Pole-Open Settings:
3POD    := 0.50     50LP    := 0.05

Demand Metering Settings:
DMTC    := 5        PDEMP   := OFF
GDEMP   := OFF      QDEMP   := OFF
```

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```
Math Variable Settings:
MV01    := 2.00

Trip Logic Settings:
TDURD   := 40.00

Trip Logic SELogic Equations:
TR3P    :=51PT OR 51G1T OR PB12_PUL OR OC3
TR3X    :=0
ULTR3P  :=1

Close Logic Settings:
CFD     := 60.00

Close Logic SELogic Equations:
52A_3P  :=SW1 AND NOT (RCCL1X)
CL3P    :=(PB11_PUL AND LT05 OR CC3) AND LT06 AND TCCAP # CLOSE FROM PUSHBUTTON
    SUPERVISED BY LOCK. ALL CLOSING SUPERVISED BY HOT LINE TAG (LT06) AND TRIP/CLOSE
    CAPACITOR (TCCAP).
ULCL3P  :=TRIP3P OR (NOT IN201 AND SW1) OR NOT (LT06 AND TCCAP OR CLOSE3P) OR NOT
    (LT05 OR CLOSE3P OR CC3 OR 79CY3P) # SW1 ONLY ACTIVE FOR 14-PIN RECLOSERS

Recloser Interface Trip and Close Settings:
RCTR1   :=TRIP3P OR TRIPA OR TRIPB OR TRIPC
RCTR2   :=TRIP3P OR TRIPA OR TRIPB OR TRIPC
RCTR3   :=TRIP3P OR TRIPA OR TRIPB OR TRIPC
RCCL1   :=CLOSE3P
RCCL2   :=CLOSE3P
RCCL3   :=CLOSE3P

=>
```

TR3X :=R_TRIG SV02T # QUALIFIED YELLOW HANDLE OPERATION (G&W Viper-ST, Kyle NOVA-TS or NOVA-STS Triple-Single, and Siemens SDR Triple-Single)

52A_3P replaced by 52A_A := IN201, 52A_B := IN202, 52A_C := IN203 for G&W Viper-ST, Joslyn TriMod 600R, Kyle NOVA-TS or NOVA-STS Triple-Single, and Siemens SDR Triple-Single

52A_3P replaced by 52A_A := NOT IN201, 52A_B := NOT IN202, 52A_C := NOT IN203 for ABB OVR/VR35 and Tavrida OSM

52A_3P:= IN201 (Control-Powered Kyle NOVA and Siemens SDR Three-Phase)

ULCL3P := TRIP3P OR NOT (LT06 AND TCCAP OR CLOSE3P) OR NOT (LT05 OR CLOSE3P OR CC3 OR 79CY3P) [all other reclosers except Traditional Retrofit (14-pin) reclosers]

Figure 9.27 Group Settings (SHO) With Factory Default Values

```
=>SHO L <Enter>
Group 1

Logic Settings

SELogic Enable Settings:
ELAT    := 9        ESV     := 1        ESC     := 1
```

ESV := 2 (G&W Viper-ST, Kyle NOVA-TS or NOVA-STS Triple-Single, Joslyn TriMod 600R, and Siemens SDR Triple-Single)

ESV := 3 (Tavrida OSM)

```
Latch Bits Set/Reset SELogic Equations:
SET01   :=PB01_PUL AND NOT (LT01) AND LT05 # GROUND ENABLED
RST01   :=PB01_PUL AND LT01 AND LT05
SET02   :=PB02_PUL AND NOT (LT02) AND LT05 AND LT06 # RECLOSE ENABLED
RST02   :=PB02_PUL AND LT02 AND LT05 OR NOT (LT06) OR (79SH3P = -1.00) # LAST TERM IS
    "RECLOSING RELAY DEFEATED"
SET03   :=PB03_PUL AND NOT (LT03) AND LT05 # REMOTE ENABLED
RST03   :=PB03_PUL AND LT03 AND LT05
SET04   :=PB05_PUL AND NOT (LT04) AND LT05 # FAST CURVE ENABLED
RST04   :=PB05_PUL AND LT04 AND LT05
SET05   :=R_TRIG SC01QU AND NOT (LT05) # LOCK PUSH BUTTONS, MUST PRESS FOR THREE
    SECONDS (LOCKED WHEN LT05 DEASSERTED)
RST05   :=R_TRIG SC01QU AND LT05
SET06   :=PB07_PUL AND NOT (LT06) AND LT05 # HOT LINE TAG (WHEN LT06 DEASSERTED)
RST06   :=PB07_PUL AND LT06 AND LT05
SET07   :=PB08_PUL AND NOT (LT07) AND LT05 # AUX 1
RST07   :=PB08_PUL AND LT07 AND LT05
SET08   :=PB09_PUL AND NOT (LT08) AND LT05 # AUX 2
RST08   :=PB09_PUL AND LT08 AND LT05
SET09   :=PB10_PUL AND NOT (LT09) AND LT05 # AUX 3
RST09   :=PB10_PUL AND LT09 AND LT05

SELogic Variable and Timer Settings:
SV01PU  := 29.75    SV01DO  := 29.75
SV01    :=NOT (SV01T) AND PB06 # 1 HZ BLINK GENERATOR FOR LOCK PUSH BUTTON
```

SV02PU := 5.00 SV02DO := 60.00
SV02 := IN204 # QUALIFY YELLOW HANDLE OPERATION (G&W Viper-ST, and Siemens SDR Triple-Single)
SV02 := NOT IN204 # QUALIFY YELLOW HANDLE OPERATION (Joslyn TriMod 600R)
SV02 := IN204 or IN205 or IN206 # QUALIFY YELLOW HANDLE OPERATION (Kyle NOVA-TS or NOVA-STS Triple-Single)

```
SELogic Counter Settings:
SC01PV  := 3
SC01R   :=NOT (PB06)
SC01LD  :=0 # SET TO 1 TO DEFEAT 3 BLINK DELAY
SC01CU  :=SV01T # COUNT THE BLINKS FOR LOCK PUSH BUTTONS CONTROL
SC01CD  :=0

Output Contact SELogic Equations:
OUT101  :=0
OUT102  :=0
OUT103  :=0
OUT104  :=0
OUT105  :=0
OUT106  :=0
OUT107  :=0
OUT108  :=0
OUT201  :=NOT (SALARM OR HALARM)
OUT202  :=0
```

SV02PU := 150.00 SV02DO := 150.00
SV02 := IN105 # QUALIFY YELLOW HANDLE OPERATION
SV03PU := 150.00 SV03DO := 150.00
SV03 := NOT(IN105) AND 52A3P # QUALIFY DISCONNECTED CABLE (Tavrida OSM)

```
Mirrored Bits Transmit SELogic Equations:
TMB1A   :=NA
TMB2A   :=NA
TMB3A   :=NA
TMB4A   :=NA
TMB5A   :=NA
TMB6A   :=NA
TMB7A   :=NA
TMB8A   :=NA
TMB1B   :=NA
TMB2B   :=NA
TMB3B   :=NA
TMB4B   :=NA
TMB5B   :=NA
TMB6B   :=NA
TMB7B   :=NA
TMB8B   :=NA

=>
```

SV02PU := 5.00 SV02DO := 60.00
SV02 := IN204 # QUALIFY YELLOW HANDLE OPERATION (G&W Viper-ST, and Siemens SDR Triple-Single)
SV02 := NOT IN204 # QUALIFY YELLOW HANDLE OPERATION (Joslyn TriMod 600R)
SV02 := IN204 or IN205 or IN206 # QUALIFY YELLOW HANDLE OPERATION (Kyle NOVA-TS or NOVA-STS Triple-Single)

Figure 9.28 Logic Settings (SHO L) With Factory Default Values

```
=>SHO F <Enter>

Front Panel Settings
                                   EDP    := 4   (Tavrida OSM)
General Settings:
EDP     := 2         ELB     := N        FP_TO   := 15       FP_CONT := 8
FPNGD   := IG        FPVYD   := ON       FPVZD   := OFF
LEDENAC := G         RSTLED  := Y

Operator Control LED Settings:

PB01_LED:=LT01 # GROUND ENABLED

PB02_LED:=LT02 # RECLOSE ENABLED

PB03_LED:=0 # REMOTE ENABLED

PB04_LED:=NOT (SG1) # ALT SETTINGS

PB05_LED:=LT04 # FAST CURVE ENABLED

PB06_LED:=NOT (LT05 AND NOT (SV01T AND PB06 AND NOT (SC01QU)) OR NOT (LT05) AND SV01T
    AND PB06 AND NOT (SC01QU)) # LOCK PUSH BUTTONS

PB07_LED:=NOT (LT06) # HOT LINE TAG

PB08_LED:=0 # AUX 1

PB09_LED:=0 # AUX 2

PB10_LED:=0 # AUX 3
PB11LEDC:= RO
PB11_LED:=52A3P # RECLOSER CLOSED
PB12LEDC:= GO
PB12_LED:=NOT (52A3P) # RECLOSER OPEN

Target LED Settings:
T01LEDL := N
T01_LED :=PWR_SRC1 # SUPPLY
T02LEDL := N
T02_LED :=BTFAIL # BATTERY PROBLEM
T03LEDL := Y
T03_LED :=PHASE_A # A FAULT
T04LEDL := Y
T04_LED :=PHASE_B # B FAULT
T05LEDL := Y
T05_LED :=PHASE_C # C FAULT
T06LEDL := Y
T06_LED :=51G1 # GROUND
T07LEDL := Y
T07_LED :=0 # SEF
T08LEDL := Y
T08_LED :=NOT (51G1S) AND 51G1T OR NOT (51PS) AND 51PT # FAST CURVE
T09LEDL := Y
T09_LED :=51G1S AND 51G1T OR 51PS AND 51PT # DELAY CURVE
T10LEDL := Y
T10_LED :=0 # HIGH CURRENT
T11LEDL := Y
T11_LED :=0 # FREQUENCY
T12LEDL := Y
T12_LED :=0 # VOLTAGE
T13LEDL := N
T13_LED :=79RS3P # 79 RESET
T14LEDL := N
T14_LED :=79CY3P # 79 CYCLE
T15LEDL := N
T15_LED :=79LO3P # 79 LOCKOUT
T16LEDL := N
T16_LED :=51P OR 51G1 # ABOVE MIN TRIP
T17LEDL := N
T17_LED :=0 # COLD LOAD SCHEME ON
T18LEDL := N
T18_LED :=0 # REVERSE POWER
T19LEDL := N
T19_LED :=59YA1 # VAY ON
T20LEDL := N
T20_LED :=59YB1 # VBY ON
T21LEDL := N
T21_LED :=59YC1 # VCY ON
T22LEDL := N
T22_LED :=0 # VAZ ON
T23LEDL := N
T23_LED :=0 # VBZ ON
T24LEDL := N
T24_LED :=0 # VCZ ON
```

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```
Display Point Settings:
DP01    :=1,"FACTORY DEFAULT"
DP02    :=1,"   SETTINGS"

=>
```

DP03 := SV02T,"YELLOW HANDLE",RESET,LOCK-OPEN
DP04 := SV03T,,"CABLE DISCONNECTED"
(Tavrida OSM)

Figure 9.29 Front-Panel Settings (SHO F) With Factory Default Values (Without Tricolor LED Option)

=>SHO F <Enter>

```
Front Panel Settings

General Settings:
EDP     := 2          ELB     := N        FP_TO   := 15       FP_CONT := 8
FPNGD   := IG         FPVYD   := ON       FPVZD   := OFF
LEDENAC := G          LEDTRAC := R        RSTLED  := Y

Operator Control LED Settings:
PB01LEDC:= AO
PB01_LED:=LT01 # GROUND ENABLED
PB02LEDC:= AO
PB02_LED:=LT02 # RECLOSE ENABLED
PB03LEDC:= AO
PB03_LED:=0 # REMOTE ENABLED
PB04LEDC:= AO
PB04_LED:=NOT (SG1) # ALT SETTINGS
PB05LEDC:= AO
PB05_LED:=LT04 # FAST CURVE ENABLED
PB06LEDC:= AO
PB06_LED:=NOT (LT05 AND NOT (SV01T AND PB06 AND NOT (SC01QU)) OR NOT (LT05) AND SV01T
    AND PB06 AND NOT (SC01QU)) # LOCK PUSH BUTTONS
PB07LEDC:= AO
PB07_LED:=NOT (LT06) # HOT LINE TAG
PB08LEDC:= AO
PB08_LED:=0 # AUX 1
PB09LEDC:= AO
PB09_LED:=0 # AUX 2
PB10LEDC:= AO
PB10_LED:=0 # AUX 3
PB11LEDC:= RO
PB11_LED:=52A3P # RECLOSER CLOSED
PB12LEDC:= GO
PB12_LED:=NOT (52A3P) # RECLOSER OPEN

Target LED Settings:
T01LEDL := N        T01LEDC := G
T01_LED :=PWR_SRC1 # SUPPLY
T02LEDL := N        T02LEDC := R
T02_LED :=BTFAIL # BATTERY PROBLEM
T03LEDL := Y        T03LEDC := R
T03_LED :=PHASE_A # A FAULT
T04LEDL := Y        T04LEDC := R
T04_LED :=PHASE_B # B FAULT
T05LEDL := Y        T05LEDC := R
T05_LED :=PHASE_C # C FAULT
T06LEDL := Y        T06LEDC := R
T06_LED :=51G1 # GROUND
T07LEDL := Y        T07LEDC := R
T07_LED :=0 # SEF
T08LEDL := Y        T08LEDC := R
T08_LED :=NOT (51G1S) AND 51G1T OR NOT (51PS) AND 51PT # FAST CURVE
T09LEDL := Y        T09LEDC := R
T09_LED :=51G1S AND 51G1T OR 51PS AND 51PT # DELAY CURVE
T10LEDL := Y        T10LEDC := R
T10_LED :=0 # HIGH CURRENT
T11LEDL := Y        T11LEDC := R
T11_LED :=0 # FREQUENCY
T12LEDL := Y        T12LEDC := R
T12_LED :=0 # VOLTAGE
T13LEDL := N        T13LEDC := G
T13_LED :=79RS3P # 79 RESET
T14LEDL := N        T14LEDC := R
T14_LED :=79CY3P # 79 CYCLE
T15LEDL := N        T15LEDC := R
T15_LED :=79LO3P # 79 LOCKOUT
T16LEDL := N        T16LEDC := R
T16_LED :=51P OR 51G1 # ABOVE MIN TRIP
T17LEDL := N        T17LEDC := R
T17_LED :=0 # COLD LOAD SCHEME ON
```

EDP := 4 (Tavrida OSM)

(Continued on next page)

```
                                            (Continued from previous page)
T18LEDL := N        T18LEDC := R
T18_LED :=0 # REVERSE POWER
T19LEDL := N        T19LEDC := R
T19_LED :=59YA1 # VAY ON
T20LEDL := N        T20LEDC := R
T20_LED :=59YB1 # VBY ON
T21LEDL := N        T21LEDC := R
T21_LED :=59YC1 # VCY ON
T22LEDL := N        T22LEDC := R
T22_LED :=0 # VAZ ON
T23LEDL := N        T23LEDC := R
T23_LED :=0 # VBZ ON
T24LEDL := N        T24LEDC := R
T24_LED :=0 # VCZ ON

Display Point Settings:
DP01    :=1,"FACTORY DEFAULT"
DP02    :=1,"   SETTINGS"

=>
```

DP03 := SV02T,"YELLOW HANDLE","RESET","LOCK-OPEN"
DP04 := SV03T,,"CABLE DISCONNECTED"
(Tavrida OSM)

Figure 9.30 Front-Panel Settings (SHO F) With Factory Default Values (With Tricolor LED Option)

```
=>SHO R <Enter>

Report Settings

Sequential Events Recorder Trigger Lists:
SER1    :=TRIP3P,51P,51PT,51G1,51G1T,PB12_PUL,OC3
SER2    :=CLOSE3P,52A3P,CF3P,79RS3P,79CY3P,79LO3P,RCSF3P,SH03P,SH13P,SH23P
SH33P,SH43P,PB11_PUL,CC3
SER3    :=PWR_SRC1,TOSLP,BTFAIL,DTFAIL
SER4    :=0

Event Report Settings:
LER     := 15       PRE     := 4
ER      :=R_TRIG 51P OR R_TRIG 51G1

Load Profile Settings:
LDLIST  :=0
LDAR    := 15

=>
```

Figure 9.31 Report Settings (SHO R) With Factory Default Values

```
=>SHO P <Enter>
Port 1

Port Settings

Protocol Selection
PROTO   := SEL

Communication Settings
SPEED   := 9600     BITS    := 8        PARITY  := N        STOP    := 1
RTSCTS  := N        T_OUT   := 15

SEL Protocol Settings
AUTO    := N        FASTOP  := N

=>
```

Figure 9.32 Port Settings (SHO P) With Factory Default Values

Settings Sheets

NOTE: If the ACSELERATOR QuickSet SEL-5030 settings editor is being used in conjunction with these settings sheets, some differences in setting order will be seen between the two formats, especially in the location of the enable settings. The Print option in ACSELERATOR QuickSet will list the settings in a similar order as these settings sheets.

The settings sheets that follow include the definition and input range for each setting in the SEL-651R. Many of the settings categories in the settings sheets include a reference to a page, table, or figure (in parentheses) that further explains the settings.

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SEL-651R Settings Sheets

Global Settings

(Serial Port Command SET G and Front Panel SET/SHOW Global Menu*)

* SELOGIC equations can be viewed, but not changed, via the front panel `Set/Show > Global Menu`.
For most applications, make Global settings (page *SET.1–SET.4*) before making the Group 1–6 settings.

General Settings

(See General Global Settings on page 9.27)

Nominal Frequency (50, 60 Hz)	**NFREQ**	:= ________
Phase Rotation (ABC, ACB)	**PHROT**	:= ________
Date Format (MDY, YMD, DMY)	**DATE_F**	:= ________

(See Battery System Monitor on page 8.34)

Power-Off Delay After AC Loss (OFF, 1–1440 min)	**PWRDN_AC**	:= ________
Power-Off Delay After Wake Up (OFF, 1–1440 min)	**PWRDN_WU**	:= ________

(See SELOGIC Control Equation Setting FAULT on page 5.13)

Request Battery Test SELOGIC Equation
TESTBATT := ____

Fault Condition SELOGIC Equation
FAULT := ____

Current and Voltage Connection Settings

(See Current and Voltage Connection Settings on page 9.28)

I1, I2, I3 Current Terminal Connections (ABC, ACB, BAC, BCA, CAB, CBA)	**IPCONN**	:= ________
Enable Ground Current Switch (Y, N)	**EGNDSW**	:= ________
Current Transformer Polarity (POS, NEG)	**CTPOL**	:= ________
Breaker Type (Single-Phase=1, Three-Phase=3)	**BKTYP**	:= ________
VY Voltage Terminal Connections (OFF, Combination of A, B, C) *Valid combinations: ABC, ACB, BAC, BCA, CAB, CBA, A, B, C, AB, BC, CA*	**VYCONN**	:= ________
VZ Voltage Terminal Connections (OFF, Combination of A, B, C) *Valid combinations: ABC, ACB, BAC, BCA, CAB, CBA, A, B, C, AB, BC, CA*	**VZCONN**	:= ________

Enable Phantom Voltage Source (OFF, VY, VZ) *Setting EPHANT is only available when one or both of VYCONN or VZCONN is set to single-phase voltages A, B, C, AB, BC, or CA.*	**EPHANT**	:=	________
Voltage Source Selection (OFF, VY, VZ) *Setting VSELECT is only available when one or both of VYCONN or VZCONN is set to three-phase combinations ABC, ACB, BAC, BCA, CAB, or CBA*	**VSELECT**	:=	________
Frequency Source Selection (OFF, VY, VZ) *Setting FSELECT is only available when one or both of VYCONN or VZCONN is not set to OFF*	**FSELECT**	:=	________

Global Enable Settings

(See Table 9.19)

Independent Control Input Settings (Y, N)	**EICIS**	:=	________
Breaker Monitor (Y, N)	**EBMON**	:=	________

Optoisolated Input Timers

(See Figure 7.18)

Make the following settings when the SEL-651R is ordered with extra input/outputs, and if preceding enable setting EICIS := Y.

Input IN101–IN107 Debounce Time Settings (0.00–2.00 cycles in 0.0625-cycle steps)	**IN101D**	:=	________
	IN102D	:=	________
	IN103D	:=	________
	IN104D	:=	________
	IN105D	:=	________
	IN106D	:=	________
	IN107D	:=	________

Status Input Timers

(See Figure 7.17)

Make the following settings when the preceding enable setting EICIS := Y.

Input IN201–IN206 Debounce Time (0.00–2.00 cycles in 0.0625-cycle steps)	**IN201D**	:=	________
	IN202D	:=	________
	IN203D	:=	________
	IN204D	:=	________
	IN205D	:=	________
	IN206D	:=	________

Settings Group Change Delay

(See Multiple Settings Groups on page 7.22)

Group Change Delay (0.00–16000.00 cycles in 0.25-cycle steps)	**TGR**	:=	________

Setting Group Selection SELOGIC Equations

(See Table 7.8)

Select Setting Group 1
SS1 := ____________________

Select Setting Group 2
SS2 := ____________________

Select Setting Group 3
SS3 := ____________________

Select Setting Group 4
SS4 := ____________________

Select Setting Group 5
SS5 := ____________________

Select Setting Group 6
SS6 := ____________________

Select Setting Group 7 (SEL-651R-1 only)
SS7 := ____________________

Select Setting Group 8 (SEL-651R-1 only)
SS8 := ____________________

Voltage Ratio Correction Factors for VY-Terminal Voltage Inputs

(See Voltage Ratio Correction Factors for VY- and VZ-Terminal Voltage Inputs on page 9.34)

Make the following settings when the SEL-651R is ordered with LEA ac inputs on the VY terminals.

Ratio Correction Factor (0.500–1.500) **V1YRCF** := ________

Ratio Correction Factor (0.500–1.500) **V2YRCF** := ________

Ratio Correction Factor (0.500–1.500) **V3YRCF** := ________

Voltage Ratio Correction Factors for VZ-Terminal Voltage Inputs

(See Voltage Ratio Correction Factors for VY- and VZ-Terminal Voltage Inputs on page 9.34)

Make the following settings when the SEL-651R is ordered with LEA ac inputs on the VZ terminals.

Ratio Correction Factor (0.500–1.500) **V1ZRCF** := ________

Ratio Correction Factor (0.500–1.500) **V2ZRCF** := ________

Ratio Correction Factor (0.500–1.500) **V3ZRCF** := ________

Voltage Phase Angle Correction for VY Terminals

(See Voltage Phase Angle Correction Settings for VY-Terminal Voltage Inputs on page 9.36)

Make the following settings when the SEL-651R is ordered with Kyle/Cooper NOVA LEA or Lindsey SVMI LEA ac inputs on the VY terminals.

Phase Angle Correction (–10.0–0 degrees)	**V1YPAC**	:= ________
Phase Angle Correction (–10.0–0 degrees)	**V2YPAC**	:= ________
Phase Angle Correction (–10.0–0 degrees)	**V3YPAC**	:= ________

Voltage Phase Angle Correction for VZ Terminals

(See Voltage Phase Angle Correction Settings for VZ-Terminal Voltage Inputs on page 9.37)

Make the following settings when the SEL-651R is ordered with Lindsey SVMI LEA or Siemens LEA ac inputs on the VZ terminals.

Phase Angle Correction (–10.0–0 degrees)	**V1ZPAC**	:= ________
Phase Angle Correction (–10.0–0 degrees)	**V2ZPAC**	:= ________
Phase Angle Correction (–10.0–0 degrees)	**V3ZPAC**	:= ________

Breaker Monitor Settings

(See Breaker Monitor Setting Example on page 8.22)

Make the following settings if preceding enable setting EBMON := Y.

Close/Open Set Point 1—Max. (0–65000 operations)	**COSP1**	:= ________
Close/Open Set Point 2—Mid. (0–65000 operations)	**COSP2**	:= ________
Close/Open Set Point 3—Min. (0–65000 operations)	**COSP3**	:= ________
kA Interrupted Set Point 1—Min. (0.00–999.00 kA primary in 0.01 kA steps)	**KASP1**	:= ________
kA Interrupted Set Point 2—Mid. (0.00–999.00 kA primary in 0.01 kA steps)	**KASP2**	:= ________
kA Interrupted Set Point 3—Max. (0.00–999.00 kA primary in 0.01 kA steps)	**KASP3**	:= ________

NOTES:

- ➤ COSP1 must be set greater than COSP2.
- ➤ COSP2 must be set greater than or equal to COSP3.
- ➤ KASP1 must be set less than KASP2.
- ➤ If COSP2 is set the same as COSP3, then KASP2 must be set the same as KASP3.
- ➤ KASP3 must be set at least 5 times (but no more than 100 times) the KASP1 setting value.
- ➤ KASP2 must be set less than or equal to KASP3.

Breaker Monitor Initiate SELOGIC Equations

(See Breaker/Recloser Contact Wear Monitor on page 8.19)

Make setting BKMON3P when setting BKTYP := 3.

BKMON3P := ______________________________

Make settings BKMONA, BKMONB, and BKMONC when setting BKTYP := 1.

BKMONA := ______________________________

BKMONB := ______________________________

BKMONC := ______________________________

Data Reset Control

(See Programmable Front-Panel Target LEDs on page 5.11)

Target Reset SELOGIC Equation

RSTTRGT := ______________________________

Group Settings

(Serial Port Command SET n [a] and Front Panel Set/Show Group menu[b])

[a] Where *n* = Group 1–6; defaults to active group.
[b] SELOGIC equations can be viewed, but not changed, via the front-panel SET/SHOW Group Menu.

Identifier Labels

(See Identifier Labels on page 9.39)

Relay Identifier (30 characters) (0–9, A–Z, -, /, ., space)

RID := ______________________________

Terminal Identifier (30 characters) (0–9, A–Z, -, /, ., space)

TID := ______________________________

Current and Potential Transformer Ratios

(See Current Transformer (CT) Ratios on page 9.39)

Phase (IA, IB, IC) Current Transformer Ratio (1.0–6000.0) **CTR** := ________

Neutral (IN) Current Transformer Ratio (1.0–6000.0) **CTRN** := ________

VY-Side (V1Y, V2Y, V3Y) Potential Transformer Ratio (1.00–10000.00) **PTRY** := ________

For LEA inputs, see Potential Transformer (PT) Ratios on page 9.40 for PTRY setting calculation.

VZ-Side (V1Z, V2Z, V3Z) Potential Transformer Ratio (1.00–10000.00) **PTRZ** := ________

Nominal Voltage (line-to-neutral) on VSELECT-designated side (25.00-300.00 V secondary) (*When VSELECT := OFF, VNOM* is hidden) **VNOM** := ________

See Table 9.18 for proper VNOM setting adjustment when 8 V LEA inputs are used.

Enable Settings

(See Breaker/Recloser Type Setting (BKTYP) and Enable Single-Phase Breaker Setting (ESPB) on page 9.30)

Make ESPB setting when global setting BKTYP := 1.

Single Phase Breaker Settings (Y, N) *When BKTYP := 3, ESPB := N*	**ESPB**	:= ________

Instantaneous/Definite-Time Overcurrent Enable Settings

Phase Element Levels (N, 1–6) (see *Figure 4.1* through *Figure 4.7*)	**E50P**	:= ________

Make E50N setting when global setting EGNDSW is set to N. Setting E50N cannot be changed when EGNDSW := Y.

Neutral Element Levels—Channel IN (N, 1–6) (see *Figure 4.10* and *Figure 4.11*)	**E50N**	:= ________
Ground Element Levels (N, 1–6) (see *Figure 4.12* and *Figure 4.13*)	**E50G**	:= ________
Negative-Sequence Element Levels (N, 1–6) (see *Figure 4.14* and *Figure 4.15*)	**E50Q**	:= ________

Time-Overcurrent Enable Settings

(See Table 4.1)

Maximum-Phase Elements (N, 1, 2)	**E51P**	:= ________
Single-Phase Elements (N, 1, 2)	**E51ABC**	:= ________
Ground #1 Elements (N, 1, 2)	**E51G1**	:= ________
Ground #2 Elements (N, 1, 2)	**E51G2**	:= ________
Negative-Sequence Elements (N, 1, 2)	**E51Q**	:= ________

Other Enable Settings

Load Encroachment (Y, N) (*When VSELECT := OFF, ELOAD := N*; see *Figure 4.43*)	**ELOAD**	:= ________
Directional Elements (Y, AUTO, N) (*When VSELECT := OFF, E32 := N*; see *Figure 4.46* through *Figure 4.56*)	**E32**	:= ________
Voltage Elements (Y, N) (see *Figure 4.23* through *Figure 4.26*)	**EVOLT**	:= ________
Frequency Elements (N, 1–6) (*When FSELECT := OFF, E81 := N*; see *Figure 4.34*)	**E81**	:= ________
Fault Location (Y, N) (*When VSELECT = OFF, EFLOC := N*; see *Fault Location on page 12.5*)	**EFLOC**	:= ________
Loss-of-Potential (Y, Y1, N) (*When VSELECT = OFF, EFLOP := N*; see *Figure 4.45*)	**ELOP**	:= ________

Power Element Levels (N, 3P1–3P4) (*When VSELECT = OFF, EPWR := N*; see *Power Elements on page 4.53*)	**EPWR**	:= ________
Synchronism Check (Y, N) (*When FSELECT = OFF, E25 := N*; see *Figure 4.27* and *Figure 4.28*)	**E25**	:= ________
Reclosures (N, 1– 4) (see *Reclosing Relay on page 6.17*)	**E79**	:= ________
Switch-Onto-Fault (Y, N) (see *Figure 5.6*)	**ESOTF**	:= ________
Demand Metering (THM = Thermal, ROL = Rolling) (see *Figure 8.4*)	**EDEM**	:= ________
Voltage Sag/Swell/Interruption (Y, N) (see *Figure 4.35*, *Figure 4.36*, and *Figure 4.37*)	**ESSI**	:= ________
Math Variable Settings (N, 1–32) (see *Analog Comparators and Checks on page 7.6*)	**EMV**	:= ________

Line Parameter Settings

(See Impedance Settings Conversions on page 9.47 and Line Length Setting on page 9.46)

Make line parameter settings when global setting VSELECT ≠ OFF.

Positive-Sequence Line Impedance Magnitude (0.50–2550.00 Ω secondary)	**Z1MAG**	:= ________
Positive-Sequence Line Impedance Angle (5.00–90.00 degrees)	**Z1ANG**	:= ________
Zero-Sequence Line Impedance Magnitude (0.50–2550.00 Ω secondary)	**Z0MAG**	:= ________
Zero-Sequence Line Impedance Angle (5.00–90.00 degrees)	**Z0ANG**	:= ________
Line Length (0.10–999.00, unitless)	**LL**	:= ________

Phase Instantaneous/Definite-Time Overcurrent Elements

(See Figure 4.1 and Figure 4.2)

Number of phase element pickup settings dependent on preceding enable setting E50P := 1–6.

Pickup (OFF, 0.05–20.00 A)	**50P1P**	:= ________
	50P2P	:= ________
	50P3P	:= ________
	50P4P	:= ________
	50P5P	:= ________
	50P6P	:= ________

Phase Definite-Time Overcurrent Elements

(See Figure 4.3 through Figure 4.6)

Number of phase element time delay settings dependent on preceding enable setting E50P = 1–6; all four time delay settings are enabled if E50P ≥ 4.

Time Delay (0.00–16000.00 cycles in 0.25-cycle steps) **50P1D** := ________

50P2D := ________

50P3D := ________

50P4D := ________

Phase Definite-Time Overcurrent Element Torque Control SELOGIC Equations

(See Figure 4.3 through Figure 4.6)

Number of levels of phase element torque control settings dependent on preceding enable setting E50P := 1–6; all four levels of torque control settings are enabled if E50P > 4.

Torque control equations cannot be set directly to logical 0 or NA.

Level 1—Maximum Phase

50P1TC := ____

Level 1—A-Phase

50A1TC := ____

Level 1—B-Phase

50B1TC := ____

Level 1—C-Phase

50C1TC := ____

Level 2—Maximum Phase

50P2TC := ____

Level 2—A-Phase

50A2TC := ____

Level 2—B-Phase

50B2TC := ____

Level 2—C-Phase

50C2TC := ____

Level 3—Maximum Phase

50P3TC := ____

Level 3—A-Phase

50A3TC := ____

Level 3—B-Phase

50B3TC := ____

Level 3—C-Phase

50C3TC := ____

Level 4—Maximum Phase
50P4TC := ______________________________

Level 4—A-Phase
50A4TC := ______________________________

Level 4—B-Phase
50B4TC := ______________________________

Level 4—C-Phase
50C4TC := ______________________________

Neutral Instantaneous/Definite-Time Overcurrent Elements—Channel IN

(See Figure 4.10 and Figure 4.11)

Number of neutral element pickup settings dependent on preceding enable setting E50N := 1–6.

Pickup (OFF, 0.005–2.500 A)	**50N1P**	:= ________
	50N2P	:= ________
	50N3P	:= ________
	50N4P	:= ________
	50N5P	:= ________
	50N6P	:= ________

Neutral Definite-Time Overcurrent Elements

(See Figure 4.10)

Number of neutral element time delay settings dependent on preceding enable setting E50N := 1–6; all four time delay settings are enabled if E50N ≥ 4.

Time Delay (0.00–16000.00 cycles in 0.25-cycle steps)	**50N1D**	:= ________
	50N2D	:= ________
	50N3D	:= ________
	50N4D	:= ________

Neutral Definite-Time Overcurrent Element Torque Control SELOGIC Equations

(See Figure 4.10)

Number of neutral element torque control settings dependent on preceding enable setting E50N := 1–6; all four torque control settings are enabled if E50N > 4.

Torque control equations cannot be set directly to logical 0 or NA.

Level 1
50N1TC := ______________________________

Level 2
50N2TC := ______________________________

Level 3
50N3TC := ______________________________

Level 4
50N4TC := ______________________________

Ground Instantaneous/Definite-Time Overcurrent Elements

(See Figure 4.12 and Figure 4.13)

Number of ground element pickup settings dependent on preceding enable setting E50G := 1–6.

Pickup OFF, 0.005–20.000 A on channel IN base (see Note), when global setting EGNDSW := Y and relay setting CTR = CTRN 0.005 – [20 • (CTR/CTRN)] A on channel IN base, when global setting EGNDSW := Y and relay setting CTR ≠ CTRN 0.010–20.000 A on IA, IB, IC base, when global setting EGNDSW := N	**50G1P** **50G2P** **50G3P** **50G4P** **50G5P** **50G6P**	:= ________ := ________ := ________ := ________ := ________ := ________

NOTE: In the case where EGNDSW := Y and CTR = CTRN, there is no difference between the IN current base and the IA, IB, IC current base. This is the standard configuration for the SEL-651R, because the factory wiring includes a wired residual connection to the IN channel.

Ground Definite-Time Overcurrent Elements

(See Figure 4.12)

Number of ground element time delay settings dependent on preceding enable setting E50G := 1–6; all four time delay settings are enabled if E50G ≥ 4.

Time Delay (0.00–16000.00 cycles in 0.25-cycle steps)	**50G1D**	:= ________
	50G2D	:= ________
	50G3D	:= ________
	50G4D	:= ________

Ground Definite-Time Overcurrent Element Torque Control SELOGIC Equations

(See Figure 4.12)

Number of ground element torque control settings dependent on preceding enable setting E50G := 1–6; all four torque control settings are enabled if E50G > 4.

Torque control equations cannot be set directly to logical 0 or NA.

Level 1

50G1TC := ________________________________

Level 2

50G2TC := ________________________________

Level 3

50G3TC := ________________________________

Level 4

50G4TC := ________________________________

Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements

(See Figure 4.14 and Figure 4.15)*

Number of negative-sequence element time delay settings dependent on preceding enable setting E50Q := 1–6.

* IMPORTANT: See Setting Negative-Sequence Time-Overcurrent Elements on page 4.88 for information.

Pickup (OFF, 0.05–20.00 A)	**50Q1P**	:= ________
	50Q2P	:= ________
	50Q3P	:= ________
	50Q4P	:= ________
	50Q5P	:= ________
	50Q6P	:= ________

Negative-Sequence Definite-Time Overcurrent Elements

(See Figure 4.14)*

Number of negative-sequence element time delay settings dependent on preceding enable setting E50Q := 1–6; all four time delay settings are enabled if E50Q ≥ 4.

* IMPORTANT: See Setting Negative-Sequence Time-Overcurrent Elements on page 4.88 for information.

Time Delay (0.00–16000.00 cycles in 0.25-cycle steps)	**50Q1D**	:= ________
	50Q2D	:= ________
	50Q3D	:= ________
	50Q4D	:= ________

Negative-Sequence Definite-Time Overcurrent Element Torque Control SELogic Equations

(See Figure 4.14)

Number of negative-sequence element torque control settings dependent on preceding enable setting E50Q := 1–6; all four torque control settings are enabled if E50Q > 4.

Torque control equations cannot be set directly to logical 0 or NA.

Level 1
50Q1TC := ______________________________

Level 2
50Q2TC := ______________________________

Level 3
50Q3TC := ______________________________

Level 4
50Q4TC := ______________________________

Maximum-Phase Time-Overcurrent Element J

(See Figure 4.16)

Make the following settings if preceding enable setting E51P := 1 or 2.

Pickup (OFF, 0.10–3.20 A)	**51PJP**	:= ________
Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51PJC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51PJTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51PJRS**	:= ________
Constant Time Adder (0.00–60.00 cycles)	**51PJCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51PJMR**	:= ________

Maximum-Phase Time-Overcurrent Element K

(See Figure 4.16)

Make the following settings if preceding enable setting E51P := 2.

Pickup (OFF, 0.10–3.20 A)	**51PKP**	:= ________
Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51PKC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51PKTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51PKRS**	:= ________
Constant time adder (0.00–60.00 cycles)	**51PKCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51PKMR**	:= ________

Maximum-Phase Time-Overcurrent Element SELOGIC Settings

(See Figure 4.16)

Make 51PTC setting when preceding enable setting E51P := 1 or 2.

51P Torque Control (SELOGIC Equation)
Cannot be set directly to logical 0 or NA

51PTC := ____

Make 51PSW setting when preceding enable setting E51P := 2.

51P J/K Selection (SELOGIC Equation)
Cannot be set to NA

51PSW := ____

A-Phase Time-Overcurrent Element J

(See Figure 4.17)

Make the following settings if preceding enable setting E51ABC := 1 or 2.

Pickup (OFF, 0.10–3.20 A)	**51AJP**	:= ________
Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51AJC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51AJTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51AJRS**	:= ________
Constant Time Adder (0.00–60.00 cycles)	**51AJCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51AJMR**	:= ________

A-Phase Time-Overcurrent Element K

(See Figure 4.17)

Make the following settings if preceding enable setting E51ABC := 2.

Pickup (OFF, 0.10–3.20 A)	**51AKP**	:= ________
Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51AKC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51AKTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51AKRS**	:= ________
Constant time adder (0.00–60.00 cycles)	**51AKCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51AKMR**	:= ________

A-Phase Time-Overcurrent Element SELOGIC Settings

(See Figure 4.17)

Make 51ATC setting when preceding enable setting E51ABC := 1 or 2.

51A Torque Control (SELOGIC Equation)
Cannot be set directly to logical 0 or NA

51ATC := ____

Make 51ASW setting when preceding enable setting E51ABC := 2.

51A J/K Selection (SELOGIC Equation)
Cannot be set to NA

51ASW := ____

B-Phase Time-Overcurrent Element J

(See Figure 4.18)

Make the following settings if preceding enable setting E51ABC := 1 or 2.

Pickup (OFF, 0.10–3.20 A)	**51BJP**	:= ________
Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51BJC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51BJTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51BJRS**	:= ________
Constant Time Adder (0.00–60.00 cycles)	**51BJCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51BJMR**	:= ________

B-Phase Time-Overcurrent Element K

(See Figure 4.18)

Make the following settings if preceding enable setting E51ABC := 2.

Pickup (OFF, 0.10–3.20 A)	**51BKP**	:= ________
Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51BKC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51BKTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51BKRS**	:= ________
Constant Time Adder (0.00–60.00 cycles)	**51BKCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51BKMR**	:= ________

B-Phase Time-Overcurrent Element SELogic Settings

(See Figure 4.18)

Make 51BTC setting when preceding enable setting E51ABC := 1 or 2.

51B Torque Control (SELogic Equation)
Cannot be set directly to logical 0 or NA

51BTC := ____

Make 51BSW setting when preceding enable setting E51ABC := 2.

51B J/K Selection (SELogic Equation)
Cannot be set to NA

51BSW := ____

C-Phase Time-Overcurrent Element J

(See Figure 4.19)

Make the following settings if preceding enable setting E51ABC := 1 or 2.

Pickup (OFF, 0.10–3.20 A)	**51CJP**	:= ________
Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51CJC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51CJTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51CJRS**	:= ________
Constant time adder (0.00–60.00 cycles)	**51CJCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51CJMR**	:= ________

C-Phase Time-Overcurrent Element K

(See Figure 4.19)

Make the following settings if preceding enable setting E51ABC := 2.

Pickup (OFF, 0.10–3.20 A)	**51CKP**	:= ________
Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51CKC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51CKTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51CKRS**	:= ________
Constant Time Adder (0.00–60.00 cycles)	**51CKCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51CKMR**	:= ________

C-Phase Time-Overcurrent Element SELOGIC Settings

(See Figure 4.19)

Make 51CPTC setting when preceding enable setting E51ABC := 1 or 2.

51C Torque Control (SELOGIC Equation)
Cannot be set directly to logical 0 or NA

51CTC := ____

Make 51CSW setting when preceding enable setting E51ABC := 2.

51C J/K Selection (SELOGIC Equation)
Cannot be set to NA

51CSW := ____

Ground Time-Overcurrent Element #1—J

(See Figure 4.20)

Make the following settings if preceding enable setting E51G1 := 1 or 2.

Pickup	**51G1JP**	:= ________

OFF, 0.005–3.200 A
on channel IN base (see Note), when global setting EGNDSW := Y and relay setting CTR = CTRN

OFF, 0.005–[3.2 • (CTR/CTRN)] A
on channel IN base, when global setting EGNDSW := Y and relay setting CTR ≠ CTRN

OFF, 0.020–3.200 A
on IA, IB, IC base, when global setting EGNDSW := N

NOTE: In the case where EGNDSW := Y and CTR = CTRN, there is no difference between the IN current base and the IA, IB, IC current base. This is the standard configuration for the SEL-651R, because the factory wiring includes a wired residual connection to the IN channel.

Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51G1JC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51G1JTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51G1JRS**	:= ________
Constant Time Adder (0.00–60.00 cycles)	**51G1JCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51G1JMR**	:= ________

Ground Time-Overcurrent Element #1—K

(See Figure 4.20)

Make the following settings if preceding enable setting E51G1 := 2.

Pickup	**51G1KP**	:= ________

OFF, 0.005–3.200 A
on channel IN base (see Note), when global setting EGNDSW := Y and relay setting CTR = CTRN

OFF, 0.005–[3.2 • (CTR/CTRN)] A
on channel IN base, when global setting EGNDSW := Y and relay setting CTR ≠ CTRN

OFF, 0.020–3.200 A
on IA, IB, IC base, when global setting EGNDSW := N

NOTE: In the case where EGNDSW := Y and CTR = CTRN, there is no difference between the IN current base and the IA, IB, IC current base. This is the standard configuration for the SEL-651R, because the factory wiring includes a wired residual connection to the IN channel.

Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51G1KC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51G1KTD**	:= ________

Electromechanical Reset (Y, N) **51G1KRS** := ________
Applicable only to curves U1–U5, C1–C5

Constant Time Adder (0.00–60.00 cycles) **51G1KCT** := ________

Minimum Response (0.00–60.00 cycles) **51G1KMR** := ________

Ground Time-Overcurrent Element #1 SELOGIC Settings

(See Figure 4.20)

Make 51G1TC setting when preceding enable setting E51G1 := 1 or 2.

51G1 Torque Control (SELOGIC Equation)
Cannot be set directly to logical 0 or NA

51G1TC := ____

Make 51G1SW setting when preceding enable setting E51G1 := 2.

51G1 J/K Selection (SELOGIC Equation)
Cannot be set to NA

51G1SW := ____

Ground Time-Overcurrent Element #2—J

(See Figure 4.21)

Make the following settings if preceding enable setting E51G2 := 1 or 2.

Pickup **51G2JP** := ________

OFF, 0.005–3.200 A
on channel IN base (see Note), when global setting
EGNDSW := Y and relay setting CTR = CTRN

OFF, 0.005 – [3.2 • (CTR/CTRN)] A
on channel IN base, when global setting EGNDSW := Y and
relay setting CTR ≠ CTRN

OFF, 0.020–3.200 A
on IA, IB, IC base, when global setting EGNDSW := N

NOTE: In the case where EGNDSW := Y and CTR = CTRN, there is no difference between the IN current base and the IA, IB, IC current base. This is the standard configuration for the SEL-651R, because the factory wiring includes a wired residual connection to the IN channel.

Curve (U1–U5, C1–C5, recloser curves) **51G2JC** := ________
See *Figure 9.1* through *Figure 9.20*

Time-Dial **51G2JTD** := ________
0.50–15.00 for curves U1–U5
0.05–1.00 for curves C1–C5
0.10–2.00 for recloser curves

Electromechanical Reset (Y, N) **51G2JRS** := ________
Applicable only to curves U1–U5, C1–C5

Constant Time Adder (0.00–60.00 cycles) **51G2JCT** := ________

Minimum Response (0.00–60.00 cycles) **51G2JMR** := ________

Ground Time-Overcurrent Element #2-K

(See Figure 4.21)

Make the following settings if preceding enable setting E51G2 := 2.

Pickup **51G2KP** := ________

OFF, 0.005–3.200 A
on channel IN base (see Note), when global setting EGNDSW := Y and relay setting CTR = CTRN

OFF, 0.005–[3.2 • (CTR/CTRN)] A
on channel IN base, when global setting EGNDSW := Y and relay setting CTR ≠ CTRN

OFF, 0.020–3.200 A
on IA, IB, IC base, when global setting EGNDSW := N

NOTE: In the case where EGNDSW := Y and CTR = CTRN, there is no difference between the IN current base and the IA, IB, IC current base. This is the standard configuration for the SEL-651R, because the factory wiring includes a wired residual connection to the IN channel.

Curve (U1–U5, C1–C5, recloser curves) **51G2KC** := ________
See *Figure 9.1* through *Figure 9.20*

Time-Dial **51G2KTD** := ________
0.50–15.00 for curves U1–U5
0.05–1.00 for curves C1–C5
0.10–2.00 for recloser curves

Electromechanical Reset (Y, N) **51G2KRS** := ________
Applicable only to curves U1–U5, C1–C5

Constant Time Adder (0.00–60.00 cycles) **51G2KCT** := ________

Minimum Response (0.00–60.00 cycles) **51G2KMR** := ________

Ground Time-Overcurrent Element #2 SELogic Settings

(See Figure 4.21)

Make 51G2TC setting when preceding enable setting E51G2 := 1 or 2.

51G2 Torque Control (SELogic Equation)
Cannot be set directly to logical 0 or NA

51G2TC := ____

Make 51G2SW setting when preceding enable setting E51G2 := 2.

51G2 J/K Selection (SELogic Equation)
Cannot be set to NA

51G2SW := ____

Negative-Sequence Time-Overcurrent Element J

(See Figure 4.22)[1]

Make the following settings if preceding enable setting E51Q := 1 or 2.

Pickup (OFF, 0.10–3.20 A)	**51QJP**	:= ________
Curve (U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51QJC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51QJTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51QJRS**	:= ________
Constant Time Adder (0.00–60.00 cycles)	**51QJCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51QJMR**	:= ________

Negative-Sequence Time-Overcurrent Element K

(See Figure 4.22)[1]

Make the following settings if preceding enable setting E51Q := 2.

Pickup (OFF, 0.10–3.20 A)	**51QKP**	:= ________
Curve U1–U5, C1–C5, recloser curves) See *Figure 9.1* through *Figure 9.20*	**51QKC**	:= ________
Time-Dial 0.50–15.00 for curves U1–U5 0.05–1.00 for curves C1–C5 0.10–2.00 for recloser curves	**51QKTD**	:= ________
Electromechanical Reset (Y, N) *Applicable only to curves U1–U5, C1–C5*	**51QKRS**	:= ________
Constant Time Adder (0.00–60.00 cycles)	**51QKCT**	:= ________
Minimum Response (0.00–60.00 cycles)	**51QKMR**	:= ________

Negative-Sequence Time-Overcurrent SELOGIC Settings

(See Figure 4.22)

Make 51QTC setting when preceding enable setting E51Q := 1 or 2.

51Q Torque Control (SELOGIC Equation)
Cannot be set directly to logical 0 or NA

51QTC := ____

Make 51QSW setting when preceding enable setting E51Q := 2.

51Q J/K Selection (SELOGIC Equation)
Cannot be set to NA

51QSW := ____

[1] IMPORTANT: See Setting Negative-Sequence Time-Overcurrent Elements on page 4.88 for information on setting negative-sequence overcurrent elements.

 Date ____________

Load-Encroachment Elements

(See Figure 4.43)

Make the following settings if preceding enable setting ELOAD := Y.

Forward Load Impedance (0.50–640.00 Ω secondary) (see *Impedance Settings Conversions on page 9.47*)	**ZLF**	:= ________
Reverse Load Impedance (0.50–640.00 Ω secondary) (see *Impedance Settings Conversions on page 9.47*)	**ZLR**	:= ________
Positive Forward Load Angle (–90.00° to +90.00°)	**PLAF**	:= ________
Negative Forward Load Angle (–90.00° to +90.00°)	**NLAF**	:= ________
Positive Reverse Load Angle (+90.00° to +270.00°)	**PLAR**	:= ________
Negative Reverse Load Angle (+90.00° to +270.00°)	**NLAR**	:= ________

Directional Elements

(See Figure 4.46 through Figure 4.56)

Make the following settings if preceding enable setting E32 := Y or AUTO.

Ground directional element priority (combination of Q and V, or OFF)	**ORDER**	:= ________
Three-phase threshold for phase directional element (0.10–2.00 A secondary) (*When ELOAD:= OFF, 50P32P is hidden*; see *Figure 4.55*)	**50P32P**	:= ________

If E32 := AUTO, following settings Z2F, Z2R, 50QFP, 50QRP, a2 and k2 are made automatically—see Directional Control Settings on page 4.78.

Forward directional Z2 threshold (–640.00 to +640.00 Ω secondary)	**Z2F**	:= ________
Reverse directional Z2 threshold (–640.00 to +640.00 Ω secondary)	**Z2R**	:= ________
Forward directional negative-sequence current pickup (0.05–1.00 A secondary)	**50QFP**	:= ________
Reverse directional negative-sequence current pickup (0.05–1.00 A secondary)	**50QRP**	:= ________
Positive-sequence current restraint factor, I_2/I_1 (0.02–0.50, unitless)	**a2**	:= ________
Zero-sequence current restraint factor, I_2/I_0 (0.02–0.50, unitless)	**k2**	:= ________

If setting ORDER does not contain V, then following settings 50GFP, 50GRP, a0G, Z0F, Z0R, and E32IV are hidden. If E32 := AUTO, then following settings 50GFP, 50GRP, a0G, Z0F, and Z0R are made automatically—see Directional Control Settings on page 4.78.

Forward directional ground current pickup	**50GFP**	:= ________
Reverse directional ground current pickup	**50GRP**	:= ________

0.005–1.00 A secondary
on channel IN base, when global setting EGNDSW:= Y and group setting CTR = CTRN

0.005– [1.00 • (CTR/CTRN)] A secondary
on channel IN base, when global setting EGNDSW:= Y and group setting CTR ≠ CTRN

0.010–1.00 A secondary
on IA, IB, IC base, when global setting EGNDSW := N

Positive-sequence current restraint factor, I_0/I_1 (0.001–0.500, unitless)	**a0G**	:= ________
Forward directional Z0 threshold (–640.00 to +640.00 Ω secondary)	**Z0F**	:= ________
Reverse directional Z0 threshold (–640.00 to +640.00 Ω secondary)	**Z0R**	:= ________
Enable for zero-sequence voltage-polarized directional elements (SELOGIC Equation)	**E32IV**	:= ________

VY-Terminal Voltage Elements

(See Figure 4.23 and Figure 4.24)

Make the following settings if preceding enable setting EVOLT := VY or BOTH.

See Table 9.18 and accompanying text for proper VY-terminal voltage elements settings adjustments when LEA inputs are used.

Phase Undervoltage Pickup (OFF, 1.00–300.00 V secondary)	**27YP1P**	:= ________
Phase Undervoltage Pickup (OFF, 1.00–300.00 V secondary)	**27YP2P**	:= ________
Phase-to-Phase Undervoltage Pickup (OFF, 1.76–520.00 V secondary)	**27YPP1P**	:= ________
Phase Overvoltage Pickup (OFF, 1.00–300.00 V secondary)	**59YP1P**	:= ________
Phase Overvoltage (OFF, 1.00–300.00 V secondary)	**59YP2P**	:= ________
Phase-to-Phase Overvoltage Pickup (OFF, 1.76–520.00 V secondary)	**59YPP1P**	:= ________
Zero-Sequence (3V0) Overvoltage Pickup (OFF, 2.00–300.00 V secondary)	**59YN1P**	:= ________
Zero-Sequence (3V0) Overvoltage Pickup (OFF, 2.00–300.00 V secondary)	**59YN2P**	:= ________
Negative-Sequence (V2) Overvoltage Pickup (OFF, 2.00–300.00 V secondary)	**59YQ1P**	:= ________
Positive-Sequence (V1) Overvoltage Pickup (OFF, 2.00–300.00 V secondary)	**59YV1P**	:= ________

VZ-Terminal Voltage Elements

(See Figure 4.25 and Figure 4.26)

Make the following settings if preceding enable setting EVOLT := VZ or BOTH.

See Table 9.18 and accompanying text for proper VZ-terminal voltage elements settings adjustments when LEA inputs are used.

Phase Undervoltage Pickup (OFF, 1.00–300.00 V secondary)	**27ZP1P**	:= ________
Phase Undervoltage Pickup (OFF, 1.00–300.00 V secondary)	**27ZP2P**	:= ________
Phase-to-Phase Undervoltage Pickup (OFF, 1.76–520.00 V secondary)	**27ZPP1P**	:= ________
Phase Overvoltage Pickup (OFF, 1.00–300.00 V secondary)	**59ZP1P**	:= ________
Phase Overvoltage (OFF, 1.00–300.00 V secondary)	**59ZP2P**	:= ________
Phase-to-Phase Overvoltage Pickup (OFF, 1.76–520.00 V secondary)	**59ZPP1P**	:= ________
Zero-Sequence (3V0) Overvoltage Pickup (OFF, 2.00–300.00 V secondary)	**59ZN1P**	:= ________
Zero-Sequence (3V0) Overvoltage Pickup (OFF, 2.00–300.00 V secondary)	**59ZN2P**	:= ________
Negative-Sequence (V2) Overvoltage Pickup (OFF, 2.00–300.00 V secondary)	**59ZQ1P**	:= ________
Positive-Sequence (V1) Overvoltage Pickup (OFF, 2.00–300.00 V secondary)	**59ZV1P**	:= ________

Frequency Elements

(See Figure 4.30 through Figure 4.34)

Number of frequency element settings dependent on preceding enable setting E81 := 1–6.

Phase Undervoltage Block (12.50–300.00 V secondary)	**27B81P**	:= ________

See Table 9.18 for possible 27B81P setting adjustment when 8 V LEA inputs are used.

Level 1 Pickup (OFF, 40.00–65.00 Hz)	**81D1P**	:= ________
Level 1 Time Delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D1D**	:= ________
Level 2 Pickup (OFF, 40.00–65.00 Hz)	**81D2P**	:= ________
Level 2 Time Delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D2D**	:= ________
Level 3 Pickup (OFF, 40.00–65.00 Hz)	**81D3P**	:= ________
Level 3 Time Delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D3D**	:= ________
Level 4 Pickup (OFF, 40.00–65.00 Hz)	**81D4P**	:= ________
Level 4 Time Delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D4D**	:= ________
Level 5 Pickup (OFF, 40.00–65.00 Hz)	**81D5P**	:= ________
Level 5 Time Delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D5D**	:= ________

Level 6 Pickup (OFF, 40.00–65.00 Hz)	**81D6P**	:= ________
Level 6 Time Delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D6D**	:= ________

Power Elements

(See Figure 4.39)

Number of power element settings dependent on preceding enable setting EPWR := 3P1O–3P4.

See Table 9.18 for possible 3PWR1P, 3PWR2P, 3PWR3P, and 3PWR4P settings adjustments when LEA inputs are used.

Make settings 3PWR1P, PWR1T, and PWR1D if EPWR := 3P1–3P4.

Three-Phase Power Element Pickup (OFF, 1.20–7800.00 VA secondary three-phase)	**3PWR1P**	:= ________
Power Element Type (+WATTS, –WATTS, +VARS, –VARS)	**PWR1T**	:= ________
Power Element Time Delay (0.00–16000.00 cycles)	**PWR1D**	:= ________

Make settings 3PWR2P, PWR2T, and PWR2D if EPWR := 3P2–3P4.

Three-Phase Power Element Pickup (OFF, 1.20–7800.00 VA secondary three-phase)	**3PWR2P**	:= ________
Power Element Type (+WATTS, –WATTS, +VARS, –VARS)	**PWR2T**	:= ________
Power Element Time Delay (0.00–16000.00 cycles)	**PWR2D**	:= ________

Make settings 3PWR3P, PWR3T, and PWR3D if EPWR := 3P3–3P4.

Three-Phase Power Element Pickup (OFF, 1.20–7800.00 VA secondary three-phase)	**3PWR3P**	:= ________
Power Element Type (+WATTS, –WATTS, +VARS, –VARS)	**PWR3T**	:= ________
Power Element Time Delay (0.00–16000.00 cycles)	**PWR3D**	:= ________

Make settings 3PWR4P, PWR4T, and PWR4D if EPWR := 3P4.

Three-Phase Power Element Pickup (OFF, 1.20–7800.00 VA secondary three-phase)	**3PWR4P**	:= ________
Power Element Type (+WATTS, –WATTS, +VARS, –VARS)	**PWR4T**	:= ________
Power Element Time Delay (0.00–16000.00 cycles)	**PWR4D**	:= ________

Synchronism-Check Elements

(See Figure 4.27 and Figure 4.28)

Make the following settings if preceding enable setting E25 := Y.

VP Window—Low Threshold (12.50–300.00 V, secondary)	**25VPLO**	:= ________
VP Window—High Threshold (12.50–300.00 V, secondary)	**25VPHI**	:= ________
VS Window—Low Threshold (12.50–300.00 V, secondary)	**25VSLO**	:= ________
VS Window—High Threshold (12.50–300.00 V, secondary)	**25VSHI**	:= ________

See Table 9.18 for possible 25VPLO, 25VPHI, 25SLO, and 25VSHI settings adjustments when 8 V LEA inputs are used.

Maximum Slip Frequency (0.005–0.500 Hz)	**25SF**	:= ________
Maximum Angle 1 (0.00°–80.00°)	**25ANG1**	:= ________

Maximum Angle 2 (0.00°–80.00°)	**25ANG2**	:= ________
Synchronizing Phase VS (0°–330° lagging VP, in 30° steps)	**SYNCP**	:= ________
Breaker close time for angle compensation (0.00–60.00 cycles in 0.25-cycle steps)	**TCLOSD**	:= ________

Block Synchronism-Check SELOGIC Equation

BSYNCH := ____

Reclosing Relay

(See Table 6.6 and Table 6.7)

Number of recloser open interval timer settings dependent on preceding enable setting E79 := 1–4.

Open Interval 1 Time (OFF, 12.00–999999.00 cycles in 0.25-cycle steps)	**79OI1**	:= ________
Open Interval 2 Time (OFF, 90.00–999999.00 cycles in 0.25-cycle steps)	**79OI2**	:= ________
Open Interval 3 Time (OFF, 120.00–999999.00 cycles in 0.25-cycle steps)	**79OI3**	:= ________
Open Interval 4 Time (OFF, 120.00–999999.00 cycles in 0.25-cycle steps)	**79OI4**	:= ________
Reset Time From Reclose Cycle (180.00–999999.00 cycles in 0.25-cycle steps)	**79RSD**	:= ________
Reset Time From Lockout [2] (0.00–999999.00 cycles in 0.25-cycle steps)	**79RSLD**	:= ________
Reclose Supervision Time Limit (OFF, 0.00–999999.00 cycles in 0.25-cycle steps)	**79CLSD**	:= ________

Reclosing Relay SELOGIC Equations

(See Reclosing Relay on page 6.17)

Make the following two settings if E79 := 1–4 **and** ESPB := N.

Reclose Initiate

79RI3P := ____

Reclose Initiate Supervision

79RIS3P := ____

Make the following two settings if E79 := 1–4.

Drive-to-Lockout

79DTL3P := ____

Drive-to-Lockout—Extra Equation

79DTL3X := ____

[2] 180.00 cycles is the 79RSLD setting range lower limit for SEL-651R recloser controls with older firmware versions (see Table A.1, Manual Date Code entry 20120824).

Make the following six settings if E79 := 1–4 **and** ESPB := N.

Drive-to-Last Shot
79DLS3P := ______________________________

Skip Shot
79SKP3P := ______________________________

Stall Open Interval Timing
79STL3P := ______________________________

Block Reset Timing
79BRS3P := ______________________________

Sequence Coordination
79SEQ3P := ______________________________

Reclose Supervision
79CLS3P := ______________________________

Make the following settings if E79 := 1–4 **and** ESPB := Y.

Reclose Initiate
79RIA := ______________________________

Reclose Initiate Supervision
79RISA := ______________________________

Drive-to-Lockout
79DTLA := ______________________________

Drive-to-Last Shot
79DLSA := ______________________________

Skip Shot
79SKPA := ______________________________

Stall Open Interval Timing
79STLA := ______________________________

Block Reset Timing
79BRSA := ______________________________

Sequence Coordination
79SEQA := ______________________________

Reclose Supervision
79CLSA := ______________________________

Reclose Initiate
79RIB := ______________________________

Reclose Initiate Supervision
79RISB := ______________________________

Date ___________

Drive-to-Lockout
79DTLB := ____________________

Drive-to-Last Shot
79DLSB := ____________________

Skip Shot
79SKPB := ____________________

Stall Open Interval Timing
79STLB := ____________________

Block Reset Timing
79BRSB := ____________________

Sequence Coordination
79SEQB := ____________________

Reclose Supervision
79CLSB := ____________________

Reclose Initiate
79RIC := ____________________

Reclose Initiate Supervision
79RISC := ____________________

Drive-to-Lockout
79DTLC := ____________________

Drive-to-Last Shot
79DLSC := ____________________

Skip Shot
79SKPC := ____________________

Stall Open Interval Timing
79STLC := ____________________

Block Reset Timing
79BRSC := ____________________

Sequence Coordination
79SEQC := ____________________

Reclose Supervision
79CLSC := ____________________

Switch-Onto-Fault

(See Figure 5.6)

Make the following settings if preceding enable setting ESOTF := Y.

Close Enable Time Delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	**CLOEND**	:= ________
52A Enable Time Delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	**52AEND**	:= ________
SOTF Duration (0.50–16000.00 cycles in 0.25-cycle steps)	**SOTFD**	:= ________

Close Signal Monitor SELOGIC Equation

CLMON := ____

Pole-Open Settings

(See Pole Open Logic on page 5.7)

Make SPOD setting when setting ESPB := Y.

Single-Pole Open Time Delay (0.00–60.00 cycles)	**SPOD**	:= ________
Three-Pole Open Time Delay (0.00–60.00 cycles in 0.25-cycle steps)	**3POD**	:= ________
Load Detection Phase Pickup (OFF, 0.05–1.00 A)	**50LP**	:= ________

Demand Metering Settings

(See Figure 8.4)

Make the following settings, whether preceding enable setting EDEM := THM or ROL.

Time Constant (5, 10, 15, 30, 60 minutes)	**DMTC**	:= ________
Phase Pickup (OFF, 0.10–3.20 A)	**PDEMP**	:= ________

Make setting NDEMP when global setting EGNDSW := N.

Neutral Pickup—Channel IN (OFF, 0.005–0.640 A)	**NDEMP**	:= ________
Ground Pickup	**GDEMP**	:= ________

OFF, 0.005–3.200 A
on channel IN base (see Note), when global setting EGNDSW := Y and relay setting CTR = CTRN

OFF, 0.005–[3.2 • (CTR/CTRN)] A
on channel IN base, when global setting EGNDSW := Y and relay setting CTR ≠ CTRN

OFF, 0.020–3.200 A
on IA, IB, IC base, when global setting EGNDSW := N

NOTE: In the case where EGNDSW := Y and CTR = CTRN, there is no difference between the IN current base and the IA, IB, IC current base. This is the standard configuration for the SEL-651R, because the factory wiring includes a wired residual connection to the IN channel.

Negative-Sequence Pickup (OFF, 0.10–3.20 A)	**QDEMP**	:= ________

Voltage Sag/Swell/Interrupt

(See Figure 4.35 Through Figure 4.37)

Make the following settings if preceding enable setting ESSI := Y.

Percent Phase Interruption Pickup (OFF, 5.00–95.00) *(Cannot be set higher than VSAG)*	**VINT**	:= ________
Percent Phase Voltage Sag Pickup (OFF, 10.00–95.00)	**VSAG**	:= ________
Percent Phase Voltage Swell Pickup (OFF, 105.00–180.00)	**VSWELL**	:= ________

SSI Trigger SELOGIC Equation

SSI_TRIG := ____

Math Variable Settings

(See Analog Comparators and Checks on page 7.6)

Number of math variable settings dependent on preceding enable setting EMV := 1–32.

Math Variable (–16000.00 to +16000.00)	**MV01**	:= ________
	MV02	:= ________
	MV03	:= ________
	MV04	:= ________
	MV05	:= ________
	MV06	:= ________
	MV07	:= ________
	MV08	:= ________
	MV09	:= ________
	MV10	:= ________
	MV11	:= ________
	MV12	:= ________
	MV13	:= ________
	MV14	:= ________
	MV15	:= ________
	MV16	:= ________
	MV17	:= ________
	MV18	:= ________
	MV19	:= ________
	MV20	:= ________
	MV21	:= ________
	MV22	:= ________
	MV23	:= ________
	MV24	:= ________
	MV25	:= ________
	MV26	:= ________
	MV27	:= ________
	MV28	:= ________
	MV29	:= ________
	MV30	:= ________
	MV31	:= ________
	MV32	:= ________

Trip Logic Settings

(See Figure 5.1)

Minimum trip duration time (4.00–16000.00 cycles in 0.25-cycle steps) **TDURD** := ________

Trip Logic SELOGIC Settings

Three-Phase Trip Conditions

TR3P := ____

Three-Phase Trip Conditions—Extra Equation

TR3X := ____

Make settings TRA, TRB, and TRC when setting ESPB := Y.

A-Phase Trip Conditions

TRA := ____

B-Phase Trip Conditions

TRB := ____

C-phase trip conditions

TRC := ____

Make setting TRSOTF when setting ESOTF := Y.

Switch-Onto-Fault Trip Conditions

TRSOTF := ____

Make setting ULTR3P when setting ESPB := N.

Unlatch Trip Conditions

ULTR3P := ____

Close Logic Settings

(See Figure 6.1 and Figure 6.2)

Close Failure Time Delay (OFF, 0.00–16000.00 cycles) **CFD** := ________

Close Logic SELOGIC Settings

Make setting 52A_3P when global setting BKTYP :=3.

Three-Phase Circuit Breaker Status *(Cannot be set to NA)*

52A_3P := ____

Make settings 52A_A, 52A_B, 52A_C when global setting BKTYP := 1.

A-Phase Circuit Breaker Status *(Cannot be set to NA)*

52A_A := ____

B-Phase Circuit Breaker Status *(Cannot be set to NA)*

52A_B := ____

C-Phase Circuit Breaker Status *(Cannot be set to NA)*

52A_C := ____

Make setting CL3P when setting ESPB := N.

Three-Phase Close Conditions

CL3P := ______________________________

Make settings CLA, CLB, CLC when setting ESPB := Y.

A-Phase Close Conditions

CLA := ______________________________

B-Phase Close Conditions

CLB := ______________________________

C-Phase Close Conditions

CLC := ______________________________

Make setting ULCL3P when setting ESPB := N.

Three-Phase Unlatch Close Conditions

ULCL3P := ______________________________

Make settings ULCLA, ULCLB, ULCLC when setting ESPB := Y.

A-Phase Unlatch Close Conditions

ULCLA := ______________________________

B-Phase Unlatch Close Conditions

ULCLB := ______________________________

C-Phase Unlatch Close Conditions

ULCLC := ______________________________

Recloser Interface Trip and Close Settings

(See Trip and Close Mapping and Output Logic on page 7.29)

Pole 1 Trip Mapping SELOGIC Equation

RCTR1 := ______________________________

Make RCTR2 and RCTR3 settings when a single-phase recloser interface is ordered.

Pole 2 Trip Mapping SELOGIC Equation

RCTR2 := ______________________________

Pole 3 Trip Mapping SELOGIC Equation

RCTR3 := ______________________________

Pole 1 Close Mapping SELOGIC Equation

RCCL1 := ______________________________

Make RCCL2 and RCCL3 settings when a single-phase recloser interface is ordered.

Pole 2 Close Mapping SELOGIC Equation

RCCL2 := ______________________________

Pole 3 Close Mapping SELOGIC Equation

RCCL3 := ______________________________

Logic Settings

(Serial Port Command SET L n, [where n = group 1–6; defaults to active group])

SELOGIC Enable Settings

(See Enable Settings on page 9.45)

SELOGIC Latches (N, 1–32)	**ELAT**	:= ________
SELOGIC Variables/Timers (N, 1–48) (N, 1–64 for SEL-651R-1 only)	**ESV**	:= ________
SELOGIC Counters (N, 1–16)	**ESC**	:= ________

Latch Bits Set/Reset SELOGIC Equations

(See Figure 7.6)

Number of latch bit set/reset settings dependent on preceding enable setting ELAT := 1–32.

Set Latch Bit LT01
SET01 := ____________________

Reset Latch Bit LT01
RST01 := ____________________

Set Latch Bit LT02
SET02 := ____________________

Reset Latch Bit LT02
RST02 := ____________________

Set Latch Bit LT03
SET03 := ____________________

Reset Latch Bit LT03
RST03 := ____________________

Set Latch Bit LT04
SET04 := ____________________

Reset Latch Bit LT04
RST04 := ____________________

Set Latch Bit LT05
SET05 := ____________________

Reset Latch Bit LT05
RST05 := ____________________

Set Latch Bit LT06
SET06 := ____________________

Reset Latch Bit LT06
RST06 := ____________________

Set Latch Bit LT07
SET07 := ______________________________

Reset Latch Bit LT07
RST07 := ______________________________

Set Latch Bit LT08
SET08 := ______________________________

Reset Latch Bit LT08
RST08 := ______________________________

Set Latch Bit LT09
SET09 := ______________________________

Reset Latch Bit LT09
RST09 := ______________________________

Set Latch Bit LT10
SET10 := ______________________________

Reset Latch Bit LT10
RST10 := ______________________________

Set Latch Bit LT11
SET11 := ______________________________

Reset Latch Bit LT11
RST11 := ______________________________

Set Latch Bit LT12
SET12 := ______________________________

Reset Latch Bit LT12
RST12 := ______________________________

Set Latch Bit LT13
SET13 := ______________________________

Reset Latch Bit LT13
RST13 := ______________________________

Set Latch Bit LT14
SET14 := ______________________________

Reset Latch Bit LT14
RST14 := ______________________________

Set Latch Bit LT15
SET15 := ______________________________

Reset Latch Bit LT15
RST15 := ______________________________

Set Latch Bit LT16
SET16 := ______________________

Reset Latch Bit LT16
RST16 := ______________________

Set Latch Bit LT17
SET17 := ______________________

Reset Latch Bit LT17
RST17 := ______________________

Set Latch Bit LT18
SET18 := ______________________

Reset Latch Bit LT18
RST18 := ______________________

Set Latch Bit LT19
SET19 := ______________________

Reset Latch Bit LT19
RST19 := ______________________

Set Latch Bit LT20
SET20 := ______________________

Reset Latch Bit LT20
RST20 := ______________________

Set Latch Bit LT21
SET21 := ______________________

Reset Latch Bit LT21
RST21 := ______________________

Set Latch Bit LT22
SET22 := ______________________

Reset Latch Bit LT22
RST22 := ______________________

Set Latch Bit LT23
SET23 := ______________________

Reset Latch Bit LT23
RST23 := ______________________

Set Latch Bit LT24
SET24 := ______________________

Reset Latch Bit LT24
RST24 := ______________________

Set Latch Bit LT25
SET25 := ______________________________

Reset Latch Bit LT25
RST25 := ______________________________

Set Latch Bit LT26
SET26 := ______________________________

Reset Latch Bit LT26
RST26 := ______________________________

Set Latch Bit LT27
SET27 := ______________________________

Reset Latch Bit LT27
RST27 := ______________________________

Set Latch Bit LT28
SET28 := ______________________________

Reset Latch Bit LT28
RST28 := ______________________________

Set Latch Bit LT29
SET29 := ______________________________

Reset Latch Bit LT29
RST29 := ______________________________

Set Latch Bit LT30
SET30 := ______________________________

Reset Latch Bit LT30
RST30 := ______________________________

Set Latch Bit LT31
SET31 := ______________________________

Reset Latch Bit LT31
RST31 := ______________________________

Set Latch Bit LT32
SET32 := ______________________________

Reset Latch Bit LT32
RST32 := ______________________________

SELOGIC Variable/Timer Settings

(See Figure 7.3)

Number of SELOGIC variables/timers settings dependent on preceding enable setting ESV := 1–48 (1–64 for SEL-651R-1).

SV01 Timer Pickup (0.00–999999.00 cycles) **SV01PU** := ________

SV01 Timer Dropout (0.00–999999.00 cycles) **SV01DO** := ________

SV01 Input SELOGIC Equation

SV01 := ____

Pickup and dropout timers SV02 through SV48 (SV02 through SV64 for SEL-651R-1) have the same setting range as SV01.

SV02PU := ________
SV02DO := ________
SV02 := ____

SV03PU := ________
SV03DO := ________
SV03 := ____

SV04PU := ________
SV04DO := ________
SV04 := ____

SV05PU := ________
SV05DO := ________
SV05 := ____

SV06PU := ________
SV06DO := ________
SV06 := ____

SV07PU := ________
SV07DO := ________
SV07 := ____

SV08PU := ________
SV08DO := ________
SV08 := ____

SV09PU := ________
SV09DO := ________
SV09 := ____

SV10PU := ________
SV10DO := ________
SV10 := ____

SV11PU := ________
SV11DO := ________
SV11 := ____

SV12PU := ________
SV12DO := ________
SV12 := ____

SV13PU := ________
SV13DO := ________
SV13 := ____

SV14PU := ________
SV14DO := ________
SV14 := ____

SV15PU := ________
SV15DO := ________
SV15 := ____

SV16PU := ________
SV16DO := ________
SV16 := ____

SV17PU := ________
SV17DO := ________
SV17 := ____

SV18PU := ________
SV18DO := ________
SV18 := ____

SV19PU := ________
SV19DO := ________
SV19 := ____

SV20PU := ________
SV20DO := ________
SV20 := ____

SV21PU := ________
SV21DO := ________
SV21 := ____

SV22PU := ________
SV22DO := ________
SV22 := ____

SV23PU := ________
SV23DO := ________
SV23 := ____

SV24PU := ________
SV24DO := ________
SV24 := ____________________

SV25PU := ________
SV25DO := ________
SV25 := ____________________

SV26PU := ________
SV26DO := ________
SV26 := ____________________

SV27PU := ________
SV27DO := ________
SV27 := ____________________

SV28PU := ________
SV28DO := ________
SV28 := ____________________

SV29PU := ________
SV29DO := ________
SV29 := ____________________

SV30PU := ________
SV30DO := ________
SV30 := ____________________

SV31PU := ________
SV31DO := ________
SV31 := ____________________

SV32PU := ________
SV32DO := ________
SV32 := ____________________

SV33PU := ________
SV33DO := ________
SV33 := ____________________

SV34PU := ________
SV34DO := ________
SV34 := ____________________

SV35PU := ________
SV35DO := ________
SV35 := ____________________

SV36PU := ________
SV36DO := ________
SV36 := ____________________

SV37PU := ________
SV37DO := ________
SV37 := ____________________

SV38PU := ________
SV38DO := ________
SV38 := ____________________

SV39PU := ________
SV39DO := ________
SV39 := ____________________

SV40PU := ________
SV40DO := ________
SV40 := ____________________

SV41PU := ________
SV41DO := ________
SV41 := ____________________

SV42PU := ________
SV42DO := ________
SV42 := ____________________

SV43PU := ________
SV43DO := ________
SV43 := ____________________

SV44PU := ________
SV44DO := ________
SV44 := ____________________

SV45PU := ________
SV45DO := ________
SV45 := ____________________

SV46PU := ________
SV46DO := ________
SV46 := ____________________

SV47PU := ________
SV47DO := ________
SV47 := ____________________

SV48PU := ________
SV48DO := ________
SV48 := ____________________

Following SV49 through SV64 for SEL-651R-1 only.

SV49PU := ________
SV49DO := ________
SV49 := ____

SV50PU := ________
SV50DO := ________
SV50 := ____

SV51PU := ________
SV51DO := ________
SV51 := ____

SV52PU := ________
SV52DO := ________
SV52 := ____

SV53PU := ________
SV53DO := ________
SV53 := ____

SV54PU := ________
SV54DO := ________
SV54 := ____

SV55PU := ________
SV55DO := ________
SV55 := ____

SV56PU := ________
SV56DO := ________
SV56 := ____

SV57PU := ________
SV57DO := ________
SV57 := ____

SV58PU := ________
SV58DO := ________
SV58 := ____

SV59PU := ________
SV59DO := ________
SV59 := ____

SV60PU := ________
SV60DO := ________
SV60 := ____

SV61PU := ________
SV61DO := ________
SV61 := ____

SV62PU := ________
SV62DO := ________
SV62 := ____

SV63PU := ________
SV63DO := ________
SV63 := ____

SV64PU := ________
SV64DO := ________
SV64 := ____

SELOGIC Counter Settings

(See Counters on page 7.13)

Number of SELOGIC counter settings dependent on preceding enable setting ESC := 1–16.

NOTE: For any counter, if the last setting (e.g., SC12CD) is set to NA, the entire counter (SC12, in this example) is disabled and the counter value (if SC12 = 10, when setting SC12CD to NA, SC12 will be frozen at 10) will be frozen. If the count-down function is not needed for a particular counter application, set the count-down setting to logical 0 (e.g., SC12CD := 0) to allow the rest of the counter to function.

SC01 Preset Value, unitless (1–65000) **SC01PV** := ________

SC01 Reset Input SELOGIC Equation
SC01R := ____

SC01 Load Input SELOGIC Equation
SC01LD := ____

SC01 Count-Up Input SELOGIC Equation
SC01CU := ____

SC01 Count-Down Input SELOGIC Equation
SC01CD := ____

SC02 Preset Value, unitless (1–65000) **SC02PV** := ________

SC02 Reset Input SELOGIC Equation
SC02R := ____

SC02 Load Input SELOGIC Equation
SC02LD := ____

SC02 Count-Up Input SELOGIC Equation
SC02CU := ____

SC02 Count-Down Input SELOGIC Equation
SC02CD := ____

SC03 Preset Value, unitless (1–65000) **SC03PV** := ________

SC03 Reset Input SELOGIC Equation
SC03R := ________________________________

SC03 Load Input SELOGIC Equation
SC03LD := ________________________________

SC03 Count-Up Input SELOGIC Equation
SC03CU := ________________________________

SC03 Count-Down Input SELOGIC Equation
SC03CD := ________________________________

SC04 Preset Value, unitless (1–65000) **SC04PV** := ________

SC04 Reset Input SELOGIC Equation
SC04R := ________________________________

SC04 Load Input SELOGIC Equation
SC04LD := ________________________________

SC04 Count-Up Input SELOGIC Equation
SC04CU := ________________________________

SC04 Count-Down Input SELOGIC Equation
SC04CD := ________________________________

SC05 Preset Value, unitless (1–65000) **SC05PV** := ________

SC05 Reset Input SELOGIC Equation
SC05R := ________________________________

SC05 Load Input SELOGIC Equation
SC05LD := ________________________________

SC05 Count-Up Input SELOGIC Equation
SC05CU := ________________________________

SC05 Count-Down Input SELOGIC Equation
SC05CD := ________________________________

SC06 Preset Value, unitless (1–65000) **SC06PV** := ________

SC06 Reset Input SELOGIC Equation

SC06R := ____________________

SC06 Load Input SELOGIC Equation

SC06LD := ____________________

SC06 Count-Up Input SELOGIC Equation

SC06CU := ____________________

SC06 Count-Down Input SELOGIC Equation

SC06CD := ____________________

SC07 Preset Value, unitless (1–65000) **SC07PV** := ________

SC07 Reset Input SELOGIC Equation

SC07R := ____________________

SC07 Load Input SELOGIC Equation

SC07LD := ____________________

SC07 Count-Up Input SELOGIC Equation

SC07CU := ____________________

SC07 Count-Down Input SELOGIC Equation

SC07CD := ____________________

SC08 Preset Value, unitless (1–65000) **SC08PV** := ________

SC08 Reset Input SELOGIC Equation

SC08R := ____________________

SC08 Load Input SELOGIC Equation

SC08LD := ____________________

SC08 Count-Up Input SELOGIC Equation

SC08CU := ____________________

SC08 Count-Down Input SELOGIC Equation

SC08CD := ____________________

SC09 Preset Value, unitless (1–65000) **SC09PV** := ________

SC09 Reset Input SELOGIC Equation
SC09R := ____________________

SC09 Load Input SELOGIC Equation
SC09LD := ____________________

SC09 Count-Up Input SELOGIC Equation
SC09CU := ____________________

SC09 Count-Down Input SELOGIC Equation
SC09CD := ____________________

SC10 Preset Value, unitless (1–65000) **SC10PV** := ________

SC10 Reset Input SELOGIC Equation
SC10R := ____________________

SC10 Load Input SELOGIC Equation
SC10LD := ____________________

SC10 Count-Up Input SELOGIC Equation
SC10CU := ____________________

SC10 Count-Down Input SELOGIC Equation
SC10CD := ____________________

SC11 Preset Value, unitless (1–65000) **SC11PV** := ________

SC11 Reset Input SELOGIC Equation
SC11R := ____________________

SC11 Load Input SELOGIC Equation
SC11LD := ____________________

SC11 Count-Up Input SELOGIC Equation
SC11CU := ____________________

SC11 Count-Down Input SELOGIC Equation
SC11CD := ____________________

SC12 Preset Value, unitless (1–65000) **SC12PV** := ________

SC12 Reset Input SELOGIC Equation

SC12R := ____________________

SC12 Load Input SELOGIC Equation

SC12LD := ____________________

SC12 Count-Up Input SELOGIC Equation

SC12CU := ____________________

SC12 Count-Down Input SELOGIC Equation

SC12CD := ____________________

SC13 Preset Value, unitless (1–65000) **SC13PV** := ________

SC13 Reset Input SELOGIC Equation

SC13R := ____________________

SC13 Load Input SELOGIC Equation

SC13LD := ____________________

SC13 Count-Up Input SELOGIC Equation

SC13CU := ____________________

SC13 Count-Down Input SELOGIC Equation

SC13CD := ____________________

SC14 Preset Value, unitless (1–65000) **SC14PV** := ________

SC14 Reset Input SELOGIC Equation

SC14R := ____________________

SC14 Load Input SELOGIC Equation

SC14LD := ____________________

SC14 Count-Up Input SELOGIC Equation

SC14CU := ____________________

SC14 Count-Down Input SELOGIC Equation

SC14CD := ____________________

SC15 Preset Value, unitless (1–65000) **SC15PV** := ________

SC15 Reset Input SELOGIC Equation
SC15R := ________________________________

SC15 Load Input SELOGIC Equation
SC15LD := ________________________________

SC15 Count-Up Input SELOGIC Equation
SC15CU := ________________________________

SC15 Count-Down Input SELOGIC Equation
SC15CD := ________________________________

SC16 Preset Value, unitless (1–65000) **SC16PV** := ________

SC16 Reset Input SELOGIC Equation
SC16R := ________________________________

SC16 Load Input SELOGIC Equation
SC16LD := ________________________________

SC16 Count-Up Input SELOGIC Equation
SC16CU := ________________________________

SC16 Count-Down Input SELOGIC Equation
SC16CD := ________________________________

Output Contact SELOGIC Equations

(See Output Contacts on page 7.32)

Make setting OUT101 through OUT108 if extra I/O is ordered.

NOTE: Output Contact Equations cannot be set to NA

Output Contact OUT101
OUT101 := ________________________________

Output Contact OUT102
OUT102 := ________________________________

Output Contact OUT103
OUT103 := ________________________________

Output Contact OUT104
OUT104 := ________________________________

Output Contact OUT105
OUT105 := ________________________________

Output Contact OUT106
OUT106 := ________________________________

Output Contact OUT107

OUT107 := ______________________________

Output Contact OUT108

OUT108 := ______________________________

Output Contact OUT201

OUT201 := ______________________________

Output Contact OUT202

OUT202 := ______________________________

MIRRORED BITS® Transmit SELOGIC Equations

(See Appendix D: MIRRORED BITS Communications)

Channel A, Transmit Bit 1

TMB1A := ______________________________

Channel A, Transmit Bit 2

TMB2A := ______________________________

Channel A, Transmit Bit 3

TMB3A := ______________________________

Channel A, Transmit Bit 4

TMB4A := ______________________________

Channel A, Transmit Bit 5

TMB5A := ______________________________

Channel A, Transmit Bit 6

TMB6A := ______________________________

Channel A, Transmit Bit 7

TMB7A := ______________________________

Channel A, Transmit Bit 8

TMB8A := ______________________________

Channel B, Transmit Bit 1

TMB1B := ______________________________

Channel B, Transmit Bit 2

TMB2B := ______________________________

Channel B, Transmit Bit 3

TMB3B := ______________________________

Channel B, Transmit Bit 4

TMB4B := ______________________________

Channel B, Transmit Bit 5

TMB5B := ______________________________

Channel B, Transmit Bit 6
TMB6B := ______________________________

Channel B, Transmit Bit 7
TMB7B := ______________________________

Channel B, Transmit Bit 8
TMB8B := ______________________________

Front-Panel Settings

(Serial Port Command SET F Set/Show Front-Panel Menu*)

* SELOGIC control equations can be viewed, but not changed, via the front-panel set/show front-panel menu.

General Settings

(See Enable Settings on page 9.45)

Enable Display Points (N, 1–32)	**EDP**	:= ________
Enable Local Bits (N, 1–16)	**ELB**	:= ________

(See Human-Machine Interface on page 11.2)

Front Panel Time-Out (OFF, 1–30min)	**FP_TO**	:= ________
Front Panel Contrast (1–16)	**FP_CONT**	:= ________

(See Rotating Display on page 11.12)

Front Panel Neutral/Ground Display (OFF, IN, IG)	**FPNGD**	:= ________
Front Panel VY-Terminal Voltage Display (OFF, ON)	**FPVYD**	:= ________
Front Panel VZ-Terminal Voltage Display (OFF, ON)	**FPVZD**	:= ________

(See Status and Trip Target LEDs on page 11.19)

ENABLED LED Asserted Color (R, G, A)[1]	**LEDENAC**	:= ________

Make setting LEDTRAC if Tricolor LED option is ordered.

TRIP LED Asserted Color (R, G, A)[1]	**LEDTRAC**	:= ________

(See Figure 5.9)

Reset Trip-Latched LEDs On Close (Y, N)	**RSTLED**	:= ________

NOTE 1: Asserted color choices: R=Red, G=Green, A=Amber

Operator Control LED Settings

(See Figure 11.15)

PB01 LED Asserted/Deasserted Colors (R,G,A,O)[2, 3] **PB01LEDC** := ________

PB01 LED SELOGIC Equation

PB01_LED := ____

PB02 LED Asserted/Deasserted Colors (R,G,A,O)[2, 3] **PB02LEDC** := ________

PB02 LED SELOGIC Equation

PB02_LED := ____

PB03 LED Asserted/Deasserted Colors (R,G,A,O)[2, 3] **PB03LEDC** := ________

PB03 LED SELOGIC Equation

PB03_LED := ____

PB04 LED Asserted/Deasserted Colors (R,G,A,O)[2, 3] **PB04LEDC** := ________

PB04 LED SELOGIC Equation

PB04_LED := ____

PB05 LED Asserted/Deasserted Colors (R,G,A,O) [2, 3] **PB05LEDC** := ________

PB05 LED SELOGIC Equation
PB05_LED := ____________________

PB06 LED Asserted/Deasserted Colors (R,G,A,O) [2, 3] **PB06LEDC** := ________

PB06 LED SELOGIC Equation
PB06_LED := ____________________

PB07 LED Asserted/Deasserted Colors (R,G,A,O) [2, 3] **PB07LEDC** := ________

PB07 LED SELOGIC Equation
PB07_LED := ____________________

PB08 LED Asserted/Deasserted Colors (R,G,A,O) [2, 3] **PB08LEDC** := ________

PB08 LED SELOGIC Equation
PB08_LED := ____________________

PB09 LED Asserted/Deasserted Colors (R,G,A,O) [2, 3] **PB09LEDC** := ________

PB09 LED SELOGIC Equation
PB09_LED := ____________________

PB10 LED Asserted/Deasserted Colors (R,G,A,O) [2, 3] **PB10LEDC** := ________

PB10 LED SELOGIC Equation
PB10_LED := ____________________

PB11 LED Asserted/Deasserted Colors (R,G,A,O) [3] **PB11LEDC** := ________

PB11 LED SELOGIC Equation
PB11_LED := ____________________

PB12 LED Asserted/Deasserted Colors (R,G,A,O) [3] **PB12LEDC** := ________

PB12 LED SELOGIC Equation
PB12_LED := ____________________

NOTE 2: Make PB01LEDC through PB10LEDC settings only when Tricolor LEDs are ordered.

NOTE 3: Setting is a two letter combination of the letters R, G, A, O, where:

Asserted/deasserted color choices: R=Red, G=Green, A=Amber, O=Off

Asserted and deasserted colors must be different

Example:

Setting	Condition	LED Beside Pushbutton 11
PB11LEDC := RA	PB11_LED = logical 1	Illuminates Red
PB11LEDC := RA	PB11_LED = logical 0	Illuminates Amber

Target LED Settings

(See Table 5.3, and Figure 11.13)

Target LED01:

Trip Latch (Y, N) **T01LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T01LEDC** := ________

SELOGIC Equation

T01_LED := ____

Target LED02:

Trip Latch (Y, N) **T02LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T02LEDC** := ________

SELOGIC Equation

T02_LED := ____

Target LED03:

Trip Latch (Y, N) **T03LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T03LEDC** := ________

SELOGIC Equation

T03_LED := ____

Target LED04:

Trip Latch (Y, N) **T04LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T04LEDC** := ________

SELOGIC Equation

T04_LED := ____

Target LED05:

Trip Latch (Y, N) **T05LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T05LEDC** := ________

SELOGIC Equation

T05_LED := ____

Target LED06:

Trip Latch (Y, N) **T06LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T06LEDC** := ________

SELOGIC Equation

T06_LED := ____

Target LED07:

Trip Latch (Y, N) **T07LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T07LEDC** := ________

SELOGIC Equation

T07_LED := ____

Target LED08:

Trip Latch (Y, N) **T08LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T08LEDC** := ________

SELOGIC Equation

T08_LED := ______________________________

Target LED09:

Trip Latch (Y, N) **T09LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T09LEDC** := ________

SELOGIC Equation

T09_LED := ______________________________

Target LED10:

Trip Latch (Y, N) **T10LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T10LEDC** := ________

SELOGIC Equation

T10_LED := ______________________________

Target LED11:

Trip Latch (Y, N) **T11LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T11LEDC** := ________

SELOGIC Equation

T11_LED := ______________________________

Target LED12:

Trip Latch (Y, N) **T12LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T12LEDC** **:=** ________

SELOGIC Equation

T12_LED := ______________________________

Target LED13:

Trip Latch (Y, N) **T13LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T13LEDC** := ________

SELOGIC Equation

T13_LED := ______________________________

Target LED14:

Trip Latch (Y, N) **T14LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T14LEDC** := ________

SELOGIC Equation

T14_LED := ______________________________

Target LED15:

Trip Latch (Y, N) **T15LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T15LEDC** := ________

SELOGIC Equation

T15_LED := ____

Target LED16:

Trip Latch (Y, N) **T16LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T16LEDC** := ________

SELOGIC Equation

T16_LED := ____

Target LED17:

Trip Latch (Y, N) **T17LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T17LEDC** := ________

SELOGIC Equation

T17_LED := ____

Target LED18:

Trip Latch (Y, N) **T18LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T18LEDC** := ________

SELOGIC Equation

T18_LED := ____

Target LED19:

Trip Latch (Y, N) **T19LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T19LEDC** := ________

SELOGIC Equation

T19_LED := ____

Target LED20:

Trip Latch (Y, N) **T20LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T20LEDC** := ________

SELOGIC Equation

T20_LED := ____

Target LED21:

Trip Latch (Y, N) **T21LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T21LEDC** := ________

SELOGIC Equation

T21_LED := ____

Target LED22:

Trip Latch (Y, N) **T22LEDL** := ________

LED Asserted Color (R,G,A) [4, 5] **T22LEDC** := ________

SELOGIC Equation

T22_LED := ____

Target LED23:

Trip Latch (Y, N) **T23LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T23LEDC** := ________

SELOGIC Equation

T23_LED := ____

Target LED24:

Trip Latch (Y, N) **T24LEDL** := ________

LED Asserted Color (R, G, A) [4, 5] **T24LEDC** := ________

SELOGIC Equation

T24_LED := ____

NOTE 4: Make T01LEDC through T24LEDC settings only when Tricolor LEDs are ordered.

NOTE 5: Asserted color choices: R=Red, G=Green, A=Amber

Display Point Settings

(See Rotating Display on page 11.12)

Number of display point settings dependent on preceding enable setting EDP := 1–32.

For all display point settings:

- Maximum 60 characters: 0–9, A–Z, -, /, ", ., {, }, space, comma
- Enter NA to clear a label.
- Use one of two types of settings:
  - **Boolean**: Relay Word Bit Name, “Alias”, “Set String”, “Clear String”

Example Setting	Condition	Display
DP04 := IN101,,"EXTERNAL ON","EXTERNAL OFF"	IN101 = Asserted	"EXTERNAL ON"
DP04 := IN101,,"EXTERNAL ON","EXTERNAL OFF"	IN101 = Deasserted	"EXTERNAL OFF"

  - **Analog**: Analog Quantity Name, “User Text and Formatting”

Example Setting	Condition	Display
DP05 := ICDEM,"C DEMAND={4.2,0.001} KA"	Always Displayed	C DEMAND=0.28 KA

DP01 := ____

DP02 := ____

DP03 := ____

DP04 := ____

DP05 := ____

DP06 := ____

DP07 := ____

DP08 := ____________________

DP09 := ____________________

DP10 := ____________________

DP11 := ____________________

DP12 := ____________________

DP13 := ____________________

DP14 := ____________________

DP15 := ____________________

DP16 := ____________________

DP17 := ____________________

DP18 := ____________________

DP19 := ____________________

DP20 := ____________________

DP21 := ____________________

DP22 := ____________________

DP23 := ____________________

DP24 := ____________________

DP25 := ____________________

DP26 := ____________________

DP27 := ____________________

DP28 := ____________________

DP29 := ____________________

DP30 := ____________________

DP31 := ____________________

DP32 := ____________________

Local Bit Settings

(See Control Menu on page 11.7)

Number of local bit settings dependent on preceding enable setting ELB := 1–16.

For all local bit settings:

- ➤ Allowable characters: 0–9, A–Z, -, /, ., space
- ➤ Enter NA to clear a label.

For each Local Bit nn = 01 through 16, make settings:

- ➤ NLBnn is the local bit Name (label) (14 characters, maximum)
- ➤ CLBnn is the local bit Clear Label (7 characters, maximum)
- ➤ SLBnn is the local bit Set Label (7 characters, maximum)
- ➤ PLBnn is the local bit Pulse Label (7 characters, maximum)

See *Table 11.4* for the three possible local bit switch configurations.

Local Bit 01			
Name (label) (14 characters maximum)	**NLB01**	:=	________
Clear Label (7 characters maximum)	**CLB01**	:=	________
Set Label (7 characters maximum)	**SLB01**	:=	________
Pulse Label (7 characters maximum)	**PLB01**	:=	________
Local Bit 02			
Name (label) (14 characters maximum)	**NLB02**	:=	________
Clear Label (7 characters maximum)	**CLB02**	:=	________
Set Label (7 characters maximum)	**SLB02**	:=	________
Pulse Label (7 characters maximum)	**PLB02**	:=	________
Local Bit 03			
Name (label) (14 characters maximum)	**NLB03**	:=	________
Clear Label (7 characters maximum)	**CLB03**	:=	________
Set Label (7 characters maximum)	**SLB03**	:=	________
Pulse Label (7 characters maximum)	**PLB03**	:=	________
Local Bit 04			
Name (label) (14 characters maximum)	**NLB04**	:=	________
Clear Label (7 characters maximum)	**CLB04**	:=	________
Set Label (7 characters maximum)	**SLB04**	:=	________
Pulse Label (7 characters maximum)	**PLB04**	:=	________
Local Bit 05			
Name (label) (14 characters maximum)	**NLB05**	:=	________
Clear Label (7 characters maximum)	**CLB05**	:=	________
Set Label (7 characters maximum)	**SLB05**	:=	________
Pulse Label (7 characters maximum)	**PLB05**	:=	________
Local Bit 06			
Name (label) (14 characters maximum)	**NLB06**	:=	________
Clear Label (7 characters maximum)	**CLB06**	:=	________
Set Label (7 characters maximum)	**SLB06**	:=	________
Pulse Label (7 characters maximum)	**PLB06**	:=	________
Local Bit 07			
Name (label) (14 characters maximum)	**NLB07**	:=	________
Clear Label (7 characters maximum)	**CLB07**	:=	________
Set Label (7 characters maximum)	**SLB07**	:=	________
Pulse Label (7 characters maximum)	**PLB07**	:=	________

Local Bit 08			
Name (label) (14 characters maximum)	**NLB08**	:=	________
Clear Label (7 characters maximum)	**CLB08**	:=	________
Set Label (7 characters maximum)	**SLB08**	:=	________
Pulse Label (7 characters maximum)	**PLB08**	:=	________
Local Bit 09			
Name (label) (14 characters maximum)	**NLB09**	:=	________
Clear Label (7 characters maximum)	**CLB09**	:=	________
Set Label (7 characters maximum)	**SLB09**	:=	________
Pulse Label (7 characters maximum)	**PLB09**	:=	________
Local Bit 10			
Name (label) (14 characters maximum)	**NLB10**	:=	________
Clear Label (7 characters maximum)	**CLB10**	:=	________
Set Label (7 characters maximum)	**SLB10**	:=	________
Pulse Label (7 characters maximum)	**PLB10**	:=	________
Local Bit 11			
Name (label) (14 characters maximum)	**NLB11**	:=	________
Clear Label (7 characters maximum)	**CLB11**	:=	________
Set Label (7 characters maximum)	**SLB11**	:=	________
Pulse Label (7 characters maximum)	**PLB11**	:=	________
Local Bit 12			
Name (label) (14 characters maximum)	**NLB12**	:=	________
Clear Label (7 characters maximum)	**CLB12**	:=	________
Set Label (7 characters maximum)	**SLB12**	:=	________
Pulse Label (7 characters maximum)	**PLB12**	:=	________
Local Bit 13			
Name (label) (14 characters maximum)	**NLB13**	:=	________
Clear Label (7 characters maximum)	**CLB13**	:=	________
Set Label (7 characters maximum)	**SLB13**	:=	________
Pulse Label (7 characters maximum)	**PLB13**	:=	________
Local Bit 14			
Name (label) (14 characters maximum)	**NLB14**	:=	________
Clear Label (7 characters maximum)	**CLB14**	:=	________
Set Label (7 characters maximum)	**SLB14**	:=	________
Pulse Label (7 characters maximum)	**PLB14**	:=	________

Local Bit 15		
Name (label) (14 characters maximum)	**NLB15**	:= ____________
Clear Label (7 characters maximum)	**CLB15**	:= ____________
Set Label (7 characters maximum)	**SLB15**	:= ____________
Pulse Label (7 characters maximum)	**PLB15**	:= ____________
Local Bit 16		
Name (label) (14 characters maximum)	**NLB16**	:= ____________
Clear Label (7 characters maximum)	**CLB16**	:= ____________
Set Label (7 characters maximum)	**SLB16**	:= ____________
Pulse Label (7 characters maximum)	**PLB16**	:= ____________

Report Settings

(Serial Port Command SET R)

Sequential Events Recorder (SER) Trigger Lists

(See Sequential Events Recorder (SER) Report on page 12.34)

Sequential Events Recorder settings are comprised of four trigger lists. Each trigger list can include up to 24 Relay Word bits (see *Table F.1*) delimited by commas. Enter NA to remove a list of these Relay Word bit settings.

SER Trigger List 1
SER1 := ______________________________

SER Trigger List 2
SER2 := ______________________________

SER Trigger List 3
SER3 := ______________________________

SER Trigger List 4
SER4 := ______________________________

Event Report Settings

(See Standard 15/30-Cycle Event Reports on page 12.2)

Length of Event Report (15, 30 cycles) **LER** := ________

Length of Prefault in Event Report (1 to LER—1 cycle in 1-cycle steps) **PRE** := ________

Event Report Trigger SELOGIC Equation
ER := ______________________________

Load Profile settings

(See Load Profile Report on page 8.38)

Load Profile List (15 elements max., enter NA to null)
LDLIST := ______________________________

Load Profile Acquisition Rate (5,10,15,30,60 min) **LDAR** := ________

NOTE: LDLIST may contain any elements listed in Table G.1 that have a dot in the “Load Profile” column.

Port Settings

(Serial Port Command SET P p* and Front Panel Set/Show Port Menu)

* [where *p* = 1, 2, 3, or F; defaults to active port]

Protocol Selection (See Below)

Protocol (SEL, DNP, MBA, MBB, MB8A, MB8B, MBTA, MBTB) **PROTO** := ________

PROTO Setting	Description
SEL	Standard SEL ASCII protocol (see *Table 10.4*)
DNP	Distributed Network Protocol (optional) (see *Appendix E: DNP3 Communications*) Only one of ports 2, 3, or 4 may be used for DNP. The DNP setting choice does not appear if the SEL-651R is not ordered with DNP.
MBA, MBB, MB8A, MB8B, MBTA, MBTB	MIRRORED BITS protocols (see *Appendix D: MIRRORED BITS Communications*) Only one port may be set to MBA, MB8A, or MBTA at a time. Only one port may be set to MBB, MB8B, or MBTB at a time.

Communications Settings for PROTO := SEL

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400, 57600) **SPEED** := ________

Data Bits (6, 7, 8) **BITS** := ________

Parity (O, E, N) **PARITY** := ________
O = Odd, E = Even, N = None

Stop Bits (1, 2) **STOP** := ________

Enable Hardware Handshaking (Y, N) **RTSCTS**[1] := ________

Minutes to Port Time-Out (0–30) **T_OUT**[2] := ________

Send Auto Messages to Port (Y, N) **AUTO**[3] := ________

Fast Operate Enable (Y, N) **FASTOP**[4] := ________

1 Set RTSCTS := Y to enable hardware handshaking. With RTSCTS := Y, the relay will not send characters until the CTS input is asserted. Also, if the relay is unable to receive characters, it deasserts the RTS line (see *Hardware Flow Control on page 10.4*).

2 Set T_OUT to the number of minutes of serial port inactivity for an automatic logout. Set T_OUT := 0 for no port time out (see *Serial Port Time-Out on page 10.7*).

3 Set AUTO := Y to allow automatic messages at the serial port (see *Table 10.5*).

4 Set FASTOP := Y to enable binary Fast Operate messages at the serial port. Set FASTOP := N to block binary Fast Operate messages. Refer to *Control Points on page C.6* for the description of the SEL-651R Fast Operate commands.

Communications Settings for PROTO := MBA, MBB, MB8A, MB8B, MBTA, MBTB

(See Appendix D: MIRRORED BITS Communications)

NOTE: Make setting SPEED only when PROTO := MBA, MBB, MB8A, or MB8B

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400)	**SPEED**	:= ________
MIRRORED BITS Transmit Identifier (1–4)	**TXID**	:= ________
MIRRORED BITS Receive Identifier (1–4)	**RXID**	:= ________
MIRRORED BITS RX Bad Pickup Time (1–10000 seconds)	**RBADPU**	:= ________
PPM MIRRORED BITS Channel Bad Pickup (1–10000)	**CBADPU**	:= ________
MIRRORED BITS Receive Default State (string of 1s, 0s or Xs) 87654321	**RXDFLT**	:= ________________________

MIRRORED BITS Pickup and Dropout settings

Range: 1–8 messages

RMB1 Pickup	**RMB1PU**	:= ________
RMB1 Dropout	**RMB1DO**	:= ________
RMB2 Pickup	**RMB2PU**	:= ________
RMB2 Dropout	**RMB2DO**	:= ________
RMB3 Pickup	**RMB3PU**	:= ________
RMB3 Dropout	**RMB3DO**	:= ________
RMB4 Pickup	**RMB4PU**	:= ________
RMB4 Dropout	**RMB4DO**	:= ________
RMB5 Pickup	**RMB5PU**	:= ________
RMB5 Dropout	**RMB5DO**	:= ________
RMB6 Pickup	**RMB6PU**	:= ________
RMB6 Dropout	**RMB6DO**	:= ________
RMB7 Pickup	**RMB7PU**	:= ________
RMB7 Dropout	**RMB7DO**	:= ________
RMB8 Pickup	**RMB8PU**	:= ________
RMB8 Dropout	**RMB8DO**	:= ________

Communications Settings for PROTO := DNP

(See Appendix E: DNP3 Communications)

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400, 57600)	**SPEED**	:= ________
Minutes to Port Time-Out (0–30)	**T_OUT**	:= ________
DNP Address (0–65534)	**DNPADR**	:= ________
DNP Address to Report To (0–65534)	**REPADR**	:= ________
Class for Binary Event Data (0–3)	**ECLASSB**	:= ________

Class for Counter Event Data (0–3)	**ECLASSC**	:=	________
Class for Analog Event Data (0–3)	**ECLASSA**	:=	________
Class for Virtual Terminal Response Data (0–3)	**ECLASSV**	:=	________
Currents Scaling Decimal Places (0–3)	**DECPLA**	:=	________
Voltages Scaling Decimal Places (0–3)	**DECPLV**	:=	________
Miscellaneous Data Scaling Decimal Places (0–3)	**DECPLM**	:=	________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ**	:=	________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO**	:=	________
Data Link Retries (0–15)	**DRETRY**	:=	________
Make setting DTIMEO when DRETRY > 0.			
Seconds to Data Link Time-Out (0–5)	**DTIMEO**	:=	________
Minimum Seconds From DCD to TX (0.00–1.00)	**MINDLY**	:=	________
Maximum Seconds From DCD to TX (0.00–1.00)	**MAXDLY**	:=	________
Settle Time From RTS On to TX (OFF, 0.00–30.00 seconds)	**PREDLY**	:=	________
Make setting PSTDLY when PREDLY ≠ OFF.			
Settle Time From TX to RTS OFF (0.00–30.00 seconds)	**PSTDLY**	:=	________
Make settings ANADBA and ANADBV when ECLASSA ≠ 0			
Amps Reporting Deadband Counts (0–32767)	**ANADBA**	:=	________
Volts Reporting Deadband Counts (0–32767)	**ANADBV**	:=	________
Make setting ANADBM when ECLASSA or ECLASSC is set to non-zero values.			
Miscellaneous Data Reporting Deadband Counts (0–32767)	**ANADBM**	:=	________
Event Summary Lock Period (0–1000 seconds)	**EVELOCK**	:=	________
Event Message Confirm Time-Out (1–50 seconds)	**ETIMEO**	:=	________
Make setting UNSOL when settings ECLASSA, ECLASSB, or ECLASSC are set to non-zero values.			
Enable Unsolicited Reporting (Y, N)	**UNSOL**	:=	________
Make settings PUNSOL, NUMEVE, AGEEVE, URETRY, and UTIMEO when UNSOL := Y.			
Enable Unsolicited Reporting at Power-Up (Y, N)	**PUNSOL**	:=	________
Number of Class 1 Events to Transmit On (1–200)	**NUMEVE1**	:=	________
Oldest Class 1 Event to Tx On (0.0–99999 seconds)	**AGEEVE1**	:=	________
Number of Class 2 Events to Transmit On (1–200)	**NUMEVE2**	:=	________
Oldest Class 2 Event to Tx On (0.0–99999 seconds)	**AGEEVE2**	:=	________
Number of Class 3 Events to Transmit On (1–200)	**NUMEVE3**	:=	________
Oldest Class 3 Event to Tx On (0.0–99999 seconds)	**AGEEVE3**	:=	________
Unsolicited Message Max Retry Attempts (2–10)	**URETRY**	:=	________

Unsolicited Message Offline Time-Out (1–5000 seconds)	**UTIMEO**	:=	________
Modem Connected to Port (Y, N)	**MODEM**	:=	________

Make setting MSTR when MODEM := Y.

Modem Startup String (30 chars max)

MSTR := ____

Make settings PH_NUM1, PH_NUM2, RETRY1, RETRY2, MDTIME, and MDRET when MODEM := Y and UNSOL := Y.

Phone Number 1 for Dial-Out (30 characters maximum)

PH_NUM1 := ____

Phone Number 2 for Dial-Out (30 characters maximum)

PH_NUM2 := ____

Retry Attempts for Phone Number 1 Dial-Out (1–20)	**RETRY1**	:=	________
Retry Attempts for Phone Number 2 Dial-Out (1–20)	**RETRY2**	:=	________
Time to Attempt Dial (5–300 seconds)	**MDTIME**	:=	________
Time Between Dial-Out Attempts (5–3600 seconds)	**MDRET**	:=	________

Section 10
Communications

Introduction

A communications interface and protocol are required for communicating with the SEL-651R Recloser Control.

A communications interface is the physical connection on a device. Serial ports that conform to the EIA-232 standard (often called RS-232) use DB-9 or DB-25 connectors as the physical interface. The SEL-651R has three rear-panel serial ports and one front-panel serial port that use DB-9 connectors.

Once you have established a physical connection, you must use a communications protocol to interact with the recloser control. A communications protocol is a language used to perform recloser control operations and collect data.

Communications Interfaces

The SEL-651R physical interfaces (DB-9 connectors) support a communications interface, power supply for communications interface converters, and time synchronization source (IRIG-B), as shown in *Table 10.1*. Several optional SEL devices are available to provide alternative physical interfaces, including EIA-485 and fiber-optic cable.

Table 10.1 SEL-651R Port Interfaces

	EIA-232 Serial Port	Demodulated IRIG-B	+5 Vdc Power Supply
Port 1	x	x	x
Port 2	x		x
Port 3	x		x
Port F	x		

Serial Port

Connect the serial port to a computer serial port for local communication or to a modem for remote communication. Other useful communications devices include the following:

- SEL Communications Processors
- SEL-2505 Remote I/O Module
- SEL-2100 Logic Processor

A variety of terminal emulation programs on personal computers can communicate with the recloser control. For the best display, use VT-100 terminal emulation or the closest variation.

The default settings for all serial ports are:

Baud Rate = 9600
Data Bits = 8
Parity = N
Stop Bits = 1

To change the port settings, use the **SET P** command (see *Section 9: Settings*) or the front-panel. *SET/SHOW Menu on page 11.12* provides details on making settings with the front panel.

IRIG-B

Two physical interfaces are provided for the demodulated IRIG-B time-code input. One physical interface is the IRIG-B BNC connector and the other is part of the Serial Port 1 physical interface. Only one interface can be used at a time. When using Serial Port 1, connect to an SEL Communications Processor with Cable C273A (see the cable diagrams that follow in this section or Cable SELECTOR Software (SEL-5801).

+5 Vdc Power Supply

Port power can provide as much as 0.5 A total from all of the +5 Vdc pins. See *Rear-Panel Serial Port Voltage Jumpers on page 2.48* for information on how to install the jumpers necessary to access the power supply. Some SEL communications devices require the +5 Vdc power supply.

Port Connector and Communications Cables

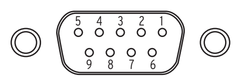


Figure 10.1 EIA-232 Serial Port DB-9 Connector Pinout

Table 10.2 EIA-232 Serial Port Pin Functions

Pin	Port 1	Ports 2 and 3	Port F
1	N/C or +5 Vdc[a]	N/C or +5 Vdc[a]	N/C
2	RXD	RXD	RXD
3	TXD	TXD	TXD
4	+IRIG-B	N/C	N/C
5	GND	GND	GND
6	–IRIG-B	N/C	N/C
7	RTS	RTS	RTS
8	CTS	CTS	CTS
9	GND	GND	GND

[a] See Rear-Panel Serial Port Voltage Jumpers on page 2.48.

Table 10.3 EIA-232 Serial Port Pin Function Definitions (Sheet 1 of 2)

Pin Function	Definition
N/C	No Connection
+5 Vdc (0.5 A limit)	5 Vdc Power Connection
RXD, RX	Receive Data
TXD, TX	Transmit Data
IRIG-B	IRIG-B Time-Code Input
GND	Ground
SHIELD	Shielded Ground
RTS	Request To Send

Table 10.3 EIA-232 Serial Port Pin Function Definitions (Sheet 2 of 2)

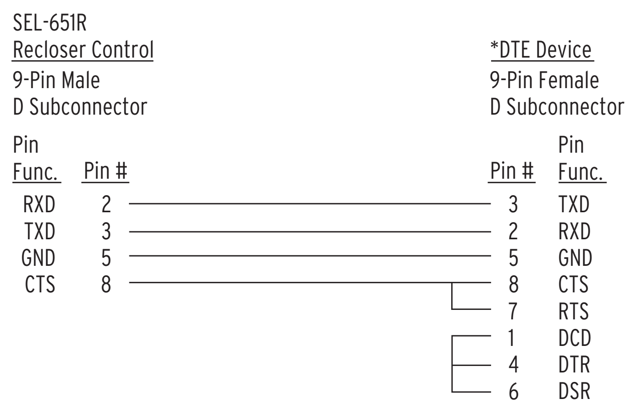
Pin Function	Definition
CTS	Clear To Send
DCD	Data Carrier Detect
DTR	Data Terminal Ready
DSR	Data Set Ready

For long-distance communication up to 500 meters, and for electrical isolation of communications ports, use the SEL-2800 series of fiber-optic transceivers. Contact SEL for more details on these devices.

The following cable diagrams show several types of EIA-232 serial communications cables that connect the SEL-651R to other devices. Information on these and other cables are available by using the SEL-651R Cable SELECTOR Software (SEL-5801). Contact the factory for more information.

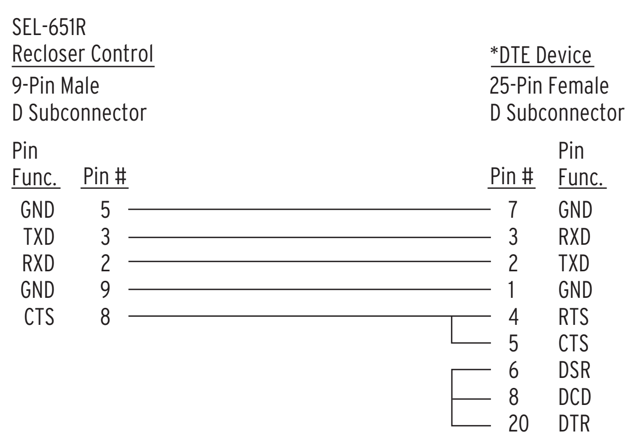
SEL-651R to Computer

Cable C234A



*DTE = Data Terminal Equipment (Computer, Terminal, etc.)

Cable C227A



*DTE = Data Terminal Equipment (Computer, Terminal, etc.)

SEL-651R to Modem

Cable C222

SEL-651R Recloser Control 9-Pin Male D Subconnector			**DCE Device 25-Pin Female D Subconnector	
Pin Func.	Pin #		Pin #	Pin Func.
GND	5		7	GND
TXD	3		2	TXD (IN)
RTS	7		20	DTR (IN)
RXD	2		3	RXD (OUT)
CTS	8		8	CD (OUT)
GND	9		1	GND

**DCE = Data Communications Equipment (Modem, etc.)

SEL-651R to SEL Communications Processor

Cable C273A

SEL Communications Processor 9-Pin Male D Subconnector			SEL-651R Recloser Control 9-Pin Male D Subconnector	
Pin Func.	Pin #		Pin #	Pin Func.
RXD	2		3	TXD
TXD	3		2	RXD
IRIG+	4		4	IRIG+
GND	5		5	GND
IRIG-	6		6	IRIG-
RTS	7		8	CTS
CTS	8		7	RTS

Communications Protocol

Hardware Flow Control

All EIA-232 serial ports support RTS/CTS hardware handshaking (hardware flow control).

To enable hardware handshaking, use the **SET P** command or front-panel `Set Port` submenu to set RTSCTS := Y. Disable hardware handshaking by setting RTSCTS := N.

If RTSCTS := N, the recloser control permanently asserts the RTS line.

If RTSCTS := Y, the recloser control deasserts RTS when it is unable to receive characters.

If RTSCTS := Y, the recloser control does not send characters until the CTS input is asserted.

Protocols

The SEL-651R supports the protocols and command sets shown in *Table 10.4*.

Table 10.4 PROTO Setting and Command Sets

PROTO Setting Value	Command Set	Description
SEL	SEL ASCII	Commands and responses
SEL	SEL Compressed ASCII	Commands and comma-delimited response.
SEL	Fast Meter	Binary meter and digital element commands and response.
SEL	Fast Operate	Binary operation command.
SEL	Fast SER	Unsolicited binary SER event response (SEL-651R-1 only)
MBA, MBB, MB8A, MB8B, MBTA, MBTB[a]	SEL MIRRORED BITS® Communications	Binary high-speed control command.
DNP[b]	DNP3 Level 2 Slave	Binary commands and response.

[a] Available on any two ports.
[b] Available on any one of the three rear ports.

SEL Communications Protocols

SEL ASCII protocol is described in *SEL ASCII Protocol Details on page 10.6*.

SEL Compressed ASCII protocol provides compressed versions of some of the ASCII commands. The commands are described in *SEL ASCII Protocol Details on page 10.6* and the protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Meter protocol supports binary messages to transfer metering and digital element messages. ASCII commands that support the protocol are described in *SEL ASCII Protocol Details on page 10.6* and the protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Operate protocol supports binary messages to transfer operation messages. The protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Sequential Events Recorder (SER) Protocol, also known as SEL Unsolicited Sequential Events Recorder, provides SER events to an automated data collection system. SEL Fast SER Protocol is available on any serial port. The protocol is described in *Appendix H: Fast SER Protocol (SEL-651R-1 Only)*.

MIRRORED BITS Communications

The recloser control supports MIRRORED BITS relay-to-relay communications on two ports simultaneously. See *Appendix D: MIRRORED BITS Communications*.

DNP3 Level 2 Slave Communications

The recloser control provides Distributed Network Protocol (DNP) slave support. DNP3 is an optional protocol and is described in *Appendix E: DNP3 Communications*.

SEL ASCII Protocol Details

Message Format

SEL ASCII protocol is designed for manual and automatic communication.

All commands received by the recloser control 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, which sends the proper ASCII code to the SEL-651R.

A command transmitted to the recloser control 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, **EVENT 1 <Enter>** becomes **EVE 1 <Enter>**. Use upper- and lowercase characters without distinction, except in passwords.

The recloser control 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 recloser control implements XON/XOFF flow control. You can use the XON/XOFF protocol to control the relay during data transmission. When the recloser control receives XOFF during transmission, it pauses until it receives an XON character. If there is no message in progress when the recloser control receives XOFF, it blocks transmission of any message presented to its buffer. Messages will be accepted after the relay receives XON.

The recloser control transmits XON (ASCII hex 11) and asserts the RTS output (if hardware handshaking is enabled) when the recloser control input buffer drops below 25 percent full.

The recloser control transmits XOFF (ASCII hex 13) when the buffer is more than 75 percent full. If hardware handshaking is enabled, the recloser control deasserts the RTS output when the buffer is approximately 95 percent full. 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 XOFF is received and can resume when the recloser control sends XON.

The CAN character (ASCII hex 18) aborts a pending transmission. This is useful for terminating an unwanted transmission.

Control characters can be sent 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 AUTO setting is Y, the recloser control sends automatic messages to indicate specific conditions. The automatic messages are described in *Table 10.5*.

Table 10.5 Serial Port Automatic Messages

Condition	Description
Power Up	The recloser control sends a message containing the present date and time, Relay and Terminal Identifiers, and the Access Level 0 prompt when the recloser control is turned on.
Event Trigger	The recloser control sends an event summary each time an event report is triggered. See *Section 12: Analyzing Events*.
Group Switch	The recloser control displays the active settings group after a group switch occurs. See *GROUP Command on page 10.24*.
Self-Test Warning or Failure	The SEL-651R sends a status report each time a self-test warning or failure condition is detected. See *STATUS Command (Recloser Control Self-Test Status) on page 10.38*.

Access Levels

Commands can be issued to the SEL-651R via the serial port to view metering values, change recloser settings, etc. The available serial port commands are listed in the *SEL-651R Recloser Control Command Summary* at the end of this manual. These commands can be accessed only from the corresponding access level as shown in the *SEL-651R Recloser Control Command Summary*. The access levels are:

NOTE: In this manual, commands you type appear in bold/uppercase: **SET**. Computer keys you press appear in bold/brackets: **<Enter>**. Recloser control front-panel pushbuttons you press appear in bold/initial caps/curly brackets: **{Left Arrow}**.

- Access Level 0 (the lowest access level)
- Access Level 1
- Access Level B
- Access Level 2 (the highest access level)
- Access Level C (restricted access level, should be used under direction of SEL only)

Serial Port Time-Out

The serial port time-out function automatically returns the access level to Level 0 for any ports that have been inactive for a period of time exceeding the port setting T_OUT. There are separate T_OUT settings for each serial port. See *Port Settings on page SET.59*.

Access Level 0

Once serial port communication is established with the SEL-651R, the recloser control 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-651R Recloser Control 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-651R to Access Level 1. See *Access Commands (ACCESS, BACCESS, 2ACCESS, and CAL; Go to Access Level 1, B, 2, or C) on page 10.11* for more detail.

Access Level 1

When the SEL-651R is in Access Level 1, the recloser control sends the following prompt:

```
=>
```

See the *SEL-651R Recloser Control Command Summary* at the end of this manual for the commands available from Access Level 1. The recloser control can go to Access Level B or Access Level 2 from this level.

The **2AC** command places the recloser control in Access Level 2. See *Access Commands (ACCESS, BACCESS, 2ACCESS, and CAL; Go to Access Level 1, B, 2, or C)* for more detail. Enter the **2AC** command at the Access Level 1 prompt:

```
=>2AC <Enter>
```

The **BAC** command places the recloser control in Access Level B. See *Access Commands (ACCESS, BACCESS, 2ACCESS, and CAL; Go to Access Level 1, B, 2, or C)* for more detail. Enter the **BAC** command at the Access Level 1 prompt:

```
=>BAC <Enter>
```

Access Level B

When the recloser control is in Access Level B, the SEL-651R sends the prompt:

```
==>
```

See the *SEL-651R Recloser Control Command Summary* at the end of this manual for the commands available from Access Level B.

Any of the Access Level 1 commands are also available in Access Level B.

The **2AC** command places the recloser control in Access Level 2. See *Access Commands (ACCESS, BACCESS, 2ACCESS, and CAL; Go to Access Level 1, B, 2, or C)* for more detail. Enter the **2AC** command at the Access Level B prompt:

```
==>2AC <Enter>
```

Access Level 2

When the recloser control is in Access Level 2, the SEL-651R sends the prompt:

```
=>>
```

See the *SEL-651R Recloser Control Command Summary* at the end of this manual for the commands available from Access Level 2.

Any of the Access Level 1 and Access Level B commands are also available in Access Level 2.

Access Level C

The CAL access level is intended for use by the SEL factory, and for use by SEL field service personnel to help diagnose troublesome installations. A list of commands available at the CAL level is available from SEL upon request. Do not enter the CAL access level except as directed by SEL.

The **CAL** command allows the relay to go to Access Level C (see *Access Commands (ACCESS, BACCESS, 2ACCESS, and CAL; Go to Access Level 1, B, 2, or C) on page 10.11* for more detail). Enter the **CAL** command at the Access Level 2 prompt:

```
=>>CAL <Enter>
```

Command Summary

The *SEL-651R Recloser Control 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 required by SEL communications processors.
- The Access Level 1 commands are primarily for reviewing information only (settings, metering, etc.), not changing it.
- The Access Level B commands are primarily for operating output contacts or changing the active setting group.
- The Access Level 2 commands are primarily for changing recloser control settings.
- The Access Level C commands are restricted and should be used under the direction of SEL only.

The SEL-651R responds with `Invalid Access Level` when a command is entered from an access level lower than the specified access level for the command. The recloser control 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:

```
[RID Setting]                                    Date: mm/dd/yyyy  Time: hh:mm:ss.sss
[TID Setting]                                    Time Source: external
```

The definitions follow:

[RID Setting]:	This is the RID (Relay Identifier) setting. The recloser control is shipped with the default setting RID = FEEDER 1; see *Identifier Labels on page 9.39*.
[TID Setting]:	This is the TID (Terminal Identifier) setting. The recloser control is shipped with the default setting TID = STATION A; see *Identifier Labels on page 9.39*.
Date:	This is the date when the command response was given, except for recloser control response to the **EVE** command (Event), when it is the date the event occurred. You can modify the date display format (Month/Day/Year, Year/Month/Day, or Day/Month/Year) by changing the DATE_F global setting.
Time:	This is the time when the command response was given, except for recloser control response to the **EVE** command, when it is the time the event occurred.
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, circuit breaker number ***n*** = 1 or 2, remote bit number ***nn*** = 01–32, 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.

The Command Summary located at the end of this manual, provides a convenient reference.

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, Access Level B (breaker), Access Level 2, and Access Level C.

Access Commands (ACCESS, BACCESS, 2ACCESS, and CAL; Go to Access Level 1, B, 2, or C)

The **ACC**, **BAC**, **2AC**, and **CAL** commands provide entry to the multiple access levels. Different commands are available at the different access levels as shown in the *SEL-651R Recloser Control Command Summary* at the end of this manual. Commands **ACC**, **BAC**, **2AC**, and **CAL** are explained together because they operate similarly. See *Access Levels on page 10.7* for a discussion of placing the recloser control in an access level.

Command	Description
ACC	Moves from Access Level 0 to Access Level 1
BAC	Moves from Access Level 1 to Access Level B
2AC	Moves from Access Level 1 or B to Access Level 2
CAL	Moves from Access Level 2 to Access Level C

Password Requirements

Passwords are required if the main board Password jumper is **not** in place (Password jumper is OFF). Passwords are not required if the main board Password jumper **is** in place (Password jumper is ON). Refer to *Table 2.3* and *Table 2.4* for Password jumper information. See *PASSWORD Command (View/Change Passwords) on page 10.32* for the list of default passwords and for more information on changing passwords.

Access Level Attempt (Password Required)

Assume the following conditions: Password jumper is OFF (not in place); Access Level is 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the Password jumper is not in place, the recloser control prompts you for the Access Level 1 password:

```
Password: ? @@@@@@@@
```

The recloser control is shipped with the default Access Level 1 password shown in *PASSWORD Command (View/Change Passwords) on page 10.32*. At the prompt, enter the default password and press the **<Enter>** key. The recloser control responds with the following:

```
FEEDER 1                                    Date: 08/29/2003  Time: 08:00:00.000
STATION A                                   Time Source: internal


Level 1
=>
```

The => prompt indicates the recloser control is now in Access Level 1.

If the entered password is incorrect, the recloser control prompts you for the password again (`Password: ?`). The recloser control prompts for the password as many as three times. If the requested password is incorrectly entered three times, the recloser control pulses the SALARM Relay Word bit for one second and remains at Access Level 0 (= prompt).

Access Level Attempt (Password Not Required)

Assume the following conditions: Password jumper is ON (in place), Access Level is 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the Password jumper is in place, the recloser control does not prompt you for a password and goes directly to Access Level 1. The recloser control responds with the following:

```
FEEDER 1                                   Date: 08/29/2003  Time: 08:00:00.000
STATION A                                  Time Source: internal


Level 1
=>
```

The => prompt indicates the recloser control 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 B, Access Level 1 to Access Level 2, Access Level B to Access Level 2, or Access Level 2 to Access Level C is much the same, with command **BAC**, **2AC**, or **CAL** entered at the access level screen prompt. The recloser control pulses the SALARM Relay Word bit for one second after a successful Level B, Level 2, or Level C access, or if access is denied.

BNAMES Command

The **BNA** command produces ASCII names of all relay status bits reported in the Fast Meter Data Block (A5D1) message in compressed ASCII format.

Command	Description	Access Level
BNA	Display ASCII names of all relay status bits.	0

BREAKER Command

BRE (Breaker Monitor Data)

Use the **BRE** command to view the breaker monitor report.

Command	Description	Access Level
BRE	Display the breaker/recloser contact wear monitor report.	1

Following is a sample of the breaker monitor report:

```
=>BRE <Enter>

FEEDER 1                                   Date: 08/29/2003  Time: 08:00:00.000
STATION A                                  Time Source: internal

                                A           B           C          G
Internal Trip Counter          14           7          10
Internal Current (kA)          32.4        18.6        22.6

External Trip Counter           2           1           2
External Current (kA)           0.8         0.6         0.7

Percent Wear                    22          28          25

Involved Phase Counter          10          5           8          3

LAST RESET 02/12/2003 09:25:14
=>
```

See *Breaker/Recloser Contact Wear Monitor on page 8.19* for further details on the breaker monitor.

BRE R (Reset Breaker Data)

Use the **BRE R** command to reset the breaker monitor.

Command	Description	Access Level
BRE R	Reset breaker/recloser contact wear monitor.	B

The recloser control produces a screen similar to the following when the breaker monitor is reset:

```
==>BRE R <Enter>

Reset Trip Counters and Accumulated Currents/Wear
Are you sure (Y,N)? Y <Enter>


FEEDER 1                                   Date: 07/30/2003  Time: 16:07:18.039
STATION A                                  Time Source: internal

                                A           B           C           G
Internal Trip Counter           0           0           0
Internal Current (kA)           0.0         0.0         0.0

External Trip Counter           0           0           0
External Current (kA)           0.0         0.0         0.0

Percent Wear                    0           0           0

Involved Phase Counter          0           0           0           0

LAST RESET 07/30/2003 16:07:17
==>
```

BRE W (Preload Breaker Wear)

Use the **BRE W** command to preload breaker monitor data.

Command	Description	Access Level
BRE W	Preload breaker/recloser contact wear monitor data.	B

Following is a sample terminal display when preloading the breaker monitor:

```
==> BRE W <Enter>

Breaker Monitor Preload

Internal Trip Counter (0-65000)              A-phase =        0   ? 14 <Enter>
                                             B-phase =        0   ? 7 <Enter>
                                             C-phase =        0   ? 10 <Enter>
Internal Current (0.0-999999 kA)             IA      =      0.0   ? 32.4 <Enter>
                                             IB      =      0.0   ? 18.6 <Enter>
                                             IC      =      0.0   ? 22.6 <Enter>

External Trip Counter (0-65000)              A-phase =        0   ? 2 <Enter>
                                             B-phase =        0   ? 1 <Enter>
                                             C-phase =        0   ? 2 <Enter>
External Current (0.0-999999 kA)             IA      =      0.0   ? 0.8 <Enter>
                                             IB      =      0.0   ? 0.6 <Enter>
                                             IC      =      0.0   ? 0.7 <Enter>

Percent Wear (0-100%)                        A-phase =        0   ? 22 <Enter>
                                             B-phase =        0   ? 28 <Enter>
                                             C-phase =        0   ? 25 <Enter>

Involved Phase Counter (0-65000)             A-phase =        0   ? 10 <Enter>
                                             B-phase =        0   ? 5 <Enter>
                                             C-phase =        0   ? 8 <Enter>
                                             Ground  =        0   ? 3 <Enter>

Last Reset                                   Date    = 07/30/2003 ? 02/12/2003
                                             Time    = 16:07:17 ? 09:25:14
Save Changes(Y/N)? Y <Enter>

FEEDER 1                                  Date: 08/29/2003  Time: 08:00:00.000
STATION A                                 Time Source: internal

                                A           B           C          G
Internal Trip Counter          14           7          10
Internal Current (kA)          32.4        18.6        22.6

External Trip Counter           2           1           2
External Current (kA)           0.8         0.6         0.7

Percent Wear                    22          28          25

Involved Phase Counter          10          5           8          3

LAST RESET 02/12/2003 09:25:14
==>
```

The **BRE W** command saves new settings only after the `Save Changes(Y/N)?` prompt. If a data entry error is made using the **BRE W** command, the SEL-651R echoes the previous **BRE** values and responds with `Invalid format, changes not saved`. The aborted **BRE W** attempt does not change the stored breaker wear values.

BTT Command

Use the **BTT** commands to display battery test results or force a battery test. See *Section 8: Metering and Monitoring* for details on how the battery system monitor operates.

BTT (View Battery Test Results)

Use the **BTT** command to display the daily battery test results.

Command	Description	Access Level
BTT	Display daily battery test.	B

- ➤ If the most recent battery test passed, the following message is displayed:

```
Battery test state is:  OK
Time until next battery test:  XX hours
```

  Where XX is the estimated time until the next automatic battery test, in hours.

- ➤ If the DTFAIL Relay Word bit is already asserted (most recent test failed), the following message is displayed:

```
Battery Failure
```

- ➤ If a battery test is in progress, the following message is displayed:

```
Battery test in progress
```

BTT NOW (Initiate Battery Test)

Use the **BTT NOW** command to request an immediate battery test.

Command	Description	Access Level
BTT NOW	Force a battery test and view the results.	B

1. If a battery test is already in progress, the following message is displayed:

```
Battery test in progress
```

2. If the battery charger is in Discharge mode or Startup mode, no test is performed, and the following message is displayed:

```
Command Failed: Battery charger in Discharge or
Startup mode.
```

3. If neither (1) nor (2) apply, a test is performed, and the following message is displayed, and a new period appears after the massage for each second of the battery test.

```
Battery test initiated...
```

4. At the end of the test, the display will be one of the following:

```
Battery test state is:  OK
```

or

```
Battery test state is:  FAILED
```

CASCII Command

The **CAS** command produces the Compressed ASCII configuration message. This configuration instructs an external computer on the method for extracting data from other Compressed ASCII commands.

Command	Description	Access Level
CAS	Return the Compressed ASCII configuration message.	0

CEVENT Command (Compressed Event Report)

The **CEV** command provides event report data in a Compressed ASCII response. These data are similar to those produced by the **EVENT** command. Use this command to retrieve data that can be displayed by PC software in oscillographic form. See *Event (EVE) Reports on page 12.1* for further details on event reports.

Command (Parameters in [ ] are Optional)	Description	Access Level
CEV [*n* S*x* L*y*]	Return event report *n* (including settings and summary) with 4 samples/cycle analog[a] data and 4 samples/cycle digital data.	1
CEV L [*n* S*x* L*y*]	Return event report *n* (including settings and summary) with 32 samples/cycle analog[a] data and 4 samples/cycle digital data.	1
CEV C [*n* S*x* L*y*]	Return event report *n* (including settings and summary) with 32 samples/cycle analog[a] data and 4 samples/cycle digital data.	1
CEV R [*n* S*x* L*y*]	Return the most recent event report (including settings and summary) with raw (unfiltered) 32 samples/cycle analog[a] data and 32 samples/cycle digital data.	1

[a] Unless overridden by Sx parameter.

Parameter	Description
n	Append parameter *n* to specify the event report number to be returned with the default equal to 1 (most recent). Use the **HISTORY** command to determine the event report number of the event you want to display.
Sx	Append parameter *x* to specify analog samples per cycle (4 or 32) with the default equal to 4 (32 for raw event reports). The ***Sx*** parameter overrides the **CEV L** samples/cycle rate.
Ly	Append parameter *y* to specify the event report length (1– LER) in cycles with the default equal to 15. **CEV R** event reports include an extra prefault cycle of data as cycle zero.

CHISTORY Command

The **CHI** command is the **HISTORY** command for the Compressed ASCII command set.

Command	Description	Access Level
CHI	Return the data as contained in the History report in Compressed ASCII format.	1

CLOSE Command (Close Breaker)

Use the close command (**CLO**, **CLO A**, **CLO B**, or **CLO C**) to assert the specified Relay Word bit (CC3, CCA, CCB, or CCC) for 1/4 cycle.

Command	Description	Access Level
CLO	This command asserts the three-phase close Relay Word bit CC3.	B
CLO *n*	This command asserts a single-phase close Relay Word bit (**CLO A** asserts CCA, **CLO B** asserts CCB, **CLO C** asserts CCC).	B

Program the close command Relay Word bit into the close control equation (CL3P, CLA, CLB, or CLC) to enable assertion of the close Relay Word bit (CLOSE3P, CLOSEA, CLOSEB, or CLOSEC) with the close command.

Program the close Relay Word bit to enable assertion of an output contact (e.g., OUT201 := CLOSE3P) to close a recloser/circuit breaker. See *Section 6: Close and Reclose Logic* for a detailed explanation of the close logic.

To issue the **CLO** command, enter the following:

```
==>CLO <Enter>
Close Breaker  (Y/N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
==>
```

Typing **N <Enter>** after either of the `Y/N` prompts aborts the command.

The main board breaker jumper supervises the **CLO** command (see *Table 2.3* and *Table 2.4*). If the breaker jumper is not in place (breaker jumper = OFF), the recloser control does not perform the **CLO** command and responds with the following message:

```
Aborted: No Breaker Jumper
```

COMMUNICATIONS Command

The **COMM** command displays integral relay-to-relay (MIRRORED BITS) communications data. For more information on MIRRORED BITS communications, see *Appendix D: MIRRORED BITS Communications*.

Command	Description	Access Level
COM *n* **COM *n row1 row*2** **COM *n date1 date2***	Return a summary report of the records in the communications buffer.	1
COM *n* L	Display all available records. The most recent record is row 1 (at the top of the report) and the oldest record is at the bottom of the report.	1
COM C	Clear/reset communications buffer data. If both MIRRORED BITS channels are enabled, omitting the channel specifier in the clear command will cause both channels to be cleared.	1

Parameter	Description
n	Parameter ***n*** is A for Channel A, and B for Channel B. If only one MIRRORED BITS port is enabled the channel specifier may be omitted.
row1 row2	Append *row1* to return a chronological progression of the first *row 1* 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 DATE_F.

To get a summary report, enter the command with the channel parameter (A or B):

```
=>COMM A <Enter>

FEEDER 1                                    Date: 08/29/2003  Time: 08:00:00.000
STATION A                                   Time Source: internal

FID=SEL-651R-Rxxx-V0-Zxxxxxx-D2003xxxx       CID=xxxx
Summary for Mirrored Bits channel A

For 08/05/2003 09:33:57.453 to 08/05/2003 11:43:23.327

    Total failures      1                    Last error  Data error
    Relay Disabled      1
    Data error          0                    Longest Failure     1.113 sec.
    Re-Sync             0
    Underrun            0                    Unavailability  0.000143
    Overrun             0
    Parity error        0
    Framing error       0                    Loop-back     0
    Bad Re-Sync         0

=>
```

If only one MIRRORED BITS port is enabled, you can omit the channel specifier. Use the **L** parameter to get a summary report, followed by a listing of the COMM records.

```
=>COMM L <Enter>

FEEDER 1                                    Date: 08/29/2003  Time: 08:00:00.000
STATION A                                   Time Source: internal

FID=SEL-651R-Rxxx-V0-Zxxxxxx-D2003xxxx       CID=xxxx
Summary for Mirrored Bits channel A

For 08/29/2003 08:00:00.000 to 08/30/2003 08:00:00.000

    Total failures      1                    Last error  Relay Disabled
    Relay Disabled      1
    Data error          0                    Longest Failure   203.388 sec.
    Re-Sync             0
    Underrun            0                    Unavailability  0.999979
    Overrun             0
    Parity error        0
    Framing error       0                    Loop-back     0
    Bad Re-Sync         0


Failure                  Recovery
#   Date       Time          Date       Time          Duration  Cause
1   08/29/2003 08:00:00.000  08/29/2003 08:00:45.000   045.000  Relay Disabled

=>
```

The SEL-651R can display as many as 255 records in the extended report.

CONTROL Command (Control Remote Bit)

The **CON** command is a two-step command for controlling remote bits, which are Relay Word bits RB01 through RB32.

Command	Description	Access Level
CON *n*[a]	First step of a two-command sequence. The SEL-651R will prompt for the second step (sub-command), shown below.	2

[a] Parameter n is a number from 1 to 32 representing RB01–RB32.

Subcommand	Description
SRB *n*	Set Remote Bit *n* (“ON” position)
CRB *n*	Clear Remote Bit *n* (“OFF” position)
PRB *n*	Pulse Remote Bit *n* for 1/4 cycle (“MOMENTARY” position)

Use the **CON** command to exercise remote bits.

```
=>>CON 5 <Enter>

CONTROL RB5: PRB 5 <Enter>
=>>
```

You must enter the same remote bit number in both steps in the command. If the bit numbers do not match, the recloser control responds with the following:

```
Invalid Command
```

See *Remote Bits on page 7.20* for more information.

COPY Command (Copy Setting Group)

Copy group settings and general logic settings from setting Group *m* to setting Group *n* with the **COP *m n*** command.

Command	Description	Access Level
COPY *m n*	Copy settings from instance *m* of the Group settings to instance *n* of the group settings.	2

Parameter	Description
m	Parameter *m* is a number from 1 to 6 (1 to 8 for SEL-651R-1).
n	Parameter *n* is a number from 1 to 6 (1 to 8 for SEL-651R-1).

Setting group numbers range from 1 to 6 (1 to 8 for SEL-651R-1). After entering settings into one setting group with the **SET** and **SET L** commands, copy this group to the other groups with the **COP** command. Use the **SET** and **SET L** commands to modify the copied settings.

The recloser control disables for a few seconds and the SALARM Relay Word bit pulses if you copy settings into the active group. This is similar to a group change; see *Section 7: SELOGIC Control Equation Programming* and *Table 9.4*.

For example, to copy settings from Group 1 to Group 3, issue the following command:

```
=>>COP 1 3 <Enter>

Copy 1 to 3
Are you sure (Y/N) ? Y <Enter>

Please wait...
Settings copied
=>>
```

COUNTER Command (View SELOGIC Counters)

The **COU** command displays the present value of the SELOGIC® counters.

Command	Description	Access Level
COU *k*	Display the present value of the counters *k* times.	1

NOTE: The counter data displayed by the **COU** command may not be from the same processing interval for each counter.

The **COU** command is convenient to use while testing the SELOGIC Counter settings—see *Counters on page 7.13*. Below is a sample of the **COU** command response.

```
=>COU <Enter>

FEEDER 1                                  Date: 08/05/2003  Time: 12:07:32.532
STATION A                                 Time Source: internal

     SC01     SC02     SC03     SC04     SC05     SC06     SC07     SC08
        0       14        0        0        0        0        0        0


     SC09     SC10     SC11     SC12     SC13     SC14     SC15     SC16
        0        0        0        0        0        0        0        0


=>
```

CSTATUS Command (Compressed Status)

The **CST** command generates a recloser control status report in compressed ASCII format.

Command	Description	Access Level
CST	Return the recloser control status in Compressed ASCII.	1

CSUMMARY Command

The **CSU** command retrieves the event summary information event report *n* in compressed ASCII format. See *Section 12: Analyzing Events*.

Command	Description	Access Level
CSU *n*	Return the event summary for event report *n* (with label lines) in Compressed ASCII format. If *n* is omitted, defaults to 1 (most recent).	1

DATE Command (View/Change Date)

Use the **DATE** command to view and set the recloser control date.

Command	Description	Access Level
DATE	Display the internal clock date.	1
DATE *date*	Set the internal clock date (DATE_F set to MDY, YMD, or DMY).	1

The recloser control can overwrite the date entered by using other time sources such as IRIG and DNP. Enter the **DATE** command with a date to set the internal clock date.

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). Global setting DATE_F sets the date format.

DNAMES Command

The **DNA** command produces the ASCII names of all Relay Word bits reported in a Fast Meter message in Compressed ASCII format.

Command	Description	Access Level
DNA	Display ASCII names of all Relay Word bits digital I/O.	0

DNP Command

The **DNP** command accesses the DNP map settings. See *Appendix E: DNP3 Communications* for additional details on the DNP3 Level 2 Slave protocol, data map, and using this command.

Command	Description	Access Level
DNP or DNP VIEW	View all of the maps.	1
DNP AI VIEW	View the analog input map.	1
DNP AO VIEW	View the analog output map.	1
DNP BI VIEW	View the binary input map.	1
DNP BO VIEW	View the binary output map.	1
DNP C VIEW	View the binary output map.	1
DNP AI	Modify the analog input map.	2
DNP AO	Modify the analog output map.	2
DNP BI	Modify the binary input map.	2
DNP BO	Modify the binary output map.	2
DNP C	Modify the binary output map.	2

EVENT Command (Event Reports)

Use the **EVE** command to view event reports. See *Standard 15/30-Cycle Event Reports on page 12.2* for further details on retrieving and analyzing event reports.

See the **HIS C** command for details on clearing event reports.

Command (Parameters in [ ] are Optional)	Description	Access Level
EVE [*n* S*x* L*y* A D M]	Return event report *n* (including settings and summary) at full length with 4-samples/cycle data.	1
EVE L [*n* S*x* L*y* A D M]	Return event report *n* (including settings and summary) at full length with 32 samples/cycle analog data and 4 samples/cycle digital data.	1
EVE C [*n* S*x* L*y*]	Return event report *n* (including settings and summary) in compressed-ASCII format at full length with 32 samples/cycle analog data and 4 samples/cycle digital data.	1
EVE R [*n* S*x* L*y* A D M]	Return event report *n* (including settings and summary) at full-length with raw (unfiltered) 32 samples/cycle analog data and 4 samples/cycle digital data.	1

Parameter	Description
n	Parameter *n* specifies the event report number to be returned. Use the **HISTORY** command to determine the event report number of the event you want to display. If *n* is not specified, it will default to 1 (for the most recent event report).
S*x*	Parameter *x* specifies analog samples per-cycle (4 or 32) with the default equal to 4. The *Sx* parameter overrides the **EVE L** samples/cycle rate.
L*y*	Parameter *y* specifies the event report length (1–LER) in cycles with the default equal to full-length. **EVE R** event reports include an extra prefault cycle of data as cycle zero.
A	Specifies displaying only the analog and event summary sections of the event report.
D	Specifies displaying only the protection and control elements (digital) and event summary sections of the event report.
M	Specifies displaying only the MIRRORED BITS communications and automation elements and event summary sections of the event report.
V	Parameter V specifies variable scaling for analog values.

FILE Command

The **FILE** command provides a safe and efficient means of transferring files between intelligent electronic devices (IEDs) and external support software (ESS). Use the **FILE** commands for sending settings to the SEL-651R and receiving settings from the recloser control.

The **FILE** command uses Y-modem transfer protocol to transfer files.

Command	Description	Access Level
FILE DIR	Return a list of files.	1
FILE READ ***filename***	Transfer settings file *filename* from the recloser control to the PC.	1
FILE WRITE ***filename***	Transfer settings file *filename* from the PC to the recloser control.	2
FILE SHOW ***filename***	Filename 1 displays contents of the file *filename*.	1

Below is a sample of the FILE DIR command response.

```
=>>FILE DIR <Enter>
SET_ALL.TXT                                R
CFG.TXT                                    R
ERR.TXT                                    R
SET_P1.TXT                                 RW
SET_P2.TXT                                 RW   Port Settings
SET_P3.TXT                                 RW
SET_P4.TXT                                 RW
SET_G.TXT                                  RW   Global Settings
SET_1.TXT                                  RW
SET_2.TXT                                  RW
SET_3.TXT                                  RW
SET_4.TXT                                  RW   Group Settings
SET_5.TXT                                  RW
SET_6.TXT                                  RW
SET_7.TXT                                  RW
SET_8.TXT   SEL-651R-1 only                RW
SET_F.TXT                                  RW   Front-Panel Settings
SET_L1.TXT                                 RW
SET_L2.TXT                                 RW
SET_L3.TXT                                 RW
SET_L4.TXT                                 RW   Logic Settings
SET_L5.TXT                                 RW
SET_L6.TXT                                 RW
SET_L7.TXT                                 RW
SET_L8.TXT   SEL-651R-1 only               RW
SET_R.TXT                                  RW   SER Settings
SET_D.TXT                                  RW   DNP Settings
SWCFG.ZIP   SEL-651R-1 only                RW
```

SET_ALL.TXT File (Read-Only)

The SET_ALL.TXT file contains all of the settings for all of the settings classes in the relay.

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 connected relay.

ERR.TXT File (Read-Only)

The ERR.TXT file contents are based on the most recent SET_*cn*.TXT file you wrote 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.

SWCFG.ZIP File (SEL-651R-1 Only)

The SWCFG.ZIP file is a fixed name, general purpose file that can be up to 2 MB in length. The user may store any type of data or information file they choose, even nonzipped data as long as the file is named SWCFG.ZIP. The ACSELERATOR QuickSet® SEL-5030 Software uses the SWCFG.ZIP file to store template files created with the licensed version of ACSELERATOR QuickSet software.

GROUP Command

Use the **GRO** command to view the present group number or the **GRO *n*** command to change the active settings group number.

Command	Description	Access Level
GRO	Display the presently active group	1
GRO *n*	Change the active group to Group *n*.	B

When you change the active group, the recloser control responds with a confirmation prompt, `Are you sure (Y/N)?` Answer **Y <Enter>** to change the active group. The recloser control asserts the Relay Word bit SALARM for one second when you change the active group (see *Table 9.4*).

If any of the SELOGIC control equations SS1–SS6 (SS1–SS8 for SEL-651R-1) are set when you issue the **GROUP *n*** command, the group change fails. The recloser control responds, `No group change (see manual)`. For information on SELOGIC control equations SS1–SS6 (SS1–SS8 for SEL-651R-1), see *Multiple Settings Groups on page 7.22*.

HISTORY Command

Use the **HIS** command to view a list of one-line descriptions of recloser control events or clear the list (and corresponding event reports) from nonvolatile memory.

Command	Description	Access Level
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1
HIS *n*	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
HIS C	Clear/reset the event history and all corresponding event reports from nonvolatile memory.	1

For more information on event reports, see *Event History (HIS) on page 12.7*.

IDENTIFICATION

Use the **ID** command to extract device identification codes.

Command	Description	Access Level
ID	Return a list of device identification codes.	0

IRIG Command

The **IRIG** command directs the recloser control to use the next available demodulated IRIG-B time code to update the recloser control internal clock.

Command	Description	Access Level
IRI	Lock the recloser control internal clock to the IRIG-B time code input.	1

The SEL-651R automatically scans the rear-panel time inputs for valid time source data and switches to IRIG time mode after a confirmation period. Issuing the **IRIG** command forces the relay to immediately validate and switch to IRIG time mode. If the recloser control has a valid IRIG-B time code, the recloser control updates the internal clock time using the new time code and displays the general command header on the communications port.

If the recloser control has no valid IRIG-B time code at the rear panel, the SEL-651R responds to the **IRIG** command with the following error message:

```
IRIG-B DATA ERROR
```

L_D Command (Load Firmware)

Use the **L_D** command to load firmware. See *Appendix A: Firmware and Manual Versions* for information on changes to the firmware and instruction manual. See *Appendix B: SEL-651R Recloser Control Relay Firmware Upgrade Instructions* for further details on downloading firmware.

Command	Description	Access Level
L_D	Download firmware to the control.	2

Only download firmware from the front port.

LDP Command (Load Profile Report)

Use the **LDP** commands to view and manage the Load Profile report. See *Load Profile Report on page 8.38*.

Command	Description	Access Level
LDP *row1 row2* **LDP *date1 date2***	Use the **LDP** command to display a numeric progression of all load profile report rows. Use the **LDP** command with parameters to display a numeric or reverse numeric subset of the load profile rows.	1
LDP D	Use this command to display the maximum number of days of data the recloser control can acquire with the present settings, before the oldest data are overwritten.	1
LDP C	Use this command to clear the load profile report from nonvolatile memory.	1

Setting LDLIST must contain an analog quantity. Otherwise `the command is not available` is displayed.

Parameter	Description
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 DATE_F.

LOOPBACK Command

The **LOOP** command tests the MIRRORED BITS communications channel.

Command	Description	Access Level
LOOP c t	Begin loopback of a single enabled MIRRORED BITS communications channel (either Channel A or Channel B); ignore input data and force receive bits (RMB) to defaults.	2
LOOP c t DATA	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B): pass input data to receive data as in nonloopback mode.	2
LOOP c R	Cease loopback on MIRRORED BITS communications channel c. Reset the channel to normal use.	2

Parameter	Description
c	Append this parameter (*c* = A or B) to specify which channel to use if more than one MIRRORED BITS communications channel is enabled
t	Append this parameter to specify the timeout period in *t* minutes; *t* range is 1–5000 minutes. Defaults to 5 minutes if unspecified.

With the transmitter physically looped back to the receiver, MIRRORED BITS addressing is wrong and ROK is deasserted. The **LOOPBACK** command tells the MIRRORED BITS software to temporarily expect to see its own data looped back as its input. In this mode, LBOK asserts when receiving error-free data.

For more information on MIRRORED BITS, see *Appendix D: MIRRORED BITS Communications*.

METER Command (Metering Data)

The **MET** commands provide access to recloser control metering data. Metered quantities include phase voltages and currents, sequence component voltages and currents, power, frequency, energy, demand, and maximum/minimum logging of selected quantities. To make the extensive amount of meter information manageable, the recloser control divides the displayed information into six groups:

- Fundamental
- Demand

- Energy
- THD/Harmonics
- Maximum/Minimum
- RMS

Metering data retrieval and display is described in the following subsections. See *Section 8: Metering and Monitoring* for details on metering.

MET k—Fundamental Metering

Use the **MET *k*** command to display fundamental metering data.

Command	Description	Access Level
MET *k*	Display instantaneous metering data *k* times.	1

The **MET *k*** command displays instantaneous magnitudes, and angles if applicable, of the following quantities:

NOTE: See Ground Switch Option on page 8.3 for details on the IG quantity used in the SEL-651R metering functions.

NOTE: Three-phase MVA (MVA3P) is the arithmetic sum of the single-phase measurements MVAA, MVAB, and MVAC. Three-phase power factor (PF3P) is calculated with MW3P and MVAR3P (not MVA3P).

Currents	IA,B,C,N	Input currents (A primary)
	IG	Ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$ when Relay Word bit GNDSW = 0; I_G = IN when GNDSW = 1)
Voltages	VAY, VBY, VCY, VAZ, VBZ, VCZ	Phase-to-neutral voltages (kV primary)
	VABY, VBCY, VCAY, VABZ, VBCZ, VCAZ	Calculated phase-to-phase voltages (kV primary)
	Vbase	Demand average value based on V_1, (subject to the operating logic of the *Voltage Sag, Swell, and Interruption Elements on page 4.48*) when setting ESSI :=Y in the active setting group. Vbase registers a value only after valid three-phase voltage signals have been present since the last Vbase initialization.
Power	MVAA,B,C	Single-phase MVA
	MVA3P	Three-phase MVA
	MWA,B,C	Single-phase megawatts
	MW3P	Three-phase megawatts
	MVARA,B,C	Single-phase megavars
	MVAR3P	Three-phase megavars
Power Factor	PFA,B,C	Single-phase power factor; leading or lagging
	PF3P	Three-phase power factor; leading or lagging
Sequence	I1, 3I2, 3I0	Positive-, negative-, and zero-sequence currents (A primary)

	V1Y, V2Y, V1Z, V2Z	Positive- and negative-sequence voltages (kV primary)
	3V0Y, 3V0Z	Zero-sequence voltage (kV primary)
Frequency	FREQ (Hz)	Instantaneous power system frequency (measured on voltage terminal V1Y or V1Z—see *Table 8.1*).

The recloser control references metering angles to voltage VAY or VAZ (according to Global Setting VSELECT), if the reference voltage is greater than 13 V secondary; otherwise, angles are referenced to A-phase current. Angles range from –179.99 to 180.00 degrees.

To view instantaneous metering values, use the **MET k** command, where *k* is an optional parameter to specify the number of times (1–32767) to repeat the meter display. The recloser control displays the meter report once if *k* is not specified. Below is a sample of metering data from the SEL-651R.

```
=>MET <Enter>

FEEDER 1                                     Date: 08/29/2003  Time: 08:00:00.000
STATION A                                    Time Source: internal
                  A         B         C         N         G
I MAG (A)      279.528   309.668   270.246    34.967    34.967
I ANG (deg)    -14.60   -134.55    105.36   -119.03   -119.03

                 I1        3I2       3I0
I MAG (A)      286.480    35.784    35.615
I ANG (deg)    -14.60     93.00   -120.97

                 VAY       VBY       VCY       VAZ       VBZ       VCZ
V MAG (kV)      14.356    14.356    14.358    14.358    14.356    14.357
V ANG (deg)      0.00   -120.00    120.01      0.01   -119.99    120.01

                VABY      VBCY      VCAY      VABZ      VBCZ      VCAZ
V MAG (kV)      24.866    24.866    24.868    24.868    24.866    24.868
V ANG (deg)     30.00    -89.99    150.00     30.01    -89.99    150.01

                 V1Y       V2Y      3V0Y       V1Z       V2Z      3V0Z
V MAG (kV)      14.357     0.001     0.003    14.357     0.001     0.002
V ANG (deg)      0.00    -47.78    173.66      0.01    -16.33     45.40

                  A         B         C         3P
MW               3.883     4.303     3.754    11.940
MVAR             1.012     1.117     0.981     3.110
MVA              4.013     4.446     3.880    12.339
PF               0.97      0.97      0.97      0.97
                 LAG       LAG       LAG       LAG

FREQ  (Hz)      59.99
Vbase (kV)       0.000

=>
```

MET D Demand Metering

Use the following commands to view or reset demand and peak demand metering values.

Command	Description	Access Level
MET D	Display demand metering data.	1
MET RD	Reset demand metering data.	1
MET RP	Reset peak demand metering data.	1

The **MET D** command displays the demand and peak demand values of the following quantities:

Currents	IA,B,C,N	Input currents (A primary)
	IG	Ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$ when Relay Word bit GNDSW = 0; I_G = IN when GNDSW = 1)
	3I2	Negative-sequence current (A primary)
Power	MVAA,B,C	Single-phase MVA
	MVA3P	Three-phase MVA
	MWA,B,C	Single-phase megawatts
	MW3P	Three-phase megawatts
	MVARA,B,C	Single-phase megavars
	MVAR3P	Three-phase megavars
Reset Time	Demand, Peak	Last reset times for the demands and peak demands

Below is a sample of demand metering data from the SEL-651R.

```
=>MET D <Enter>

FEEDER 1                                        Date: 08/29/2003  Time: 08:00:00.000
STATION A                                       Time Source: internal
              IA        IB        IC        IN        IG        3I2
DEMAND       190.1     206.2     184.9      17.3      17.3      20.8
PEAK         190.1     206.2     184.9      17.3      17.3      20.8

             MVAA      MVAB      MVAC      MVA3P
DEMAND         2.7       3.0       2.7       8.3
PEAK           2.7       3.0       2.7       8.3

              MWA     MWB     MWC    MW3P    MVARA   MVARB   MVARC  MVAR3P
DEMAND IN      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
PEAK IN        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
DEMAND OUT     2.6     2.9     2.6     8.1     0.7     0.7     0.7     2.1
PEAK OUT       2.6     2.9     2.6     8.1     0.7     0.7     0.7     2.1
LAST DEMAND RESET 08/29/2003 08:00:00.000
LAST PEAK   RESET 08/29/2003 08:05:00.000

=>
```

For more information on recloser control demand metering quantity calculations, see *Demand Metering on page 8.6*.

MET E Energy Metering

Use the following commands to view or reset energy metering values.

Command	Description	Access Level
MET E	Display energy metering data.	1
MET RE	Reset energy metering data.	1

Energy	MWhA,B,C	Single-phase megawatt hours (in and out)
	MWh3P	Three-phase megawatt hours (in and out)
	MVARhA,B,C	Single-phase megavar hours (in and out)
	MVARh3P	Three-phase megavar hours (in and out)
Reset Time		Last energy meter reset time

Below is a sample of energy metering data from the SEL-651R:

```
=>MET E <Enter>

FEEDER 1                                   Date: 08/29/2003  Time: 08:00:00.000
STATION A                                  Time Source: internal
       MWhA     MWhB     MWhC    MWh3P    MVARhA   MVARhB   MVARhC  MVARh3P
IN       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
OUT      0.2      0.2      0.2      0.5      0.0      0.0      0.0      0.1
LAST RESET 08/29/2003 08:00:00.000

=>
```

For more information on recloser control energy metering quantity calculations, see *Energy Metering on page 8.15*.

Recloser control accumulated energy metering values function like those in an electromechanical energy meter. The SEL-651R starts over at 0 after energy metering reaches 99999 MWh or 99999 MVARh.

MET H THD and Harmonic Metering

Use the **MET H** command to display the following for each measured quantity:

Command	Description	Access Level
MET H	Display fundamental magnitudes Display rms (root mean square) magnitudes Display Total Harmonic Distortion Display harmonic magnitudes for the first 15 harmonics	1

Below is a sample of harmonic metering data from the SEL-651R:

```
=>MET H <ENTER>

FEEDER 1                                   Date: 08/29/2003  Time: 08:00:00.000
STATION A                                  Time Source: internal
             IA         IB        IC        IN
Fund(A)    279.475   309.706   270.302    34.972
RMS (A)    279.442   309.768   270.302    34.986
THD (%)      0          2         0         3

             VAY       VBY       VCY       VAZ       VBZ       VCZ
Fund(kV)    14.359    14.355    14.357    14.361    14.356    14.357
RMS (kV)    14.357    14.357    14.358    14.359    14.357    14.358
THD (%)      0         2         1         0         1         1

Harmonic    IA     IB     IC     IN    VAY    VBY    VCY    VAZ    VBZ    VCZ
2   (%)      0      0      0      0      0      0      0      0      0      0
3   (%)      0      0      0      0      0      0      0      0      0      0
4   (%)      0      0      0      0      0      0      0      0      0      0
5   (%)      0      0      0      0      0      0      0      0      0      0
6   (%)      0      0      0      0      0      0      0      0      0      0
7   (%)      0      0      0      0      0      0      0      0      0      0
8   (%)      0      0      0      0      0      0      0      0      0      0
9   (%)      0      0      0      0      0      0      0      0      0      0
10  (%)      0      0      0      0      0      0      0      0      0      0
11  (%)      0      0      0      0      0      0      0      0      0      0
12  (%)      0      0      0      0      0      0      0      0      0      0
13  (%)      0      0      0      0      0      0      0      0      0      0
14  (%)      0      0      0      0      0      0      0      0      0      0
15  (%)      0      0      0      0      0      0      0      0      0      0

=>
```

MET M Maximum/Minimum Metering

Use the following commands to view or reset maximum and minimum metering values.

Command	Description	Access Level
MET M	Display maximum and minimum metering data.	1
MET RM	Reset maximum and minimum metering data. All values will display RESET until new maximum/minimum values are recorded.	1

Maximum and minimum values include:

Currents	IA,B,C,N	Input currents (A primary)
	IG	Ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$ when Relay Word bit GNDSW = 0; I_G = IN when GNDSW = 1)
Voltages	VAY, VBY, VCY, VAZ, VBZ, VCZ	Voltages (kV primary)
Power	MW3P	Three-phase megawatts
	MVAR3P	Three-phase megavars
	MVA3P	Three-phase megavolt-amperes
Reset Time		Last maximum/minimum reset time

Below is a sample of maximum/minimum metering data from the SEL-651R:

```
=>MET M <Enter>

FEEDER 1                                    Date: 08/29/2003  Time: 08:00:00.000
STATION A                                   Time Source: internal
             Max      Date         Time          Min      Date         Time
IA(A)      280.1  07/08/2003  11:57:32.648     235.3  07/08/2003  11:57:24.647
IB(A)      310.0  07/08/2003  11:58:37.199     269.6  07/08/2003  11:56:49.976
IC(A)      270.4  07/08/2003  11:58:18.522     269.8  07/08/2003  11:57:34.782
IN(A)       35.0  07/08/2003  11:58:40.925      35.0  07/08/2003  11:58:12.121
IG(A)       35.0  07/08/2003  11:58:40.925       0.0  07/08/2003  11:57:34.249
VAY(kV)     14.4  07/08/2003  11:57:36.391      14.4  07/08/2003  11:56:50.509
VBY(kV)     14.4  07/08/2003  11:57:07.578      14.4  07/08/2003  11:57:35.849
VCY(kV)     14.4  07/08/2003  11:57:58.786      14.4  07/08/2003  11:58:40.391
VAZ(kV)     14.4  07/08/2003  11:58:42.529      14.4  07/08/2003  11:56:46.242
VBZ(kV)     14.4  07/08/2003  11:59:07.062      14.4  07/08/2003  11:58:44.659
VCZ(kV)     14.4  07/08/2003  11:58:53.727      14.4  07/08/2003  11:57:12.916
MW3P        11.9  07/08/2003  11:58:30.790      10.8  07/08/2003  11:57:24.647
MVAR3P       3.1  07/08/2003  11:59:03.861       2.8  07/08/2003  11:57:24.647
MVA3P       12.3  07/08/2003  11:58:30.790      11.1  07/08/2003  11:57:24.647
LAST RESET 08/29/2003 08:00:00.000

=>
```

For more information on recloser control maximum/minimum metering quantity calculations, see *Maximum/Minimum Metering on page 8.16*.

MET RMS Metering

Use the **MET RMS** command to display rms (root mean square) quantities.

Command	Description	Access Level
MET RMS	Display rms (root mean square) quantities.	1

Below is a sample of rms metering data from the SEL-651R:

```
=>MET RMS <Enter>

FEEDER 1                                       Date: 08/29/2003  Time: 08:00:00.000
STATION A                                      Time Source: internal
              IA        IB         IC          IN
RMS (A)    279.676   309.791   270.219     34.990

              VAY       VBY        VCY         VAZ        VBZ        VCZ
RMS (kV)    14.357    14.357    14.358      14.359     14.357     14.357

               A         B          C           3P
Avg. MW      3.885     4.305      3.755     11.944

=>
```

OPEN Command (Open Breaker)

Use the open command (**OPE**, **OPE A**, **OPE B**, or **OPE C**) to assert the specified Relay Word bit (OC3, OCA, OCB, or OCC) for 1/4 cycle.

Command	Description	Access Level
OPE	Assert the three-phase close Relay Word bit OC3.	B
OPE *n*	Assert a single-phase close Relay Word bit (**OPE A** asserts OCA, **OPE B** asserts OCB, **OPE C** asserts OCC).	B

Program the open command Relay Word bit into the trip control equation (TR3P, TRA, TRB, or TRC) to enable assertion of the trip Relay Word bit (TRIP3P, TRIPA, TRIPB, or TRIPC) with the open command. Program the trip Relay Word bit to enable assertion of an output contact (e.g. OUT201 := TRIP3P) to trip a recloser/circuit breaker. See *Section 5: Trip and Target Logic* for a detailed explanation of the trip logic.

NOTE: Though the intention of serial port commands OPE A, OPE B, and OPE C is to provide tripping for separate recloser poles A, B, and C, respectively, there is no direct connection. Rather, these commands receive their function by virtue of how their corresponding Relay Word bits OCA, OCB, and OCC are programmed, as inferred above.

Also, no settings have control over the OPE serial port commands or their resultant Relay Word bits. Thus, settings such as global setting BKTYP (breaker type), though involved in structuring single-phase or three-phase logic, have no effect on the OPE serial port commands or their resultant Relay Word bits.

To issue the **OPE** command, enter the following:

```
==>OPE <Enter>

Open Breaker (Y/N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
==>
```

Typing **N <Enter>** after either of the Y/N prompts aborts the command.

The main board breaker jumper supervises the **OPEN** command (see *Table 2.3* and *Table 2.4*). If the breaker jumper is not in place (breaker jumper is OFF), the recloser control does not perform the **OPEN** command and responds with the following:

```
Aborted: No Breaker Jumper
```

PASSWORD Command (View/Change Passwords)

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

Use the **PAS** command to inspect or change existing passwords.

Command	Description	Access Level
PAS	Display the passwords for each access level (except Access Level 0, which has no password).	2

Command	Description	Access Level
PAS *level new-password*	Set a password *new-password* for Access Level *level*.	2
PAS *level* **DISABLE**	Display password protection for the Access Level *level*.	2

Parameter	Description
level	Parameter *level* represents the recloser control access levels 1, B, or 2.
new-password	New password.

The factory default passwords are as shown in *Table 10.6*.

Table 10.6 Factory Default Passwords for Access Levels 1, B, and 2

Access Level	Factory Default Password
1	OTTER
B	EDITH
2	TAIL
C	CLARKE

To change the password for Access Level 1 to Ot3579, enter the following command:

```
=>>PAS 1 Ot3579 <Enter>

Set
=>>
```

Similarly, use **PAS B**, **PAS 2**, and **PAS C** to change the Level B, Level 2, and Level C passwords, respectively.

Table 10.7 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	! " # $ % & ' ( ) * + , - . / : ; < = > ? @ [\ ] ^ _ ` { | } ~

Passwords can contain as many as eight characters. Upper- and lowercase letters are treated as different characters. Strong passwords consist of 8 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. Examples of valid, distinct strong passwords include:

#0t3579! $A24.68&   (Ih2dcs)   *4u-Iwg+

After entering new passwords, type **PAS <Enter>** to confirm that you entered the password correctly. Make sure that the passwords are what you intended, and record the new passwords. If the passwords are lost or you wish to operate the SEL-651R without password protection, put the main board Password jumper in place (Password jumper = ON). Refer to *Table 2.3* and *Table 2.4* for Password jumper information.

If you want to disable password protection for a specific access level, even if the Password jumper is not in place (Password jumper is OFF), simply set the password to DISABLE. For example, **PAS 1 DISABLE** disables password protection for Level 1.

PULSE Command (Pulse Output Contact)

The **PUL** command pulses any of the output contacts for a specified time.

Command	Description	Access Level
PUL OUT*nnn*	Pulse output OUT*nnn* for 1 second.	B
PUL OUT*nnn s*	Pulse output OUT*nnn* for *s* seconds.	B

Parameter	Description
nnn	201, 202 (all models); 101–108 (models with extra I/O).
s	Parameter *s* is time in seconds, with a range of 1 through 30.

To pulse OUT101 for five seconds, enter the following:

```
==>PUL OUT101 5 <Enter>

Are you sure (Y/N) ? Y <Enter>
==>
```

The recloser control aborts the command if the response to the `Are you sure (Y/N) ?` prompt is `N` or `n`.

The main board breaker jumper supervises the **PUL** command (see *Table 2.3* and *Table 2.4*). If the breaker is not in place (breaker jumper is OFF), the recloser control does not perform the **PUL** command and responds with the following:

```
Aborted:  No Breaker Jumper
```

The recloser control generates an event report if any of the output contacts are pulsed. The **PULSE** command is primarily for testing purposes.

QUIT Command

Use the **QUIT** command to revert to Access Level 0.

Command	Description	Access Level
QUI	Go to Access Level 0.	0

Access Level 0 is the lowest access level; the SEL-651R performs no password check to descend to this level (or to remain at this level).

R_S Command (Restore Factory Defaults)

Use the **R_S** command to restore factory default settings.

Command	Description	Access Level
R_S	Restore the factory default settings and passwords and reboot the system.[a]	2

[a] Only available after a settings or critical RAM failure.

SER Command (Sequential Events Recorder Report)

Use the **SER** commands to view and manage the Sequential Events Recorder report. See *Sequential Events Recorder (SER) Report on page 12.34* for further details on SER reports.

Command	Description	Access Level
SER ***row1*** **SER** ***row1 row2*** **SER** ***date1*** **SER** ***date1 date2***	Use the **SER** command to display a chronological progression of all available SER rows (up to 1000 rows). Row 1 is the most recently triggered row and row 1000 is the oldest. Use the **SER** command with parameters to display a chronological or reverse chronological subset of the SER rows.	1
SER C	Use this command to clear/reset the SER records.	1

Parameter	Description
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 *row2* and ending with *row1*. Enter the smaller number first to display a chronological progression of rows through the report. Enter the larger number first to display a reverse chronological 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 DATE_F.

If the requested SER report rows do not exist, the recloser control responds with the following:

```
No SER data
```

SET Command (Change Settings)

The **SET** command is for viewing or changing the recloser control settings (see *Table 9.2* and *Settings Changes Via the Serial Port on page 9.2*).

Command	Description	Access Level
SET ***n***	Set the Group *n* settings, beginning at the first setting in each instance (*n* = 1, 2, 3, 4, 5, or 6; *n* = 1, 2, 3, 4, 5, 6, 7, or 8 for SEL-651R-1); *n* defaults to the active setting group if not listed.	2
SET L ***n***	Set general logic settings for setting group *n* (*n* = 1, 2, 3, 4, 5, or 6; *n* = 1, 2, 3, 4, 5, 6, 7, or 8 for SEL-651R-1); *n* defaults to the active setting group if not listed.	2
SET G	Set global settings.	2
SET P ***n***	Set serial port settings. *n* specifies the port (1, 2, 3, or F); *n* defaults to the active port if not listed.	2
SET R	Set report settings.	2
SET F	Set front-panel settings.	2

SHOW Command (Show/View Settings)

When showing settings, the recloser control displays the settings label and the present value from nonvolatile memory for each setting class.

Command	Description	Access Level
SHO *n*	Show settings. *n* specifies the setting group (1, 2, 3, 4, 5, or 6; *n* = 1, 2, 3, 4, 5, 6, 7, or 8 for SEL-651R-1); *n* defaults to the active setting group if not listed.	1
SHO L *n*	Show general logic settings. *n* specifies the setting group (1, 2, 3, 4, 5, or 6; *n* = 1, 2, 3, 4, 5, 6, 7, or 8 for SEL-651R-1); *n* defaults to the active setting group if not listed.	1
SHO G	Show global settings.	1
SHO P *n*	Show serial port settings. *n* specifies the port (1, 2, 3, or F); *n* defaults to the active port if not listed.	1
SHO R	Show report settings.	1
SHO F	Show front-panel settings.	1

Append a setting name to each of the commands to specify the first setting to display. For example, **SHO 1 E50P** displays the setting group settings starting with setting E50P. The SEL-651R begins at the first setting in a setting class if you do not specify a setting.

SSI Command (Voltage Sag/Swell/Interruption Report)

View and manage voltage SSI data with the SSI commands. See *Sag/Swell/Interruption (SSI) Report on page 12.36* for further details on the SSI report, and *Voltage Sag, Swell, and Interruption Elements on page 4.48* for details on the VSSI elements, and Vbase value.

Command	Description	Access Level
SSI *row1 row2* **SSI *date1 date2***	Use the **SSI** command to display a chronological progression of all SSI report rows. Use the **SSI** command with parameters to display a chronological or reverse chronological subset of the SSI report rows.	1
SSI T	Use this command to manually trigger the VSSI recorder.	1
SSI C	Use this command to clear the SSI report from nonvolatile memory.	1
SSI R	Use this command to reset the VSSI recorder logic and clear the Vbase value.	1

Parameter	Description
row1 row2	Append *row1* to return a chronological progression of the first *row 1* 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 2* 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 DATE_F.

Viewing the SSI Report

The recorded voltage SSI data can be viewed from any setting group, even if setting ESSI := N. Row 1 is the most recently triggered row. View the SSI report by date or by SSI row number.

See *Figure 12.8* for an example SSI report.

If the requested SSI event report rows do not exist, the recloser control responds with the following:

```
No Voltage Sag/Swell/Interruption Data
```

Clearing the SSI Report

Clear the SSI report from nonvolatile memory with the **SSI C** command, as shown in the following example:

```
=> SSI C <Enter>

Clear the Voltage/Sag/Swell Interruption buffer
Are you sure (Y/N)? Y <Enter>
Clearing Complete
```

The **SSI C** command is available in any setting group and on any serial port.

If the **SSI C** command is issued on one serial port while another serial port is being used to display an SSI report, the clearing action will terminate the SSI report retrieval.

Triggering the SSI Recorder

Manually trigger the voltage SSI Recorder using the **SSI T** command. The **SSI T** command is available only if group setting ESSI := Y in the active setting group.

If an **SSI T** command is issued when setting ESSI := N, the recloser control responds as follows:

```
Command is not available
```

If an **SSI T** command is issued before Vbase has initialized, the recloser control responds as follows:

```
Did Not Trigger
```

See *Vbase Initialization on page 4.51* for details on the initializing conditions.

Resetting the SSI Recorder Logic

After the recloser control detects satisfactory voltage signals for at least 12 seconds, the SSI Recorder is armed and a Ready entry is written to the SSI archive.

The **SSI R** command is available only if group setting ESSI := Y in the active setting group. Attempting the **SSI R** command when ESSI := N will display the following:

```
Command is not available
```

See *Positive-Sequence Reference Voltage, Vbase on page 4.50* for more details.

STATUS Command (Recloser Control Self-Test Status)

The **STA** command displays the status report.

Command	Description	Access Level
STA *k*	Display the recloser control self-test information *k* times (*k* = 1–32767). Defaults to 1 if *k* is not specified.	1
STA S	Display the memory and execution utilization for the SELOGIC control equations.	1
STA C	Reboot the recloser control and clear self-test warning and failure status results.	2
STA D	Display the DNP communication statistics.	1
STA RD	Reset the DNP communication statistics.	2

STA (View)

Below is a sample SEL-651R status output:

```
=>STA <Enter>

Serial Number: xxxxxxxxxxxxxxx

FEEDER 1                                    Date: 08/29/2003  Time: 08:00:00.000
STATION A                                   Time Source: internal

FID=SEL-651R-R1xx-V0-Zxxxxxx-D2003xxxx       CID=xxxx

SELF TESTS

Channel Offsets (mV)   W=Warn    F=Fail
     I1     I2     I3     IN    V1Y    V2Y    V3Y    V1Z    V2Z    V3Z    MOF
      0      0      0      0      0      0      0      0      0      0      0

Power Supply Voltages (V)   W=Warn    F=Fail
 2.5V_PS 3.3V_PS  +5V_PS +5V_REG -5V_REG +12V_PS -12V_PS +15V_PS -15V_PS
    2.49    3.28    4.96    5.10   -4.98   11.99  -11.99   14.99  -14.99

Temperature
  26.0 degrees Celsius

Integrated Circuit and Board Status
     RAM     ROM     A/D  CR_RAM   FLASH  IO_BRD    FPGA
      OK      OK      OK      OK      OK      OK      OK

Mains, Battery Monitor, and Capacitor Monitor
   INPBV  12VAUX    MODE    VBAT    IBAT  TCCAPV
   12.00   12.00 FLT_CHG   12.20     150   155.0

Relay [Enabled]

=>
```

Serial Number	Recloser Control Serial Number
FID	Firmware identifier string containing the module firmware revision number.
CID	Firmware checksum identifier.
Channel Offsets[a]	Display measured dc offset voltages in millivolts for the current and voltage channels. The MOF (master) status is the dc offset in the A/D circuit when a grounded input is selected.
Power Supply Voltages[a]	Display power supply voltages in Vdc for the power supply outputs.
Temperature	Displays the internal module temperature in degrees Celsius.
Integrated Circuit and Board Status	RAM, ROM, CR_RAM, FLASH, FPGA—These tests verify the SEL-651R memory components. The columns display OK if memory is functioning properly; the columns display FAIL if the memory area has failed. A/D—Analog to Digital convert status. IO_BRD—Extra I/O board status.

Mains, Battery Monitor, and Capacitor Monitor	INPBV	DC POWER IN voltage (see *Figure 2.11*)
	12VAUX	AUXILIARY POWER SUPPLY voltage (see *Figure 2.11*)
	MODE	Battery charger mode: STARTUP Startup CUR_CHG Constant current charge FST_CHG Fast charge FLT_CHG Float charge DISCHRG Discharge BAT_FLR Battery failure BAT_TST Battery discharge test
	VBAT	BATTERY voltage (see *Figure 2.11*)
	IBAT	BATTERY current in milliamps dc (see *Figure 2.11*). If the battery is discharging, a minus sign precedes the current value.
	TCCAPV	CAPACITORS voltage (see *Figure 2.11*)

[a] W (Warning) or F (Failure) is appended to the values to indicate an out-of-tolerance condition.

Refer to *Table 13.1* for self-test thresholds and corrective actions.

STA S (View SELOGIC Utilization)

Below is a sample of SEL-651R **STA S** response. See *SELOGIC Control Equation Capacity on page 7.1*.

```
=>STA S <Enter>

Serial Number: xxxxxxxxxxxxxxx

FEEDER 1                                   Date: 08/06/2003  Time: 11:49:00.294
STATION A                                  Time Source: internal

FID=SEL-651R-Rxxx-V0-Zxxxxxx-D2003xxxx       CID=xxxx

SELogic Available Capacity
Act. Group:              1    2    3    4    5    6
Execution               84%  57%  82%  86%  86%  86%
Settings (Group)        77%  77%  77%  77%  77%  77%
Settings (Logic)        84%  83%  84%  85%  85%  85%

Settings (Global)       82%
Settings (Report)       97%
Settings (Front Panel)  60%


=>
```

STA C (Clear)

The **STA C** command reboots the SEL-651R. Thus, this command clears a transient status failure in the unlikely event that a transient status failure occurs.

Also use this command if the battery is replaced after a battery test failure to clear the battery test failure status.

STA D (Display DNP Communication Statistics)

Below is an example of a SEL-651R STA D response. See *Appendix E: DNP3 Communications* for more information.

```
STATUS D

Serial Number: xxxxxxxxxxxxxxx

FEEDER 1                                   Date: 12/15/2003  Time: 11:49:00.294
STATION A                                  Time Source: internal

FID=SEL-651R-Rxxx-V0-Zxxxxxx-D2003xxxx       CID=xxxx

DNP Communication Statistics

           Bytes   Frames  Fragments
Sent       31509     982     968
Received   28606    1589    1577

Last Data Sent     12/15/2003  16:34:00.068
Last Data Received 12/15/2003  16:33:59.985

Last Data Reset    RESET


=>>
```

STA RD (Reset DNP Communication Statistics)

Use the **STA RD** command to reset the DNP communications statistics. You would use this command to clear all the counters in the STA D report so that you could monitor subsequent DNP communications activity more easily. See *Appendix E: DNP3 Communications* for more information.

TARGET Command (Display Relay Word Bit Status)

The **TAR** command displays the status of front-panel target LEDs or Relay Word bit, whether they are asserted or deasserted.

Command	Description	Access Level
TAR *name k* **TAR *n k***	Use **TARGET** without parameters to display Relay Word row 0 or last displayed target row.	1
TAR R	Clears front-panel tripping targets. Shows Relay Word Row 0.	1

Parameter	Description
name	Display the Relay Word row with Relay Word bit Name.
n k	Show Relay Word row number *n* (0–99; 0–103 for SEL-651R-1) and repeat *k* times (1–32767).

Option[a]	Description
ROW	Adding **ROW** to the command displays the Relay Word Row number at the start of each line.
LIST	Adding **LIST** to the **TARGET** command displays of all of the Relay Word bits in all of the rows.

[a] You can use the **ROW** and **LIST** option in the same command.

The elements are represented as Relay Word bits and are listed in rows of eight, called Relay Word rows. The first four rows represent the front-panel status and trip target LEDs, and correspond to *Table 10.8*. All Relay Word rows are described in *Table F.1* and *Table F.2*.

Relay Word bits are used in SELOGIC control equations. See *Relay Word Bits on page 7.2*.

The **TAR** command does not remap the front-panel target LEDs, as is done in some previous SEL relays.

Table 10.8 Front-Panel Targets and the TAR Command

TAR 0 (Front-Panel LEDs)	EN	TRIPLED	*	*	*	*	*	*
TAR 1 (Front-Panel LEDs)	TLED_08	TLED_07	TLED_06	TLED_05	TLED_04	TLED_03	TLED_02	TLED_01
TAR 2 (Front-Panel LEDs)	TLED_16	TLED_15	TLED_14	TLED_13	TLED_12	TLED_11	TLED_10	TLED_09
TAR 3 (Front-Panel LEDs)	TLED_24	TLED_23	TLED_22	TLED_21	TLED_20	TLED_19	TLED_18	TLED_17

TEST DNP Command

The **TEST DNP** command is for testing the DNP interface. For more information on DNP and the SEL-651R, see *Appendix E: DNP3 Communications* for more information on DNP and the **TEST DNP** command.

TEST DNP

Use the **TEST DNP** command to write override values in the DNP map with a test value.

Table 10.9 TEST DNP Command

Command	Description	Access Level
TEST DNP	Display present override values.	1, B, P, A, O, 2
TEST DNP ***type***[a] ***n***[b] ***value***	Write new data *value* of *type* to the DNP map at DNP point number *n*.	B, P, A, O, 2

[a] Parameter type is A for analog, B for binary, or C for counter inputs.
[b] n is a DNP point number based on active map.

When displaying DNP test data, the relay shows the report header, then the DNP Object Type, Index, and Override Value for binary inputs, counters, and analog inputs.

The point number and override value must be valid for the given data type; see *Appendix E: DNP3 Communications*.

The relay asserts Relay Word bit TESTDNP while any DNP test data are present in the relay.

DNP Status Bytes. Whenever a DNP value is overridden and the value is read via DNP, the status byte for the overridden value does not indicate that the bit is locally forced to a test value. Not all masters properly handle a forced status.

TEST DNP OFF

Use the **TEST DNP OFF** command to remove override values. The relay returns the database registers to the pretest values.

Table 10.10 TEST DNP OFF Command

Command	Description	Access Level
TEST DNP *type*[a] *n*[b] OFF	Clear the override testing value of *type* from the DNP point number *n*.	B, P, A, O, 2
TEST DNP OFF	Clear all override testing values from the DNP map.	B, P, A, O, 2

[a] Parameter n is a DNP point number.
[b] Type is A for analog, B for binary, or C for counter inputs.

TIME Command (View/Change Time)

The **TIME** command returns information about the SEL-651R 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.

Command	Description	Access Level
TIME	Display the present internal clock time.	1
TIME *hh:mm*	Set the internal clock to *hh:mm*.	1
TIME *hh:mm:ss*	Set 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 recloser control updates and saves the time in the nonvolatile clock, and displays the time you just entered. If you enter an invalid time, the SEL-651R responds, `Invalid Time`.

TRIGGER Command (Trigger Event Report)

Use the **TRI** command to trigger the SEL-651R to record data for high-resolution oscillography and event reports.

Command	Description	Access Level
TRI	Trigger event report data capture.	1

When you issue the **TRI** command, the SEL-651R responds, `Triggered`. If the event did not trigger within 1 second, the recloser control responds, `Did not trigger`.

See *Standard 15/30-Cycle Event Reports on page 12.2* for further details on event reports.

VERSION Command (Show SEL-651R Configuration and Firmware Version)

The **VER** command provides recloser control configuration and information such as nominal current input ratings.

Command	Description	Access Level
VER	Display information about the configuration of the recloser control.	1

Below is an example of the **VER** command for an SEL-651R:

```
=>VER <Enter>
Partnumber: 0651Rxxxxxxxxxxxxx

Mainboard: 600MB1
Data FLASH Size:  1024 Kbytes
Analog Voltage Inputs (PT): 300 Vac(VY)-300 Vac(VZ)
Analog Current Inputs (CT): 1 Amp Phase, 0.2 Amp Neutral
Extended Relay Features:
  DNP
  Power Quality Monitoring

FID=SEL-651R-R1xx-V0-Zxxxxxx-D2003xxxx

SELboot checksum xxxx OK
SLBT-6XX-R1xx-V0-Zxxxxxx-D2003xxxx

If above information is unexpected,
contact SEL for assistance

=>
```

Section 11
Front-Panel Operations

Introduction

The SEL-651R Recloser Control front panel makes power system data collection and system control quick and efficient. Use the front panel to analyze power system operating information, view and change recloser control settings, and perform control functions. The SEL-651R features a straightforward menu-driven control structure presented on the front-panel liquid crystal display (LCD). Front-panel targets and other LED indicators give a quick look at SEL-651R operation status. Perform often-used control actions rapidly by using the large direct-action pushbuttons. The features that help you operate the recloser control from the front panel include the following:

- Reading metering
- Inspecting targets
- Accessing settings
- Controlling recloser control operations

Front-Panel Layout

Figure 11.1 shows and identifies the following regions:

- EIA-232 Serial Port. See *Section 10: Communications* for details on the serial port.
- Human-Machine Interface (HMI)
- Status and trip target LEDs
- Operator control pushbuttons and LEDs

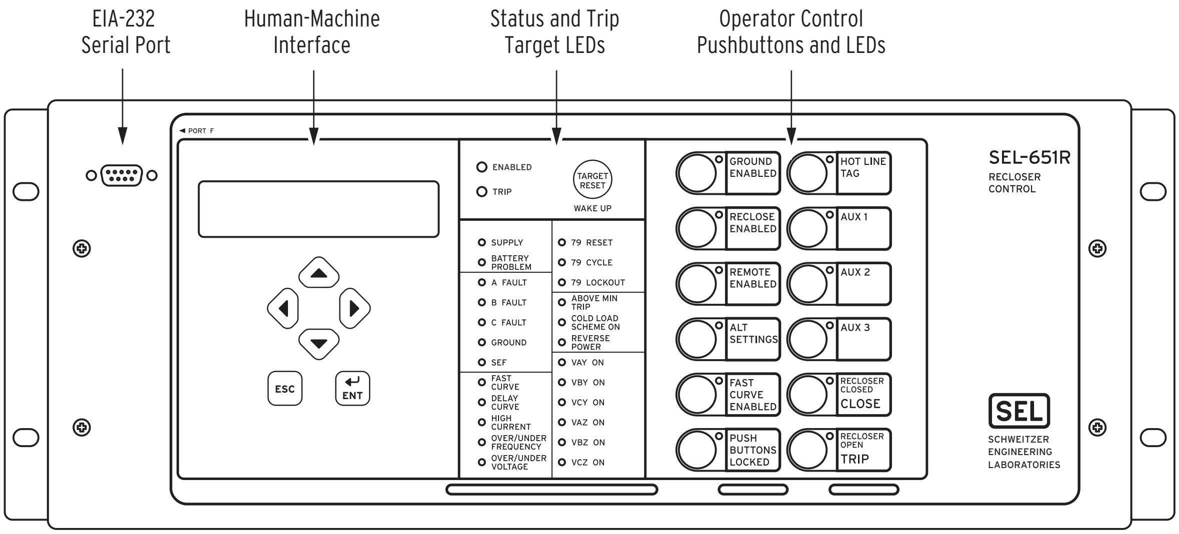


Figure 11.1 SEL-651R Front-Panel Pushbuttons—Overview

This versatile front panel supports the following features so you can customize it for your needs:

➤ Rotating display and control points on the HMI
➤ Programmable status and trip target LEDs
➤ Programmable operator control pushbuttons and LEDs
➤ Slide-in configurable front-panel labels to change the identification of status and trip target LEDs and operator control pushbuttons and LEDs. The configurable labels are discussed in more detail in *Section 2: Installation*.

Human-Machine Interface

Contrast

NOTE: See the Preface for an explanation of typographic conventions used to describe menus, the front-panel display, and the front-panel pushbuttons.

You can adjust the LCD screen contrast to suit your viewing angle and lighting conditions. To change screen contrast, press and hold the **{ESC}** pushbutton for two seconds. The SEL-651R displays a contrast adjustment box. Pressing the **{Right Arrow}** pushbutton increases the contrast. Pressing the **{Left Arrow}** pushbutton decreases the screen contrast. When you are finished adjusting the screen contrast, press the **{ENT}** pushbutton; this process is a short cut for changing the LCD contrast setting FP_CONT in the front-panel settings.

Front-Panel Automatic Messages

The recloser control displays an automatic message if a self-test failure occurs.

Front-Panel Security

Front-Panel Access Levels

The SEL-651R front panel typically operates at Access Level 1 and provides viewing of recloser control measurements and settings. Some activities, such as editing settings and controlling output contacts, are restricted to those operators who know the Access Level B or Access Level 2 passwords or can disable these passwords from the front panel.

In the figures that follow, restricted activities are marked with the padlock symbol shown in *Figure 11.2*.

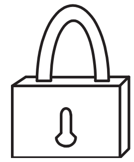


Figure 11.2 Access Level Security Padlock Symbol

Before you can perform a front-panel menu activity that is marked with the padlock symbol, you must enter the correct Access Level B or Access Level 2 passwords. After you have correctly entered the password, you can perform other Access Level B or Access Level 2 activities without reentering the password.

Access Level 2 Password Entry

When you try to perform an Access Level B or Access Level 2 activity, the recloser control determines whether you have entered the correct Access Level B or Access Level 2 password since the front-panel inactivity timer expired. If you have not, the recloser control displays the screen shown in *Figure 11.3* for you to enter the password.

```
Password=
Del Clr Accept
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 . . . . . .
0 1 2 3 4 5 6 7
8 9 . . . . . .
! " # $ % & ' (
) * + , - . / :
; < = > ? @ [ \
] ^ _ ` { | } ~
```

Figure 11.3 Password Entry Screen

See *PASSWORD Command (View/Change Passwords) on page 10.32* for the list of default passwords and for more information on changing passwords.

Front-Panel Time-Out

To help prevent unauthorized access to password-protected functions, the SEL-651R provides a front-panel time-out, setting FP_TO. A timer is reset every time a front-panel pushbutton is pressed. Once the time-out period has expired, the access level is reset to Access Level 1. Manually reset the access level by selecting `Reset Access Lvl` from the `MAIN` menu.

Front-Panel Menus and Screens

Navigating the Menus

The SEL-651R front panel gives you access to most of the information that the recloser control measures and stores. You can also use front-panel controls to view or modify recloser control settings.

All of the front-panel functions are accessible using the six-button keypad and LCD display. Use the keypad (shown in *Figure 11.4*) to maneuver within the front-panel menu structure, described in detail throughout the remainder of this section. *Table 11.1* describes the function of each front-panel pushbutton.

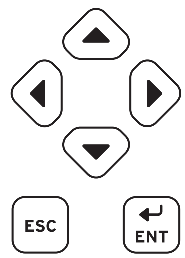


Figure 11.4 Front-Panel Pushbuttons

Table 11.1 Front-Panel Pushbutton Functions

Pushbutton		Function
	{Up Arrow}	Move up within a menu or data list. While editing a setting value, increase the value of the underlined digit.
	{Down Arrow}	Move down within a menu or data list. While editing a setting value, decrease the value of the underlined digit.
	{Left Arrow}	Move the cursor to the left.
	{Right Arrow}	Move the cursor to the right.
 ESC	{ESC}	Escape from the current menu or display. Hold for 2 seconds to display contrast adjustment screen.
 ENT	{ENT}	Move from the rotating display to the `MAIN` menu. Select the menu item at the cursor. Select the displayed setting to edit that setting.

The SEL-651R automatically scrolls information that requires more space than provided by a 16-character LCD line. Use the **{Left Arrow}** and **{Right Arrow}** pushbuttons to suspend automatic scrolling and enable manual scrolling of this information.

SEL-651R Menu Card

Figure 11.5 describes the menu hierarchy. Each SEL-651R is supplied with a menu card that is a laminated duplicate of this figure. Menus and displays are available for most SEL-651R functions. Several of these menus and displays are described in detail later in this section.

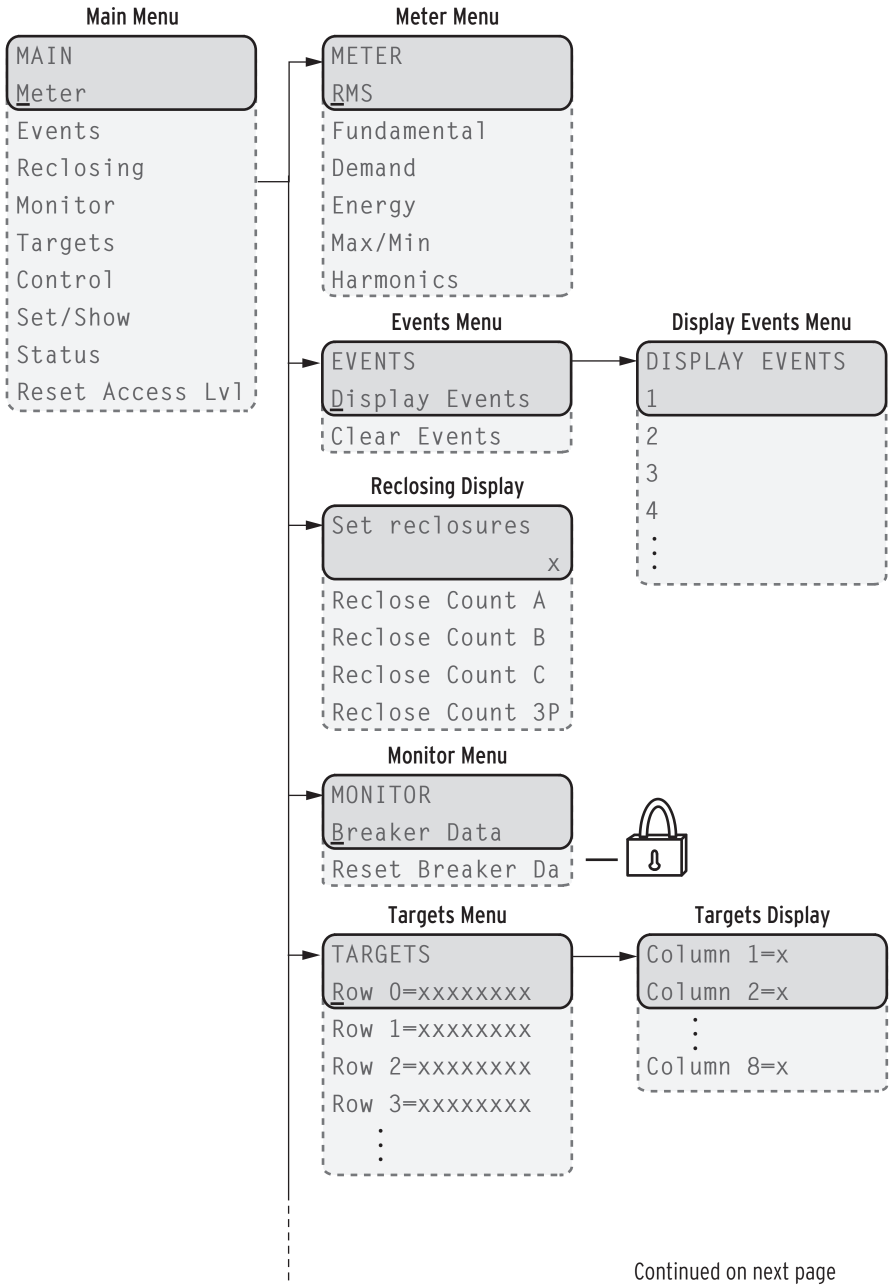


Figure 11.5 SEL-651R Front-Panel Menu Hierarchy (continued)

Continued from previous page

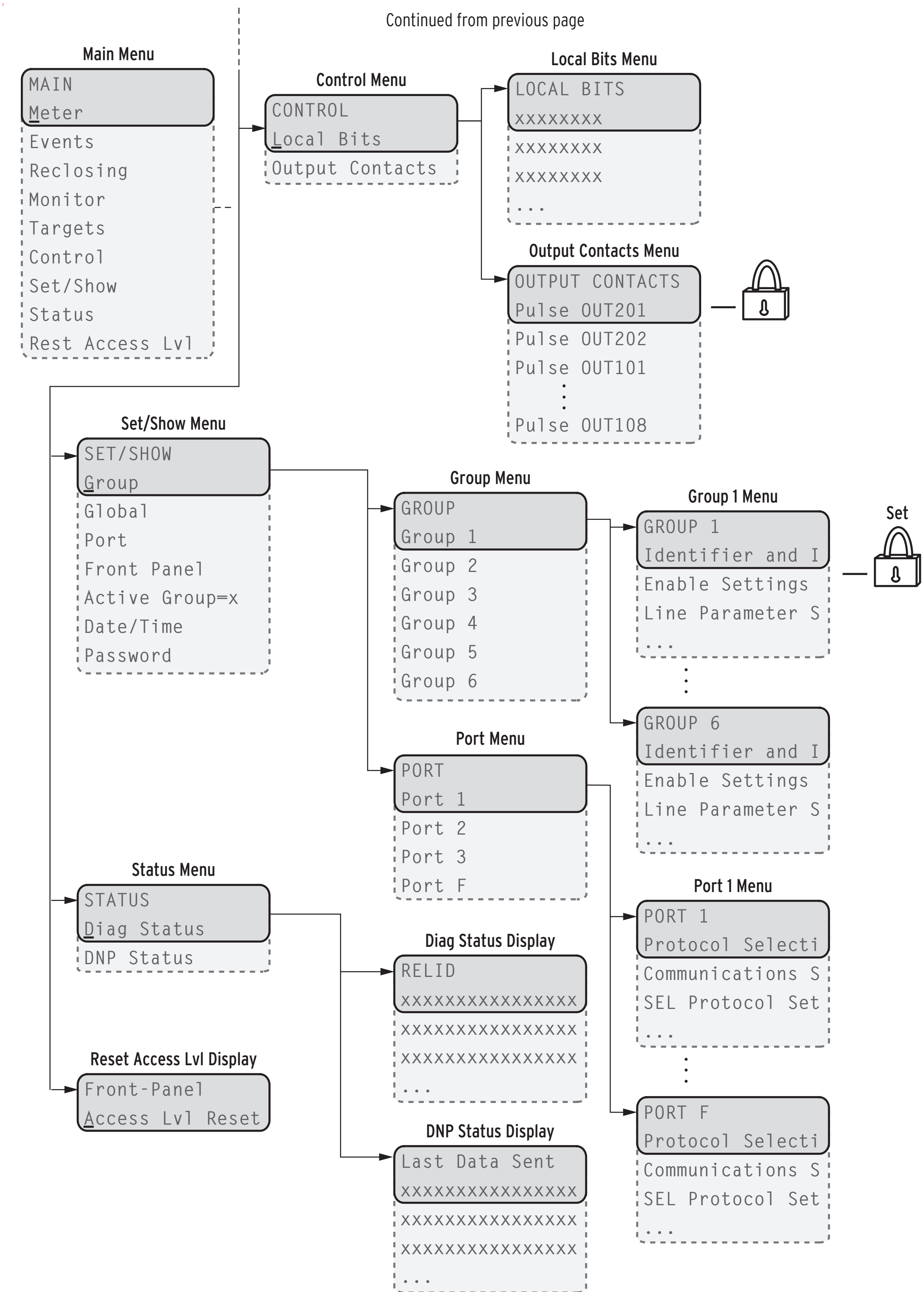


Figure 11.5 SEL-651R Front-Panel Menu Hierarchy

Reclosing Display

Use the RECLOSING display to see the shot counter progression during reclosing relay testing. Select the RECLOSING menu to access this display on the MAIN menu. *Table 11.2* shows example reclosing displays.

Table 11.2 Reclosing Display

The number (2) in the example display corresponds to the last shot value, which is a function of the number of open intervals, setting E79. There are two set open intervals in these example settings, thus two reclosures (shots) are possible in a reclose sequence.	Set Reclosures 2
For three-phase reclosers, the number (0) in the example display corresponds to the present shot value. If the breaker is closed and the reclosing relay is reset, then RECLOSE COUNT = 0. If the breaker is open and the reclosing relay is locked out after a reclose sequence, then RECLOSE COUNT = 2.	Reclose Count 3P 0
For single-phase reclosers, the number (0) in the example displays corresponds to the present shot value for each phase.	Reclose Count A 0
	Reclose Count B 0
	Reclose Count C 0
The example display shows the front-panel LCD when reclosing is disabled.	No Reclosing Set

Targets Menu

Select the TARGETS menu item on the MAIN menu to access the target rows (Relay Word bits). Use the following features to monitor the recloser control during operation and testing.

Navigate to the target row that contains the Relay Word bit you want to access. Monitor two consecutive rows that contain 16 Relay Word bits with this display.	Row 11=01001100 Row 12=11000100
Display the Relay Word bit names and status of two consecutive bits by pressing **{ENT}** while the cursor is at the row you want to access. Use the **{Up Arrow}** or **{Down Arrow}** to navigate to any of the Relay Word bits in the selected row.	51CS=0 51CR=1

Control Menu

The SEL-651R provides great flexibility in power system control through the Control menu. Use the front-panel Control menu to perform these functions:

- ➤ Operate local control switches. The output states of these switches are known as local bits.
- ➤ Test output contacts (password required).

Local Bits: Menu

Use the local bits menu option to operate as many as 16 local control switches. These local control switches replace traditional panel-mounted control switches. The SEL-651R saves the output states of the local control switches in nonvolatile memory and restores these states at power-up.

NOTE: Any unused local control bits default to the clear (logical 0) state.

Also, any reconfigured local bit retains the existing bit state after you change the bit setting. Disabling a local bit sets that bit to the clear (logical 0) state.

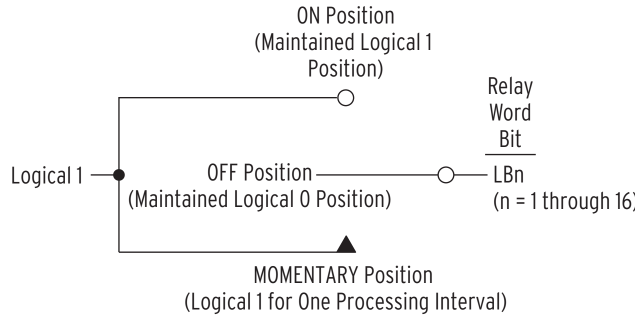


Figure 11.6 OFF/MOMENTARY Local Control Switch

The output of the switch in *Figure 11.6* is a Relay Word bit (LB01–LB16), called a local bit, and repeats for each local bit.

Local Bits: Switch Types

Use the settings in *Table 11.3* to create menu items that aid in using on, off, or momentary switches. Set ELB to the required number of local bits to enable the local bits settings. Use the **SET F** command, see *Table 9.2*.

Table 11.3 Local Bits Labels

Local Bits Switch Position	Label Setting	Setting Definition	Logic State
	NLB*n*	Name of local bit	
OFF	CLB*n*	"Clear" local bit LB*n*	Logical 0
ON	SLB*n*	"Set" local bit LB*n*	Logical 1
MOMENTARY	PLB*n*	"Pulse" local bit LB*n*	Logical 1 for one processing interval

Setting NLB*n*, the local bit name, must always contain a valid name. Enter other local bit label settings to configure the local bit switch type in accordance with *Table 11.4*. Enter **NA** to clear a setting.

Table 11.4 Local Bits Switch Configuration

Local Bits Switch Type	Label NLBn	Label CLBn	Label SLBn	Label PLBn
ON/OFF	x	x	x	
OFF/MOMENTARY	x	x		x
ON/OFF/MOMENTARY	x	x	x	x

ON/OFF Switch. Local bit LB*n* can be in the ON (LB*n* = logical 1) or OFF (LB*n* = logical 0) position.

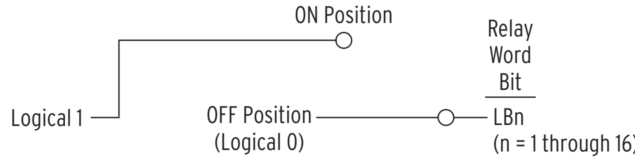


Figure 11.7 ON/OFF Local Control Switch

OFF/MOMENTARY Switch. Local bit LB*n* is maintained in the OFF (LB*n* = logical 0) position and pulses to the MOMENTARY (LB*n* = logical 1) position for one processing interval (1/4 cycle).

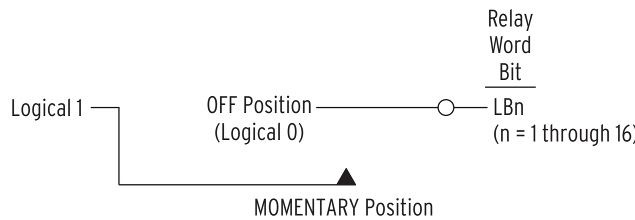


Figure 11.8 OFF/MOMENTARY Local Control Switch

ON/OFF/MOMENTARY Switch. Local bit LB*n* can be in the ON (LB*n* = logical 1) position, OFF (LB*n* = logical 0) position, or is maintained in the OFF (LB*n* = logical 0) position and pulses to the MOMENTARY (LB*n* = logical 1) position for one processing interval (1/4 cycle).

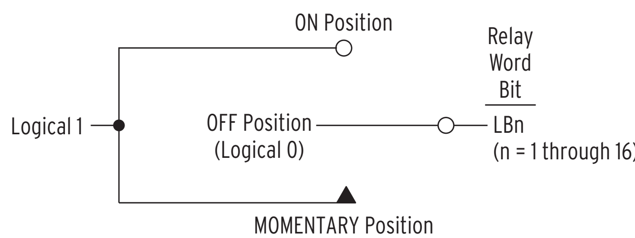


Figure 11.9 ON/OFF/MOMENTARY Local Control Switch

Local Bits: Operation

Table 11.5 shows examples of the local bit displays using setting names.

Table 11.5 Local Bits Menu (Sheet 1 of 2)

Select the `Local Bits` menu item on the `CONTROL` menu to access the local control switches.	`CONTROL` `Local Bits`
The LCD displays a menu empty of local bits if no local bits are enabled or programmed.	`LOCAL BITS`

Table 11.5 Local Bits Menu (Sheet 2 of 2)

The LCD will display a menu of local bits in numerical order if at least one local bit is enabled and programmed. The menu also shows the present position of the local control switches. Use the cursor keys to move to the desired local bit and press **{ENT}** to select it.	LOCAL BITS NLB01 = CLB01 NLB02 = CLB02 ⋮ NLB31 = CLB31 NLB32 = CLB32
Use the cursor keys to move to the desired position (SLB01, CLB01, or PLB01) and press **{ENT}** to select that position.	NLB01 = CLB01 SLB01 PLB01
Use the cursor keys to move to `Yes` and press **{ENT}** to activate that position. The local bit present state updates to the new position.	SLB01 No Yes

Local Bits: Nonvolatile State

The SEL-651R **stores local bit states in nonvolatile memory and retains these switch states during power-off conditions**. When power is restored, the recloser control restores the local bit states. If a local control switch is in the ON position (corresponding local bit is asserted to logical 1) when power is lost, this switch returns to the ON position (corresponding local bit is still asserted to logical 1) when power is restored. If a local control switch is in the OFF position (corresponding local bit is deasserted to logical 0) when power is lost, this switch returns to the OFF position (corresponding local bit is still deasserted to logical 0) when power is restored. This feature makes the local bit feature behave as a traditional installation with panel-mounted control switches. **If power is lost to the panel, the front-panel control switch positions remain unchanged**.

If a local bit is routed to a programmable output contact and control power is lost, the SEL-651R stores the state of the local bit in nonvolatile memory but the output contact goes to the de-energized state. When the control power is reapplied to the recloser control, the programmed output contact returns to the local bit state after recloser control initialization.

Local Bits: Application Example

An example of manual trip and close functions using local bits LB03 and LB04 follows. The following label settings configure the local bits as OFF/ MOMENTARY switches (enable local bits first with front-panel setting ELB := 4 or greater).

Table 11.6 Local Bits Example Settings (Sheet 1 of 2)

Local Bit	Function	Setting
LB03	Name	NLB03 = MANUAL TRIP
	OFF Position	CLB03 = RETURN
	ON Position	SLB03 =
	MOMENTARY Position	PLB03 = TRIP

Table 11.6 Local Bits Example Settings (Sheet 2 of 2)

Local Bit	Function	Setting
LB04	Name	NLB04 = MANUAL CLOSE
	OFF Position	CLB04 = RETURN
	ON Position	SLB04 =
	MOMENTARY Position	PLB03 = CLOSE

Use the following steps to change the local bits state.

Select the `Local Bits` menu item on the `CONTROL` menu to access the local control switches.	LOCAL BITS MANUAL TRIP = RETURN
Press the **{Down Arrow}** cursor key to display both the `MANUAL TRIP` and `MANUAL CLOSE` local bits.	MANUAL TRIP = RETURN MANUAL CLOSE = RETURN
Use the cursor keys to select the `MANUAL CLOSE` menu item and press **{ENT}** to select that item.	MANUAL CLOSE = RETURN CLOSE
Use the cursor keys to move to `Yes` and press **{ENT}** to activate that position. This is an OFF/MOMENTARY switch; the `MANUAL CLOSE` switch moves momentarily to the `CLOSE` position and then moves back to the `RETURN` position.	CLOSE No Yes
Press the **{ESC}** to return to the `CONTROL` menu. Use the cursor keys to move to the `MANUAL TRIP` menu item and press **{ENT}** to select that item.	MANUAL TRIP = RETURN TRIP
Use the cursor keys to move to `Yes` and press **{ENT}** to activate that position. This is an OFF/MOMENTARY switch; the `MANUAL TRIP` switch moves momentarily to the `TRIP` position and then moves back to the `RETURN` position.	TRIP No Yes

Local Bits: Application Ideas

The preceding settings example is for an OFF/MOMENTARY switch. Local bits configured as ON/OFF switches can be used for other applications, such as the following:

- ➤ Reclosing relay enable/disable
- ➤ Ground element enable/disable
- ➤ Remote control supervision
- ➤ Sequence coordination enable/disable

Output Contacts: Menu

Use the `Output Contacts` menu item to test recloser control output contacts and associated circuits. You can pulse trip outputs, close outputs, and general-purpose contact outputs from this menu.

Press the **{ENT}** pushbutton to pulse the output.	OUTPUT CONTACTS Pulse OUT202
The LCD displays a password screen if a password is required. Enter your Level B or Level 2 password.	Password= _ Del Clr Accept
Press the **{Right Arrow}** to select `Yes` and then press **{ENT}**.	Pulse OUT202 No Yes

SET/SHOW Menu

The SEL-651R settings are arranged in easy-to-understand categories. The settings structure simplifies setting the recloser control. Access the settings class (group, global, port, or front-panel) and instance (i.e., Group 1, Group 2, etc.) required by performing the following steps, which are similar to issuing the appropriate **SET/SHOW** command:

Step 1. Select the `SET/SHOW` menu item on the `MAIN` menu to view or modify the settings (refer to *SEL-651R Menu Card on page 11.4*).

Step 2. Select the settings class or select the active group, date/time, or password settings from the `SET/SHOW` menu.

Step 3. If necessary, select an instance of the setting class.

Each settings class includes headings that create subgroups of associated settings. These headings are displayed in the settings screen captures in *Section 9: Settings*. Select the heading that contains the setting of interest. An example of the GROUP 1 headings is shown in *Figure 11.10*.

```
Identifier and Instrument Transformer Settings
Enable Settings:
Line Parameter Settings:
Maximum -Phase T Overcurrent Element J Settings
Maximum -Phase T Overcurrent Elment K Settings
Maximum -Phase T Overcurrent Torque Control Settings:
Ground Time-Overcurrent Element #1-J Settings:
...
```

Figure 11.10 GROUP 1 Heading Example

NOTE: Report settings (those displayed by the **SET R** command) and general logic settings (those displayed by the **SET L n** command) are not available on the front-panel HMI. Other SELOGIC control equations can be viewed but not edited.

Navigate to the setting of interest. View or edit the setting by pressing **{ENT}**. For text settings, use the four navigation pushbuttons to scroll through available alphanumeric and special character settings. For numeric settings, use the **{Left Arrow}** and **{Right Arrow}** pushbuttons to select the digit to change and the **{Up Arrow}** and **{Down Arrow}** pushbuttons to change the value. Press **{ENT}** to enter the new setting.

Setting changes can also be made using ACSELERATOR QuickSet® SEL-5030 software or ASCII communications commands.

Rotating Display

Meters and indicating panel lights can be replaced by the SEL-651R rotating display. This feature rotates screens of information on the LCD when the front-panel menus are not in use.

After front-panel time out, the LCD presents each of the display screens in the following sequence:

- Any active (filled) display points screens
- Enabled metering screens

Screen Scrolling

The rotating display has two screen scrolling modes: auto-scrolling mode and manual-scrolling mode.

Press the **{ESC}** pushbutton while in the MAIN menu to enter the rotating display mode. The SEL-651R automatically begins auto-scrolling the enabled metering and display points screens.

Press the **{Up Arrow}** or **{Down Arrow}** pushbutton while in the rotating display mode to begin manual scrolling and to navigate to the desired screen. The recloser control remains in manual scrolling mode for 60 seconds, at which time the front-panel LCD resumes auto-scrolling.

Press the **{ENT}** or **{ESC}** key to exit the rotating display and view the MAIN menu.

Display Points

Use the 32 display points to show the status of Relay Word bits or display the value of analog quantities (analog values, settings). Set EDP to the required number of display points to enable the display point settings.

See *Table F.1* for a list of digital quantities that can be used with display points. Select the following:

- Relay Word bit
- Alias
- String to display when bit is set
- String to display when bit is cleared

See *Table G.1* for a list of analog quantities that can be used with display points. Select the following:

- Analog quantity
- Formatting, scaling, and programmable text

Status Indications

Circuit breaker auxiliary contacts, front-panel switches, SCADA contacts, and other devices activate traditional indicating panel lights. These indicators signal conditions, such as the following:

- Circuit Breaker or Recloser Open/Closed
- Reclosing Relay Enabled/Disabled

Figure 11.11 shows traditional indicating panel lights wired in parallel with SEL-651R optoisolated inputs. Input IN101 provides circuit breaker status to the recloser control, and input IN102 enables/disables reclosing via the following SELOGIC® control equation settings:

52A3P := **IN101** (Circuit breaker status)

79DTL3P := **NOT IN102** (Reclosing Drive-to-Lockout Setting)

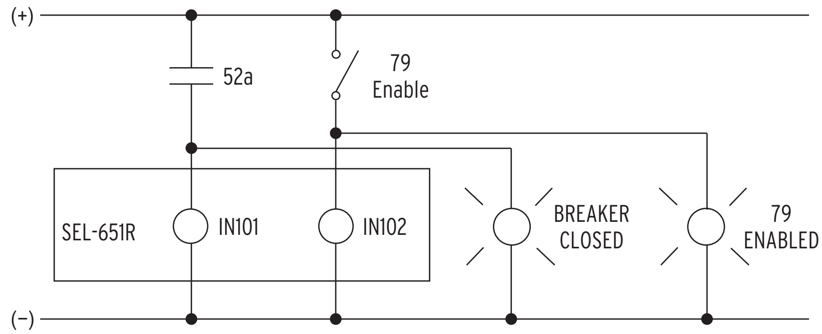


Figure 11.11 Traditional Panel Light Installations

The 79 ENABLED panel light illuminates when the 79 ENABLE switch is closed. When the 79 ENABLE switch is open, the 79 ENABLED panel light extinguishes, indicating that the reclosing relay is disabled.

The BREAKER CLOSED panel light illuminates when the 52a circuit breaker auxiliary contact is closed. When the 52a circuit breaker auxiliary contact is open, the BREAKER CLOSED panel light extinguishes, and it is understood that the breaker is open.

The indicating panel lights are not needed with the rotating display feature in the SEL-651R. *Figure 11.12* shows how to eliminate the indicating panel lights using the rotating display.

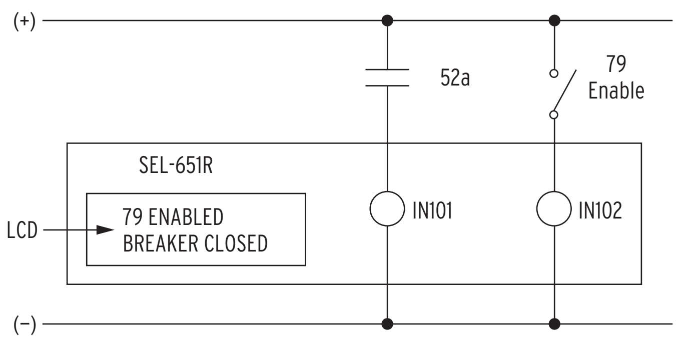


Figure 11.12 Rotating Display Replaces Traditional Panel Light Installations

Setting Syntax

NOTE: DPxx indicates DP01 ... DP32.

Use the following syntax to display the given entry (Relay Word bits or analog quantities) exactly as seen in the navigational menu (name, value, and units).

DPxx := **Name** (see examples later in this section)

Use the following syntax to display the given entry (Relay Word bits or analog quantities) as seen in the navigational menu, replacing the name of the value with the given alias string. Relay Word bits require one row, while analog quantities require two rows.

DPxx := **Name, "Alias"** (see examples later in this section)

Use the following syntax to display the given entry (Relay Word bits only), with the given alias. If the Relay Word bit is asserted (logical 1), the LCD displays the set string in the place of the value. If the Relay Word bit is deasserted (logical 0), the LCD displays the clear string in the place of the value. One or all of Alias, Set String, or Clear String can be empty. If Alias is empty, then the LCD displays only the Set or Clear Strings. If either Set String or Clear String is empty, then the item is not visible when the bit matches that state. If an empty line is required in this case, instead of hiding the line altogether, then use empty curly braces ({}) for the Set or Clear String. This entry requires at most one display row.

DPxx := **Name, "Alias", "Set String", "Clear String"** (see examples later in this section)

Use the following syntax to display the given entry (analog quantities only) with the given text and formatting. Formatting must be in the form {Width.Decimal,Scale} with the value of Name, scaled by 'Scale', formatted with total width 'Width' and 'Decimal' decimal places. The width value includes the decimal point and sign character, if applicable. The 'scale' value is optional; if omitted, the scale factor is processed as 1. If the numeric value is smaller than the field size requested, the field is padded with spaces to the left of the number. If the numeric value will not fit within the field width given, the field grows (to the left of the decimal point) to accommodate the number. All display points formatted in this manner occupy one, and only one, line on the display at all times. You can use multiple display points to simulate multiple lines.

DPxx := **Name, "Text1 {Width.Decimal,Scale} Text2"** (see examples later in this section)

Relay Word Bits Settings Examples

The following settings examples use optoisolated inputs IN101 and IN102 in the display points settings. Local bits (LB01 through LB16), latch bits (LT01 through LT16), remote bits (RB01 through RB16), setting group indicators (SG1 through SG6), and any other Relay Word bits can also be used. These examples use the following syntax:

DPxx := **Name, "Alias", "Set String", "Clear String"**

Example: Continually Display a Message. To always display the message SEL-651R `CONTROL` on the rotating display, enter the display point setting DP01 as follows:

Setting	
DP01 = 1, "SEL-651R CONTROL"	SEL-651R CONTROL

Example: Reclosing Relay Status Indication. Enter SELOGIC control equation display point setting DP02 as follows to display `79 ENABLED` when input IN102 asserts and display `79 DISABLED` when IN102 deasserts.

Settings	IN102 is Asserted	IN102 is Deasserted
DP02 = IN102, , "79 ENABLED", "79 DISABLED"		
	79 ENABLED	79 DISABLED

Example: Circuit Breaker Status Indication. Use one of the following setting methods to display the circuit breaker status.

Settings	IN101 is Asserted	IN101 is Deasserted
52A = IN101 DP03 = 52A	52A=1	52A=0
52A = IN101 DP03 = 52A, , "BREAKER CLOSED", "BREAKER OPEN"	BREAKER CLOSED	BREAKER OPEN
52A = IN101 DP03 = 52A, "BREAKER", "CLOSED", "OPEN"	BREAKER=CLOSED	BREAKER=OPEN

Example: Display Only One Message. Enter settings 52A and DP03 as follows to display `BREAKER CLOSED` when input IN101 asserts, but display nothing when input IN101 deasserts.

Settings	IN102 is Asserted	IN102 is Deasserted
52A = IN101 DP03 = 52A, , "BREAKER CLOSED"	BREAKER CLOSED	

Analog Quantities Settings Examples

These examples use the following setting syntax:

DPxx := **Name, "Text1 {Width.Decimal,Scale} Text2"**

Example: Display A-Phase RMS Current. Set display point DP04 using one of the following methods to display IA rms current.

Setting	
DP04 = IAR	IA xxx.x A
DP04 = IAR, "IA={7.2} A RMS" DP05 = IBR, "IB={7.2} A RMS"	IA=xxxx.xx A RMS IB=xxxx.xx A RMS

Setting	
DP04 = IAR, “IA={6.2,1000} KA RMS” DP05 = IBR, “IB={6.2,1000} KA RMS”	IA=xxx.xx KA RMS IB=xxx.xx KA RMS
DP04 = IAR, “A-PH RMS Current”	A-PH RMS CURRENT xxx.x A

Example: Display Time-Overcurrent Pickup. Set display point DP06 using one of the following methods to display time-overcurrent pickup current:

Setting	
DP06 = 51PJP	51PJP x.xx A sec
DP06 = 51PJP, “TOC PICKUP J={3.0}” DP07 = 51PKP, “TOC PICKUP K={3.0}”	TOC PICKUP J=xxx TOC PICKUP K=xxx
DP06 = 51PJP, “TIMEO/C Pickup J”	TIMEO/C PICKUP J x.xx A sec

Example: Display Time-Overcurrent Curve and Time Dial (SEL-651R-1 only). Set display points DP07 through DP10 using one of the following methods to display time-overcurrent curve and time dial for a “fast” phase curve (e.g., 51PJC = A, 51PJTD = 0.94) and a “slow” phase curve (e.g., 51PKC = U3, 51PKTD = 13.58).

Setting	
DP07 = 51PJC	51PJC A curve
DP08 = 51PJTD	51PJTD 0.94 time dial
DP09 = 51PKC	51PKC U3 curve
DP10 = 51PKTD	51PKTD 13.58 time dial
DP07 = 51PJC, “fast ph curve = {}” DP08 = 51PJTD, “Fast PH Time DL = {0.2}”	FAST PH CURVE = A FAST PH TIME DL = 0.94
DP09 = 51PKC, “Slow Ph Curve={}” DP10 = 51PKTD, “Slow ph Time dl={0.2}”	SLOW PH CURVE=U3 SLOW PH TIME DL=13.58

Setting	
DP07 = 51PJC, “fast Curve-phase”	`FAST CURVE-PHASE` `A curve`
DP08 = 51PJTD, “fast time Dial-phase”	`FAST TIME DIAL-PHASE` `0.94 time dial`
DP09 = 51PKC, “Slow curve-phase”	`SLOW CURVE-PHASE` `U3 curve`
DP10 = 51PKTD, “slow time dial-phase”	`SLOW TIME DIAL-PHASE` `13.58 time dial`

Some of the examples above show text continuing to the right of the front-panel display (longer than the 16 horizontal spaces of the front-panel display). In these display situations, the text will automatically scroll to the left to display all the text.

In the examples above, where all the information for a curve or time dial value is displayed in a single line, note the bracket values {} for curve display settings and {0.2} for time-dial display settings. No other variation of these bracket values is needed for displaying curve or time-dial values, respectively, in a single-line fashion.

Metering Screens

The SEL-651R displays enabled metering screens in the following order:

Setting	

Use setting FPNGD to select IA, IB, IC, IN or IA, IB, IC, IG currents or to disable the screen.	`IA=xxxx IB=xxxx`
	`IC=xxxx IN=xxxx`
	or
	`IA=xxxx IB=xxxx`
	`IC=xxxx IG=xxxx`

Use setting FPVYD to enable/disable the Y-Side Voltages screen.	`VAY VBY VCY` `xx.x xx.x xx.xkV`
Use setting FPVZD to enable/disable the Z-Side Voltages screen.	`VAZ VBZ VCZ` `xx.x xx.x xx.xkV`

Status and Trip Target LEDs

Programmable LEDs

The SEL-651R provides quick confirmation of recloser control conditions via status and trip target LEDs. *Figure 11.13* shows this region with factory default text on the front-panel configurable labels.

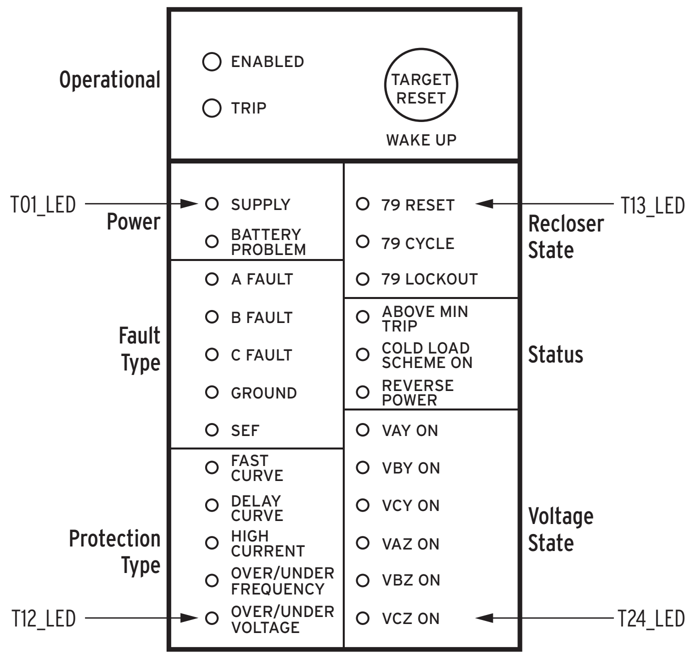


Figure 11.13 Factory Default Front-Panel LEDs (Dual-Door Enclosure)

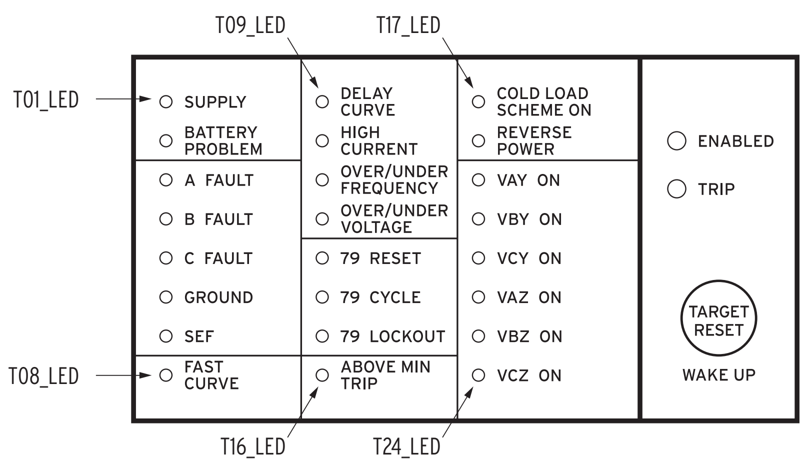


Figure 11.14 Factory Default Front-Panel LEDs (Single-Door Enclosure)

You can reprogram all of these indicators except the **ENABLED** and **TRIP** LEDs to reflect operating conditions other than the factory default programming described in this subsection. This front-panel region provides tricolor (red, green, or amber) LEDs for the **ENABLED** and **TRIP** LEDs. Use settings LEDENAC and LEDTRAC to select the assert color.

Settings T*n*_LED are SELOGIC control equations that, when asserted during a recloser control trip event, illuminate the corresponding LED. Parameter *n* is a number from 1 through 24 that indicates each LED. Program setting T*n*LEDL := Y to latch the LEDs during trip events; when you set T*n*LEDL := N, trip latch supervision has no effect and the LED follows the state of the

T*n*_LED SELOGIC control equation. With the tricolor LED option, target LED settings T*n*_LEDC select the assert color. After setting the target LEDs, issue the **TAR R** command to reset the target LEDs. For a concise listing of the default programming on the front-panel LEDs, see *Table 5.3*.

The SEL-651R 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. Included on the SEL-651R Product Literature CD are Customer Label Templates to print labels for the slide-in label carrier.

The ENABLED LED indicates that the recloser control 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. See *Front-Panel Target LEDs ENABLED and TRIP on page 5.11*.

Figure 11.13 shows the arrangement of the status and trip target LEDs region into seven areas. See *Table 11.7* for a description of these areas.

Table 11.7 Target LED Areas

Target LED Area	Description
Operational	ENABLED, TRIP
Power	SUPPLY and BATTERY PROBLEM LEDs indicate whether the control is powered from the power supply mains and whether the battery is healthy.
Fault Type	Use these LEDs to determine whether A FAULT, B FAULT, C FAULT, GROUND, or SEF were involved in the fault.
Protection Type	Use these LEDs to determine whether FAST CURVE, DELAY CURVE, HIGH CURRENT, OVER/UNDER FREQUENCY, or OVER/UNDER VOLTAGE protection caused the trip.
Recloser State	79 RESET, 79 CYCLE, and 79 LOCKOUT LEDs indicate the state of the recloser.
Status	ABOVE MIN TRIP, COLD LOAD SCHEME ON, and REVERSE POWER indicate important operating conditions.
Voltage State	VAY ON, VBY ON, VCY ON, VAZ ON, VBZ ON, and VCZ ON LEDs indicate whether the phase voltages are above a programmable threshold.

See *Front-Panel Target LEDs on page 5.10* for additional details on the functionality of these status and trip target LEDs.

TARGET RESET Pushbutton

TARGET RESET

For a trip event, the SEL-651R latches the trip-involved target LEDs except for the ENABLED LED and the Recloser Status area LEDs. Press the {TARGET RESET} pushbutton to reset the latched target LEDs. When a new trip event occurs and the previously latched trip targets have not been reset, the recloser control clears the latched targets and displays the new trip targets. Pressing and holding the {TARGET RESET} pushbutton illuminates all the LEDs. Upon release of the {TARGET RESET} pushbutton, two possible trip situations can exist: the conditions that caused the recloser control to trip have cleared, or the trip conditions remain present at the recloser control inputs. If the trip conditions have cleared, the latched target LEDs turn off. If the trip event conditions remain, the recloser control re-illuminates the corresponding target LEDs.

Lamp Test

The {TARGET RESET} pushbutton also provides a front-panel lamp 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 target LEDs return to a normal operational state after release of the {TARGET RESET} pushbutton.

Wake Up

Use this pushbutton to reconnect the battery to the recloser control when external power is not present and the recloser control has disconnected the battery. Once the battery has been reconnected, the SEL-651R will automatically initiate its startup sequence and then enable protection. The battery was initially disconnected after external power was removed and the PWRDN_AC (power-off delay after ac loss) timer expired. The battery will be disconnected again when the PWRDN_WU (power-off delay after wake up) timer expires or 15 minutes after the last front-panel pushbutton is pushed, once the timer begins running. Use these timers to manage the remaining battery capacity. See *Battery System Monitor on page 8.34* for more information.

Other Target Reset Options

Use the ASCII command **TAR R** to reset the target LEDs; see *TARGET Command (Display Relay Word Bit Status) on page 10.41* for more information. Programming specific conditions in the SELOGIC control equation RSTTRGT is another method for resetting the targets LEDs. Access RSTTRGT in the Global settings (Data Reset Control). See *Section 9: Settings* for further information.

Operator Controls

The SEL-651R front panel features large operator control pushbuttons coupled with amber annunciator LEDs for local control. *Figure 11.15* shows this region of the SEL-651R front panel with factory default text on the front-panel configurable labels.

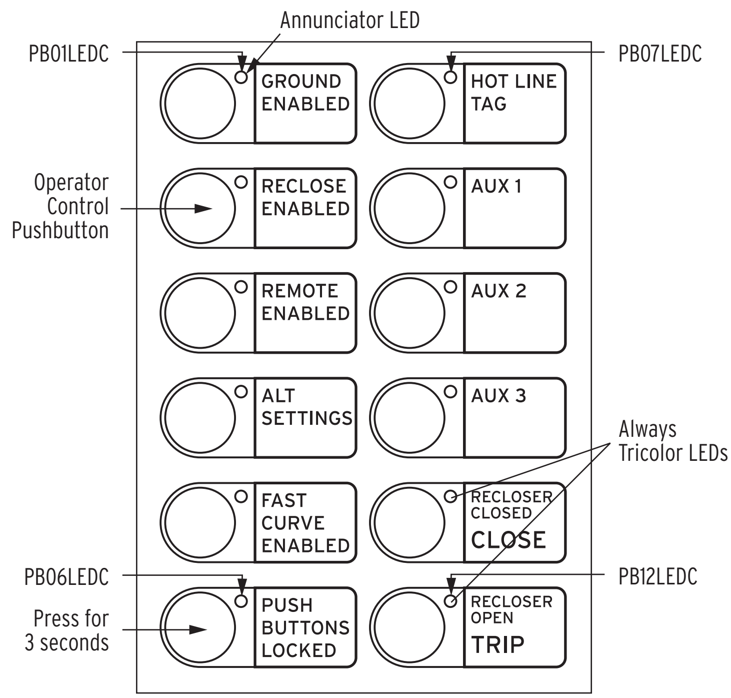


Figure 11.15 Operator Control Pushbuttons and LEDs (Dual-Door Enclosure)

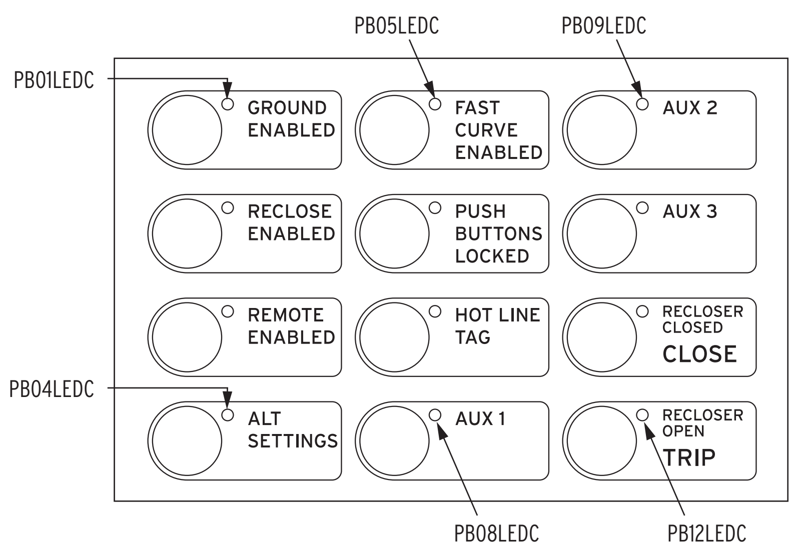


Figure 11.16 Operator Control Pushbuttons and LEDs (Single-Door Enclosure)

Factory Default Settings

With the tricolor LED option, pushbutton LED settings PB*n*LEDC select the asserted and deasserted colors.

Factory default programming associates specific recloser control functions with the 12 pushbuttons and LEDs, as listed in *Table 11.8*. *Table 11.9* describes the factory default settings for the operator controls.

Table 11.8 Operator Control Pushbuttons and LEDs—Factory Defaults (Dual-Door Enclosure)

LED	Pushbutton	Function
GROUND ENABLED	GROUND ENABLED	Enable ground overcurrent tripping
RECLOSE ENABLED	RECLOSE ENABLED	Enable auto reclosing
REMOTE ENABLED	REMOTE ENABLED	Enable remote control
ALT SETTINGS	ALT SETTINGS	Change to alternate settings
FAST CURVE ENABLED	FAST CURVE ENABLED	Enable fast curve
PUSH BUTTONS LOCKED	PUSH BUTTONS LOCKED	Engage/disengage pushbutton lock
HOT LINE TAG	HOT LINE TAG	Enable hot-line tag
AUX 1	AUX 1	Programmable
AUX 2	AUX 2	Programmable
AUX 3	AUX 3	Programmable
RECLOSER CLOSED	CLOSE	Close recloser or circuit breaker
RECLOSER OPEN	TRIP	Open recloser or circuit breaker

Press the operator control pushbuttons momentarily to toggle on and off the functions listed adjacent to each LED/pushbutton combination. This applies to all operator control pushbuttons except the {PUSH BUTTONS LOCKED}, which must be pressed continually for three or more seconds, and the {AUX 1}, {AUX 2}, {AUX 3}, and {REMOTE ENABLED} pushbuttons, which are not programmed with factory default functionality. The {CLOSE} and {TRIP} pushbuttons momentarily assert the close and trip outputs after a short delay.

Table 11.9 Operator Control (Dual-Door Enclosure) (Sheet 1 of 2)

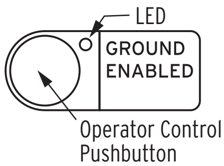
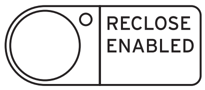
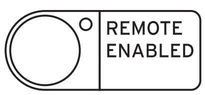
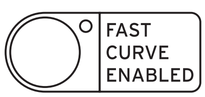
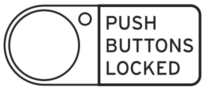
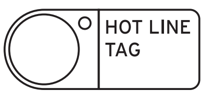
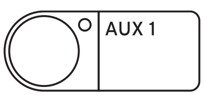
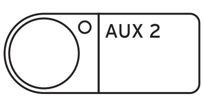
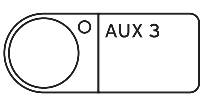
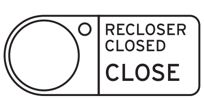
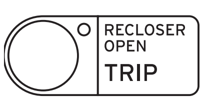
Operator Control Pushbutton	Relay Word Bit Output	SELogic Factory Setting and LED Color	Function
	PB01 PB01_PUL	PB01_LED = LT01 PB01LEDC = AO (AO is Amber, Off)	Press the {GROUND ENABLED} operator control pushbutton to enable/disable ground overcurrent element tripping. The corresponding LED illuminates to indicate the enabled state.
	PB02 PB02_PUL	PB02_LED = LT02 PB02LEDC = AO (AO is Amber, Off)	Press the {RECLOSE ENABLED} operator control pushbutton to enable/disable auto reclosing. The corresponding LED illuminates to indicate the enabled state. The {RECLOSE ENABLED} operator control is overridden by operating the {HOT LINE TAG} operator control in the following scenario: Initial state: {RECLOSE ENABLED} is on or off and {HOT LINE TAG} is off. Action: Press the {HOT LINE TAG} operator control pushbutton. Result: {RECLOSE ENABLED} is off and {HOT LINE TAG} is on. The {RECLOSE ENABLED} operator control is now nonfunctional (remains off). {RECLOSE ENABLED} cannot be turned on again until {HOT LINE TAG} is turned off. Once {HOT LINE TAG} is off, the {RECLOSE ENABLED} operator control is then functional, but remains off until the {RECLOSE ENABLED} operator control pushbutton is pressed again.
	PB03 PB03_PUL	PB03_LED =0 PB03LEDC = AO (AO is Amber, Off)	Press the {REMOTE ENABLED} operator control pushbutton to enable/disable remote control. The corresponding LED illuminates to indicate the enabled state. **NOTE**: This operator control does not perform any function with the factory settings.
	PB04 PB04_PUL	PB04_LED = NOT(SG1) PB04LEDC = AO (AO is Amber, Off)	Press the {ALTERNATE SETTINGS} operator control pushbutton to switch the active setting group between the main setting group (Setting Group 1) and the alternate setting group (Setting Group 2). The corresponding LED illuminates to indicate that the alternate setting group is active.
	PB05 PB05_PUL	PB05_LED = LT04 PB05LEDC = AO (AO is Amber, Off)	Press the {FAST CURVE ENABLED} operator control pushbutton to enable/disable the fast curve; this leaves the slow curve enabled. The corresponding LED illuminates to indicate the enabled state.

Table 11.9 Operator Control (Dual-Door Enclosure) (Sheet 2 of 2)

Operator Control Pushbutton	Relay Word Bit Output	SELogic Factory Setting and LED Color	Function
	PB06 PB06_PUL	PB06_LED = NOT(LT05 AND NOT(SV01T AND PB06 AND NOT(SC01QU)) OR NOT(LT05) AND SV01T AND PB06 AND NOT(SC01QU)) PB06LEDC = AO (AO is Amber, Off)	Continually press the {PUSH BUTTONS LOCKED} operator control pushbutton for three (3) or more seconds to engage/disengage the lock function. While this pushbutton is pressed, the corresponding LED flashes on and off, indicating a pending engagement or disengagement of the lock function. The LED illuminates constantly to indicate the engaged state. While the lock function is engaged, the following operator controls are locked in position (assuming factory default settings): {GROUND ENABLED} {HOT LINE TAG} {RECLOSE ENABLED} {AUX 1} {REMOTE ENABLED} {AUX 2} {ALT SETTINGS} {AUX 3} {FAST CURVE ENABLED} While locked in position, these operator controls cannot change state if pressed—the corresponding LEDs remain in the same state. When the lock function is engaged, the {CLOSE} operator control cannot close the breaker, but the {TRIP} operator control can still trip the breaker.
	PB07 PB07_PUL	PB07_LED = NOT(LT06) PB07LEDC = AO (AO is Amber, Off)	Press the {HOT LINE TAG} operator control pushbutton to enable/disable the hot-line tag function. The corresponding LED illuminates to indicate the enabled state. While the hot-line tag function is enabled, no closing or auto reclosing can take place via the control (e.g., the {CLOSE} operator control is inoperative). The {HOT LINE TAG} operator overrides the {RECLOSE ENABLED} operator control (see previous {RECLOSE ENABLED} operator control description).
	PB08 PB08_PUL	PB08_LED =0 PB08LEDC = AO (AO is Amber, Off)	Press the {AUX 1}, {AUX 2}, or {AUX 3} operator control pushbutton to enable/disable user-programmed auxiliary control. Program the corresponding LED to indicate the required state. **NOTE**: These operator controls do not perform any function with the factory settings.
	PB09 PB09_PUL	PB09_LED =0 PB09LEDC = AO (AO is Amber, Off)	
	PB010 PB010_PUL	PB10_LED =0 PB10LEDC = AO (AO is Amber, Off)	
	PB011 PB011_PUL	PB11_LED =52A3P PB11LEDC = RO (RO is Red, Off)	Press the {CLOSE} operator control pushbutton to close the breaker. The corresponding {RECLOSER CLOSED} LED illuminates to indicate the breaker is closed.
	PB012 PB012_PUL	PB12_LED = NOT(52A3P) PB12LEDC = GO (GO is Green, Off)	Press the {TRIP} operator control pushbutton to trip the breaker and take the SEL-651R to the lockout state. The corresponding {RECLOSER OPEN} LED illuminates to indicate the breaker is open. If the recloser is a regular Traditional Retrofit recloser, SELogic setting PB12_LED can be changed, if desired. See the *Motor-Operated Traditional Retrofit Reclosers on page 2.56* for more detail.

Custom Settings

Use SELOGIC control equations to change the default pushbutton and LED functions. Use the slide-in labels to mark the pushbuttons and pushbutton LEDs with custom names to reflect any programming changes. The Operator Control Labels are keyed and can be inserted in only one position on the front panel. Included on the SEL-651R Recloser Control Product Literature CD are word processor templates for printing slide-in labels. See SEL-651R Configurable Labels instructions for more information on changing the slide-in labels.

The SEL-651R has two types of outputs for each of the front-panel pushbuttons. Relay Word bits represent the pushbutton presses. Relay Word bits PB01 through PB12 are the outputs that follow the presses on the pushbutton. Relay Word bits PB01_PUL through PB12_PUL are the outputs that pulse for one processing interval when the pushbutton is pressed.

Annunciator LEDs for each operator control pushbutton are PB01_LED through PB12_LED. The factory defaults programmed for these LEDs are latches, settings groups, Relay Word bits (NOT SG1), and the status of the circuit breaker auxiliary contacts (52A3P). You can change the LED indications to fit specific control and operational requirements. This programmability allows great flexibility and provides operator confidence and safety, especially in indicating the status of functions that are controlled both locally and remotely. The **RECLOSER CLOSED** and **RECLOSER OPEN** LEDs feature tricolor LEDs. Use settings PB11LEDC and PB12LEDC to select whether the asserted and deasserted colors are red, green, or amber. Additional asserted/deasserted color settings PB01LEDC–PB10LEDC are available when the tricolor option is ordered.

Section 12
Analyzing Events

Introduction

The SEL-651R Recloser Control offers three styles of event reports:

- ➤ Standard 15/30-cycle event (EVE) reports (called "Event Reports" for the remainder of this section)
- ➤ Sequential events recorder (SER) report
- ➤ Sag/Swell/Interruption (SSI) report

Resolution: 1 ms

Accuracy: +1/4 cycle

All three reports are stored in nonvolatile memory, ensuring that a loss of power supply to the SEL-651R module will not result in lost data.

Event (EVE) Reports

Event reports capture highly detailed information over a relatively brief period of time (15 or 30 cycles). Information stored includes:

- ➤ Date and time of the event
- ➤ Individual sample analog inputs (currents and voltages, plus frequency)
- ➤ Digital element states of selected Relay Word bits (listed in *Table 12.4*)
- ➤ Event summary, including the front-panel target states at the time of tripping, fault location, and fault type
- ➤ Group, logic, global, and report settings (that were in service when the event was recorded)

Event report information is stored at a fixed sample rate. An adjustable pre-fault recording period allows system conditions to be captured prior to the actual event report trigger. Event reports are stored to nonvolatile memory a short time after an event trigger is processed.

Event reports are useful in commissioning tests, system disturbance analysis, and protective device or scheme performance analysis. The SEL-5601 Software and ACSELERATOR QuickSet® SEL-5030 Software can read a Compressed ASCII version of the event report, which contains even more information than the standard ASCII event report. With this software, oscillographic traces and digital element traces can be produced on the PC display. A phasor analysis screen allows the protection engineer to analyze the prefault, fault, and post-fault intervals, observing both the directly measured inputs, as well as the calculated sequence component signals.

Sequential Events Recorder (SER)

The SER report captures detailed digital element state changes over a long time period. Programmable trigger lists allow up to 96 Relay Word bits to be monitored, in addition to the automatically generated triggers for recloser control power-up, settings changes, and active setting group changes. State changes are time-tagged to the nearest millisecond.

SER report data are useful in commissioning tests and during operation for system monitoring and control.

SER information is stored when state changes occur.

Sag/Swell/Interruption (SSI) Report

The SSI report captures power quality data related to voltage disturbances over a long period of time. Data captured includes the magnitude of currents, one set of three-phase voltages, a reference voltage, and the status of the voltage sag/sell/interrupt (VSSI) Relay Word bits—see *Voltage Sag, Swell, and Interruption Elements on page 4.48*.

SSI report information is useful for analyzing power quality disturbances, or protective device actions that last longer than the time window of a conventional event report.

The SSI recording rate varies from fast to slow, depending on changes in the triggering elements. SSI data are stored to nonvolatile memory just after it is generated.

Standard 15/30-Cycle Event Reports

See *Figure 12.4* for an example event report. Note that *Figure 12.4* is on multiple pages.

Event Report Length (Settings LER and PRE)

The SEL-651R provides user-selectable event report length and prefault length. Event report length is either 15 or 30 cycles. Prefault length ranges from 1 to 29 cycles. Prefault length is the first part of the total event report length (LER) and precedes the event report triggering point.

The event report capacity depends on the LER setting. The SEL-651R can store the following:

- 40 event reports in nonvolatile memory when LER := 15
- 25 event reports in nonvolatile memory when LER := 30

Set the event report length with the LER setting. Set the prefault length with the PRE setting. See the **SET R** command in *Table 9.2* and corresponding *Report Settings on page SET.58* for instructions on setting the LER and PRE settings.

Changing the LER setting will erase all events stored in nonvolatile memory. Changing the PRE setting has no effect on the stored reports.

Standard Event Report Triggering

The recloser control triggers (generates) a standard event report when any of the following occur:

- Relay Word bit TRIP3P, TRIPA, TRIPB, or TRIPC asserts
- Programmable SELOGIC® control equation setting ER asserts to logical 1 (in Report settings)

- **TRI** (Trigger Event Reports) serial port command executed
- Output contacts OUT101 through OUT108, or OUT201, or OUT202 are pulsed via the serial port or front-panel **PUL** (Pulse Output Contact) command

Relay Word Bits TRIP3P, TRIPA, TRIPB, TRIPC

Refer to *Figure 5.1*. If Relay Word bit TRIP3P, TRIPA, TRIPB, or TRIPC asserts to logical 1, an event report is automatically generated. Thus, any condition that causes a trip does **not** have to be entered in SELOGIC control equation setting ER.

For example, SELOGIC control equation trip setting TR3P is unsupervised. Any trip condition that asserts in setting TR3P causes the TRIP3P Relay Word bit to assert immediately. The factory setting for trip setting TR3P is:

TR3P := **51PT OR 51G1T OR PB12_PUL OR OC3**

If any of the individual conditions 51PT, 51G1T, PB12_PUL, or OC3 assert, Relay Word bit TRIP3P asserts, and an event report is automatically generated. Thus, these conditions do **not** have to be entered in SELOGIC control equation setting ER.

Relay Word bit TRIP3P (in *Figure 5.1*) is usually assigned to an output for tripping a recloser (such as SELOGIC control equation setting RCTR1 := TRIP3P, in group settings).

Programmable SELOGIC Control Equation Setting ER

The programmable SELOGIC control equation event report trigger setting ER is set to trigger standard event reports for conditions other than trip conditions (see *Report Settings on page SET.58*). When setting ER detects a logical 0 to logical 1 transition, it generates an event report (if the SEL-651R is not already generating a report that encompasses the new transition). The factory setting is:

ER := **R_TRIG 51P OR R_TRIG 51G1**

The elements in this example setting are:

51P Maximum phase current above pickup setting 51PJP or 51PKP for phase time-overcurrent element 51PT (see *Figure 4.16*).

51G1 Ground current above pickup setting 51G1JP or 51G1KP for residual ground time-overcurrent element 51G1T (see *Figure 4.20* or *Figure 4.21*).

Note the rising edge operator R_TRIG in front of each of these elements. See *R_TRIG Operator on page 7.4* for more information on rising edge operators and SELOGIC control equations in general.

Rising edge operators are especially useful in generating an event report at fault inception and then generating another later if a breaker failure condition occurs. For example, at the inception of a ground fault, pickup indicator 51G1 asserts and an event report is generated:

ER := **... OR R_TRIG 51G1 OR ... = logical 1** (for one processing interval)

Even though the 51G1 pickup indicator will remain asserted for the duration of the ground fault, the rising edge operator R_TRIG in front of 51G1 (R_TRIG 51G1) causes setting ER to be asserted for only one processing interval.

Falling edge operators F_TRIG are also used to generate event reports. See *F_TRIG Operator on page 7.5* for more information on falling edge operators.

TRI (Trigger Event Report) and PUL (Pulse Output Contact) Commands

The sole function of the **TRI** serial port command is to generate event reports, primarily for testing purposes.

The **PUL** command asserts the output contacts for testing purposes or for remote control. If output contact OUT101 through OUT108, or OUT201, or OUT202, asserts via the **PUL** command, the recloser control triggers a standard event report. The **PUL** command is available at the serial port and the recloser control front-panel via `MAIN > Control > Output Contacts`.

See *Section 10: Communications* for more information on the **TRI** (Trigger Event Report) and **PUL** (Pulse Output Contact) commands. See *Control Menu on page 11.7* for front-panel initiated output contact testing.

Accessing Event Data

Analyze events with the following:

- ➤ Event Summaries—Enable automatic messaging to allow the recloser control to send event summaries out the serial port when appropriate port setting AUTO := Y. A summary provides a quick overview of an event. The summaries may also be retrieved in compressed ASCII form using the **CSUMMARY** command.
- ➤ Event History—The recloser control keeps an index of stored nonvolatile event reports. Use the **HISTORY** command to obtain this index. The index includes most of the event summary information so that the appropriate event report can be identified and retrieved.
- ➤ Event Reports—These detailed reports are stored in nonvolatile memory for later retrieval and detailed analysis.

Event Summaries

Each time the recloser control generates a standard event report, it also generates a corresponding event summary (see *Figure 12.1*). Event summaries contain the following information:

- ➤ Recloser control and terminal identifiers (settings RID and TID)
- ➤ Date and time when the event was triggered
- ➤ Event type
- ➤ Fault location
- ➤ Recloser shot count at the start of the event report
- ➤ System frequency at the start of the event report
- ➤ Front-panel fault targets at the time of trip
- ➤ Phase (IA, IB, IC), ground ($I_G = 3I_0$), and negative-sequence ($3I_2$) current magnitudes in amps primary measured at the largest phase current magnitude in the triggered event report

The recloser control includes the event summary in the standard event report. The identifiers, date, and time information is at the top of the standard event report, and the other information follows at the end. See *Figure 12.4*.

NOTE: Figure 12.4 is on multiple pages.

The example event summary in *Figure 12.1* corresponds to the full-length standard 15-cycle event report in *Figure 12.4*.

```
=

MOUNTAIN F-22                                Date: 07/02/2003  Time: 17:06:35.965
P180                                         Time Source: internal

Event: BG  Location:    3.02  Shot: 0  Frequency:  60.01
Targets: 11 100101001000 001000000111
Currents (A Pri), ABCGQ:    400  3320   377  3019  3032

=
```

Figure 12.1 Example Event Summary

The recloser control sends event summaries to all serial ports with setting AUTO := Y each time an event triggers.

Event Type

The `Event:` field shows the event type. The possible event types and their descriptions are shown in *Table 12.1*. Note the correspondence to the preceding event report triggering conditions (see *Standard Event Report Triggering on page 12.2*).

Table 12.1 Event Types

Event Type	Description
AG, BG, CG	Single phase-to-ground faults. Appends T if TRIP*p*[a] asserted.
ABC	Three-phase faults. Appends T if TRIP*p*[a] asserted.
AB, BC, CA	Phase-to-phase faults. Appends T if TRIP*p*[a] asserted.
ABG, BCG, CAG	Phase-to-phase-to-ground faults. Appends T if TRIP*p*[a] asserted.
TRIP	Assertion of Relay Word bit TRIP*p*[a] (phase involvement is indeterminate, so just TRIP is displayed).
ER	SELOGIC control equation setting ER. Phase involvement is indeterminate.
TRIG	Execution of **TRIGGER** command.
PULSE	Execution of **PULSE** command.

[a] p = A, B, C, or 3P.

NOTE: The fault locator will not operate properly unless three-phase voltages are connected.

NOTE: The fault locator is most accurate when the fault currents last longer than two cycles.

NOTE: Do not use the phase overcurrent elements discussed in Section 4: Protection Functions for load current detection if the fault locator is enabled (setting EFLOC := Y). Set these elements above load current levels, so that the fault locator will work correctly. Use the 50L element instead for load current detection (see Figure 5.5).

NOTE: Do not use the ground- and negative-sequence overcurrent elements discussed in Section 4: Protection Functions for load unbalance current detection if the fault locator is enabled (setting EFLOC :=Y). Set these elements above load unbalance current levels so that the fault locator will work correctly.

The event type designations AG through CAG in *Table 12.1* are only entered in the `Event:` field if the fault type is determined successfully. If the fault type is not determined successfully, just TRIP or ER is displayed.

Fault Location

The recloser control reports the fault location if the EFLOC setting := Y and the fault locator operates successfully after an event report is generated. If the fault locator does not operate successfully, or if EFLOC := N, `$$$$$$` is listed in the field. Fault location is based upon the line impedance settings Z1MAG, Z1ANG, Z0MAG, and Z0ANG; and corresponding line length setting LL. See *Line Length Setting on page 9.46* and *Impedance Settings Conversions on page 9.47* and *Line Parameter Settings on page SET.7*.

Shot Count

When three-phase reclosing is enabled, the SEL-651R reports the reclosing recloser control shot count present at the start of the event report. When single-phase reclosing is enabled, the SEL-651R reports the highest reclosing recloser control shot count present at the start of the event report. When the reclosing recloser control is defeated, the shot count field will contain a blank.

Targets

The recloser control reports the targets from the last row of the event report. The targets are displayed in binary format. The order of the binary targets is shown in *Figure 12.2* and *Table 12.2*. See Front-Panel LEDs in *Table 5.3*, and *Figure 11.13*.

Table 12.2 Target LED Relay Word Bits and Binary Target Positions

Left-Hand Target Column of SEL-651R			Right-Hand Target Column of SEL-651R		
Relay Word Bit of LED	**SELOGIC Setting**	**Binary Target Position**	**Relay Word Bit of LED**	**SELOGIC Setting**	**Binary Target Position**
EN	N/A	L1			
TRIPLED	N/A	L2			
TLED_01	T01_LED	1	TLED_13	T13_LED	13
TLED_02	T02_LED	2	TLED_14	T14_LED	14
TLED_03	T03_LED	3	TLED_15	T15_LED	15
TLED_04	T04_LED	4	TLED_16	T16_LED	16
TLED_05	T05_LED	5	TLED_17	T17_LED	17
TLED_06	T06_LED	6	TLED_18	T18_LED	18
TLED_07	T07_LED	7	TLED_19	T19_LED	19
TLED_08	T08_LED	8	TLED_20	T20_LED	20
TLED_09	T09_LED	9	TLED_21	T21_LED	21
TLED_10	T10_LED	10	TLED_22	T22_LED	22
TLED_11	T11_LED	11	TLED_23	T23_LED	23
TLED_12	T12_LED	12	TLED_24	T24_LED	24

The sample target data presented in *Figure 12.2* indicates that **EN** and **TRIP** LEDs were asserted in the last row of the event report, plus the programmable targets TLED_01, TLED_04, TLED_05, TLED_06, TLED_09, TLED_15, TLED_16, TLED_19, TLED_20, and TLED_21.

Binary Target Position	L1	L2		1	2	3	4	5	6	7	8	9	10	11	12		13	14	15	16	17	18	19	20	21	22	23	24
Sample Target Data	1	1		1	0	0	1	1	1	0	0	1	0	0	0		0	0	1	1	0	0	1	1	1	0	0	0

Figure 12.2 Event Summary Targets' Correspondence to Front-Panel Targets

Currents

The `Currents (A pri), ABCGQ:` field shows the currents present in the event report row containing the maximum phase current. The listed currents are:

Phase (A = channel IA, B = channel IB, C = channel IC)

Ground ($I_G = 3I_0$; calculated from channels IA, IB, and IC; or I_G = channel IN; depending on the state of the GNDSW Relay Word bit in the peak current row. See *Ground Switch Logic on page 4.64*.)

Negative-sequence ($Q = 3I_2$; calculated from channels IA, IB, and IC)

Event History (HIS)

The event history gives you a quick look at recent recloser control activity. The recloser control labels each new event in reverse chronological order with 1 as the most recent event. See *Figure 12.3* for a sample event history.

The event history contains the following:

- Standard report header
  - Recloser control and terminal identification
  - Date and time of report
- Event number
- Event date and time
- Event type
- Location of fault (if applicable)
- Maximum phase current from summary fault data
- Power system frequency at start of event report
- Active group at the trigger instant
- Reclosing recloser control shot count (same as standard Event Report Summary)
- Targets

Figure 12.3 is a sample event history from a terminal.

```
=>>HIS <Enter>

MOUNTAIN F-22                                   Date: 07/02/2003  Time: 17:06:52.064
P180                                            Time Source: internal

#     DATE        TIME     EVENT LOCAT  CURR FREQ GST          TARGETS
                                                  RHR   COLUMN 1     COLUMN 2
1   07/02/2003 17:06:35.965 BG     3.02  3320 60.0 101 100101001000 001000000111
2   06/18/2003 13:45:49.020 TRIG  $$$$$   291 60.0 100 100000000000 100000111111

=>
```

Event Number
Event Type
Maximum Current
Active Setting Group
Shot Count
Target LEDs (See Table 12.2 and Figure 12.2)

Figure 12.3 Sample Event History

Fault location data can be indeterminate (for example, when you trigger an event and there is no fault on the power system). If this is the case, the recloser control displays `$$$$.$$` for the location entry in the event history. The SEL-651R will also display `$$$$.$$` if the fault location enable setting EFLOC := N.

The event types in the event history are the same as the event types in the event summary. See *Table 12.1* for event types.

Viewing the Event History

Access the history report from the communications ports or the Human Machine Interface. View and download history reports from Access Level 1 and higher. You can also clear or reset history data from Access Levels 1 and higher. Clear/reset history data at any communications port.

Use the **HIS** command from a terminal to obtain the event history. You can specify the number of the most recent events that the recloser control returns. See *HISTORY Command on page 10.24* for information on the **HIS** command.

Use the front-panel `MAIN > Events > Display Events` menu to display event history data on the SEL-651R LCD. See *Figure 11.5*.

Use the ACSELERATOR QuickSet software to retrieve the recloser control event history. View the Recloser Control Event History dialog box via the **Analysis > Get Event Files. . .** menu. See *ACSELERATOR Event Analysis on page 3.13*.

Standard Event Reports

The latest event reports are stored in nonvolatile memory. Each event report includes five sections:

- Analog values of current, voltage, and frequency, and digital states of the various trip, close, 52A_, and ground switch Relay Word bits. (**EVE** command option A)
- Digital states of the Protection and Control elements, including overcurrent, voltage, synchronism check, and frequency elements, plus reclosing recloser control status and digital output and input states. (**EVE** command option D)
- Digital states of the MIRRORED BITS®, Communications, and Automation Elements, including power elements, and operator control pushbutton status. (**EVE** command option M)
- Event Summary
- Recloser Control Settings in service at the time of event trigger, consisting of Group, Logic, Global, and Report settings classes.

Use the **EVE** command to retrieve the reports. There are several options to customize the report format. The general command format is:

EVE [*n* S*x* L*y* L R A D V C M]

NOTE: Use the **HIS** command to obtain a brief listing of all of the event reports in nonvolatile memory, including the event number "n". See HISTORY Command on page 10.24.

NOTE: The Digital (D) and MIRRORED BITS (M) sections of the event report are always displayed with quarter-cycle resolution.

where:

n	Event number (1–number of events stored). Defaults to 1 if not listed, where 1 is the most recent event.
S*x*	Display *x* samples per cycle (4 or 32). Defaults to 4 if not listed.
L*y*	Display *y* cycles of data (1–LER). Defaults to LER value if not listed. Unfiltered reports (R parameter) display an extra cycle of data.
L	Display 32 samples per cycle; same as the S32 parameter.

where:

- *n* Event number (1–number of events stored). Defaults to 1 if not listed, where 1 is the most recent event.
- **R** Specifies the unfiltered (raw) event report. Defaults to 32 samples per cycle unless overridden with the S*x* parameter.
- **A** Specifies that only the analog section of the event is displayed.
- **D** Specifies that only the digital section (Protection and Control Elements) of the event is displayed. Fixed at 1/4-cycle resolution.
- **V** Specifies variable scaling for analog values.
- **C** Display the report in Compressed ASCII format. Defaults to 1/32-cycle analog and 1/4-cycle digital resolution.
- **M** Specifies only the MIRRORED BITS, Communication, and Automation Elements section of the event is displayed. Fixed at 1/4-cycle resolution.

Below are **EVE** command examples:

NOTE: SEL-651R ASCII event reports (**EVE** command) will not display properly in SEL-5601 Analytic Assistant software. When retrieving events for use with PC software, use the Compressed ASCII **CEV** command.

NOTE: **EVE** options have no specific order (e.g., **EVE 2 D** functions the same as **EVE D 2**).

Serial Port Command	Description
EVE	Display the most recent event report at 1/4-cycle resolution (analog and digital).
EVE 2	Display the second event report at 1/4-cycle resolution.
EVE S32 L10	Display 10 cycles of the most recent report at 1/32-cycle resolution (analog, digital portion at 1/4-cycle resolution).
EVE C 2	Display the second report in Compressed ASCII format at 1/32-cycle analog and 1/4-cycle digital resolution.
EVE L	Display most recent report at 1/32-cycle resolution (analog, digital portion at 1/4-cycle resolution).
EVE R	Display most recent report at 1/32-cycle resolution; analog data are unfiltered (raw) (digital data at 1/4-cycle resolution).
EVE 2 D L10	Display 10 cycles of the protection and control elements section of the second event report at 1/4-cycle resolution.
EVE 2 A R S4 V	Display the unfiltered analog section of the second event report at 1/4-cycle resolution, with variable scaling of the analog values.

If an event report is requested that does not exist, the recloser control responds:

```
Invalid Event
```

Compressed ASCII Event Reports, Event Summaries, and History

NOTE: Compressed event reports contain analog data from the IN channel, in addition to the IG quantity. (Regular ASCII event reports do not include a separate IN column.)

The SEL-651R provides compressed ASCII event reports to facilitate event report storage and display. SEL communications processors and the SEL-5601 Analytic Assistant software take advantage of the compressed ASCII format. Use the **CHIS** command to display compressed ASCII event history information. Use the **CSUM** command to display compressed ASCII event summary information. Use the **EVE C** command or **CEVENT** command to display compressed ASCII event reports. See the compressed ASCII commands in *Table C.2* for further information.

Compressed ASCII Event Reports contain **all** of the Relay Word bits.

Filtered and Unfiltered Event Reports

The SEL-651R samples the basic power system measurands (ac voltage and ac current) 32 times per power system cycle. The recloser control filters the measurands to remove transient signals. The recloser control operates on the filtered fundamental values and reports them in the event report.

To view the raw inputs to the recloser control, select the unfiltered event report (e.g., **EVE R**). Use the unfiltered event reports to observe:

- Power system transients on channels IA, IB, IC, IN, VAY, VBY, VCY, VAZ, VBZ, and VCZ.
- Decaying dc offset during fault conditions on channels IA, IB, and IC.
- Voltage transducer response to power system transients.
- Power system harmonics (with appropriate analytical PC software tools).

Raw event reports display one extra cycle of data at the beginning of the report.

Current and Voltage Connection Settings: Effect on Event Reports

The Global settings IPCONN, EGNDSW, CTPOL, VYCONN, VZCONN, EPHANT, VSELECT, and FSELECT are fully described in *Settings Explanations on page 9.27*. These settings are briefly presented in this section to allow their effects on the event report analog values to be explained.

The IPCONN setting controls which of the three current input terminals (I1, I2, and I3) gets routed to each of the internal analog channels IA, IB, and IC. This feature is called phase rolling for the current channels, and it allows system phasing and current transformer (CT) connections to be matched inside the SEL-651R without the need to rewire. All SEL-651R event reports display the rolled current values.

The EGNDSW setting selects the function of the neutral (IN) channel. When the IN channel is connected to a zero-sequence current source, such as the standard residual connection with terminals I1, I2, and I3, set EGNDSW := Y. In this state, the IG column in SEL-651R event reports will automatically switch between displaying the IN channel data for small signals and the calculated (residual) $3I_0$ data for large signals, such as most ground faults.

Relay Word bit GNDSW captures the IG source for each row of the event report: when EGNDSW = logical 1, IG = IN; when GNDSW = logical 0, IG = calculated $3I_0$. Setting EGNDSW := N disables the “ground switch” feature, and the IG column will always display the calculated $3I_0$ data (and GNDSW is permanently = logical 0).

The CTPOL setting allows the current phase polarity to be reversed to facilitate utility or industrial metering direction preferences, without the need to disconnect and reconnect CT wires. In the SEL-651R event reports, channels IA, IB, and IC are always affected by the CTPOL setting. Channel IN is only affected by the CTPOL setting when Global setting EGNDSW := Y.

The VYCONN setting controls which of the three Y-terminal voltage inputs (V1Y, V2Y, and V3Y) get routed to each of the internal analog channels VAY, VBY, and VCY. The VZCONN setting performs a similar function with the V1Z, V2Z, V3Z terminals and VAZ, VBZ, VCZ channels.

This feature is called phase rolling for the voltage channels, and it allows system phasing and potential transformer (PT) connections to be matched inside the SEL-651R without the need to rewire. All SEL-651R event reports display the rolled voltage values.

NOTE: All 6 voltage terminals are represented in the event report analog channels, even if VYCONN and/or VZCONN is set to contain less than three phase letters. See Figure 9.21 for further detail.

The EPHANT setting allows three-phase metering to be performed with only a single PT connected. The EPHANT setting has **no effect** on event reports—it is only used in the metering functions. See *Phantom Voltage Function on page 8.4*.

The VSELECT setting designates which set of input terminals (VY or VZ) are used in various recloser control functions. The only effect VSELECT has on event reports is to determine which set of voltages (VAY, VBY, VCY; or VAZ, VBZ, VCZ) is used in the fault locator function.

The FSELECT setting determines which voltage input (V1Y or V1Z) is used for frequency measurement and frequency tracking. The frequency column in the event report and event summary is affected by this setting.

Standard Event Report Column Definitions

NOTE: Figure 12.4 is on multiple pages.

Refer to the example event report in *Figure 12.4* to view event report columns This example event report displays rows of information each 1/4 cycle and was retrieved with the **EVE** command.

The columns contain ac current, ac voltage, frequency, output, input, and protection and control element information.

Current, Voltage, and Frequency Columns. *Table 12.3* summarizes the event report current, voltage, and frequency columns.

Table 12.3 Standard Event Report Current, Voltage, and Frequency Columns

Column Heading	Definition
IA	Current measured by channel IA[a] (primary A)
IB	Current measured by channel IB[a] (primary A)
IC	Current measured by channel IC[a] (primary A)
IG	Ground current IG = 3I0; calculated from channels IA, IB, and IC when Relay Word bit GNDSW = logical 0; or IG = channel IN; when GNDSW = logical 1 (primary A)
VAY	Voltage measured on Y-terminal, A-phase[b] (primary kV)
VBY	Voltage measured on Y-terminal, B-phase[b] (primary kV)
VCY	Voltage measured on Y-terminal, C-phase[b] (primary kV)
VAZ	Voltage measured on Z-terminal, A-phase[b] (primary kV)
VBZ	Voltage measured on Z-terminal, B-phase[b] (primary kV)
VCZ	Voltage measured on Z-terminal, C-phase[b] (primary kV)
Freq	Frequency measured on terminal V1Y when FSELECT := VY, terminal V1Z when FSELECT := VZ.

[a] Global setting IPCONN determines the current phase assignment. See Table 9.8.
[b] Global settings VYCONN or VZCONN determine the voltage phase assignment. See Table 9.9.

Note that the ac values change from plus to minus (–) values in *Figure 12.4*, indicating the sinusoidal nature of the waveforms.

Other figures help in understanding the information available in the event report current columns:

Figure 12.5: shows how event report current column data relates to the actual sampled current waveform and rms current values.

Figure 12.6: shows how event report current column data can be converted to phasor rms current values.

Variable Scaling for Analog Values. The following example shows the difference between two cycles of the analog values of an event report without variable scaling (command **EVE**) and with variable scaling (command **EVE V**). Variable scaling event reports display data for currents less than 10 A with 2 decimal places and data for voltages less than 10 kV with 3 decimal places.

Example without variable scaling (**EVE**):

```
=>EVE <Enter>
⋮
                                                                        5G
    Currents (Amps Pri)                Voltages (kV Pri)               TC2N
     IA     IB     IC     IG    VAY    VBY    VCY    VAZ    VBZ    VCZ Freq RLAD
[1]
    185   -306    122     -0   11.2  -13.4    2.2   11.2  -13.4    2.2 60.0 ..*N
    247     36   -284      0    9.0    5.2  -14.2    9.0    5.2  -14.2 60.0 ..*N
   -185    306   -122      0  -11.2   13.4   -2.2  -11.2   13.4   -2.2 60.0 ..*N
   -247    -36    283      0   -9.0   -5.2   14.2   -9.0   -5.2   14.2 60.0 ..*N
[2]
    185   -306    122     -0   11.2  -13.4    2.2   11.2  -13.4    2.2 60.0 ..*N
    247     36   -284     -0    9.0    5.2  -14.2    9.0    5.2  -14.2 60.0 ..*N
   -185    306   -122      0  -11.2   13.4   -2.2  -11.2   13.4   -2.2 60.0 ..*N
   -247    -36    284      0   -9.0   -5.2   14.2   -9.0   -5.2   14.2 60.0 ..*N
⋮
```

Example with variable scaling (**EVE V**):

NOTE: The "V" option has no effect for compressed event reports (EVE C) because the analog values automatically have variable scaling. Variable scaling for compressed data displays both currents less than 10 A and voltages less than 10 kV with 3 decimal places.

```
=>EVE V <Enter>
⋮
                                                                        5G
    Currents (Amps Pri)                Voltages (kV Pri)               TC2N
     IA     IB     IC     IG    VAY    VBY    VCY    VAZ    VBZ    VCZ Freq RLAD
[1]
    185   -306    122  -0.02   11.2  -13.4  2.154   11.2  -13.4  2.155 60.0 ..*N
    247     36   -284   0.01  8.968  5.230  -14.2  8.968  5.231  -14.2 60.0 ..*N
   -185    306   -122   0.04  -11.2   13.4 -2.155  -11.2   13.4 -2.155 60.0 ..*N
   -247    -36    283   0.06 -8.970 -5.232   14.2 -8.969 -5.233   14.2 60.0 ..*N
[2]
    185   -306    122  -0.07   11.2  -13.4  2.153   11.2  -13.4  2.153 60.0 ..*N
    247     36   -284  -0.06  8.968  5.232  -14.2  8.966  5.233  -14.2 60.0 ..*N
   -185    306   -122   0.05  -11.2   13.4 -2.154  -11.2   13.4 -2.154 60.0 ..*N
   -247    -36    284   0.01 -8.966 -5.236   14.2 -8.966 -5.237   14.2 60.0 ..*N
⋮
```

Output, Input, and Protection, and Control Columns. *Table 12.4* summarizes the event report output, input, protection and control columns. See *Table F.1* and *Table F.2* for more information on Relay Word bits shown in *Table 12.4*.

NOTE: TRIP3P is only available when Group setting ESPB := N.

NOTE: TRIPA, TRIPB, and TRIPC are only available when Group setting ESPB := Y.

NOTE: CLOSE3P is only available when Group setting ESPB := N.

NOTE: CLOSEA, CLOSEB, and CLOSEC are only available when Group setting ESPB := Y.

NOTE: 52AA, 52AB, and 52AC are only available when Global setting BKTYP := 1.

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 1 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
All columns		•	Element/input/output not picked up or not asserted, unless otherwise stated
TR	TRIP3P	*	Trip (TRIP3P asserted)
	TRIPA	A	A-phase trip (TRIPA asserted)
	TRIPB	B	B-phase trip (TRIPB asserted)
	TRIPC	C	C-phase trip (TRIPC asserted)
		a	A and B-phase trip (TRIPA and TRIPB asserted)
		b	B and C-phase trip (TRIPB and TRIPC asserted)
		c	C and A-phase trip (TRIPC and TRIPA asserted)
		3	Three-phase trip (TRIPA, TRIPB, and TRIPC asserted)
CL	CLOSE3P	*	Close (CLOSE3P asserted)
	CLOSEA	A	A-phase close (CLOSEA asserted)
	CLOSEB	B	B-phase close (CLOSEB asserted)
	CLOSEC	C	C-phase close (CLOSEC asserted)
		a	A and B-phase close (CLOSEA and CLOSEB asserted)
		b	B and C-phase close (CLOSEB and CLOSEC asserted)
		c	C and A-phase close (CLOSEC and CLOSEA asserted)
		3	Three-phase close (CLOSEA, CLOSEB, and CLOSEC asserted)
52A	52A3P	*	Breaker closed (52A3P asserted)
	52AA	A	A-phase breaker closed (52AA asserted)
	52AB	B	B-phase breaker closed (52AB asserted)
	52AC	C	C-phase breaker closed (52AC asserted)
		a	A and B-phase breakers closed (52AA and 52AB asserted)
		b	B and C-phase breakers closed (52AB and 52AC asserted)
		c	C and A-phase breakers closed (52AC and 52AA asserted)
		3	3 breakers closed (52AA, 52AB, and 52AC asserted)
GND	GNDSW	G	IG = 3I0 calculated (GNDSW deasserted)
		N	IG = IN measured (GNDSW asserted)

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 2 of 15)

NOTE: p = A, B, C, P, G1, G2, or Q.

NOTE: p = P, N, G, or Q.

NOTE: 50N_ elements are only enabled when Global setting EGNDSW := N.

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
51A 51B 51C 51P 51G1 51G2 51Q	51A, 51AT, 51AR, 51AS 51B, 51BT, 51BR, 51BS 51C, 51CT, 51CR, 51CS 51P, 51PT, 51PR, 51PS 51G1, 51G1T, 51G1R, 51G1S 51G2, 51G2T, 51G2R, 51G2S 51Q, 51QT, 51QR, 51QS	. R P T r p t 1	51*p* element is reset 51*p* J-element timing to reset 51*p* J-element picked up and timing 51*p* J-element timed out 51*p* K-element timing to reset 51*p* K-element picked up and timing 51*p* K-element timed out 51*p* element is performing a one-cycle reset (only when 51*p*RS := N)
50 ABC	50A, 50B, 50C	A	Single-phase instantaneous overcurrent element 50A picked up
		B	Single-phase instantaneous overcurrent element 50B picked up
		C	Single-phase instantaneous overcurrent element 50C picked up
		a	Both 50A and 50B picked up
		b	Both 50B and 50C picked up
		c	Both 50C and 50A picked up
		3	50A, 50B, and 50C picked up
50 P 50 N 50 G 50 Q	50P1, 50P2, 50P3, 50P4 50N1, 50N2, 50N3, 50N4 50G1, 50G2, 50G3, 50G4 50Q1, 50Q2, 50Q3, 50Q4	4 3 2 1	Instantaneous o/c element 50*p*4 picked-up; levels 1, 2, and 3 not picked-up Instantaneous o/c element 50*p*3 picked-up; levels 1 and 2 not picked-up Instantaneous o/c element 50*p*2 picked-up; level 1 not picked-up Instantaneous o/c element 50*p*1 picked-up
32 PQ	F32P	P	Forward positive-sequence voltage-polarized directional element F32P picked up
	R32P	p	Reverse positive-sequence voltage-polarized directional element R32P picked up
	F32Q	Q	Forward negative-sequence voltage-polarized directional element F32Q picked up
	R32Q	q	Reverse negative-sequence voltage-polarized directional element R32Q picked up

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 3 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
32 G	F32QG	Q	Forward negative-sequence voltage-polarized directional element F32QG picked up
	R32QG	q	Reverse negative-sequence voltage-polarized directional element R32QG picked up
	F32V	V	Forward zero-sequence voltage-polarized directional element F32V picked up
	R32V	v	Reverse zero-sequence voltage-polarized directional element R32V picked up
Dm PQ	PDEM, QDEM	P	Phase demand ammeter element PDEM picked up
		Q	Negative-sequence demand ammeter element QDEM picked up
		b	Both PDEM and QDEM picked up
Dm NG	NDEM, GDEM	N	Neutral ground demand ammeter element NDEM picked up
		G	Residual ground demand ammeter element GDEM picked up
		b	Both NDEM and GDEM picked up
27 Y P	27YA1, 27YA2, 27YB1, 27YB2, 27YC1, 27YC2	A	A-phase instantaneous undervoltage element 27YA1 or 27YA2 picked up
		B	B-phase instantaneous undervoltage element 27YB1 or 27YB2 picked up
		C	C-phase instantaneous undervoltage element 27YC1 or 27YC2 picked up
		a	27YA_ and 27YB_ elements picked up
		b	27YB_ and 27YC_ elements picked up
		c	27YC_ and 27YA_ elements picked up
		3	27YA_, 27YB_ , and 27YC_ elements picked up
27 Y PP	27YAB1, 27YBC1, 27YCA1	A	AB phase-to-phase instantaneous undervoltage element 27YAB1 picked up
		B	BC phase-to-phase instantaneous undervoltage element 27YBC1 picked up
		C	CA phase-to-phase instantaneous undervoltage element 27YCA1 picked up

NOTE: NDEM element is only enabled when Global setting EGNDSW := N.

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 4 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
		a	27YAB1 and 27YCA1 elements picked up
		b	27YAB1 and 27YBC1 elements picked up
		c	27YBC1 and 27YCA1 elements picked up
		3	27YAB1, 27YBC1, and 27YCA1 elements picked up
59 Y P	59YA1, 59YA2, 59YB1, 59YB2, 59YC1, 59YC2	A	A-phase instantaneous over-voltage element 59YA1 or 59YA2 picked up
		B	B-phase instantaneous over-voltage element 59YB1 or 59YB2 picked up
		C	C-phase instantaneous over-voltage element 59YC1 or 59YC2 picked up
		a	59YA_ and 59YB_ elements picked up
		b	59YB_ and 59YC_ elements picked up
		c	59YC_ and 59YA_ elements picked up
		3	59YA_, 59YB_, and 59YC_ elements picked up
59 Y PP	59YAB1, 59YBC1, 59YCA1	A	AB phase-to-phase instantaneous overvoltage element 59YAB1 picked up
		B	BC phase-to-phase instantaneous overvoltage element 59YBC1 picked up
		C	CA phase-to-phase instantaneous overvoltage element 59YCA1 picked up
		a	59YAB1 and 59YCA1 elements picked up
		b	59YAB1 and 59YBC1 elements picked up
		c	59YBC1 and 59YCA1 elements picked up
		3	59YAB1, 59YBC1, and 59YCA1 elements picked up

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 5 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
59 Y V1	59YV1	*	Positive-sequence instantaneous overvoltage element 59YV1 picked up
59 Y N	59YN1, 59YN2	1	Zero-sequence instantaneous overvoltage element 59YN1 picked up
		2	Zero-sequence instantaneous overvoltage element 59YN2 picked up
		b	Both 59YN1 and 59YN2 picked up
59 Y Q	59YQ1	*	Negative-sequence instantaneous overvoltage element 59YQ1 picked up
27 Z P	27ZA1, 27ZA2, 27ZB1, 27ZB2, 27ZC1, 27ZC2	A	A-phase instantaneous undervoltage element 27ZA1 or 27ZA2 picked up
		B	B-phase instantaneous undervoltage element 27ZB1 or 27ZB2 picked up
		C	C-phase instantaneous undervoltage element 27ZC1 or 27ZC2 picked up
		a	27ZA_ and 27ZB_ elements picked up
		b	27ZB_ and 27ZC_ elements picked up
		c	27ZC_ and 27ZA_ elements picked up
		3	27ZA_, 27ZB_ , and 27ZC_ elements picked up
27 Z PP	27ZAB1, 27ZBC1, 27ZCA1	A	AB phase-to-phase instantaneous undervoltage element 27ZAB1 picked up
		B	BC phase-to-phase instantaneous undervoltage element 27ZBC1 picked up
		C	CA phase-to-phase instantaneous undervoltage element 27ZCA1 picked up
		a	27ZAB1 and 27ZCA1 elements picked up
		b	27ZAB1 and 27ZBC1 elements picked up
		c	27ZBC1 and 27ZCA1 elements picked up
		3	27ZAB1, 27ZBC1, and 27ZCA1 elements picked up

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 6 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
59 Z P	59ZA1, 59ZA2, 59ZB1, 59ZB2, 59ZC1, 59ZC2	A	A-phase instantaneous overvoltage element 59ZA1 or 59ZA2 picked up
		B	B-phase instantaneous overvoltage element 59ZB1 or 59ZB2 picked up
		C	C-phase instantaneous overvoltage element 59ZC1 or 59ZC2 picked up
		a	59ZA_ and 59ZB_ elements picked up
		b	59ZB_ and 59ZC_ elements picked up
		c	59ZC_ and 59ZA_ elements picked up.
		3	59ZA_, 59ZB_, and 59ZC_ elements picked up
59 Z PP	59ZAB1, 59ZBC1, 59ZCA1	A	AB phase-to-phase instantaneous overvoltage element 59ZAB1 picked up
		B	BC phase-to-phase instantaneous overvoltage element 59ZBC1 picked up
		C	CA phase-to-phase instantaneous overvoltage element 59ZCA1 picked up
		a	59ZAB1 and 59ZCA1 elements picked up
		b	59ZAB1 and 59ZBC1 elements picked up
		c	59ZBC1 and 59ZCA1 elements picked up
		3	59ZAB1, 59ZBC1, and 59ZCA1 elements picked up
59 Z V1	59ZV1	*	Positive-sequence instantaneous overvoltage element 59ZV1 picked up
59 Z N	59ZN1, 59ZN2	1	Zero-sequence instantaneous overvoltage element 59ZN1 picked up
		2	Zero-sequence instantaneous overvoltage element 59ZN2 picked up
		b	Both 59ZN1 and 59ZN2 picked up

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 7 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
59 Z Q	59ZQ1	*	Negative-sequence instantaneous overvoltage element 59ZQ1 picked up
59 V	59VP, 59VS	P	Phase voltage window element 59VP picked up (used in synchronism check)
		S	Channel VS voltage window element 59VS picked up (used in synchronism check)
		b	Both 59VP and 59VS picked up
25 SF	SF	*	Slip frequency element SF picked up (used in synchronism check)
25 A	25A1, 25A2	1	Synchronism-check element 25A1 element picked up
		2	Synchronism-check element 25A2 element picked up
		b	Both 25A1 and 25A2 picked up
27B	27B81	*	Frequency logic instantaneous undervoltage element 27B81 picked up
81 12	81D1, 81D2	1	Frequency element 81D1 picked up
		2	Frequency element 81D2 picked up
		b	Both 81D1 and 81D2 picked up
81 34	81D3, 81D4	3	Frequency element 81D3 picked up
		4	Frequency element 81D4 picked up
		b	Both 81D3 and 81D4 picked up
81 56	81D5, 81D6	5	Frequency element 81D5 picked up
		6	Frequency element 81D6 picked up
		b	Both 81D5 and 81D6 picked up
79	RCSF3P, CF3P 79RS3P, 79CY3P, 79LO3P RCSFA, CFA, 79RSA, 79CYA, 79LOA	•	Reclosing relay nonexistent
		S	Reclose supervision failure condition (RCSF_ asserts for only 1/4 cycle)
		F	Close failure condition (CF_ asserts for only 1/4 cycle)
		R	Reclosing relay in Reset State (79RS_)
		C	Reclosing relay in Reclose Cycle State (79CY_)
		L	Reclosing relay in Lockout State (79LO_)

NOTE: Relay Word bits RCSF3P, CF3P, 79RS3P, 79CY3P, and 79LO3P are used when Group setting ESPB := N.

NOTE: Relay Word bits RCSFA, CFA, 79RSA, 79CYA, and 79LOA are used when Group setting ESPB := Y.

NOTE: Relay Word bits OPTMN3P, RSTMN3P, SH03P, SH13P, SH23P, SH33P, and SH43P are used when Group setting ESPB := N.

NOTE: Relay Word bits OPTMNA, RSTMNA, SH0A, SH1A, SH2A, SH3A, and SH4A are used when Group setting ESPB := Y.

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 8 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
Time	OPTMN3P, RSTMN3P	o	Recloser open interval timer is timing
	OPTMNA, RSTMNA	r	Recloser reset interval timer is timing
Shot	SH03P, SH13P, SH23P, SH33P, SH43P	.	Reclosing relay nonexistent
	SH0A, SH1A, SH2A, SH3A, SH4A	0	shot = 0 (SH0_)
		1	shot = 1 (SH1_)
		2	shot = 2 (SH2_)
		3	shot = 3 (SH3_)
		4	shot = 4 (SH4_)
B79	RCSFB, CFB, 79RSB, 79CYB, 79LOB	.	Reclosing relay nonexistent
		S	Reclose supervision failure condition (RCSFB asserts for only 1/4 cycle)
		F	Close failure condition (CFB asserts for only 1/4 cycle)
		R	Reclosing relay in Reset State (79RSB)
		C	Reclosing relay in Reclose Cycle State (79CYB)
		L	Reclosing relay in Lockout State (79LOB)
B Time	OPTMNB, RSTMNB	o	Recloser open interval timer is timing
		r	Recloser reset interval timer is timing
B Shot	SH0B, SH1B, SH2B, SH3B, SH4B	.	Reclosing relay nonexistent
		0	shot = 0 (SH0B)
		1	shot = 1 (SH1B)
		2	shot = 2 (SH2B)
		3	shot = 3 (SH3B)
		4	shot = 4 (SH4B)
C79	RCSFC, CFC, 79RSC, 79CYC, 79LOC	.	Reclosing relay nonexistent
		S	Reclose supervision failure condition (RCSFC asserts for only 1/4 cycle)
		F	Close failure condition (CFC asserts for only 1/4 cycle)
		R	Reclosing relay in Reset State (79RSC)
		C	Reclosing relay in Reclose Cycle State (79CYC)
		L	Reclosing relay in Lockout State (79LOC)

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 9 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
C Time	OPTMNC, RSTMNC	o	Recloser open interval timer is timing
		r	Recloser reset interval timer is timing
C Shot	SH0C, SH1C, SH2C, SH3C, SH4C	.	Reclosing relay nonexistent
		0	shot = 0 (SH0C)
		1	shot = 1 (SH1C)
		2	shot = 2 (SH2C)
		3	shot = 3 (SH3C)
		4	shot = 4 (SH4C)
Zld	ZLIN, ZLOUT	i	Load encroachment “load in” element ZLIN picked up
		o	Load encroachment “load out” element ZLOUT picked up
LOP	LOP	*	Loss-of-potential element LOP picked up
PS	PWR_SRC1	1	SEL-651R power supply input energized
TCAP	TCCAP	*	Trip and close capacitor voltage above minimum acceptable value
200 (Out) 12	OUT201, OUT202	1	Output contact OUT201 asserted
		2	Output contact OUT202 asserted
		b	Both OUT201 and OUT202 asserted
200 In 12	IN201, IN202	1	Status Input IN201 asserted
		2	Status Input IN202 asserted
		b	Both IN201 and IN202 asserted
200 In 34	IN203, IN204	3	Status Input IN203 asserted
		4	Status Input IN204 asserted
		b	Both IN203 and IN204 asserted
200 In 56	IN205, IN206	5	Status Input IN205 asserted
		6	Status Input IN206 asserted
		b	Both IN205 and IN206 asserted
100 Out 12	OUT101, OUT102	1	Output contact OUT101 asserted
		2	Output contact OUT102 asserted
		b	Both OUT101 and OUT102 asserted
100 Out 34	OUT103, OUT104	3	Output contact OUT103 asserted
		4	Output contact OUT104 asserted
		b	Both OUT103 and OUT104 asserted

NOTE: Output contacts OUT201 and OUT202 are C-type contacts. See Figure 7.27.

NOTE: Event report columns for output contacts OUT101–OUT108 are only shown when the SEL-651R is ordered with the extra inputs and outputs option. OUT101–OUT 105 are A-type contacts, OUT106–OUT108 are C-type contacts. See Section 2: Installation and Figure 7.27.

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 10 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
100 Out 56	OUT105, OUT106	5	Output contact OUT105 asserted
		6	Output contact OUT106 asserted
		b	Both OUT105 and OUT106 asserted
100 Out 78	OUT107, OUT108	7	Output contact OUT107 asserted.
		8	Output contact OUT108 asserted.
		b	Both OUT107 and OUT108 asserted.
100 In 12	IN101, IN102	1	Optoisolated input IN101 asserted
		2	Optoisolated input IN102 asserted
		b	Both IN101 and IN102 asserted
100 In 34	IN103, IN104	3	Optoisolated input IN103 asserted
		4	Optoisolated input IN104 asserted
		b	Both IN103 and IN104 asserted
100 In 56	IN105, IN106	5	Optoisolated input IN105 asserted
		6	Optoisolated input IN106 asserted
		b	Both IN105 and IN106 asserted
100 In 7	IN107	7	Optoisolated input IN107 asserted
PO	3PO, SPO, SPOA, SPOB, SPOC	3	Three-pole open condition, 3PO asserted
		A	A-phase open (SPOA AND NOT 3PO)
		B	B-phase open (SPOB AND NOT 3PO)
		C	C-phase open (SPOC AND NOT 3PO)
		a	A- and B-phases open (SPOA AND SPOB AND NOT 3PO)
		b	B- and C-phases open (SPOB AND SPOC AND NOT 3PO)
		c	C- and A-phases open (SPOC AND SPOA AND NOT 3PO)
		S	Single pole open delay timer dropping out
SOTF	SOTFE	*	Switch-onto-fault SOTF enable asserted
TMB A 12	TMB1A, TMB2A	1	MIRRORED BITS channel A transmit bit 1 TMB1A asserted
		2	MIRRORED BITS channel A transmit bit 2 TMB2A asserted
		b	Both TMB1A and TMB2A asserted

NOTE: Event report columns for optoisolated inputs IN101–IN107 are only shown when the SEL-651R is ordered with the extra inputs and outputs option.

NOTE: Relay Word bits SPO, SPOA, SPOB, and SPOC only available when Global setting BKTYP := 1.

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 11 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
TMB A 34	TMB3A, TMB4A	3	MIRRORED BITS channel A transmit bit 3 TMB3A asserted
		4	MIRRORED BITS channel A transmit bit 4 TMB4A asserted
		b	Both TMB3A and TMB4A asserted
TMB A 56	TMB5A, TMB6A	5	MIRRORED BITS channel A transmit bit 5 TMB5A asserted
		6	MIRRORED BITS channel A transmit bit 6 TMB6A asserted
		b	Both TMB5A and TMB6A asserted
TMB A 78	TMB7A, TMB8A	7	MIRRORED BITS channel A transmit bit 7 TMB7A asserted
		8	MIRRORED BITS channel A transmit bit 8 TMB8A asserted
		b	Both TMB7A and TMB8A asserted
RMB A 12	RMB1A, RMB2A	1	MIRRORED BITS channel A receive bit 1 RMB1A asserted
		2	MIRRORED BITS channel A receive bit 2 RMB2A asserted
		b	Both RMB1A and RMB2A asserted
RMB A 34	RMB3A, RMB4A	3	MIRRORED BITS channel A receive bit 3 RMB3A asserted
		4	MIRRORED BITS channel A receive bit 4 RMB4A asserted
		b	Both RMB3A and RMB4A asserted
RMB A 56	RMB5A, RMB6A	5	MIRRORED BITS channel A receive bit 5 RMB5A asserted
		6	MIRRORED BITS channel A receive bit 6 RMB6A asserted
		b	Both RMB5A and RMB6A asserted
RMB A 78	RMB7A, RMB8A	7	MIRRORED BITS channel A receive bit 7 RMB7A asserted
		8	MIRRORED BITS channel A receive bit 8 RMB8A asserted
		b	Both RMB7A and RMB8A asserted
TMB B 12	TMB1B, TMB2B	1	MIRRORED BITS channel B transmit bit 1 TMB1B asserted
		2	MIRRORED BITS channel B transmit bit 2 bit TMB2B asserted
		b	Both TMB1B and TMB2B asserted

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 12 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
TMB B 34	TMB3B, TMB4B	3	MIRRORED BITS channel B transmit bit 3 TMB3B asserted
		4	MIRRORED BITS channel B transmit bit 4 TMB4B asserted
		b	Both TMB3B and TMB4B asserted
TMB B 56	TMB5B, TMB6B	5	MIRRORED BITS channel B transmit bit 5 TMB5B asserted
		6	MIRRORED BITS channel B transmit bit 6 TMB6B asserted
		b	Both TMB5B and TMB6B asserted
TMB B 78	TMB7B, TMB8B	7	MIRRORED BITS channel B transmit bit 7 TMB7B asserted
		8	MIRRORED BITS channel B transmit bit 8 TMB8B asserted
		b	Both TMB7B and TMB8B asserted
RMB B 12	RMB1B, RMB2B	1	MIRRORED BITS channel B receive bit 1 RMB1B asserted
		2	MIRRORED BITS channel B receive bit 2 RMB2B asserted
		b	Both RMB1B and RMB2B asserted.
RMB B 34	RMB3B, RMB4B	3	MIRRORED BITS channel B receive bit 3 RMB3B asserted
		4	MIRRORED BITS channel B receive bit 4 RMB4B asserted
		b	Both RMB3B and RMB4B asserted
RMB B 56	RMB5B, RMB6B	5	MIRRORED BITS channel B receive bit 5 RMB5B asserted
		6	MIRRORED BITS channel B receive bit 6 RMB6B asserted
		b	Both RMB5B and RMB6B asserted
RMB B 78	RMB7B, RMB8B	7	MIRRORED BITS channel B receive bit 7 RMB7B asserted
		8	MIRRORED BITS channel B receive bit 8 RMB8B asserted
		b	Both RMB7B and RMB8B asserted
ROK	ROKA, ROKB	A	MIRRORED BITS channel A receive ok ROKA asserted
		B	MIRRORED BITS channel B receive ok ROKB asserted
		b	Both ROKA and ROKB asserted

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 13 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
RBAD	RBADA, RBADB	A	MIRRORED BITS channel A extended outage RBADA asserted
		B	MIRRORED BITS channel B extended outage RBADB asserted
		b	Both RBADA and RBADB asserted
CBAD	CBADA, CBADB	A	MIRRORED BITS channel A unavailability CBADA asserted
		B	MIRRORED BITS channel B unavailability CBADB asserted
		b	Both CBADA and CBADB asserted
LBOK	LBOKA, LBOKB	A	MIRRORED BITS channel A loop back ok LBOKA asserted
		B	MIRRORED BITS channel A loop back ok LBOKB asserted
		b	Both LBOKA and LBOKB asserted
Lcl 12	LB01, LB02	1	Local bit LB01 asserted
		2	Local bit LB02 asserted
		b	Both LB01 and LB02 asserted
Lcl 34	LB03, LB04	3	Local bit LB03 asserted
		4	Local bit LB04 asserted
		b	Both LB03 and LB04 asserted
Lcl 56	LB05, LB06	5	Local bit LB05 asserted
		6	Local bit LB06 asserted
		b	Both LB05 and LB06 asserted
Rem 12	RB01, RB02	1	Remote bit RB01 asserted
		2	Remote bit RB02 asserted
		b	Both RB01 and RB02 asserted
Rem 34	RB03, RB04	3	Remote bit RB03 asserted
		4	Remote bit RB04 asserted
		b	Both RB03 and RB04 asserted
Rem 56	RB05, RB06	5	Remote bit RB05 asserted
		6	Remote bit RB06 asserted
		b	Both RB05 and RB06 asserted
Rem 78	RB07, RB08	7	Remote bit RB07 asserted
		8	Remote bit RB08 asserted
		b	Both RB07 and RB08 asserted

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 14 of 15)

NOTE: Relay Word bits OC3, OCA, OCB, OCC, CC3, CCA, CCB, and CCC are checked in the order shown. The letter for the first bit found asserted will be displayed.

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
Rem OP	OC3	3	OPE command executed
	OCA	A	OPE A command executed
	OCB	B	OPE B command executed
	OCC	C	OPE C command executed
Rem CL	CC3	3	CLO command executed
	CCA	A	CLO A command executed
	CCB	B	CLO B command executed
	CCC	C	CLO C command executed
Ltch 12	LT01, LT02	1	Latch bit LT01 asserted
		2	Latch bit LT02 asserted
		b	Both LT01 and LT02 asserted
Ltch 34	LT03, LT04	3	Latch bit LT03 asserted
		4	Latch bit LT04 asserted
		b	Both LT03 and LT04 asserted
Ltch 56	LT05, LT06	5	Latch bit LT05 asserted
		6	Latch bit LT06 asserted
		b	Both LT05 and LT06 asserted
Ltch 78	LT07, LT08	5	Latch bit LT07 asserted
		6	Latch bit LT08 asserted
		b	Both LT07 and LT08 asserted
Ltch 90	LT09, LT10	9	Latch bit LT09 asserted
		0	Latch bit LT10 asserted
		b	Both LT09 and LT10 asserted
Ltch 112	LT11, LT12	1	Latch bit LT11 asserted
		2	Latch bit LT12 asserted
		b	Both LT11 and LT12 asserted
SELOGIC Var01 SELOGIC Var02 SELOGIC Var03 SELOGIC Var04 SELOGIC Var5 SELOGIC Var6 SELOGIC Var7 SELOGIC Var8 SELOGIC Var9 SELOGIC Var10 SELOGIC Var11 SELOGIC Var12 SELOGIC Var13 SELOGIC Var14 SELOGIC Var15 SELOGIC Var16	SV1, SV1T SV2, SV2T SV3, SV3T SV4, SV4T SV5, SV5T SV6, SV6T SV7, SV7T SV8, SV8T SV9, SV9T SV10, SV10T SV11, SV11T SV12, SV12T SV13, SV13T SV14, SV14T SV15, SV15T SV16, SV16T	p	SELOGIC control equation variable timer input SV*nn* asserted; timer timing on pickup time; timer output SV*nn*T not asserted.
		T	SELOGIC control equation variable timer input SV*nn* asserted; timer timed out on pickup time; timer output SV*nn*T asserted.
		d	SELOGIC control equation variable timer input SV*nn* not asserted; timer previously timed out on pickup time; timer output SV*nn*T remains asserted while timer timing on dropout time.

NOTE: nn = 01–16.

Table 12.4 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 15 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
PWR 3P 12	3PWR1, 3PWR2	1	Level 1 three-phase power element 3PWR1 picked up
		2	Level 2 three-phase power element 3PWR2 picked up
		b	Both 3PWR1 and 3PWR2 picked up
PWR 3P 34	3PWR3, 3PWR4	3	Level 3 three-phase power element 3PWR3 picked up
		4	Level 4 three-phase power element 3PWR4 picked up
		b	Both 3PWR3 and 3PWR4 picked up
PB 19	PB01, PB01_PUL	1	PB01 OR PB01_PUL asserted
	PB02, PB02_PUL	2	PB02 OR PB02_PUL asserted
	PB03, PB03_PUL	3	PB03 OR PB03_PUL asserted
	PB04, PB04_PUL	4	PB04 OR PB04_PUL asserted
	PB05, PB05_PUL	5	PB05 OR PB05_PUL asserted
	PB06, PB06_PUL	6	PB06 OR PB06_PUL asserted
	PB07, PB07_PUL	7	PB07 OR PB07_PUL asserted
	PB08, PB08_PUL	8	PB08 OR PB08_PUL asserted
	PB09, PB09_PUL	9	PB09 OR PB09_PUL asserted
PB 02	PB10, PB10_PUL	0	PB10 OR PB10_PUL asserted
	PB11, PB11_PUL	1	PB11 OR PB11_PUL asserted
	PB12, PB12_PUL	2	PB12 OR PB12_PUL asserted

NOTE: Relay Word Bits PBnn and PBnn_PUL are checked from top to bottom. The letter for the first bit found asserted will be displayed.

Example 15-Cycle Event Report

The following example standard 15-cycle event report in *Figure 12.4* also corresponds to the example SER report in *Figure 12.7*. The circled numbers in *Figure 12.4* correspond to the SER row numbers in *Figure 12.7*. The row explanations follow *Figure 12.7*.

In *Figure 12.4*, the arrow (>) in the column following the `Freq` column identifies the "trigger" row. This is the row that corresponds to the Date and Time values at the top of the event report.

The asterisk (*) in the column following the `Freq` column identifies the row with the maximum phase current. The maximum phase current is calculated from the row identified with the asterisk and the row one quarter-cycle previous (see *Figure 12.5* and *Figure 12.6*). These currents are listed at the end of the event report in the event summary. If the trigger row (>) and the maximum phase current row (*) are the same row, the * symbol takes precedence.

=>EVE 1 <Enter>

```
MOUNTAIN F-22                                       Date: 07/02/2003  Time: 17:06:35.965
P180                                                Time Source: internal

FID=SEL-651R-Rxxx-V0-Zxxxxxx-D2003xxxx       CID=xxxx
                                                                                     5G
     Currents (Amps Pri)                          Voltages (kV Pri)                TC2N
     IA      IB      IC      IG     VAY     VBY     VCY     VAZ     VBZ      VCZ Freq RLAD
[1]
    185    -306     122      -0    11.2   -13.4     2.2    11.2   -13.4      2.2 60.0 ..*N
    247      36    -284       0     9.0     5.2   -14.2     9.0     5.2    -14.2 60.0 ..*N
   -185     306    -122       0   -11.2    13.4    -2.2   -11.2    13.4     -2.2 60.0 ..*N
   -247     -36     283       0    -9.0    -5.2    14.2    -9.0    -5.2     14.2 60.0 ..*N
[2]
    185    -306     122      -0    11.2   -13.4     2.2    11.2   -13.4      2.2 60.0 ..*N
    247      36    -284      -0     9.0     5.2   -14.2     9.0     5.2    -14.2 60.0 ..*N
   -185     306    -122       0   -11.2    13.4    -2.2   -11.2    13.4     -2.2 60.0 ..*N
   -247     -36     284       0    -9.0    -5.2    14.2    -9.0    -5.2     14.2 60.0 ..*N
[3]
    184    -307     122      -0    11.2   -13.4     2.2    11.2   -13.4      2.2 60.0 ..*N
    247      37    -284      -0     9.0     5.2   -14.2     9.0     5.2    -14.2 60.0 ..*N
   -185     306    -122       0   -11.2    13.4    -2.2   -11.2    13.4     -2.2 60.0 ..*N
   -247     -37     284       0    -9.0    -5.2    14.2    -9.0    -5.2     14.2 60.0 ..*N
[4]
    185    -306     122      -0    11.2   -13.4     2.2    11.2   -13.4      2.2 60.0 ..*N
    247      37    -283       0     9.0     5.2   -14.2     9.0     5.2    -14.2 60.0 ..*N
   -215     472    -151     156   -11.4    13.0    -2.3   -11.4    13.0     -2.3 60.0 ..*N
   -254     867     274     884    -8.9    -5.1    14.3    -8.9    -5.1     14.3 60.0>..*N
[5]
    280   -1492     217   -1060    11.6   -12.3     2.5    11.6   -12.3      2.5 60.0 ..*N
    254   -2077    -272   -2093     8.7     4.7   -14.5     8.7     4.7    -14.5 60.0 ..*N
   -316    2304    -254    1808   -11.7    12.1    -2.6   -11.7    12.1     -2.6 60.0 ..*N
   -246    2388     279    2418    -8.6    -4.5    14.5    -8.6    -4.5     14.5 60.0 ..*N
[6]
    316   -2305     254   -1808    11.7   -12.1     2.6    11.7   -12.1      2.6 60.0 ..*N
    246   -2389    -279   -2418     8.6     4.5   -14.5     8.6     4.5    -14.5 60.0*..*N
   -315    2304    -254    1808   -11.7    12.1    -2.6   -11.7    12.1     -2.6 60.0 *.*N
   -246    2388     279    2418    -8.6    -4.5    14.5    -8.6    -4.5     14.5 60.0 *.*N
[7]
    315   -2304     254   -1808    11.7   -12.1     2.6    11.7   -12.1      2.6 60.0 *.*N
    246   -2389    -279   -2419     8.6     4.5   -14.5     8.6     4.5    -14.5 60.0 *.*N
   -316    2303    -253    1807   -11.7    12.1    -2.6   -11.7    12.1     -2.6 60.0 *.*N
   -246    2388     278    2419    -8.6    -4.5    14.5    -8.6    -4.5     14.5 60.0 *.*N
[8]
    315   -2304     253   -1807    11.7   -12.1     2.6    11.7   -12.1      2.6 60.0 *.*N
    246   -2389    -278   -2419     8.6     4.5   -14.5     8.6     4.5    -14.5 60.0 *.*N
   -316    2304    -254    1808   -11.7    12.1    -2.6   -11.7    12.1     -2.6 60.0 *.*N
   -246    2387     279    2418    -8.6    -4.5    14.5    -8.6    -4.5     14.5 60.0 *.*N
[9]
    315   -2305     254   -1808    11.7   -12.1     2.6    11.7   -12.1      2.6 60.0 *.*N
    246   -2388    -279   -2418     8.6     4.5   -14.5     8.6     4.5    -14.5 60.0 *.*N
   -315    2304    -254    1807   -11.7    12.1    -2.6   -11.7    12.1     -2.6 60.0 *.*N
   -246    2388     279    2418    -8.6    -4.5    14.5    -8.6    -4.5     14.5 60.0 *.*N
[10]
    316   -2305     254   -1808    11.7   -12.1     2.6    11.7   -12.1      2.6 60.0 *.*N
    246   -2389    -279   -2419     8.6     4.5   -14.5     8.6     4.5    -14.5 60.0 *.*N
   -271    2025    -175    1636    -9.9     9.1    -0.8   -11.6    12.4     -2.5 60.0 *.*N
   -149    1496     212    1554    -5.2    -4.0    10.3    -8.7    -4.7     14.5 60.0 *.*N
[11]
    113    -874      48    -732     4.1    -3.1    -0.5    11.4   -13.2      2.3 60.0 *.*N
     26    -303     -72    -345     0.9     1.7    -3.0     9.0     5.0    -14.4 60.0 *.*N
     -0      -1       0      -0    -0.0    -0.0    -0.0   -11.3    13.5     -2.2 60.0 *.*N
     -0      -1      -0       0    -0.0     0.0    -0.0    -9.1    -5.3     14.4 60.0 *.*N
[12]
      0      -1       0       0     0.0     0.0     0.0    11.3   -13.5      2.2 60.0 *.*N
     -0       0       0      -0     0.0    -0.0    -0.0     9.1     5.3    -14.4 60.0 *.*N
      0      -1       0      -0    -0.0    -0.0     0.0   -11.3    13.5     -2.2 60.0 *.*N
      0      -1      -0       0     0.0    -0.0    -0.0    -9.1    -5.3     14.4 60.0 *..N
[13]
     -0       0      -1       0     0.0     0.0     0.0    11.3   -13.5      2.2 60.0 *..N
      0       0       0       0    -0.0    -0.0     0.0     9.1     5.3    -14.4 60.0 *..N
      0       0       0       0    -0.0    -0.0    -0.0   -11.3    13.5     -2.2 60.0 *..N
     -1      -0      -0      -0    -0.0     0.0    -0.0    -9.1    -5.3     14.4 60.0 *..N
[14]
     -0      -1      -0      -0     0.0    -0.0    -0.0    11.3   -13.5      2.2 60.0 *..N
      1       0       0      -0     0.0    -0.0    -0.0     9.1     5.3    -14.4 60.0 *..N
      0      -0       0       0    -0.0    -0.0     0.0   -11.3    13.5     -2.2 60.0 *..N
     -1      -0      -0       0    -0.0     0.0    -0.0    -9.1    -5.3     14.4 60.0 *..N
[15]
      0       0      -0      -0     0.0     0.0    -0.0    11.3   -13.5      2.2 60.0 *..N
      0      -0       0       0    -0.0    -0.0     0.0     9.1     5.3    -14.4 60.0 *..N
     -0       1      -0       0    -0.0    -0.0     0.0   -11.3    13.5     -2.2 60.0 *..N
     -0      -0      -0       0    -0.0    -0.0    -0.0    -9.1    -5.3     14.4 60.0 *..N
```

firmware identifier

firmware checksum identifier

one cycle of data

8

see Figure 12.5 and Figure 12.6

3

These columns are only displayed if extra Inputs/Outputs are ordered

```
Protection and Control Elements

51     50    32 Dm 27 59     27 59     25  81   TS  TS  TS     T 200  100
       A           Y  Y     Z  Z     5   2     ih Bih Cih ZL  C  In  Out In
    GG B     P  PN  P  PV     P  PV    9S  7135 7mo 7mo 7mo 10 PA 1135 13571357
ABCP12QCPNGQ QG QG PP PP1NQ PP PP1NQ VFA B246 9et 9et 9et dP SP 2246 2468246
[1]
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
[2]
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
[3]
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
[4]                                                                              ⑬
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
............ .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
....p....... .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
...pp....... .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........>
[5]
...pp....... .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
...pp....... .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
...pp....... .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
...pp....... .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
[6]                                                                              ⑪
...pp....... .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
...pp....... .. .. .. 3.... .. 3.... ... .... R.0 ... ... .. 1* 1.b. ........
...pt....... .. .. .. 3.... .. 3.... ... .... L.0 ... ... .. 1* 1.b. ........   ⑩
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1.b. ........
[7]
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1.b. ........
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1.b. ........
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
[8]
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
[9]
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
[10]
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
...pt....... .. .. .. 3.... .. 3.... ... .... Lr3 ... ... .. 1* 1... ........
...pt....... .. .. .. c.... .. 3.... ... .... Lr3 ... ... .. 1* 1.3. ........
...pt....... .. .. .. ..... .. 3.... ... .... Lr3 ... ... .. 1* 1.3. ........
[11]
...pt....... .. .. .. ..... .. 3.... ... .... Lr3 ... ... .. 1* 1.3. ........
...pt....... .. .. .. ..... .. 3.... ... .... Lr3 ... ... .. 1* 1.3. ........
...pt....... .. .. .. ..... .. 3.... ... .... Lr3 ... ... .. 1* 1.3. ........
...rt....... .. .. .. ..... .. 3.... ... .... Lr3 ... ... .. 1* 1.3. ........
[12]                                                                             ②
...r1....... .. .. .. ..... .. 3.... ... .... Lr3 ... ... .. 1* 1.3. ........
...r1....... .. .. .. ..... .. 3.... ... .... Lr3 ... ... .. 1* 1b3. ........
...r1....... .. .. .. ..... .. 3.... ... .... Lr3 ... ... .. 1* 1b3. ........
....1....... .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
[13]
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
[14]
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
[15]
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
............ .. .. .. ..... .. 3.... ... .... L.3 ... ... .. 1* 1b3. ........
```

```
Mirrored Bits, Communication and Automation Elements

 S TMB  RMB  TMB  RMB  RRCL Lcl Rem    Ltch   SELogic          PWR
 O A    A    B    B    OBBB                 1 Variable         3P PB
PT 1357 1357 1357 1357 KAAO 135 13570C 135791          1111111 13 10
OF 2468 2468 2468 2468  DDK 246 2468PL 246802 1234567890123456 24 92
[1]
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
[2]
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
[3]
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
[4]
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..>

[Six cycles of data not shown in this example]

[11]
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
[12]
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
.. .... .... .... .... .... ... ...... 1.b... ................ .. ..
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
[13]
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
[14]
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
[15]
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..
3. .... .... .... .... .... ... ...... 1.b... ................ .. ..


Event: BG  Location:    3.02  Shot: 0  Frequency:  60.01
Targets: 11 100101001000 001000000111
Currents (A Pri), ABCGQ:    400  3320   377  3019  3232


Group Settings

Identifier and Instrument Transformer Settings:
RID     :=MOUNTAIN F-22
TID     :=P180
CTR     := 1000.0   CTRN    := 1000.0   PTRY    := 120.00   PTRZ    := 120.00
.
.
[The remainder of the Group settings are not shown in this example]


Logic Settings
.
.
[The Logic settings are not shown in this example]
```

see Figure 12.1

```
Global Settings

General Settings:
NFREQ   := 60       PHROT   := ABC      DATE_F  := MDY
PWRDN_AC:= 180      PWRDN_WU:= 20
TESTBATT:= NA
FAULT   :=51P OR 51G1
Current and Voltage Connection Settings:
IPCONN  := ABC      EGNDSW  := Y        CTPOL   := POS      BKTYP   := 3
VYCONN  := ABC      VZCONN  := ABC
VSELECT := VZ       FSELECT := VZ
.
.
[The remainder of the Global settings are not shown in this example]

Report Settings

Sequential Events Recorder Trigger Lists:
SER1    :=TRIP3P,51P,51PT,51G1,51G1T,PB12_PUL,OC3
SER2    :=CLOSE3P,52A3P,CF3P,79RS3P,79CY3P,79LO3P,RCSF3P,SH03P,SH13P,SH23P
SH33P,SH43P,PB11_PUL,CC3
SER3    :=PWR_SRC1,TOSLP,BTFAIL,DTFAIL
SER4    :=0

Event Report Settings:
LER     := 15       PRE     := 4
ER      :=R_TRIG 51P OR R_TRIG 51G1


Load Profile Settings:
LDLIST  :=0
LDAR    := 15


PARTNO=0651Rxxxxxxxxxxxxx
=>
```

Figure 12.4 Example Standard 15-Cycle Event Report 1/4-Cycle Resolution

Figure 12.5 and *Figure 12.6* look in detail at one cycle of A-phase current (channel IA) identified in *Figure 12.4*. *Figure 12.5* shows how the event report ac current column data relate to the actual sampled waveform and rms values. *Figure 12.6* shows how the event report current column data can be converted to phasor rms values. Voltages are processed similarly.

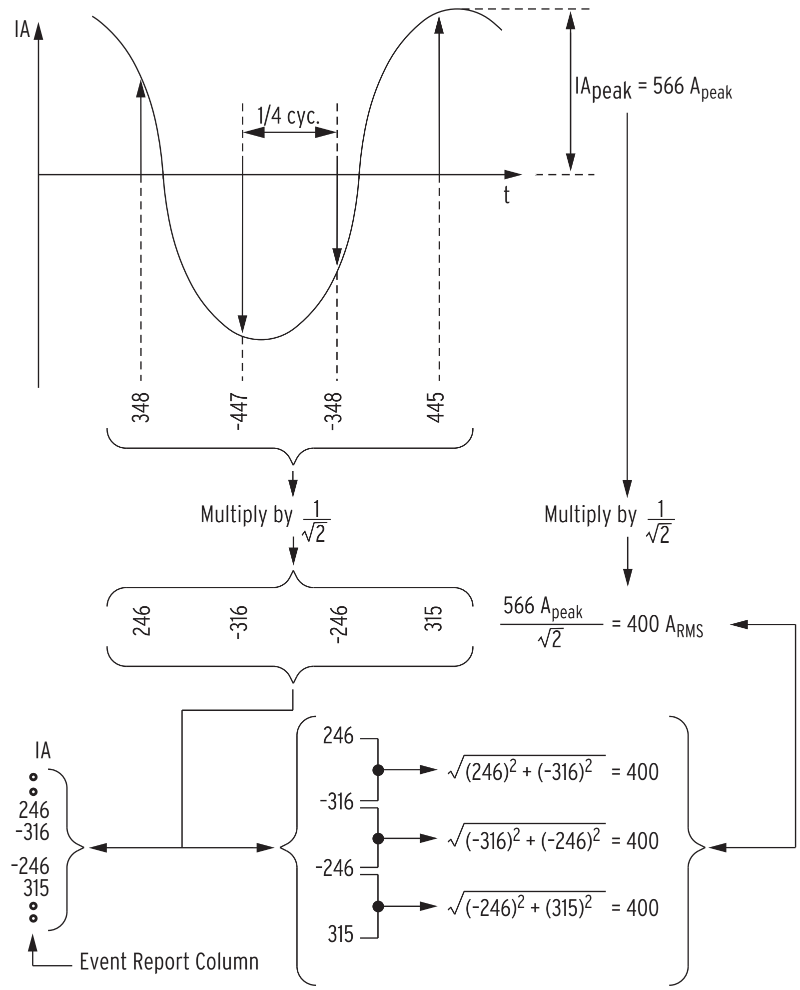


Figure 12.5 Derivation of Event Report Current Values and RMS Current Values From Sampled Current Waveform

In *Figure 12.5*, note that any two rows of current data from the event report in *Figure 12.4*, 1/4 cycle apart, can be used to calculate rms current values.

NOTE: The arctan function of many calculators and computing programs does not return the correct angle for the second and third quadrants (when X is negative). When in doubt, graph the X and Y quantities to confirm that the angle that your calculator reports is correct.

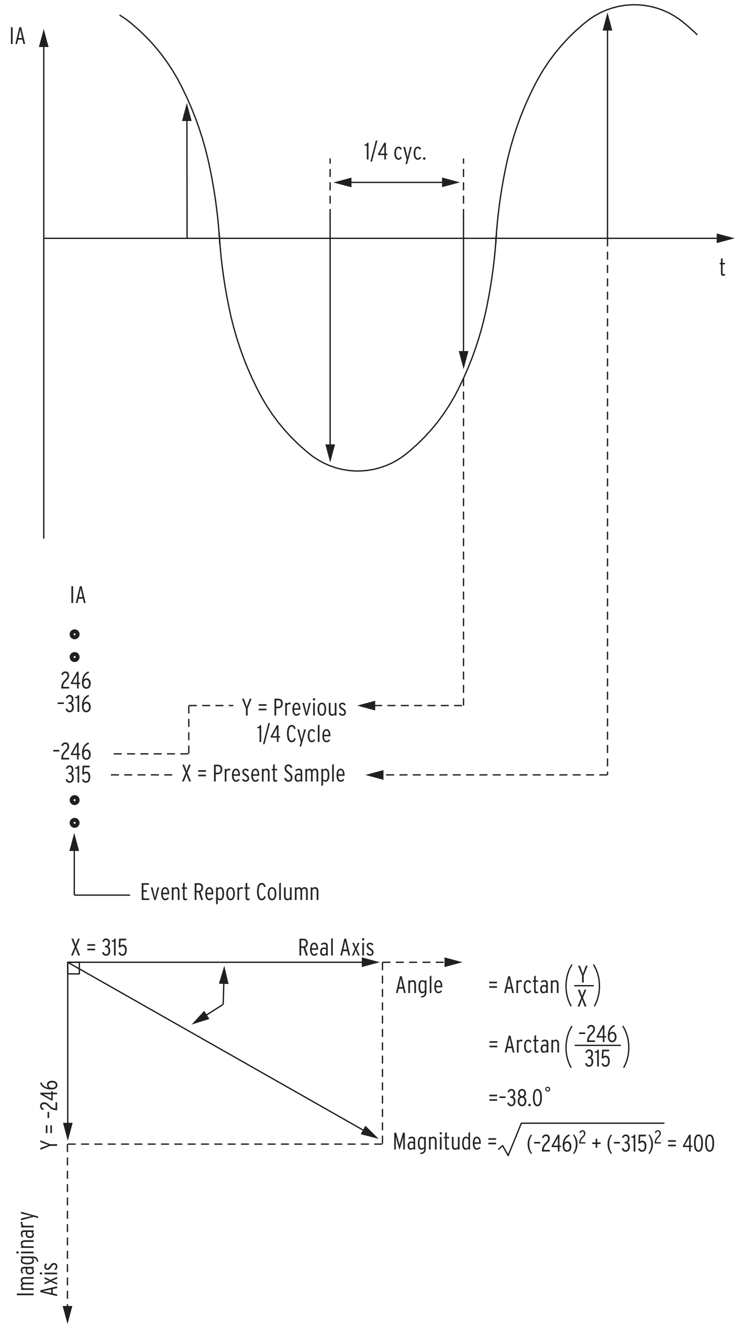


Figure 12.6 Derivation of Phasor RMS Current Values From Event Report Current Values

In *Figure 12.6*, note that two rows of current data from the event report in *Figure 12.4*, 1/4 cycle apart, can be used to calculate phasor rms current values. In *Figure 12.6*, at the present sample, the phasor rms current value is:

$$IA = 400\ A\ \angle -38.0^\circ \qquad \textbf{Equation 12.1}$$

The present sample (IA = 315 A) is a real rms current value that relates to the phasor rms current value:

$$400\ A * \cos(-38.0^\circ) = 315\ A \qquad \textbf{Equation 12.2}$$

Sequential Events Recorder (SER) Report

See *Figure 12.7* for an example SER report.

SER Triggering

The recloser control triggers (generates) an entry in the SER report for a change of state of any one of the elements listed in the SER1, SER2, SER3, and SER4 trigger settings. The factory default settings are:

SER1 := **TRIP3P, 51P, 51PT, 51G1, 51G1T, PB12_PUL, OC3**

SER2 := **CLOSE3P, 52A3P, CF3P, 79RS3P, 79CY3P, 79LO3P, RCSF3P, SH03P, SH13P, SH23P, SH33P, SH43P, PB11_PUL, CC3**

SER3 := **PWR_SRC1, TOSLP, BTFAIL, DTFAIL**

SER4 := **0**

The elements are Relay Word bits referenced in *Table F.1*. The recloser control monitors each element in the SER lists every 1/4 cycle. If an element changes state, the recloser control time-tags the changes in the SER. For example, setting SER1 contains:

Ground time-overcurrent element picked-up status (51G1)

Ground time-overcurrent element timed-out status (51G1T)

If a ground fault occurs, the 51G1 element will assert, and the change will be time-tagged in the SER (shown as `51G1 Asserted`). If the fault clears before the ground time-overcurrent element times-out (indicating that a load-side device or another element operated to clear the fault), the 51G1 element deassertion will be time-tagged in the SER (shown as `51G1 Deasserted`).

If the ground fault did not get cleared by another device, then the 51G1T element would have asserted, and this state change would also appear in the SER (51G1T Asserted).

In addition to the programmable SER trigger lists, the recloser control adds preprogrammed messages to the SER for certain occurrences:

Occurrence	Message in SER
Recloser control powered up after being shut off	Relay restarted
Recloser control settings changed (except port settings)	Settings changed
Active setting group changed	Group changed
Recloser control shuts down while running on batteries	Going to sleep
Diagnostic restart (see Note 1 with *Table 13.1*)	Diagnostic restart

Each entry in the SER includes SER row number, date, time, element name, and element state.

Making SER Trigger Settings

Enter up to 24 element names in each of the SER settings via the **SET R** command. See *Table F.1* for references to valid recloser control element (Relay Word bit) names. See the **SET R** command in *Table 9.2* and corresponding *Report Settings on page SET.58*. Use commas to delimit the elements. For example, if you enter setting SER1 as:

SER1 := **51P,51G1,51PT,,51G1T , 50P1, , 50P2**

The recloser control displays the setting as:

```
SER1 := 51P,51G1,51PT,51G1T,50P1,50P2
```

The recloser control can monitor up to 96 elements in the SER (24 in each of SER1, SER2, SER3, and SER4).

Make SER Settings With Care

The recloser control triggers a row in the SER report for any change of state in any one of the elements listed in the SER1, SER2, SER3, or SER4 trigger settings. Nonvolatile memory is used to store at least the latest 1000 rows of the SER report so they can be retained during power loss. The nonvolatile memory is rated for a finite number of write cycles. Exceeding the limit can result in a FLASH self-test failure. **An average of six (6) state changes every minute can be made for a 25-year recloser control service life.**

Retrieving SER Reports

See *SER Command (Sequential Events Recorder Report) on page 10.35* for details on the **SER** command.

Example SER Report

The following example SER report in *Figure 12.7* also corresponds to the example standard 15-cycle event report in *Figure 12.4*.

```
=>SER <Enter>

MOUNTAIN F-22                                    Date: 07/02/2003  Time: 17:06:40.931
P180                                             Time Source: internal

FID=SEL-651R-Rxxx-V0-Zxxxxxx-D2003xxxx       CID=xxxx

 #     Date        Time           Element         State

   22  05/06/2003  11:47:41.430   Relay restarted
   21  05/06/2003  11:47:41.430   52A3P           Asserted
   20  05/06/2003  11:47:41.430   PWR_SRC1        Asserted
   19  05/06/2003  11:47:41.430   SH33P           Asserted
   18  05/06/2003  11:47:41.430   79LO3P          Asserted
   17  05/06/2003  11:47:51.522   79LO3P          Deasserted
   16  05/06/2003  11:47:51.522   79RS3P          Asserted
   15  05/06/2003  11:47:51.526   SH33P           Deasserted
   14  05/06/2003  11:47:51.526   SH03P           Asserted
   13  07/02/2003  17:06:35.961   51G1            Asserted
   12  07/02/2003  17:06:35.965   51P             Asserted
   11  07/02/2003  17:06:35.994   51G1T           Asserted
   10  07/02/2003  17:06:35.994   79LO3P          Asserted
    9  07/02/2003  17:06:35.994   79RS3P          Deasserted
    8  07/02/2003  17:06:35.994   TRIP3P          Asserted
    7  07/02/2003  17:06:35.999   SH33P           Asserted
    6  07/02/2003  17:06:35.999   SH03P           Deasserted
    5  07/02/2003  17:06:36.082   51P             Deasserted
    4  07/02/2003  17:06:36.086   51G1            Deasserted
    3  07/02/2003  17:06:36.099   52A3P           Deasserted
    2  07/02/2003  17:06:36.103   51G1T           Deasserted
    1  07/02/2003  17:06:36.665   TRIP3P          Deasserted

=>
```

Figure 12.7 Example SER Report

The SER report rows in *Figure 12.7* are explained in *Table 12.5*, numbered in correspondence to the # column. The circled comments in *Figure 12.4* also correspond to the # column numbers in *Figure 12.7*. The SER report in *Figure 12.7* contains records of events that occurred before and after the standard event report in *Figure 12.4*.

Table 12.5 Example SER Detailed Description (Corresponds to Figure 12.7)

SER Row No.	Explanation
22–20	SEL-651R powered up.[a]
19–14	Reclosing relay initialization after power up.
13	Ground #1 time-overcurrent element pickup (51G1). Starts timing at fault inception.
12	Maximum-phase time overcurrent element pickup (51P). Also starts timing.
11–8	Ground #1 time-overcurrent element times-out (51G1T) and asserts trip logic (TRIP3P). Reclosing relay goes into the lockout state. Lockout occurs because {Reclose Enabled} operator control (= LT02) is deasserted.
7–6	Reclosing relay shot counter moves to last shot.
5–4	Time overcurrent elements drop-out (51P and 51G1) as recloser contacts interrupt the fault current.
3	Recloser status change—52A3P registers as open.
2	Ground #1 time-overcurrent element completes 1-cycle reset interval (51G1T deasserts).
1	Trip logic drops out.

[a] The date is a few months before the event report in Figure 12.4.

Sag/Swell/Interruption (SSI) Report

See *Figure 12.8* for an example SSI report.

SSI Triggering and Recording

The SEL-651R can perform automatic voltage disturbance monitoring for three-phase systems. The SSI Recorder uses the SSI Relay Word bits to determine when to start (trigger) and when to stop recording. The recorded data are available through the SSI Report.

See *Voltage Sag, Swell, and Interruption Elements on page 4.48* for details on the operation of the SSI Relay Word bits.

The SSI recorder operates (adds new entries to the stored SSI report) only when group setting ESSI := Y in the active setting group, although the SSI report can be viewed at any time.

The SSI recorder uses nonvolatile memory, so any stored SSI data will not be erased by de-energizing the recloser control. The recloser control needs some time to store new SSI data in nonvolatile memory, so if a system power outage also causes the recloser control power to fail, there may not be an SSI record of the disturbance. The battery system in the SEL-651R will normally keep the recloser control operating through any voltage disturbances.

The recloser control triggers (generates) entries in the SSI report upon the assertion of any sag, swell, or interruption element (Relay Word bits SAG*p*, SW*p*, INT*p*, where *p* = A, B, or C), when manually triggered by the **SSI T** Command or when the SSI_TRIG SELOGIC equation solves to logical 1. See *Voltage Sag/Swell/Interrupt on page SET.28* for the SSI_TRIG equation.

SSI Report Entries

- Entry number (1 is the most recent entry)
- Date and time stamp of entry
- Phase current magnitudes (Ia, Ib, Ic) as a percentage of the nominal current rating of the phase current inputs (1 A)
- Ground current magnitude (Ig) as a percentage of the nominal current rating of the phase current inputs (1 A)

  NOTE: When global setting EGNDSW := Y, the Ig percentage magnitude is based on channel IN data for small signals when Relay Word bit GNDSW is asserted. The percentage value displayed will be 1/5 of the displayed In percentage value, because of the difference in nominal channel ratings; the 1 A phase channel nominal rating is five times the 0.2 A nominal neutral channel rating.

  For large signals, the Ig quantity is based on a calculated residual zero-sequence current 3I0 = IA + IB + IC when Relay Word bit GNDSW is deasserted. When global setting EGNDSW := N, Ig is always based on the calculated 3I0 quantity.
- Neutral current magnitude (In) as a percentage of the nominal current rating of the neutral current input (0.2 A).
- Phase-neutral voltage magnitudes (Va, Vb, Vc), as a percentage of Vbase

  Global setting VSELECT determines which input terminals are monitored by the SSI elements, as shown in the SSI report. For example, if VSELECT := VZ, quantities VAZ, VBZ, and VCZ are reported. The other three voltage quantities (VAY, VBY, VCY) will have no effect on the SSI elements or the SSI report.
- Base voltage magnitude (Vbase) in kV primary
  Vbase = memorized positive-sequence voltage, V_1
- Phase A, B, and C SSI element status columns; see *Table 12.6*
- Trigger state, * if present (in the column marked S)
- SSI recorder status; see *Table 12.7*

NOTE: Any current or voltage value greater than 999 percent will be replaced by "$$$" in the SSI report.

Table 12.6 SSI Element Status Columns

Symbol	Meaning (for Each Column A, B, or C)
	Column A represents *p* = A Column B represents *p* = B Column C represents *p* = C
•	No SSI bits asserted for phase *p*
O	Overvoltage (SW*p* asserted)
U	Undervoltage (SAG*p* asserted)
I	Interruption (INT*p* asserted; SAG*p* asserted, unless setting VSAG := OFF)

Table 12.7 Recorder Status Column

Symbol	Meaning (Action)	Duration
R	Ready (when the SSI logic first acquires a valid V_{BASE} value)	Single entry
P	Pre-disturbance (4 samples per cycle). Always signifies a new disturbance.	12 samples (3 cycles)
F	Fast recording mode (4 samples per cycle)	Varies. At least one SSI element must be asserted.
E	End (post-disturbance at 4 samples per cycle)	Up to 16 samples (4 cycles). No SSI elements asserted.
M	Medium recording mode (one sample per cycle)	Maximum of 176 cycles
S	Slow recording mode (one sample per 64 cycles)	Maximum of 4096 cycles
D	Daily recording mode (one sample per day, just after midnight)	Indefinite
X	Data overflow (single entry that indicates that data was lost prior to the present entry)	Single entry

See *Figure 12.8* for an example Sag/Swell/Interruption (SSI) report.

SSI Recorder Operation: Overview

The SSI Recorder operation can be summarized as follows: When power is first applied to the recloser control and setting ESSI := Y, (or setting ESSI is changed from N to Y), the recloser control measures the voltage inputs specified by global setting VSELECT to determine if a valid three-phase signal is present. When the conditions are satisfied for at least twelve seconds, the positive-sequence voltage, V_1, is memorized as the Vbase reference voltage. This causes a single R entry to be placed in the SSI archive, which indicates that the recorder is armed, or ready. The Vbase value is allowed to change on a gradual basis to follow normal system voltage variations, but is locked when a disturbance occurs.

When any SSI Relay Word Bit asserts, the SSI_TRIG SELOGIC equation is asserted, or the **SSI T** serial port command is issued, the recorder will begin recording.

When operating, the SSI Recorder archives the following information:

- Currents Ia, Ib, Ic, Ig, and In as a percentage of the nominal current rating (shown in the report heading)
- Voltages Va, Vb, and Vc, as a percentage of the Vbase quantity
- The Vbase quantity, in kV primary
- The state of the Sag/Swell/Interruption Relay Word bits, by phase
- The trigger status
- The recorder status

Entries are made at a varying recording rate: fastest when the SSI Relay Word bits are changing states, and slowest if the SSI Relay Word bits are quiet. Eventually, it can get as slow as one sample per day. The faster recording mode will be initiated from any of the slower recording modes, as soon as any SSI bit or the **SSI T** condition changes state.

Recording is stopped when all SSI Relay Word bits and the trigger condition stay deasserted for at least four cycles.

The group setting SSI_TRIG is a SELOGIC equation that can be used to force the SSI recorder to trigger, regardless of the applied voltages, provided that the recorder was previously armed. The SSI_TRIG setting is treated the same as a Sag/Swell/Interruption Relay Word bit. An example application is to set SSI_TRIG := PB08_PUL for testing purposes. When the Operator Control pushbutton **{AUX 1}** is pressed, the SSI recorder would act as if the SSI T command was issued. See *Table 11.9*.

Make SSI_TRIG Setting With Care

Take care to set the SSI_TRIG equation so that it does not constantly assert and deassert, because the resulting stream of SSI triggers will cause excessive data recording. Excessive recording reduces the usefulness of the SSI report for actual power system disturbance analysis because real disturbance data could be overwritten before an operator could retrieve it. Additionally, because the SSI data is stored in nonvolatile memory that is rated for a finite number of write cycles, constant SSI triggering could lead to a FLASH self-test failure and a reduction in the recloser control service life.

SSI Recorder Operation: Detailed Description

From the SSI Recorder Ready state, upon the initial assertion of one of the SSI Relay Word bits or a manual trigger condition, the recloser control records SSI data in the following sequence:

- **Predisturbance recording:** Record pre-trigger entries at 1/4-cycle intervals with the SSI Recorder status field displaying `P`. Because no SSI elements are asserted, columns A, B, and C will display `.` (a period). The pre-disturbance state lasts for a total of 12 samples, or 3 cycles, unless there are back-to-back disturbances that reduce the number of `P` entries.
- **Fast recording (also End recording):** Record one entry every ¼-cycle, with the SSI Recorder status field displaying `F` (if any SSI elements are asserted or the trigger condition is asserted), or `E` (if none of the SSI elements are asserted). If the trigger condition is present, a `*` will be recorded. The SSI element status columns will show one of `.`, `O`, `U`, `I`. The Fast/End recording mode continues until four cycles elapse with no SSI element or trigger condition changing state. The recloser control then proceeds to the state determined by the following tests (processed in the order shown):
  - If INT3P is asserted, switch to daily recording mode. This keeps the recloser control from recording medium and slow speed detailed information during a complete outage.
  - Otherwise, if any SSI elements or the SSI_TRIG setting are asserted, switch to the medium recording mode.
  - Otherwise, stop recording.
- **Medium recording:** Record one entry per cycle, with the SSI Recorder status field displaying `M`. The phase columns will show one of `.`, `O`, `U`, `I`. The medium recording mode continues for 176 cycles, unless one of the SSI elements or the trigger condition changes state, which causes the recorder to start over in Fast mode (with up to three samples prior to the change). At the end of medium recording mode, the recorder switches to the slow recording mode.

- **Slow recording:** Record one entry every 64 cycles, with the SSI Recorder status field displaying S. The phase columns will show one of ., O, U, I. The slow recording mode continues for 4,096 cycles (64 entries), unless one of the SSI elements or the manual trigger condition changes state, which causes the recorder to start over in fast mode (with up to eight samples prior to the change). At the end of slow recording mode, the recorder switches to the daily recording mode.
- **Daily recording:** record one entry every day just past midnight (00:00:00), with the SSI Recorder status field displaying D. The phase columns will show one of ., O, U, I. The daily recording mode continues until any SSI Relay element or the manual trigger condition changes state, which causes the recorder to start over in fast mode with up to eight samples prior to the change.

An overflow condition can occur when the SSI recorder cannot keep up with the data generated during disturbances that create a large number of SSI entries. The nonvolatile memory that is used for the SSI archive has a longer write time than the Random Access Memory (RAM) that is used to temporarily store the SSI data, so it is possible that the data in RAM will overwrite itself if the transfer to Flash memory gets too far behind. The SSI report will show an X in the REC column if this happens, and it will be on the first entry after the overflow. The overflow condition may also occur if the recloser control is saving an event report to nonvolatile memory, because the memory can only be used by one procedure at a time.

SSI Report Memory Details

The recloser control retains a minimum of 4000 of the most recent SSI entries in nonvolatile memory. The recloser control can hold a maximum of approximately 8000 entries. When the recorder memory reaches 8000 entries and further entries occur, the oldest 4000 memory locations are cleared in a block to make room for newer entries. Therefore, the apparent SSI memory size can vary between 4000 and approximately 8000 entries. If the SSI recorder memory clears while an SSI report is being displayed, the SSI report will stop and display this message:

```
Command Aborted, Data overwrite occurred
```

Capacity of the SSI Report

If maximum SSI recorder capacity is desired, the SSI Report should be checked periodically, with the data captured to a computer file using a terminal emulation program. Once the data have been viewed or captured, use the **SSI C** command to clear the SSI recorder.

Clearing the SSI Recorder makes it easier to tell if any new disturbances have been recorded, and it also allows the SSI Archive to record the maximum of 8000 entries. If more than 8000 entries occur, the oldest half of the SSI archive will be erased to make room for the new entries. The most recent 4000 entries are always available.

Retrieving the SSI Report

See *SSI Command (Voltage Sag/Swell/Interruption Report) on page 10.36* for details on the **SSI** command. See *Figure 12.8* for an example SSI Report.

Commissioning Testing

The **SSI T** command is useful for testing, because it provides an easy method of creating some SSI Report entries without the need to remove voltage signals or connect a test set, providing Vbase has already been initialized.

During recloser control commissioning or test procedures, the SSI recorder may memorize the Vbase quantity when test voltages or settings are applied. This could cause the recorder to declare a false SAG or SWELL condition when normal system voltages are applied. Reset the SSI Recorder logic and clear the Vbase value by issuing the **SSI R** command.

Example SSI Report

The Sag/Swell/Interruption (SSI) report in *Figure 12.8* shows the voltage disturbances caused by the same fault simulation used for *Figure 12.4* (example event report) and *Figure 12.7* (example SER report). Notice in *Figure 12.8* that the Vb column shows the voltage sag, and the Ph B column shows a U, representing the SAGB Relay Word bit. Currents Ib and Ig display the fault current.

```
=>SSI <Enter>

MOUNTAIN F-22                               Date: 07/02/2003  Time: 17:06:44.485
P180                                        Time Source: internal

FID=SEL-651R-Rxxx-V0-Zxxxxxx-D2003xxxx       CID=xxxx

                 I nom. A B C G = 1 Amp  N = 0.20 Amp

                              Current(% I nom.)   Voltage(% Vbase) Vbase  Ph ST
#     Date       Time          Ia  Ib  Ic  Ig  In  Va  Vb  Vc      (kV)   ABC

47    07/02/2003 17:06:35.949  27  27  27   0   0 100 100 100      14.37 ... P
46    07/02/2003 17:06:35.953  27  27  27   0   0 100 100 100      14.37 ... P
45    07/02/2003 17:06:35.957  27  27  27   0   0 100 100 100      14.37 ... P
44    07/02/2003 17:06:35.961  29  47  28  16  78 101  98 100      14.37 ... P
43    07/02/2003 17:06:35.965  29  99  27  90 449 100  97 101      14.37 ... P
42    07/02/2003 17:06:35.969  33 173  31 138 690 102  93 101      14.37 ... P
41    07/02/2003 17:06:35.974  33 256  30 235 $$$ 101  92 102      14.37 ... P
40    07/02/2003 17:06:35.978  35 310  33 277 $$$ 101  90 102      14.37 ... P
39    07/02/2003 17:06:35.982  35 332  33 302 $$$ 101  90 103      14.37 ... P
38    07/02/2003 17:06:35.986  35 332  33 302 $$$ 101  90 103      14.37 ... P
37    07/02/2003 17:06:35.990  35 332  33 302 $$$ 101  90 103      14.37 ... P
36    07/02/2003 17:06:35.994  35 332  33 302 $$$ 101  90 103      14.37 ... P
35    07/02/2003 17:06:35.999  35 332  33 302 $$$ 101  90 103      14.37 .U. F
34    07/02/2003 17:06:36.003  35 332  33 302 $$$ 101  90 103      14.37 .U. F
33    07/02/2003 17:06:36.007  35 332  33 302 $$$ 101  90 103      14.37 .U. F
32    07/02/2003 17:06:36.011  35 332  33 302 $$$ 101  90 103      14.37 .U. F
31    07/02/2003 17:06:36.015  35 332  33 302 $$$ 101  90 103      14.37 .U. F
30    07/02/2003 17:06:36.019  35 332  33 302 $$$ 101  90 103      14.37 .U. F
29    07/02/2003 17:06:36.024  35 332  33 302 $$$ 101  90 103      14.37 .U. F
28    07/02/2003 17:06:36.028  35 332  33 302 $$$ 101  90 103      14.37 .U. F
27    07/02/2003 17:06:36.032  35 332  33 302 $$$ 101  90 103      14.37 .U. F
26    07/02/2003 17:06:36.036  35 332  33 302 $$$ 101  90 103      14.37 .U. F
25    07/02/2003 17:06:36.040  35 332  33 302 $$$ 101  90 103      14.37 .U. F
24    07/02/2003 17:06:36.044  35 332  33 302 $$$ 101  90 103      14.37 .U. F
23    07/02/2003 17:06:36.049  35 332  33 302 $$$ 101  90 103      14.37 .U. F
22    07/02/2003 17:06:36.053  35 332  33 302 $$$ 101  90 103      14.37 .U. F
21    07/02/2003 17:06:36.057  35 332  33 302 $$$ 101  90 103      14.37 .U. F
20    07/02/2003 17:06:36.061  32 313  29 292 $$$ 100  92 103      14.37 .U. F
19    07/02/2003 17:06:36.065  27 252  24 226 $$$ 101  92 103      14.37 .U. F
18    07/02/2003 17:06:36.069  16 173  19 172 859 100  97 102      14.37 .U. F
17    07/02/2003 17:06:36.074  10  93   8  81 405 101  98 102      14.37 .U. F
16    07/02/2003 17:06:36.078   2  30   6  34 172 101 100 102      14.37 ... E
15    07/02/2003 17:06:36.082   0   0   0   0   0 101 101 101      14.37 ... E
14    07/02/2003 17:06:36.086   0   0   0   0   0 101 101 101      14.37 ... E
13    07/02/2003 17:06:36.090   0   0   0   0   0 101 101 101      14.37 ... E
12    07/02/2003 17:06:36.094   0   0   0   0   0 101 101 101      14.37 ... E
11    07/02/2003 17:06:36.099   0   0   0   0   0 101 101 101      14.37 ... E
10    07/02/2003 17:06:36.103   0   0   0   0   0 101 101 101      14.37 ... E
9     07/02/2003 17:06:36.107   0   0   0   0   0 101 101 101      14.37 ... E
8     07/02/2003 17:06:36.111   0   0   0   0   0 101 101 101      14.37 ... E
7     07/02/2003 17:06:36.115   0   0   0   0   0 101 101 101      14.37 ... E
6     07/02/2003 17:06:36.119   0   0   0   0   0 101 101 101      14.37 ... E
5     07/02/2003 17:06:36.124   0   0   0   0   0 101 101 101      14.37 ... E
4     07/02/2003 17:06:36.128   0   0   0   0   0 101 101 101      14.37 ... E
3     07/02/2003 17:06:36.132   0   0   0   0   0 101 101 101      14.37 ... E
2     07/02/2003 17:06:36.136   0   0   0   0   0 101 101 101      14.37 ... E
1     07/02/2003 17:06:36.140   0   0   0   0   0 101 101 101      14.37 ... E

=>
```

Figure 12.8 Example Sag/Swell/Interruption (SSI) Report

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Section 13

Testing and Troubleshooting

Introduction

This section contains guidelines for determining and establishing test routines for the SEL-651R Recloser Control. Follow the standard practices of your company in choosing testing philosophies, methods, and tools. The recloser control incorporates self-tests to help you diagnose potential difficulties should these occur. The subsection *Recloser Control Troubleshooting on page 13.9* contains a quick-reference table for common recloser control operation problems.

NOTE: The SEL-651R is factory calibrated. If you suspect that the recloser control is out of calibration, please contact the factory.

Topics, tests, and troubleshooting procedures presented in this section include the following:

- Testing philosophy
- Testing methods and tools
- Self-tests
- Recloser control troubleshooting
- Recloser control calibration
- Factory assistance

The SEL-651R is factory calibrated; this section contains no calibration information. If you suspect that the recloser control is out of calibration, contact your Technical Service Center or the SEL factory.

Testing Philosophy

Recloser control testing may be divided into three categories: acceptance, commissioning, and maintenance testing. The categories are differentiated by when they take place in the life cycle of the recloser control as well as by the test complexity.

The paragraphs below describe when to perform each type of test, the goals of testing at that time, and the recloser control functions that you need to test at each point. This information is intended as a guideline for testing SEL recloser controls.

Acceptance Testing

When: When qualifying a recloser control model to be used on the utility system.

Goals:

1. Ensure that the recloser control meets published critical performance specifications such as operating speed and element accuracy.
2. Ensure that the recloser control meets the requirements of the intended application.
3. Gain familiarity with recloser control settings and capabilities.

What to test: All protection elements and logic functions critical to the intended application.

SEL performs detailed acceptance testing on all new recloser control models and versions. We are certain that the recloser controls we ship meet their published specifications. It is important to perform acceptance testing on a recloser control if you are unfamiliar with its operating theory, protection scheme logic, or settings. This helps ensure the accuracy and correctness of the recloser control settings when you issue them.

Commissioning Testing

When: When installing a new protection system.

Goals:

1. Ensure that all system ac and dc connections are correct.
2. Ensure that the recloser control functions as intended using your settings.
3. Ensure that all auxiliary equipment operates as intended.

What to test: All connected or monitored inputs and outputs, polarity and phase rotation of ac connections, simple check of protection elements.

SEL performs a complete functional check and calibration of each recloser control before it is shipped. This helps ensure that you receive a recloser control that operates correctly and accurately. Commissioning tests should verify that the recloser control is properly connected to the power system and all auxiliary equipment. Verify control signal inputs and outputs. Check breaker auxiliary inputs, SCADA control inputs, and monitoring outputs. Use an ac connection check to verify that the recloser control current and voltage inputs are of the proper magnitude and phase rotation.

Brief fault tests ensure that the recloser control settings are correct. It is not necessary to test every recloser control element, timer, and function in these tests.

At commissioning time:

1. Use the recloser control **METER** command to verify the ac current and voltage magnitude and phase rotation.
2. Use the **PULSE** command to verify recloser control output contact operation.
3. Use the **TARGET** command to verify optoisolated input operation.

Maintenance Testing

When: At regularly scheduled intervals or when there is an indication of a problem with the recloser control or system.

Goals:

1. Ensure that the recloser control is measuring ac quantities accurately.
2. Ensure that scheme logic and protection elements are functioning correctly.
3. Ensure that auxiliary equipment is functioning correctly.

What to test: Anything not shown to have operated during an actual fault within the past maintenance interval.

SEL recloser controls use extensive self-testing capabilities and feature detailed metering and event reporting functions that lower the dependence on routine maintenance testing.

1. Use the SEL recloser control reporting functions as maintenance tools.

   Periodically verify that the recloser control is making correct and accurate current and voltage measurements by comparing the recloser control METER output to other meter readings on that line.

2. Review recloser control event reports in detail after each fault.

   Using the event report current, voltage, and recloser control element data, you can determine that the recloser control protection elements are operating properly.

   Using the event report input and output data, you can determine that the recloser control is asserting outputs at the correct instants and that auxiliary equipment is operating properly.

3. At the end of your maintenance interval, the only items that need testing are those that have not operated during the maintenance interval.

The basis of this testing philosophy is simple: If the recloser control is correctly set and connected, is measuring properly, and no self-test has failed, there is no reason to test it further.

Each time a fault occurs, the protection system is tested. Use event report data to determine areas requiring attention. Slow breaker auxiliary contact operations and increasing or varying breaker operating time can be detected through detailed analysis of recloser control event reports.

Because SEL recloser controls are microprocessor based, their operating characteristics do not change over time. Time-overcurrent operating times are affected only by the recloser control settings and applied signals. It is not necessary to verify operating characteristics as part of maintenance checks.

At SEL, we recommend that maintenance tests on SEL recloser controls be limited under the guidelines provided above. The time saved may be spent analyzing event data and thoroughly testing those systems that require more attention.

Testing Methods and Tools

Test Features

The following features assist you during recloser control testing.

METER Command. The **METER** command shows the ac currents and voltages (magnitude and phase angle) presented to the recloser control in primary values. In addition, the command shows power system frequency. Compare these quantities against other devices of known accuracy. The **METER** command is available at the serial ports and front-panel display. See *Section 10: Communications* and *Section 11: Front-Panel Operations*.

EVENT Command. The recloser control generates a 15- or 30-cycle event report in response to faults or disturbances. Each report contains current and voltage information, recloser control element states, and input/output contact information. If you question the recloser control response or your test method, use the event report for more information. The **EVENT** command is available at the serial ports. See *Section 12: Analyzing Events*.

SER Command. The recloser control provides a Sequential Events Recorder (SER) event report that time-tags changes in recloser control element and input/output contact states. The SER provides a convenient means to verify the pickup/dropout of any element in the recloser control. The **SER** command is available at the serial ports. See *Section 12: Analyzing Events*.

TARGET Command. Use the **TARGET** command to view the state of recloser control inputs, recloser control outputs, and recloser control elements individually during a test. The **TARGET** command is available at the serial ports and the front panel. See *Section 10: Communications* and *Section 11: Front-Panel Operations***.**

PULSE Command. Use the **PULSE** command to test the contact output circuits. The **PULSE** command is available at the serial ports and the front panel. See *Section 10: Communications*, and *Section 11: Front-Panel Operations*.

Test Methods

Test the pickup and dropout of recloser control elements using one of three methods: target command indication, output contact closure, or sequential events recorder (SER).

The examples below show the settings necessary to route the phase time-overcurrent element 51PT to the output contacts and the SER. The 51PT element, like many in the SEL-651R, is controlled by enable settings and/or torque control SELOGIC® control equations. To enable the 51PT element, set the E51P enable setting and 51PTC torque control settings to the following:

- E51P := 1 (via the **SET** command)
- 51PTC := 1 (set directly to logical 1, via the **SET L** command)

Testing Via TARGET Commands

Display the state of recloser control elements, inputs, and outputs using the front-panel or serial port **TAR** commands. Use this method to verify the pickup settings of protection elements.

Testing With the Front-Panel TAR Command

You can use the front-panel display and navigation pushbuttons to check Relay Word bit elements. See *Section 11: Front-Panel Operations* for more information on using the recloser control front panel.

Display the `MAIN` menu. If the recloser control LCD is in the Rotating Display, press the **{ENT}** pushbutton to display the `MAIN` menu as shown in *Figure 13.1*.

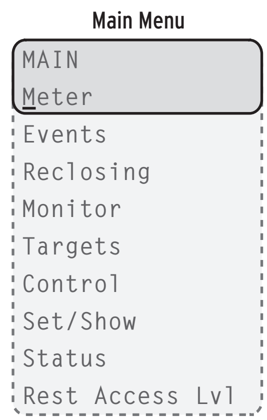

Figure 13.1 MAIN Menu

Select the `TARGETS` menu item from the `MAIN` menu and then use the cursor keys to navigate to the Relay Word row that contains the element you wish to view as shown by the Targets Menu in *Figure 13.2*. You may view the entire row at once or you can select the row using the **{ENT}** pushbutton to view more detailed information about each Relay Word bit in the row selected as shown by the Targets Display in the figure.

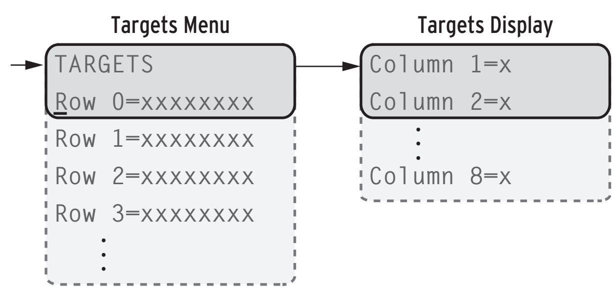

Figure 13.2 TARGETS Menu and TARGETS Display

See *Table F.1* for the correspondence between the Relay Word elements and the **TAR** command.

Testing With the Serial Port TAR Command

To view the 51PT element status from the serial port, issue the **TAR 51PT** command. The recloser control will display the state of all elements in the Relay Word row containing the 51PT element.

Review **TAR** command descriptions in *Section 10: Communications* and *Section 11: Front-Panel Operations* for further details on displaying element status via the **TAR** commands.

Testing Via Output Contacts

You can set the recloser control to operate an output contact for testing a single element. Use the **SET L** command (SELOGIC control equations) to set an output contact (e.g., OUT101 through OUT107) to the element under test. The available elements are the Relay Word bits referenced in *Table F.1*.

Use this method especially for time testing time-overcurrent elements. For example, to test the phase time-overcurrent element 51PT via output contact OUT104, make the following setting:

OUT104 := 51PT

Time-overcurrent curve and time-dial information can be found in *Section 9: Settings*.

Do not forget to reenter the correct recloser control settings when you are finished testing and ready to place the recloser control in service.

Testing Via Sequential Events Recorder

You can set the recloser control to generate an entry in the Sequential Events Recorder (SER) for testing recloser control elements. Use the **SET R** command to include the element(s) under test in any of the SER trigger lists (SER1 through SER3). See *Section 12: Analyzing Events*.

To test the phase time-overcurrent element 51PT with the SER, make the following setting:

SER1 := 51P   51PT

Element 51P asserts when phase current is above the pickup of the phase time-overcurrent element. Element 51PT asserts when the phase time-overcurrent element times out. The assertion and deassertion of these elements is time-stamped in the SER report. Use this method to verify timing associated with time-overcurrent elements, reclosing relay operation, etc.

Do not forget to reenter the correct recloser control settings when you are ready to place the recloser control in service.

Self-Tests

The SEL-651R continuously runs many self-tests to detect out-of-tolerance conditions. These tests run at the same time as recloser control protection and automation logic, but do not degrade SEL-651R performance.

Status Warning and Status Failure

The recloser control reports out-of-tolerance conditions as a status warning or a status failure. For conditions that do not compromise recloser control protection, yet are beyond expected limits, the recloser control issues a status warning and continues to operate. A severe out-of-tolerance condition causes the recloser control to declare a status failure and enter a protection-disabled state. During a protection-disabled state, the recloser control suspends protection element processing and trip/close logic processing and de-energizes all control outputs. When disabled, the **ENABLED** front-panel LED is not illuminated.

The recloser control signals a status warning by pulsing the HALARM Relay Word bit (hardware alarm) to logical 1 for five seconds. For a Status Failure, the recloser control latches the HALARM Relay Word bit at logical 1. To provide remote status indication, connect the b contact of OUT201 to your control system remote alarm input and program the output SELOGIC control equation to respond to NOT (SALARM OR HALARM).

If you repeatedly receive status warnings, check the recloser control operating conditions as soon as possible. Take preventive action early during the development of potential problems to avoid system failures. For any status failure, contact your Technical Service Center or the SEL factory immediately (see *Factory Assistance on page 13.12*).

The recloser control generates an automatic status report at the serial ports for a self-test status failure if you set Port setting AUTO := Y. The recloser control issues a status message with a format identical to the **STATUS** command output.

For certain failures, the relay automatically restarts as many as three times within 24 hours. In many instances, this will correct the failure. A “diagnostic restart” entry is recorded in the Sequential Events Recorder (SER), but the automatic restart may occur before Relay Word bit HALARM is recorded in the SER and before failure messages are displayed.

Use the serial port **STATUS** and **CSTATUS** commands, the ACSELERATOR QuickSet® **HMI Status** button, and the front-panel STATUS menu to display status warnings and status failures. See *Section 10: Communications* for more information on automatic status notifications and on viewing recloser control status.

Firmware Version Number

At the top of each status report the recloser control displays the present firmware version number that identifies the software program that controls recloser control functions. The firmware version is the four-place designator immediately following the recloser control model number (the first characters in the firmware identification string). The first character in the four-place firmware version number is “R” (representing “Release”). SEL numbers subsequent firmware releases sequentially; the next revision following R101 is R102. See *Appendix A: Firmware and Manual Versions* for firmware version information.

Status

Use the serial port **STATUS** command or select the STATUS menu item from the MAIN menu on the front-panel HMI to view the self-test status report. An example status report is shown in *STATUS Command (Recloser Control Self-Test Status) on page 10.38*. Use *Table 13.1* and *Table 13.2* to interpret the self-test results and measurements.

Table 13.1 Status Report Results (Sheet 1 of 2)

Self-Test	Condition	Limits	Protection Disabled	HALARM Relay Word Bit	Description
Channel Offsets I1, I2, I3, V1Y, V2Y, V3Y, V1Z, V2Z, V3Z	Warning	> 50 mV for current channels and voltage channels other than 8 Vac LEA; > 175 mV for 8 Vac LEA voltage channels	No	Pulsed	Measures the dc offset at each of the input channels.
Master Offset	Warning	> 20 mV	No	Pulsed	Measures the dc offset at the A/D every 10 seconds.
Master Offset	Failure	> 30 mV	Yes	Latched	
+2.5V_PS	Warning	2.40 V 2.60 V	No	Pulsed	Measures the +2.5 V power supply every 10 seconds.
+2.5V_PS	Failure	2.32 V 2.68 V	Yes	Latched	
+3.3V_PS	Warning	3.17 V 3.43 V	No	Pulsed	Measures the +3.3 V power supply every 10 seconds.
+3.3V_PS	Failure	3.07 V 3.53 V	Yes	Latched	
+5V_PS	Warning	4.80 V 5.20 V	No	Pulsed	Measures the +5 V power supply every 10 seconds.
+5V_PS	Failure	4.65 V 5.35 V	Yes	Latched	
+5V_REG	Warning	+4.75 V +5.25 V	No	Pulsed	Measures the regulated 5 V power supply every 10 seconds.
+5V_REG	Failure	+4.50 V +5.50 V	Yes	Latched	
+12V_PS	Warning	+11.52 V +12.48 V	No	Pulsed	Measures the 12 V power supply every 10 seconds.
+12V_PS	Failure	+11.16 V +12.84 V	Yes	Latched	
+15V_PS	Warning	+14.40 V +15.60 V	No	Pulsed	Measures the 15 V power supply every 10 seconds.
+15V_PS	Failure	+14.00 V +16.00 V	Yes	Latched	
Temperature	Warning	–40°C +85°C	No	–	Measures the temperature at the A/D voltage reference every 10 seconds.
Temperature	Failure	–50°C +105°C	Yes	Latched	
RAM	Failure	–	Yes	Latched	Performs a read/write test on system RAM every 60 seconds. See Note 1[a].
ROM	Failure	checksum	Yes	Latched	Performs a checksum test on the recloser control program memory every 10 seconds.
A/D	Failure	–	Yes	Latched	Validates proper number of conversions each 1/4 cycle.

Table 13.1 Status Report Results (Sheet 2 of 2)

Self-Test	Condition	Limits	Protection Disabled	HALARM Relay Word Bit	Description
CR_RAM	Failure	checksum	Yes	Latched	Performs a checksum test on the active copy of the recloser control settings every 10 seconds. See Note 1[a].
FLASH	Failure	checksum	Yes	Latched	Performs a checksum test on the nonvolatile copy of the recloser control settings every 10 seconds.
IO_BRD	Failure	–	Yes	Latched	–
FPGA	Failure	–	Yes	Latched	See Note 1[a].

[a] Note 1: Automatic restart—see paragraph preceding Table 13.1 that describes this restart.

Table 13.2 Status Report Measurements

INPBV	This value is the Input Power Bus Voltage.
12VAUX	This value is the 12 V Auxiliary Bus Voltage.
CMODE	Battery State—This value is the charger mode. See *Battery Status on page 8.37* for a list and description of modes.
VBAT	This value is the battery voltage.
IBAT	This value is the battery charging or discharging current. If the battery is discharging it shall be shown with a proceeding minus sign.
TCCAPV	This value is the Trip/Close Capacitor Voltage.

Recloser Control Troubleshooting

Inspection Procedure

Complete the following procedure before disturbing the recloser control. After you finish the inspection, proceed to the *Troubleshooting Procedure*.

Step 1. Measure and record the power supply voltage at the power input terminals.

Step 2. Check to see that the power is on. Do not turn the recloser control off.

Step 3. Measure and record the voltage at all control inputs.

Step 4. Measure and record the state of all output relays.

Step 5. Inspect the serial communications ports cabling to be sure that a communications device is connected to at least one communications port.

Troubleshooting Procedure

Troubleshooting procedures for common problems are listed in *Table 13.3*. The table lists each symptom, possible causes, and corresponding diagnoses/solutions. Related SEL-651R commands are listed in bold capitals. See *Section 10: Communications* for details on SEL-651R commands and *Section 9: Settings* for details on recloser control settings.

Table 13.3 Troubleshooting Procedures (Sheet 1 of 3)

Symptom/Possible Cause	Diagnosis/Solution
Dark Front Panel	
Power is off and recloser control has shut-down to conserve the battery.	Restore power or press {WAKE UP}.
Input power is not present.	Verify that power is present at the rear-panel terminal strip.
Blown power supply fuse.	Replace the fuse. See *Battery and Fuse Replacement on page 2.51*.
Poor contrast adjustment.	Press and hold {ESC} for two seconds. Press {Up Arrow} and {Down Arrow} pushbuttons to adjust contrast.
Status Failure Notice on Front Panel	
Self-test failure.	Contact the SEL factory or your Technical Service Center. The OUT201 recloser control b contacts will be closed if NOT HALARM is programmed to OUT201.
Alarm Output Asserts	
Power is off.	Restore power or press {WAKE UP}.
Blown power supply fuse.	Replace the fuse. See *Battery and Fuse Replacement on page 2.51*.
Power supply failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
Main board or interface board failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
Other self-test failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
System Does Not Respond to Commands	
No communication.	Confirm cable connections and types. If OK, type **<Ctrl+X>**, then **<Enter>**. This resets the terminal program.
Communications device is not connected to the system.	Connect a communications device.
Incorrect data speed (baud rate) or other communications parameters.	Configure your terminal port parameters to the particular recloser control port settings. Use the front panel to check port settings. See *SET/SHOW Menu on page 11.12*.
Incorrect communications cables.	Use SEL communications cables, or cables you build according to SEL specifications. See *Port Connector and Communications Cables on page 10.2*.
Communications cabling error.	Check cable connections.
Handshake line conflict; system is attempting to transmit information, but cannot do so.	Check communications cabling. Use SEL communications cables, or cables you build according to SEL specifications. See *Communications Interfaces on page 10.1* and *Communications Protocol on page 10.4*.
System is in the XOFF state, halting communications.	Type **<Ctrl+Q>** to put the system in the XON state.

Table 13.3 Troubleshooting Procedures (Sheet 2 of 3)

Symptom/Possible Cause	**Diagnosis/Solution**
Terminal Displays Meaningless Characters	
Data speed (baud rate) is set incorrectly.	Check the terminal parameters configuration. See *Serial Port on page 10.1*.
Terminal emulation is not optimal.	Try other terminal types, including VT-100 and VT-52 terminal emulations.
System Does Not Respond to Faults	
Recloser control is set improperly.	Review the recloser control settings. See *Section 9: Settings*.
Improper test settings.	Restore operating settings.
PT or CT connection wiring error.	Confirm PT and CT wiring.
Input voltages and currents phasing, and rotation errors.	Use recloser control metering. Use the **TRI** event trigger command and examine the generated event report.
The analog input (flat multipin ribbon) cable between the input module board and the main board is loose or defective.	Reseat both ends of the analog input cable, observing proper ESD precautions.
Check the recloser control self-test status.	Take preventive action as directed by recloser control Status Warning and Status Failure information.
Tripping Output Remains Closed Following a Fault	
Auxiliary contact control inputs are improperly wired.	Check circuit breaker auxiliary contacts wiring.
Recloser control outputs have burned closed.	Remove recloser control power. Remove the control output connection. Check continuity; a contacts will be open and b contacts will be closed. Contact the SEL factory or your Technical Service Center if continuity checks fail.
I/O interface board failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Warning	
Power supply voltage(s) are out-of-tolerance.	Log the Status Warning. If repeated warnings occur, take preventive action.
A/D converter failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Failure	
Power supply voltage(s) are out-of-tolerance.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
A/D converter failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
A/D OFFSET WARN Status Warning	
Loose ribbon cable between the input module board and the main board.	Reseat both ends of the analog input cable.
A/D converter drift.	Log the Status Warning. If repeated warnings occur, contact the SEL factory or your Technical Service Center.

Table 13.3 Troubleshooting Procedures (Sheet 3 of 3)

Symptom/Possible Cause	Diagnosis/Solution
Master offset drift.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
Battery Problem LED Illuminated	
Discharge test failure caused by an on-load battery voltage measurement < 10.5 V or a measurement of < 11 V after 10 seconds on-load. Open-circuit measurement must be > 11.58 V to begin test.	Replace failed battery.
Battery voltage measurement < 5 V.	Battery is either deeply discharged or failed. Replace battery.
Excessive current draw for excessive time during float charge mode.	Battery has probably failed. Test battery and replace if failed.
Meter Command Does Not Respond as Expected	
Sequence current or voltage magnitudes are incorrect.	Global settings NFREQ or PHROT not set correctly.
Current phase polarity or connection compensation is incorrect.	Global settings IPCONN or CTPOL not set correctly.
Voltage connection compensation is incorrect.	Global settings VYCONN, VZCONN, VSELECT or FSELECT not set correctly.
Current or voltage magnitudes are incorrect.	Group Settings CTR, CTRN, PTRY or PTRZ not set correctly.
Current or voltage angles or power magnitudes are incorrect.	Recloser control analog inputs not connected correctly.

Factory Assistance

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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Pullman, WA 99163-5603 U.S.A.
Phone: +1.509.332.1890
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Internet: selinc.com
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Appendix A

Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Relay

NOTE: Because of the processor update, R1xx firmware cannot be upgraded to R2xx or R3xx firmware and R2xx or R3xx firmware cannot be downgraded to R1xx firmware.

To find the firmware revision number in your relay, view the status report using the serial port **STATUS** command or the front-panel. The status report displays the Firmware Identification (FID) label:

FID=SEL-651R-Rxxx-V0-Z001001-Dxxxxxxxx

The firmware revision number is after the R and the release date is after the D.

Table A.1 lists the firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.1 Firmware Revision History (Sheet 1 of 4)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-651R-1-R310-V0-Z006001-D20140207 SEL-651R-R204-V0-Z007003-D20140207 SEL-651R-R115-V0-Z006003-D20140207	➤ Addressed DNP issue in which communications could be unresponsive if Object 50, Variation 3 (Time and date—absolute time at last recorded time) is sent to the control. ➤ When TIMERQ = M, the relay no longer requests time with the NEED_TIME internal indication upon connection to a DNP master. ➤ DNP Virtual Terminal now provides the response to all ASCII commands. In previous firmware, the complete response to **CEV**, **EVE**, **CAS**, and **DNA** commands was not sent in DNP Virtual Terminal. ➤ The relay now reports DNP indices 105 and 505 (control temperature) when both are included in the DNP analog input map. In previous firmware, the second of the two indices in the map did not report the temperature. ➤ Ports now time out according to Port setting T_OUT even if communications are interrupted with an XOFF control. In previous firmware, if communications are interrupted with XOFF (Ctrl + S), the port will not time out.	20140207
SEL-651R-1-R309-V0-Z006001-D20120824 SEL-651R-R203-V0-Z007003-D20120824	➤ Changed lower limit of Reset Time from Lockout setting 79RSLD from 180 cycles to 0 cycles. ➤ Relay Word bit SW1 operation corrected for SEL-651R-R203 firmware, as was done previously for SEL-651R-1-R308 firmware (see Manual Date Code entry 20120117). ➤ Added automatic restart for RAM, critical RAM, and FPGA failures—as many as three restarts allowed in a 24 hour period.	20120824
SEL-651R-R114-V0-Z006003-D20120216	➤ Corrected problem where polled DNP data might not be synchronized with data from SER events when the relay restarts following a low battery condition.	20120216

Table A.1 Firmware Revision History (Sheet 2 of 4)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-651R-1-R308-V0-Z005001-D20120117	➤ Relay Word bit SW1 operation corrected so that it is only operative for Traditional Retrofit reclosers. Otherwise, it evaluates to logical 0. Previously, it had also been operative for Control-Powered Kyle NOVA and Kyle NOVA-TS or NOVA-STS Triple-Single reclosers. See *Factory 52A Settings Example (Traditional Retrofit Recloser)* subsection, following *Figure 6.2: Breaker Status Logic* for more information on Relay Word bit SW1.	20120117
SEL-651R-1-R307-V0-Z004001-D20111007	➤ Corrected potential problem with accessing the settings template file when there is an IRIG signal applied.	20111007
SEL-651R-1-R306-V0-Z004001-D20110516	➤ Added Siemens SDR reclosers compatibility.	20110516
SEL-651R-1-R305-V0-Z003001-D20101112	➤ Added Tavrida OSM recloser compatibility.	20101112
SEL-651R-1-R303-V0-Z002001-D20100830 SEL-651R-R202-V0-Z006003-D20100830	➤ Corrected problem with Kyle NOVA-TS or NOVA-STS Triple-Single option not tripping/closing on two phases (R3XX firmware only). ➤ Corrected DNP problem where extra Binary Input transitions were reported during a Group Switch. ➤ Corrected problem with Fast SER not being recognized during auto configuration with communication processors.	20100830
SEL-651R-1-R302-V0-Z002001-D20100802 SEL-651R-R201-V0-Z006003-D20100802 SEL-651R-R113-V0-Z006003-D20100802	➤ Removed built-in 2-cycle trip delay for G&W Viper-ST, ABB OVR/VR3S, and Joslyn TriMod 600R applications. ➤ Changed low-end range from 12.50 V to 1.00 V for voltage element pickup settings 27YP1P, 27YP2P, 59YP1P, 59YP2P, 27ZP1P, 27ZP2P, 59ZP1P, and 59ZP2P. ➤ Changed low-end range from 22.00 V to 1.76 V for voltage element pickup settings 27YPP1P, 59YPP1P, 27ZPP1P, and 59ZPP1P. ➤ Changed self-test channel offset measurement threshold from 50 mV to 175 mV for 8 Vac LEA voltage channels (50 mV too tight—can cause spurious warnings). ➤ Corrected problem with storage of DNP settings which could result in the unit disabling protection during settings template download.	20100802
SEL-651R-1-R301-V0-Z001001-D20100707	➤ Corrected problem with storage of settings templates which could result in the unit disabling protection during settings template download. ➤ Corrected problem with storing VSSI or Load Profile information which could result in the unit reporting "Flash Fail" and disabling protection during normal operation.	20100707
SEL-651R-1-R300-V0-Z001001-D20100218	Created the SEL-651R-1 with the following additional features: ➤ Option for both VY-terminal and VZ-terminal voltage inputs to be ordered as 8 Vac low-energy analog (LEA) voltage inputs, resulting in 2 three-phase sets of 8 Vac LEA voltage inputs. ➤ Expanded SELOGIC variables/timers (SV*n*T) from 48 to 64 variables/timers. ➤ Expanded settings groups from 6 to 8. ➤ Allow time-overcurrent element curve and time dial information to be displayed via display points. ➤ Added template/file storage (extension of **FILE** command). ➤ Added Fast Sequential Events Recorder (SER) capability.	20100218
SEL-651R-R200-V0-Z005003-D20091016	➤ Revised firmware for processor update. ➤ Default debounce timers for IN201D, IN202D, and IN203D changed for G&W Viper-ST Recloser. ➤ Close pulse duration for Joslyn TriMod 600R recloser changed to 35 ms from 24 ms.	20091016

Table A.1 Firmware Revision History (Sheet 3 of 4)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-651R-R112-V0-Z005003-D20091014	➤ Corrected problem of LCD screen going blank momentarily when front-panel navigation keys are pressed.	20091014
SEL-651R-R111-V0-Z005003-D20090707	➤ Added a new option for DNP redialing. The new option hangs up and redials when the wait time ETIMEO would normally be lengthened to UTIMEO. ➤ Corrected a defect that reports the DNP fault targets and fault time incorrectly. ➤ Improved the logic for allowing a manual battery test using the SELOGIC equation or **BTT NOW** command when the battery status is Battery Failure mode. ➤ Added support for Cooper/Kyle NOVA Low Energy Analog and Lindsey Standard Voltage Monitoring Insulators (SVMI) to the Secondary Voltage Input options. ➤ The Front Port Speed setting can now be changed to 9600 from the front port when the Front Port Speed is 57600.	20090707
SEL-651R-R109-V0-Z004003-D20080814	➤ Three-phase breaker/recloser status (Relay Word bit 52A3P) is available all the time (formerly it wasn't available when global setting BKTYP := 1 and group setting ESPB := Y). See *Figure 6.2: Breaker Status Logic* and supporting text. ➤ Changed the processing order of Relay Word bit SW1 so that a closed recloser status for a traditional recloser doesn't appear to momentarily drop out (i.e., appear as a momentary open status) after an active settings group change (or a change made to an active setting). This problem is seen when recloser status is acquired remotely via the SEL-651R. See recloser status details for traditional reclosers in the Breaker Status Logic subsection in Section 6: Close and Reclose Logic. ➤ Removed three-pole open (3PO) and single-pole open (SPO) (see *Figure 5.4: Pole Open Logic*) as blocking conditions for fault identification logic. Available fault identification logic output during 3PO and SPO conditions improves the accuracy of fault-type determination (for event type and fault location in the event report summaries) and phase involvement (for front-panel target LEDs).	20080814
SEL-651R-R108-V0-Z004003-D20071018	➤ The PTR setting corresponding to the voltages selected with setting VSELECT (e.g., setting PTRZ corresponds to VSELECT := VZ) was erroneously applied to all six voltage inputs when generating primary voltages in event reports. This was corrected so that settings PTRY and PTRZ are applied to their respective voltage inputs when generating primary voltages in event reports, regardless of setting VSELECT.	20071018
SEL-651R-R107-V0-Z004003-D20070628	➤ Improved timing accuracy on traditional recloser curves.	20070628
SEL-651R-R106-V0-Z004003-D20070514	➤ Corrected inaccuracies in some traditional recloser curves.	20070514
SEL-651R-R105-V0-Z004003-D20060622	➤ Fixed possible communications lock-up when an XOFF command is sent to a serial port.	20060622
SEL-651R-R104-V0-Z004003-D20060329	➤ Corrected event report fault type for events containing a trip. ➤ Fixed relay lockup error when retrieving event reports containing very long comments. ➤ Corrected operation of breaker wear monitor when operating a single-phase recloser in three-phase mode. ➤ Fixed debounce timers for IN201–IN206. ➤ Increased global settings logic capacity. ➤ Added part numbers for new recloser compatibilities. ➤ Added dual-number DNP dial-out feature. ➤ Added battery test SELOGIC equation.	20060329

Table A.1 Firmware Revision History (Sheet 4 of 4)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-651R-R103-V0-Z003003-D20050316	➤ Corrected operation of Front Panel Target DNP Elements (DNP Indices 1600–1615 and 1636–1643) ➤ Corrected analog channel calibration in the following cases: 1. VYCONN, VZCONN, or IPCONN is set to CAB or BCA 2. VYCONN or VZCONN is set to B, BC, C, or CA and PHROT = ABC	20050316
SEL-651R-R102-V0-Z003003-D20040202	➤ Enhancements to DNP: ➢ Testability (**TEST DNP** Command) ➢ Troubleshooting (**STA D** Command) ➢ Virtual Terminal ➢ Class assignments on a per-point basis	20041105 20040202
SEL-651R-R101-V0-Z001001-D20031209	➤ Added loss-of-potential logic. ➤ Added directional elements. ➤ Added event report columns for loss-of-potential, directional elements, and inputs IN201–IN206. ➤ Expanded setting range for voltage ratio correction factor (RCF) settings V1YRCF, V2YRCF, and V3YRCF. ➤ Added group settings VNOM, E32, ELOP, and the directional element settings to realize the above new loss-of-potential and directional element features. ➤ Added various Relay Word bits to realize the above new loss-of-potential and directional element features.	20031209
SEL-651R-R100-V0-Z001001-D20031003	➤ Initial version.	20031003

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.2 lists the instruction manual release dates and a description of modifications. The most recent instruction manual revisions are listed at the top.

Table A.2 Instruction Manual Revision History (Sheet 1 of 9)

Revision Date	Summary of Revisions
20160715	Section 4 ➤ Enhanced the *Directional Control Settings* subsection to include a description of specific applications for the E32 setting.
20140207	Section 6 ➤ Removed references to 79CTL3P, 79CLTA, 79CLB, and 79CTLC from *Figure 6.1: Close Logic and Reclosing Relay Logic Overview for Three-Phase and Single-Phase Reclosers* and *Table 6.4: Reclosing Relay Settings/Outputs*. Section 9, Settings Sheets ➤ Clarified expected behavior in *Note* under *SELOGIC Counter Settings* on SET.40. Appendix A ➤ Updated for firmware version R310, R204, and R115. Appendix E ➤ Added a note next to *Table E.9: SEL-651R DNP Object List (Sheet 5 of 6)*. ➤ Clarified the description of Index 527 in *Table E.12: DNP3 Reference Data Map*.
20130508	Section 2 ➤ Modified *Figure 2.59: Trip/Close and Recloser Pole Status Circuit Connections Between Kyle NOVA-TS or NOVA-STS Triple-Single Recloser and SEL-651R-2 Recloser Control* and *Figure 2.60: Yellow Lockout Handle Circuit Connections Between Kyle NOVA-TS or NOVA-STS Triple-Single Recloser and SEL-651R-2 Recloser Control* by adding 53 Vdc to Pin C to support Kyle NOVA-STS recloser. ➤ Verified connection of pins D, N, P, L, and R in *Figure 2.59: Trip/Close and Recloser Pole Status Circuit Connections Between Kyle NOVA-TS or NOVA-STS Triple-Single Recloser and SEL-651R-2 Recloser Control*.
20130131	Section 2 ➤ Updated *Table 2.5: Rear-Panel Serial Port Voltage Jumper Positions for Standard Relay Shipments* to show factory-shipped positions. Pin 1 is connected to +5 Vdc for Port 3 when shipped from the factory.
20120824	Section 1 ➤ In *Specifications*, updated pulse duration for the trip and close outputs of the Siemens SDR Triple-Single and Siemens SDR Three-Phase reclosers. Section 6 ➤ Changed lower limit of Reset Time from Lockout setting 79RSLD from 180 cycles to 0 cycles in *Table 6.6 on page 6.20*. ➤ Added subsection *Momentary Drive-to-Lockout While Breaker Closed on page 6.26*. ➤ Updated *Figure 6.11 on page 6.27* for factory drive-to-lockout SELOGIC setting 79DTLX for the various supported reclosers. Section 9 ➤ Added additional explanation following *Table 9.18 on page 9.44* concerning the modification of voltage related settings for various LEA (Low Energy Analog) voltage inputs. Section 9, Settings Sheets ➤ In *Group Settings on page SET.24*, changed lower limit of Reset Time from Lockout setting 79RSLD from 180 cycles to 0 cycles. Section 12 ➤ Corrected definition for "Freq" column heading in *Table 12.3 on page 12.11*.

Table A.2 Instruction Manual Revision History (Sheet 2 of 9)

Revision Date	Summary of Revisions
	Section 13 ➤ Added Note 1 for *Table 13.1 on page 13.8*, explaining automatic restart for certain self-test failure modes. Appendix A ➤ Updated for firmware version R309 and R203. Appendix E ➤ Added explanation following *Table E.5 on page E.8* concerning DNP port setting ETIMEO and the need to set it long enough to cover the time period from the beginning of transmission through the subsequent received master confirmation. ➤ Corrected AG fault example for *Table E.14 on page E.28* (lower byte = 9 [= 1+8], not = 18).
20120216	Appendix A ➤ Updated for firmware version R114.
20120127	Section 9 ➤ Updated for *Figure 9.5: U.S. Short-Time Inverse Curve: U5*. Section 10 ➤ Added **CAL** command and **PAS C** command information. Command Summary ➤ Added **CAL** command and **PAS C** command definition. Appendix B ➤ Modified the title of the section.
20120117	Section 2 ➤ Added side column notes for the various compatible reclosers explaining the operation of Relay Word bit TCCAP and how it relates to the Vdc voltage provided from the SEL-651R for recloser operation. ➤ Expanded *Figure 2.47: Current Connections and Polarity from* G&W Viper-ST *Recloser Primary to* SEL-651R *Recloser Control Current Inputs*, showing the capacitive voltage sensors in the G&W Viper-ST recloser and their connection to the SEL-651R. ➤ Expanded *Figure 2.58: Current Connections and Polarity from Kyle NOVA-TS Triple-Single Recloser Primary to SEL-651R Recloser Control Current Inputs*, showing the resistive voltage sensors in the Kyle NOVA-TS Triple-Single recloser and their connection to the SEL-651R. ➤ In upper right-hand corner of *Figure 2.62: Trip/Close and Recloser Status Circuit Connections Between Tavrida OSM Recloser and SEL-651R Recloser Control*, changed Continuity Indicator to OSM Detection Module (its actual name). Section 5 ➤ Added Kyle NOVA-TS Triple-Single and Siemens SDR Triple-Single reclosers to the "yellow operating handle" trip logic in *Figure 5.2: Factory Default Trip Logic Settings* and accompanying text. Section 6 ➤ Clarified *Figure 6.5: Unlatch Close Conditions (Three-Phase, Factory-Default)* and accompanying text, explaining that logic term (NOT IN201 AND SW1) only applies to Traditional Retrofit reclosers. ➤ Added Joslyn TriMod 600R and Siemens SDR Triple-Single reclosers to factory-default Drive-to-Lockout (extra) setting 79DTL3X in *Table 6.8: Reclosing Relay SELOGIC Control Equation Settings*. Section 9 ➤ Following *Table 9.3: Set Command Editing Keystrokes*, added explanation on continuing a setting by using a backslash character. Appendix A ➤ Updated for firmware version R308. Appendix F ➤ Updated definition for SW1.
20111208	Section 2 ➤ Updated *Figure 2.62: Trip/Close and Recloser Status Circuit Connections Between* Tavrida OSM *Recloser and* SEL-651R *Recloser Control* with continuity indicator circuitry applied to the Tavrida OSM recloser. Added follow-on text to explain how the continuity indicator provides yellow operating handle status and disconnected control cable alarm for the Tavrida OSM recloser.

Table A.2 Instruction Manual Revision History (Sheet 3 of 9)

Revision Date	Summary of Revisions
	Section 9 ➤ Updated *Figure 9.28: Logic Settings (SHO L) With Factory Default Values* through *Figure 9.30: Front-Panel Settings (SHO F) With Factory Default Values (With Tricolor LED Option)* with factory-default settings for the addition of the continuity indicator circuitry applied to the Tavrida OSM recloser. These settings realize yellow operating handle status and disconnected control cable alarm for the Tavrida OSM recloser.
20111007	Appendix A Updated for firmware version R307.
20110714	Section 1 ➤ Added description of self-whetted status inputs IN204–IN206 for Kyle NOVA-TS Triple-Single recloser applications. Section 2 ➤ Updated *Figure 2.59: Trip/Close and Recloser Pole Status Circuit Connections Between* Kyle NOVA-TS or NOVA-STS Triple-Single *Recloser and* SEL-651R *Recloser Control* to clarify trip/close circuitry. ➤ Updated *Figure 2.60: Yellow Lockout Handle Circuit Connections Between* Kyle NOVA-TS or NOVA-STS Triple-Single *Recloser and* SEL-651R *Recloser Control* to clarify yellow lockout handle circuitry for Kyle NOVA-TS Triple-Single recloser applications. ➤ Changed/added supporting text.
20110516	Section 1 ➤ Throughout section, added Siemens SDR reclosers as compatible reclosers. Section 2 ➤ Added *Figure 2.25: Connector Panel at Bottom of Enclosure for* Siemens SDR Triple-Single *and* Siemens SDR Three-Phase *reclosers (Single-Door Enclosure)* (bottom connector panel for Siemens SDR reclosers). ➤ Added 40-pin control cable receptacle for Siemens SDR reclosers to *Figure 2.41: Control Cable Receptacle Pinouts*. ➤ Added *Figure 2.63* through *Figure 2.68* and supporting text for Siemens SDR reclosers. Section 9 ➤ Added Siemens SDR reclosers settings variations to *Factory Default Settings*. ➤ Added *Table 9.13* and *Table 9.20* and accompanying text for Siemens SDR reclosers. Appendix A ➤ Updated for firmware version R306.
20110110	Section 1 ➤ Updated references to 125 Vdc auxiliary power supply in *Models and Options* and *Specifications* to indicate that it now supports the 12 V auxiliary supply. Section 2 ➤ Updated references to 125 Vdc aux power supply in *Table 2.7: Replacement Fuses for the SEL-651R* to indicate that it now supports the 12 V aux supply. Section 9 ➤ Added Voltage Phase Angle Correction settings for Cooper NOVA 3-Phase (15 kV and 38 kV), NOVA-TS, and NOVA-STS reclosers in *Voltage Phase Angle Correction Settings for VY-Terminal Voltage Inputs*.
20101112	Section 1 ➤ Throughout section, added Tavrida OSM recloser as a compatible recloser. Section 2 ➤ Added *Figure 2.24: Connector Panel at Bottom of Enclosure for Tavrida OSM Recloser (Single-Door Enclosure)* (bottom connector panel for Tavrida OSM recloser). ➤ Added 32-pin (rectangular) control cable receptacle for Tavrida OSM recloser to *Figure 2.40: Control Cable Receptacle Pinouts*. ➤ Added *Figure 2.60: Current Connections and Polarity From Tavrida OSM Recloser Primary to SEL-651R Recloser Control Current Inputs (Voltage Connections Shown, Too)* and *Figure 2.61: Trip/Close Circuit and Recloser Status Connections Between Tavrida OSM Recloser and SEL-651R Recloser Control* and supporting text for Tavrida OSM recloser.

Table A.2 Instruction Manual Revision History (Sheet 4 of 9)

Revision Date	Summary of Revisions
	Section 8 ➤ Added 15.5 kV for G&W Viper-S and G&W Viper-ST in *Table 8.7: Recommended Breaker Monitor Settings for Various Reclosers*. Section 9 ➤ Added Tavrida OSM recloser settings variations to *Factory Default Settings*. Section 9, Settings Sheets ➤ Added "OFF" to correct setting range for reclosing relay settings 79OI1 through 79OI4. Appendix A ➤ Updated for firmware versions R203 and R304. Appendix E ➤ Corrected *Figure E.1: Application Confirmation Timing With URETRY = 2*.
20100830	Section 2 ➤ Updated *Figure 2.52* to include VTC-equipped Control-Powered Kyle NOVA reclosers. Appendix A ➤ Updated for firmware version R303 and R202.
20100802	Section 1 ➤ In *Specifications*, changed low-end range from 12.50 V to 1.00 V (300 V base) for voltage element pickups (phase values). Also made equivalent changes for other voltage input types. ➤ In *Specifications*, changed low-end range from 22.00 V to 1.76 V (300 V base) for voltage element pickups (phase-to-phase values). Also made equivalent changes for other voltage input types. Section 4 ➤ In *Table 4.9: VY-Terminal Voltage Elements Settings and Settings Ranges (VZ-Terminal Similar)*, changed low-end range from 12.50 V to 1.00 V for voltage element pickup settings 27YP1P, 27YP2P, 59YP1P, 59YP2P, 27ZP1P, 27ZP2P, 59ZP1P, and 59ZP2P. ➤ In *Table 4.9: VY-Terminal Voltage Elements Settings and Settings Ranges (VZ-Terminal Similar)*, changed low-end range from 22.00 V to 1.76 V for voltage element pickup settings 27YPP1P, 59YPP1P, 27ZPP1P, and 59ZPP1P. ➤ Added Detecting Absence of Voltage with 8 V LEA Connections at the end of the *Voltage Elements* subsection for explanation of extending the above listed low-end ranges. Section 9, Settings Sheets ➤ In *Group Settings on page SET.21*, changed low-end range from 12.50 V to 1.00 V for voltage element pickup settings 27YP1P, 27YP2P, 59YP1P, 59YP2P, 27ZP1P, 27ZP2P, 59ZP1P, and 59ZP2P. ➤ In *Group Settings on page SET.22*, changed low-end range from 22.00 V to 1.76 V for voltage element pickup settings 27YPP1P, 59YPP1P, 27ZPP1P, and 59ZPP1P. Section 13 ➤ In Table *13.1: Status Report Results*, changed channel offset limit from 50 mV to 175 mV for 8 Vac LEA voltage channels. Appendix A ➤ Updated for firmware version R302, R201, and R113.
20100707	Appendix A ➤ Updated for firmware version R301.
20100218	Updates are primarily for the newly created SEL-651R-1: Section 1 ➤ Option for 2 three-phase sets of 8 Vac LEA voltage inputs. ➤ Clarification on voltage element setting ranges for Kyle/Cooper NOVA LEA voltage inputs. Section 2 ➤ Side bar note for *Figure 2.36: 8 Vac LEA Voltage Connections for VY-Terminal Voltages* discussing 8 Vac LEA option for VY-terminal and VZ-terminal voltage inputs.

Table A.2 Instruction Manual Revision History (Sheet 5 of 9)

Revision Date	Summary of Revisions
	Section 7 ➤ Expanded SELOGIC variables/timers (SV*n*T) from 48 to 64 variables/timers. ➤ Expanded settings groups from 6 to 8. Section 9 ➤ Side bar notes for *Example 9.1: Normalizing Voltages With Ratio Correction Factors* and *Example 9.3: Voltage Setting Conversion to 300 V Base*, and surrounding text, discussing 8 Vac LEA option for VY-terminal and VZ-terminal voltage inputs. Section 9 Settings Sheets ➤ Updated Settings Sheets for expanding settings groups from 6 to 8 and expanding SELOGIC variables/timers (SV*n*T) from 48 to 64 variables/timers. Section 10 ➤ Updated *Table 10.4: PROTO Setting and Command Sets* with Fast Sequential Events Recorder (SER). ➤ Updated **COPY**, **GROUP**, **SET**, and **SHOW** commands for expanding settings groups from 6 to 8. ➤ Updated **TARGET** command for expanded Relay Word bit table. ➤ Updated **FILE** command with new template/file storage information. Section 11 ➤ Added example of displaying time-overcurrent element curve and time dial information via display points. Appendix A ➤ Created initial release of firmware version R300. Appendix E ➤ Adjusted *Table E.12: DNP3 Reference Data Map* for Relay Word bit changes. Appendix F ➤ Added Relay Word bits for expanding settings groups from 6 to 8 and expanding SELOGIC variables/timers (SV*n*T) from 48 to 64 variables/timer. Appendix G ➤ Added time-overcurrent element curve and time dial information for display via display points. Appendix H ➤ Added new appendix for Fast Sequential Events Recorder (SER) protocol. Command Summary ➤ Updated **GROUP**, **SET**, and **SHOW** command descriptions for expanding settings groups from 6 to 8.
20100208	Section 1 ➤ Corrected reference to ABB OVR-3/VR-3S. Section 2 ➤ Corrected reference to ABB OVR-3/VR-3S.
20091016	Section 1 ➤ Updated close pulse duration timer for Joslyn TriMod 600R. Section 7 ➤ Updated default debounce timer for G&W Viper-ST. Appendix A ➤ Updated for firmware version R200.
20091014	Appendix A ➤ Updated for firmware version R112.
20090707	Sections 1, 2, 4, and 9 ➤ Added details for new Low-Energy Analog (LEA) inputs: ➢ Cooper/Kyle NOVA LEA ➢ Lindsey Standard Voltage Monitoring Insulators (SVMI). Section 2 ➤ Expanded *Table 2.5: Rear-Panel Serial Port Voltage Jumper Positions for Standard Relay Shipments*.

Table A.2 Instruction Manual Revision History (Sheet 6 of 9)

Revision Date	Summary of Revisions
	Section 8 ➤ Updated the manual to match changes to the battery test logic. Section 10 ➤ Updated the **BTT NOW** command. Appendix A ➤ Updated for firmware version R111. Appendix E ➤ Added a new option for DNP redialing. The new option hangs -up and redials when the wait time ETIMEO would normally be lengthened to UTIMEO.
20080814	Section 5 ➤ Added Relay Word bit SPE in example logic in *Overcurrent Element Torque Control Setting Application*. Section 6 ➤ Added paragraph in *Breaker Status Logic*, explaining the availability of three-phase breaker/recloser status (Relay Word bit 52A3P) for monitoring, even if a single-phase recloser (setting BKTYP := 1) is set for single-phase reclosing (setting ESPB := Y). Appendix A ➤ Updated for firmware version R109.
20080528	Section 2 ➤ Made G&W clarification on Viper-ST CT connections in *Figure 2.43: Current Connections and Polarity from G&W Viper-ST Recloser Primary to* SEL-651R *Recloser Control Current Inputs*. Section 4 ➤ Added text following *Table 4.1: Time-Overcurrent Elements in the* SEL-651R, clarifying that phase time-overcurrent elements and (ground- and negative-sequence) time-overcurrent elements run in alternating processing intervals and pose possible rising-/falling-edge logic operator problems for SELOGIC control equation settings 51xTC and 51xSW. ➤ Corrected *Table 4.9: VY-Terminal Voltage Elements Settings and Settings Ranges (VZ-Terminal Similar)*, entry to 3P59Y := 59YA1 AND 59YB1 AND 59YC1. ➤ Added notes discouraging use of overcurrent elements 50Pn, 50Gn, 50Qn, 51P, 51A, 51B, 51C, 51G1, 51G2, and 51Q as load detectors. Section 7 ➤ Corrected *Figure 7.26: Trip and Close Mapping and Output Logic for Single-Phase Reclosers (BKTYP := 1)*, label to RCCLnX. Section 8 ➤ Included G&W recloser data in *Table 8.7: Recommended Breaker Monitor Settings for Various Reclosers*. ➤ Included instructions on resetting the **BATTERY PROBLEM** LED. Section 9 ➤ Made G&W clarification on Viper-ST CT connections in *Figure 9.24: Single-Phase Recloser With Straight-Through Connections*, and *Figure 9.25: Single-Phase Recloser With Complex Connections*. Appendix E ➤ Updated descriptions for Object 01,02/Index 1619 and Object 30,32,34/Index 527 and updated index to 07–10 (Object 20,22) in *Table E.12: DNP3 Reference Data Map*. ➤ Added *Reading Relay Events* following *Table E.15: Object 30, CMODE*. ➤ Updated Trip/Close descriptions for Indexes 41 and 68 in *Table E.16: Object 12 Trip/Close Pair Operation*. ➤ Updated Latch/Pulse descriptions for Indexes 41 and 68 in *Table E.17: Object 12 Code Selection Operation*.
20071018	Section 1 ➤ Modified *Protection and Control Processing* (in *Specifications*) to indicate that time-overcurrent (51) elements operate every half-cycle. Section 2 ➤ Included the battery lifetime for the Option 2 battery at +80°C. ➤ Corrected battery weight information.

Table A.2 Instruction Manual Revision History (Sheet 7 of 9)

Revision Date	Summary of Revisions
	Section 7 ➤ Corrected error in the final equation for preset values in *Example 7.1*. Section 8 ➤ Clarified and corrected voltage description on page 8.6. Appendix A ➤ Updated for firmware version R108. Appendix E ➤ Correction variation value in DNP Reference Map, Function code for Object 40. ➤ Made typographical correction in *Table E.12*, footnote a.
20070628	Appendix A ➤ Updated for firmware version R107.
20070514	Appendix A ➤ Updated for firmware version R106.
20061005	Section 1 ➤ Added 125 Vdc power supply option to *Models and Options*. ➤ Added 125 Vdc power supply option to *Specifications*. ➤ Added Cooper NOVA-TS and Cooper NOVA (control powered) to *Recloser Type Tests* in *Specifications*. Section 2 ➤ Added 125 Vdc power supply option information to *Power Connections*. ➤ Updated dimensions on *Figure 2.13*, *Figure 2.15*, *Figure 2.16*, *Figure 2.17*, *Figure 2.19*, *Figure 2.21*, *Figure 2.22*, and *Figure 2.23*. ➤ Edited *Figure 2.46*, *Figure 2.50*, *Figure 2.52*, *Figure 2.54*, and *Figure 2.55*. Section 6 ➤ Added note regarding Relay Word bit BTFAIL and the 125 Vdc power supply option. Section 8 ➤ Added note regarding Relay Word bit BTFAIL and the 125 Vdc power supply option.
20060622	Appendix A ➤ Updated for firmware version R105.

20060329	Section 1
	➤ Updated *Features*, *Models and Options*, and *Specifications* for new recloser compatibilities.
	Section 2
	➤ Added content for new recloser compatibilities including:
	  ➢ Connector Panel Drawings
	  ➢ Control Cable Receptacle Pinouts
	  ➢ Supplemental Connection Details
	Section 8
	➤ Added content on the *SELOGIC Battery Load Test*.
	Section 9
	➤ Updated *Settings Explanations* to include new recloser compatibilities.
	➤ Updated settings sheets to include new battery test and DNP settings.
	Appendix A
	➤ Updated for firmware version R104.
	Appendix E
	➤ Updated DNP information to reflect new dual-number DNP dial out feature.

20050627	Section 2 ➤ Added note to properly seal enclosure openings. ➤ Corrected *Figure 2.36*.

Table A.2 Instruction Manual Revision History (Sheet 8 of 9)

Revision Date	Summary of Revisions
	Section 4 ➤ Corrected PLAR and NLAR values. Section 6 ➤ Corrected *Figure 6.12*. Section 7 ➤ Corrected description of SS1–SS6. Section 8 ➤ Corrected description of INPBV. Section 9 ➤ Added note regarding IEC curves and equivalent Cooper curves. ➤ Corrected *Example 9.3*. Appendix C ➤ Corrected name of cable C273A.
20050316	Appendix A ➤ Updated for firmware version R103.
20041105	Section 2 ➤ Added Single-Door Enclosure information. ➤ Removed *Front-Panel Labels*, the configurable label instructions are now a separate document. Section 11 ➤ Added Single-Door Enclosure information to *Status and Trip Target LEDs*. ➤ Added Single-Door Enclosure information to *Operator Controls*.
20040202	Section 9, Settings Sheets ➤ Added new DNP Port settings. Section 10 ➤ Added **STA D** and **STA RD** commands. ➤ Added **TEST DNP** command. Section 11 ➤ Updated to include new DNP statistics display. Appendix A ➤ Updated for firmware version R102. Appendix E ➤ Updated to include new DNP features. Appendix F ➤ Added **TEST DNP** bit. Appendix G ➤ Added DNP communications statistics analog quantities. Command Summary ➤ Added **STA D**, **STA RD**, and **TEST DNP** commands.
20031209	Section 4 ➤ Added loss-of-potential and directional control logic subsections. Section 9 ➤ Corrected reset time for C4 curve. ➤ Expanded discussion on voltage ratio correction factor (RCF) settings. ➤ Expanded discussion on Low Energy Analog (LEA) inputs and their effect on PT ratio and voltage-related settings.

Table A.2 Instruction Manual Revision History (Sheet 9 of 9)

Revision Date	Summary of Revisions
	Section 9, Settings Sheets ➤ Expanded setting range for voltage ratio correction factor (RCF) settings V1YRCF, V2YRCF, and V3YRCF. ➤ Added group settings VNOM, E32, ELOP, and the directional element settings to realize the new features explained in Section 4. Section 12 ➤ Added event report column explanation for loss-of-potential, directional elements, and inputs IN201–IN206. Appendix A ➤ Updated for firmware version R101. Appendix F ➤ Added various Relay Word bits to realize the new features explained *Section 4*.
20031003	➤ Initial version.

Appendix B
SEL-651R Recloser Control Relay Firmware Upgrade Instructions

Introduction

These firmware upgrade instructions apply to the SEL-651R Recloser Control relay.

SEL occasionally offers firmware upgrades to improve the performance of your relay. Changing physical components is unnecessary because the relay stores firmware in Flash memory.

A firmware loader program called SELBOOT resides in the relay. To upgrade firmware, use the SELBOOT program to download an SEL-supplied file from a personal computer to the relay via any communications port. This procedure is described in the following steps.

Keep the AC Power On!

When upgrading firmware, make sure to keep the SEL-651R Recloser Control energized with AC power—do not have it running just off the battery. Otherwise, when the **L_D** command is issued later in the firmware upgrade procedure (to disable the unit to receive new firmware), the unit goes immediately "to sleep," thus aborting the firmware upgrade procedure.

Overview

NOTE: SEL strongly recommends that you upgrade firmware at the location of the relay and with a direct connection from the personal computer to one of the relay serial ports. Do not load firmware from a remote location; problems can arise that you will not be able to address from a distance. When upgrading at the substation, do not attempt to load the firmware into the relay through an SEL communications processor.

Perform the firmware upgrade process in the following sequence:

A. Prepare the Relay

B. Establish a Terminal Connection

C. Save Settings and Other Data

D. Start SELBOOT

E. Upload New Firmware

F. Check Relay Self-Tests

G. Verify Settings, Calibration, Status, Breaker Wear, and Metering

H. Return the Relay to Service

Required Equipment

Gather the following equipment before starting this firmware upgrade:

- Personal computer
- Terminal emulation software that supports 1K Xmodem or Xmodem (these instructions use HyperTerminal from a Microsoft® Windows® operating system)
- Serial communications cable (SEL Cable C234A or equivalent)
- Disk containing the firmware upgrade (.s19) file
- Firmware Upgrade Instructions (these instructions)

Optional Equipment

These items help you manage relay settings and understand firmware upgrade procedures:

- SEL-5010 Relay Assistant software or ACSELERATOR QuickSet® SEL-5030 software

  The newest release of the SEL-5010 Relay Assistant software (V3.0) has a new feature that guides you through the conversion process. This upgrade guide will assist you with steps C, D, E, F, and G of these upgrade instructions. If you do not have the latest SEL-5010 software, please contact your customer service representative or the factory for details on getting the SEL-5010 Relay Assistant software.

Upgrade Procedure

A. Prepare the Relay

Step 1. If the relay is in use, follow your company practices for removing a relay from service.

Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

Step 3. Use the front panel to access the port settings of the port you plan to use. Record these settings. Refer to the Front-Panel Operations section of the instruction manual.

NOTE: Firmware upgrades can only be performed on Serial Port F.

Step 4. Connect an SEL Cable C234A (or equivalent) serial communications cable to Serial Port F.

B. Establish a Terminal Connection

To establish communication between the relay and a personal computer, you must be able to modify the computer serial communications parameters (i.e., data transmission rate, data bits, parity) and set the file transfer protocol to 1K Xmodem or Xmodem protocol.

Step 1. Connect a serial communications cable to the computer serial port:

a. Check the computer for a label identifying the serial communications ports.

b. Choose a port and connect an SEL Cable C234A (or equivalent) serial communications cable to the personal computer serial port.

If there is no identification label, connect the cable to any computer serial port. Note that you might later change this computer serial port to a different port in order to establish communication between the relay and the computer.

Step 2. Disconnect any other serial port connection(s).

Step 3. From the computer, open **HyperTerminal**.

On a personal computer running Windows, you would typically click the **Start > Programs > Accessories**.

Step 4. Enter a name, select any icon, and click **OK** (*Figure B.1*).

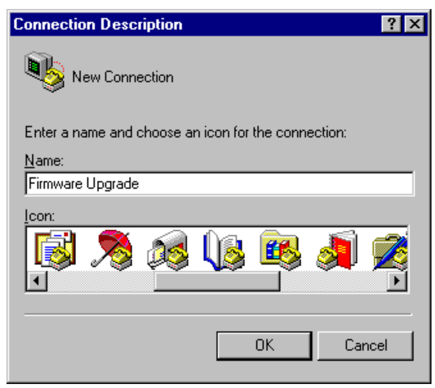

Figure B.1 Establishing a Connection

Step 5. Select the computer serial port you are using to communicate with the relay (*Figure B.2*) and click **OK**. This port matches the port connection that you made in *Step 1 on page B.3*.

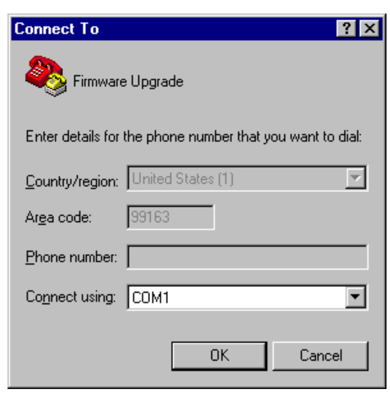

Figure B.2 Determining the Computer Serial Port

Step 6. Establish serial port communications parameters.

The settings for the computer (*Figure B.3*) must match the relay settings you recorded earlier.

a. Enter the serial port communications parameters (*Figure B.3*) that correspond to the relay settings you recorded in *Step 3 on page B.2*.

If the computer settings do not match the relay settings, change the computer settings to match the relay settings.

b. Click **OK**.

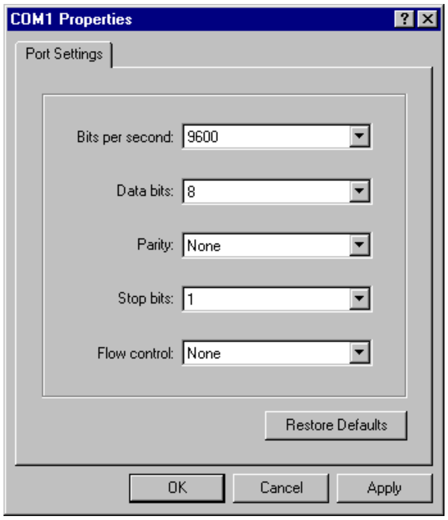

Figure B.3 Determining Communications Parameters for the Computer

Step 7. Set the terminal emulation to VT100:

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Firmware Upgrade Properties** dialog box (*Figure B.4*).

c. Select **VT100** from the **Emulation:** list box and click **OK**.

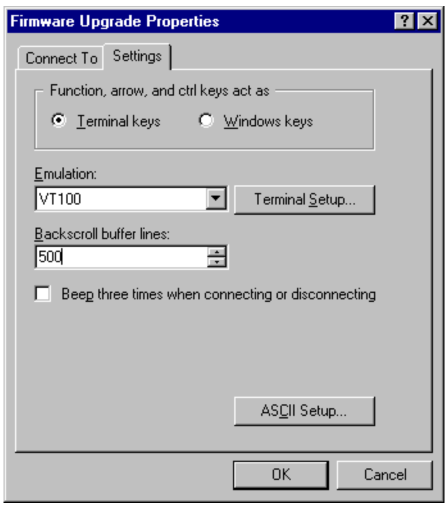

Figure B.4 Setting Terminal Emulation

Step 8. Confirm serial communication.

Press <**Enter**>. In the terminal emulation window, you should see the Access Level 0 = prompt, similar to that in *Figure B.5*.

If this is successful, proceed to *C. Save Settings and Other Data on page B.6*.

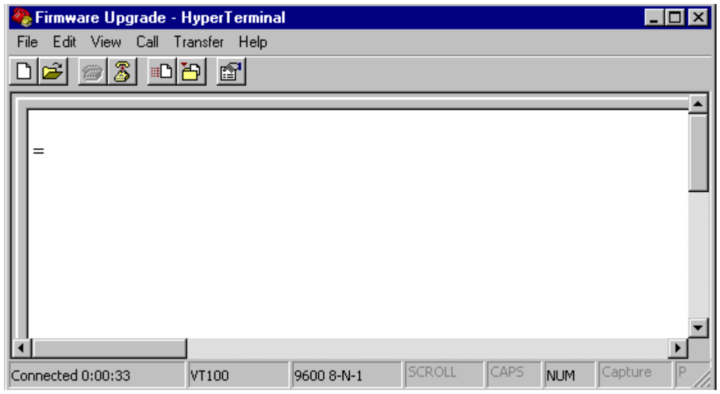

Figure B.5 Terminal Emulation Startup Prompt

Failure to Connect

If you do not see the Access Level 0 = prompt, press <**Enter**> again. If you still do not see the Access Level 0 = prompt, you have either selected the incorrect serial communications port on the computer, or the computer speed setting does not match the data transmission rate of the relay. Perform the following steps to reattempt a connection:

Step 9. From the **Call** menu, choose **Disconnect** to terminate communication.

Step 10. Correct the port setting:

a. From the **File** menu, choose **Properties**.

You should see a dialog box similar to *Figure B.6*.

b. Select a different port in the **Connect using:** list box.

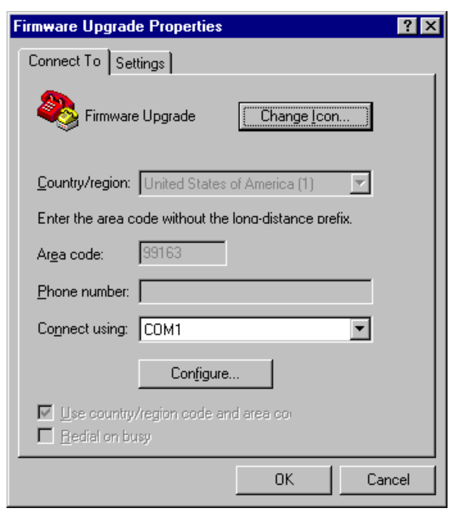

Figure B.6 Correcting the Port Setting

Step 11. Correct the communications parameters:

a. From the filename **Properties** dialog box shown in *Figure B.6*, click **Configure**.

You will see a dialog box similar to *Figure B.7*.

b. Change the settings in the appropriate list boxes to match the settings you recorded in *Step 3 on page B.2* and click **OK** twice to return to the terminal emulation window.

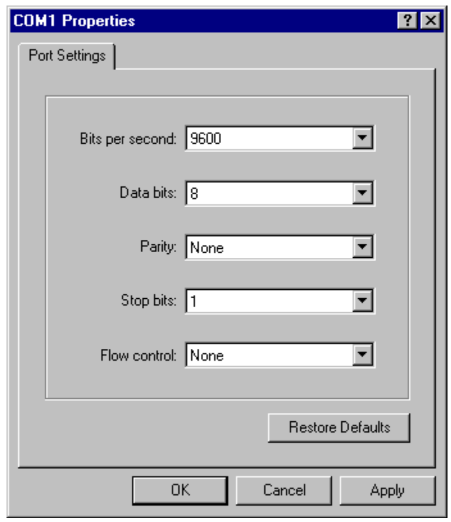

Figure B.7 Correcting the Communications Parameters

Step 12. Press **<Enter>**. In the terminal emulation window, you should see the Access Level 0 = prompt, similar to that in *Figure B.5*.

C. Save Settings and Other Data

Before upgrading firmware, retrieve and record any History (**HIS**), Event (**EVE**), Metering (**MET**), Breaker Wear Monitor (**BRE**), Communications Log Summary (**COM A** or **COM B**) or Sequential Events Recorder (**SER**) data that you want to retain (see the relay instruction manual for these procedures).

Enter Access Level 2

NOTE: If the relay does not prompt you for Access Level 1 and Access Level 2 passwords, check whether the relay has a password jumper in place. With this jumper in place, the relay is unprotected from unauthorized access (see the relay instruction manual).

Step 1. Type **ACC <Enter>** at the Access Level 0 = prompt.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Type **2AC <Enter>**.

Step 4. Type the Access Level 2 password and press **<Enter>**.

You will see the Access Level 2 =>> prompt.

Backup Relay Settings

The relay preserves settings and passwords during the firmware upgrade process. However, interruption of relay power during the upgrade process can cause the relay to lose settings. Make a copy of the original relay settings in case you need to reenter the settings. Use either the SEL-5010 Relay Assistant software or ACSELERATOR QuickSet to record the existing relay settings and proceed to *D. Start SELBOOT*.

D. Start SELBOOT

Step 1. Find and record the firmware identification string (FID):

a. Type **ID <Enter>** and record the FID number the relay displays.

Step 2. From the computer, start the SELBOOT program:

a. From the Access Level 2 =>> prompt, type the following:

L_D <Enter>.

The relay responds with the following:

```
Disable relay to send or receive firmware
(Y/N)?
```

b. Type **Y <Enter>**.

The relay responds with the following:

```
Are you sure (Y/N)?
```

c. Type **Y <Enter>**.

The relay responds with the following:

```
Relay Disabled
```

Step 3. Wait for the SELBOOT program to load.

The front-panel LCD display is cleared and remains blank

After SELBOOT loads, the computer will display the SELBOOT !> prompt.

Step 4. Press **<Enter>** to confirm that the relay is in SELBOOT.

You will see another SELBOOT !> prompt.

Commands Available in SELBOOT

For a listing of commands available in SELBOOT, type **HELP <Enter>**. You should see a screen similar to *Figure B.8*.

```
!>HELP <Enter>

BFID=SLBT-6XX-X101-V0-Z000000-D20030602

bau "rate"  ; Set baud rate to 300, 1200, 2400, 4800, 9600,
              19200, 38400, 57600, or 115200 bps
era         ; Erase the existing relay firmware
exi         ; Exit this program and restart the device
fid         ; Display the relays firmware identification (FID)
rec         ; Receive new firmware for the device using Xmodem
hel         ; Print this help list

FLASH Type : 163         Checksum = F794  OK
```

Figure B.8 List of Commands Available in SELBOOT

Establish a High-Speed Connection

Step 5. Type **BAU 115200 <Enter>** at the SELBOOT !> prompt.

Match Computer Communications Speed to the Relay

Step 6. From the **Call** menu, choose **Disconnect** to terminate communication.

Step 7. Change the communications parameters to 115200 bps:

a. From the **File** menu, choose **Properties**.

b. Choose **Configure**.

c. Change the computer communications speed to 115200 bps (*Figure B.9*).

d. Click **OK** twice.

Step 8. Press **<Enter>** to check for the SELBOOT !> prompt indicating that serial communication is successful.

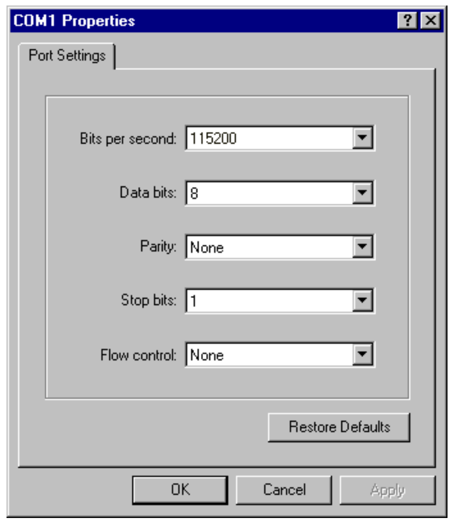

Figure B.9 Matching Computer to Relay Parameters

E. Upload New Firmware

Step 1. Prepare to load the firmware:

a. Insert the disk containing the new firmware into the appropriate disk drive on the computer.

NOTE: This example shows uploading new firmware directly from a disk. For a faster upload (and less potential for file corruption), copy the new firmware to the local hard drive and upload the new firmware from the hard drive.

b. Some firmware is in self-extracting compressed files (files with .exe extensions). For firmware in such files, from Windows Explorer double-click on the file and select the directory on the hard drive where you want to access the uncompressed files. Verify that these uncompressed files have an .s19 extension.

Step 2. Type **REC <Enter>** at the SELBOOT !> prompt to command the relay to receive new firmware.

```
!>REC <Enter>
Caution! This command erases the relays firmware.
If you erase the firmware then new firmware
must be loaded before returning the IED to service.
```

Step 3. The relay asks whether you want to erase the existing firmware.

```
Are you sure you wish to erase the existing firmware? (Y/N) Y <Enter>
```

Step 4. Type **Y** to erase the existing firmware and load new firmware. (To abort, type **N** or press **<Enter>**).

The relay responds with the following:

```
Erasing firmware
Erase successful
Press any key to begin transfer and then start transfer at the terminal. <Enter>
```

Step 5. Press **<Enter>** to start the file transfer routine.

Step 6. Send new firmware to the relay.

a. From the **Transfer** menu in **HyperTerminal**, choose **Send File** (*Figure B.10*).

b. In the **Filename** text box, type the location and filename of the new firmware or use the **Browse** button to select the firmware file.

c. In the **Protocol** text box, select **1K Xmodem** if this protocol is available.

If the computer does not have **1K Xmodem**, select **Xmodem**.

d. Click **Send** to send the file containing the new firmware.

You should see a dialog box similar to *Figure B.11*. Incrementing numbers in the **Packet** box and a bar advancing from left to right in the **File** box indicate that a transfer is in progress.

Receiving software takes 5–10 minutes at 115200 bps, depending on the relay. If you see no indication of a transfer in progress within a few minutes after clicking **Send**, use the **REC** command again and reattempt the transfer.

NOTE: Unsuccessful uploads can result from Xmodem time-out, a power failure, loss of communication between the relay and the computer, or voluntary cancellation. Check connections, reestablish communication, and start again at Step 2 on page B.8.

Contact the factory for assistance in achieving a successful firmware upgrade.

After the transfer completes, the relay displays the following:

```
Upload completed successfully. Attempting a restart.
```

A successful restart sequence can take as long as two minutes, after which time the relay leaves SELBOOT. You will see no display on your PC to indicate a successful restart.

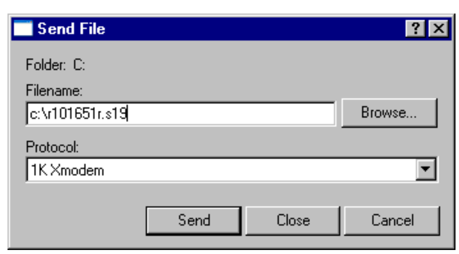

Figure B.10 Selecting New Firmware to Send to the Relay

NOTE: The relay restarts in SELBOOT if relay power fails while receiving new firmware. Upon power-up, the relay serial port will be at the default 9600 baud. Perform the steps beginning in B. Establish a Terminal Connection on page B.3 to increase the serial connection data speed. Then resume the firmware upgrade process at E. Upload New Firmware on page B.8.

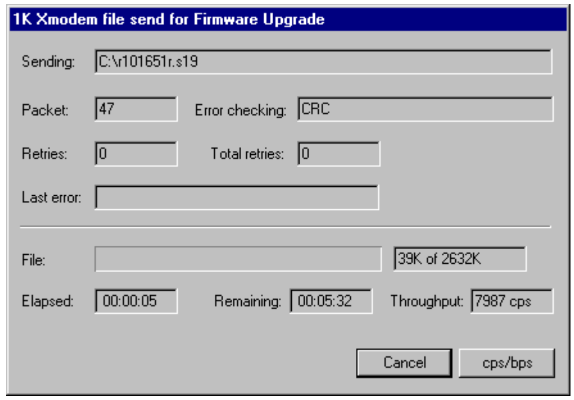

Figure B.11 Transferring New Firmware to the Relay

Step 7. Press **<Enter>** and confirm that the Access Level 0 = prompt appears on the computer screen.

Step 8. If you see the Access Level 0 = prompt, proceed to *F. Check Relay Self-Tests on page B.11*.

No Access Level 0 = Prompt

If no Access Level 0 = prompt appears in the terminal emulation window, one of three things could have occurred. Refer to *Table B.1* to determine the best solution:

Table B.1 Troubleshooting New Firmware Upload (Sheet 1 of 2)

Problem	Solution
The restart was successful, but the relay data transmission rate reverted to the rate at which the relay was operating prior to entering SELBOOT (the rate you recorded in *A. Prepare the Relay on page B.2*).	Change the computer terminal speed to match the relay data transmission rate you recorded in *A. Prepare the Relay on page B.2*. (See *Match Computer Communications Speed to the Relay on page B.8*): Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication. Step 2. Change the communications software settings to the values you recorded in *A. Prepare the Relay on page B.2*. Step 3. From the **Call** menu, choose **Connect** to reestablish communication. Step 4. Press **<Enter>** to check for the Access Level 0 = prompt indicating that serial communication is successful. Step 5. If you get no response, proceed to *Match Computer Communications Speed to the Relay on page B.8*.
The restart was successful, but the relay data transmission rate reverted to 9600 bps (the settings have been reset to default).	Match the computer terminal speed to a relay data transmission rate of 9600 bps: Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication. Step 2. Change the communications software settings to 9600 bps, 8 data bits, no parity, and 1 stop bit (See *Match Computer Communications Speed to the Relay on page B.8*). Step 3. From the **Call** menu, choose **Connect** to reestablish communication. Step 4. Press **<Enter>** to check for the Access Level 0 = prompt indicating successful serial communication.

Table B.1 Troubleshooting New Firmware Upload (Sheet 2 of 2)

Problem	Solution
	If you see a SELBOOT !> prompt, type **EXI <Enter>** to exit SELBOOT. Check for the Access Level 0 = prompt. If you see the Access Level 0 = prompt, proceed to *F. Check Relay Self-Tests*.
The restart was unsuccessful, in which case the relay is in SELBOOT.	Reattempt to upload the new firmware (beginning at *Step 5* under *Establish a High-Speed Connection on page B.7*) or contact the factory for assistance.

F. Check Relay Self-Tests

The relay can display various self-test fail status messages. The troubleshooting procedures that follow depend upon the status message the relay displays.

Step 1. Type **ACC <Enter>**.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Enter the **STATUS** command (**STA <Enter>**) to view relay status messages.

If the relay displays no fail status message, proceed to *G. Verify Settings, Calibration, Status, Breaker Wear, and Metering on page B.11*.

G. Verify Settings, Calibration, Status, Breaker Wear, and Metering

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

Step 2. Use the **SHO** command to view the relay settings and verify that these match the settings you saved earlier (see *Backup Relay Settings on page B.7*).

Step 3. Use the firmware identification string (FID) to verify download of the correct firmware:

a. Type **ID <Enter>** and compare the number the relay displays against the number from the firmware envelope label.

b. If the label FID and part number match the relay display, proceed to *Step 4*.

c. For a mismatch between a displayed FID or part number, and the firmware envelope label, reattempt the upgrade or contact the factory for assistance.

Step 4. Type **STA <Enter>** and verify that all relay self-test parameters are within tolerance.

Step 5. If you use the Breaker Wear Monitor, type **BRE <Enter>** to check the data and see if the relay retained breaker wear data through the upgrade procedure.

If the relay did not retain these data, use the **BRE W*n*** command to reload the percent contact wear values for each pole of Circuit Breaker ***n*** (***n*** = 1, 2, 3, or 4) you recorded in *C. Save Settings and Other Data on page B.6*.

Step 6. Apply current and voltage signals to the relay.

Step 7. Type **MET <Enter>** and verify that the current and voltage signals are correct.

Step 8. Use the **TRIGGER** and **EVENT** commands to verify that the magnitudes of the current and voltage signals you applied to the relay match those displayed in the event report.

If these values do not match, check the relay settings and wiring.

H. Return the Relay to Service

Step 1. Follow your company procedures for returning a relay to service.

Step 2. Autoconfigure the SEL communications processor port if you have an SEL communications processor connected to the relay.

This step reestablishes automatic data collection between the SEL communications processor and the relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

The relay is now ready for your commissioning procedure.

Factory Assistance

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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Tel: +1.509.332.1890
Fax: +1.509.332.7990
Internet: selinc.com
Email: info@selinc.com

Appendix C
SEL Communications Processors

SEL Communications Protocols

The SEL-651R Recloser Control supports the protocols and command sets shown in *Table C.1*.

Table C.1 Supported Serial Command Sets

Command Set	Description
SEL ASCII	Use this protocol to send ASCII commands and receive ASCII responses that are human-readable with an appropriate terminal emulation program.
SEL Compressed ASCII	Use this protocol to send ASCII commands and receive compressed ASCII responses that are comma delimited for use with spreadsheet and database programs or for use by intelligent electronic devices.
SEL Fast Meter	Use this protocol to send binary commands and receive binary meter and target responses.
SEL Fast Operate	Use this protocol to send binary control commands.

SEL ASCII Commands

We originally designed SEL ASCII commands for communication between the relay and a human operator via a keyboard and monitor or a printing terminal. A computer with a serial port can also use the SEL ASCII protocol to communicate with the relay, collect data, and issue commands.

SEL Compressed ASCII Commands

The relay supports a subset of SEL ASCII commands identified as Compressed ASCII commands. Each of these commands results in a comma-delimited message that includes a checksum field. Most spreadsheet and database programs can directly import comma-delimited files. Devices with embedded processors connected to the relay can execute software to parse and interpret comma-delimited messages without expending the customization and maintenance labor needed to interpret nondelimited messages. The relay calculates a checksum for each line by numerically summing all of the bytes that precede the checksum field in the message. The program that uses the data can detect transmission errors in the message by summing the characters of the received message and comparing this sum to the received checksum.

Most commands are available only in SEL ASCII or Compressed ASCII format. Selected commands have versions in both standard SEL ASCII and Compressed ASCII formats. Compressed ASCII reports generally have fewer characters than conventional SEL ASCII reports, because the compressed reports reduce blanks, tabs, and other “white space” between data fields to a single comma.

Table C.2 lists the Compressed ASCII commands and contents of the command responses.

Table C.2 Compressed ASCII Commands

Command	Response	Access Level
BNAME	ASCII names of Fast Meter status bits	0
CASCII	Configuration data of all Compressed ASCII commands available at access levels > 0	0
CEVENT	Event report	1
CHISTORY	List of events	1
CSTATUS	Relay self-test status results	1
CSUMMARY	Summary of an event report	1
DNAMES	ASCII names of digital I/O reported in Fast Meter	0
ID	Relay identification	0

Interleaved ASCII and Binary Messages

SEL relays have two separate data streams that share the same physical serial port. Human data communications with the relay consist of ASCII character commands and reports that you view using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information; the ASCII data stream continues after the interruption. This mechanism uses a single communications channel for ASCII communication (transmission of an event report, for example) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. However, you do not need a device to interleave data streams in order to use the binary or ASCII commands. Note that XON, XOFF, and CAN operations operate on only the ASCII data stream.

An example of using these interleaved data streams is when the SEL-651R communicates with an SEL Communications Processor. These SEL Communications Processors perform auto-configuration by using a single data stream and SEL Compressed ASCII and binary messages. In subsequent operations, the SEL Communications Processor uses the binary data stream for Fast Meter, and Fast Operate messages to populate a local database and to perform SCADA operations. At the same time that a binary data stream is in progress, you can connect transparently to the SEL-651R and use the ASCII data stream for commands and responses.

SEL Fast Meter, and Fast Operate

SEL Fast Meter is a binary message that you solicit with binary commands. Fast Operate is a binary message for control. 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 Processors

SEL offers SEL Communications Processors, the SEL-2020, SEL-2030, and SEL-2032, powerful tools for system integration and automation. These devices provide a single point of contact for integration networks with a star topology as shown in *Figure C.1*.

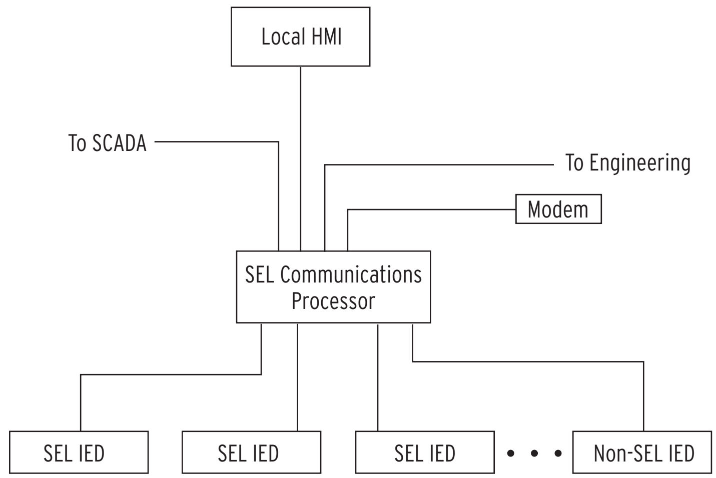

Figure C.1 SEL Communications Processor Star Integration Network

In the star topology network in *Figure C.1* the SEL Communications Processor offers the following substation integration functions:

- Collection of real-time data from SEL and non-SEL IEDs
- Calculation, concentration, and aggregation of real-time IED data into databases for SCADA, HMI, and other data consumers
- Access to the IEDs for engineering functions including configuration, report data retrieval, and control through local serial, remote dial-in, and Ethernet network connections
- Simultaneous collection of SCADA data and engineering connection to SEL IEDs over a single cable
- Distribution of IRIG-B time synchronization signal to IEDs based on external IRIG-B input, internal clock, or protocol interface
- Automated dial-out on alarms

SEL Communications Processors have 16 serial ports plus a front port. This port configuration does not limit the size of a substation integration project, because you can create a multitiered solution as shown in *Figure C.2*. In this multitiered system, the lower-tier SEL Communications Processors forward data to the upper-tier SEL Communications Processor that serves as the central point of access to substation data and station IEDs.

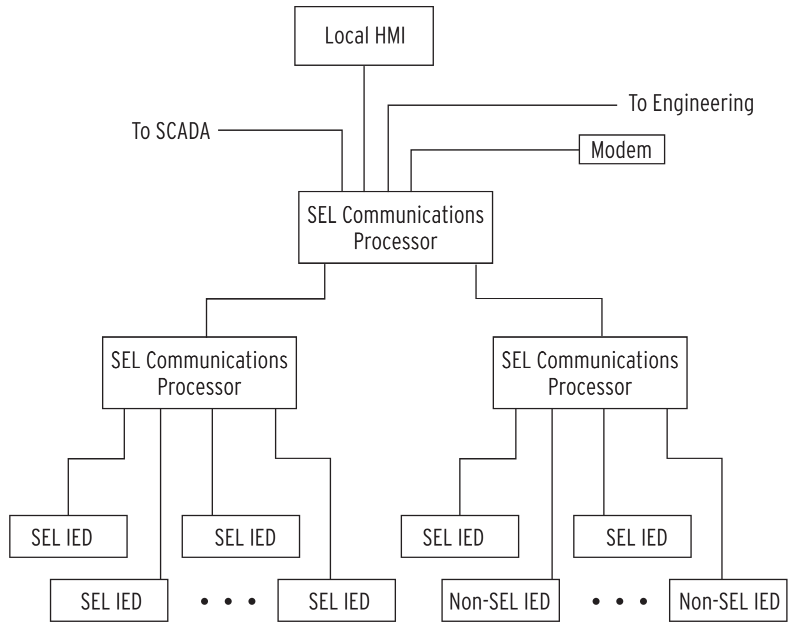

Figure C.2 Multitiered SEL Communications Processor Architecture

You can add additional communications processors to provide redundancy and eliminate possible single points of failure. SEL communications processors provide an integration solution with a reliability comparable to that of SEL relays. In terms of MTBF (mean time between failures), SEL communications processors are 100 to 1000 times more reliable than computer-based and industrial technology-based solutions.

Configuration of an SEL communications processor is different from other general-purpose integration platforms. You can configure SEL communications processors with a system of communication-specific keywords and data movement commands rather than programming in C or another general-purpose computer language. SEL communications processors offer the protocol interfaces listed in *Table C.3*.

Table C.3 SEL Communications Processors Protocol Interfaces

Protocol	Connect to
DNP3 Level 2 Slave	DNP3 masters
Modbus® RTU	Modbus masters
SEL ASCII/Fast Message Slave	SEL protocol masters
SEL ASCII/Fast Message Master	SEL protocol slaves including other communications processors and SEL relays
ASCII and Binary auto messaging	SEL and non-SEL IED master and slave devices
Modbus Plus[a]	Modbus Plus peers with global data and Modbus Plus masters
FTP (File Transfer Protocol)[b]	FTP clients
Telnet[b]	Telnet servers and clients
UCA2 GOMSFE[b]	UCA2 protocol masters
UCA2 GOOSE[b]	UCA2 protocol and peers

[a] Requires SEL-2711 Modbus Plus protocol card.
[b] Requires SEL-2701 Ethernet Processor.

SEL Communications Processor and Relay Architecture

You can apply SEL communications processors and SEL relays in a limitless variety of applications that integrate, automate, and improve station operation. Most system integration architectures using SEL communications processors involve either developing a star network or enhancing a multidrop network.

Developing Star Networks

The simplest architecture using both the SEL-651R and an SEL communications processor is shown in *Figure C.1*. In this architecture, the SEL communications processor collects data from the SEL-651R and other station IEDs. The SEL communications processor acts as a single point of access for local and remote data consumers (local HMI, SCADA, engineers). The communications processor also provides a single point of access for engineering operations including configuration and the collection of report-based information.

By configuring a data set optimized to each data consumer, you can significantly increase the usage efficiency on each link. A system that uses an SEL communications processor to provide a protocol interface to an RTU will have a shorter lag time (data latency); communication overhead is much less for a single data exchange conversation to collect all substation data (from a communications processor) than for many conversations required to collect data directly from each individual IED. You can further reduce data latency by connecting an SEL communications processor directly to the SCADA master and eliminating redundant communication processing in the RTU.

The SEL communications processor is responsible for the protocol interface, so you can install, test, and even upgrade the system in the future without disturbing protective relays and other station IEDs. This insulation of the protective devices from the communications interface assists greatly in situations where different departments are responsible for SCADA operation, communication, and protection.

SEL communications processors equipped with an SEL-2701 can provide a UCA2 interface to SEL-651R relays and other serial IEDs. The SEL-651R data appear in models in a virtual device domain. The combination of the SEL-2701 with an SEL communications processor offer a significant cost savings because you can use existing IEDs or purchase less expensive IEDs. For full details on applying the SEL-2701 with an SEL communications processor, see the SEL-2701 *Ethernet Processor Instruction Manual*.

The engineering connection can use either an Ethernet network connection through the SEL-2701 or a serial port connection. This versatility will accommodate the channel that is available between the station and the engineering center. SEL software, including the ACSELERATOR QuickSet® SEL-5030 Software Program, can use either a serial port connection or an Ethernet network connection from an engineering workstation to the relays in the field.

Enhancing Multidrop Networks

You can also use an SEL communications processor to enhance a multidrop architecture similar to the one shown in *Figure C.3*. In this example, the SEL communications processor enhances a system that uses the SEL-2701 with an Ethernet HMI multidrop network. In the example, there are two Ethernet networks, the SCADA LAN and the Engineering LAN. The SCADA LAN provides real-time data directly to the SCADA Control Center via a protocol gateway and to the HMI (Human Machine Interface).

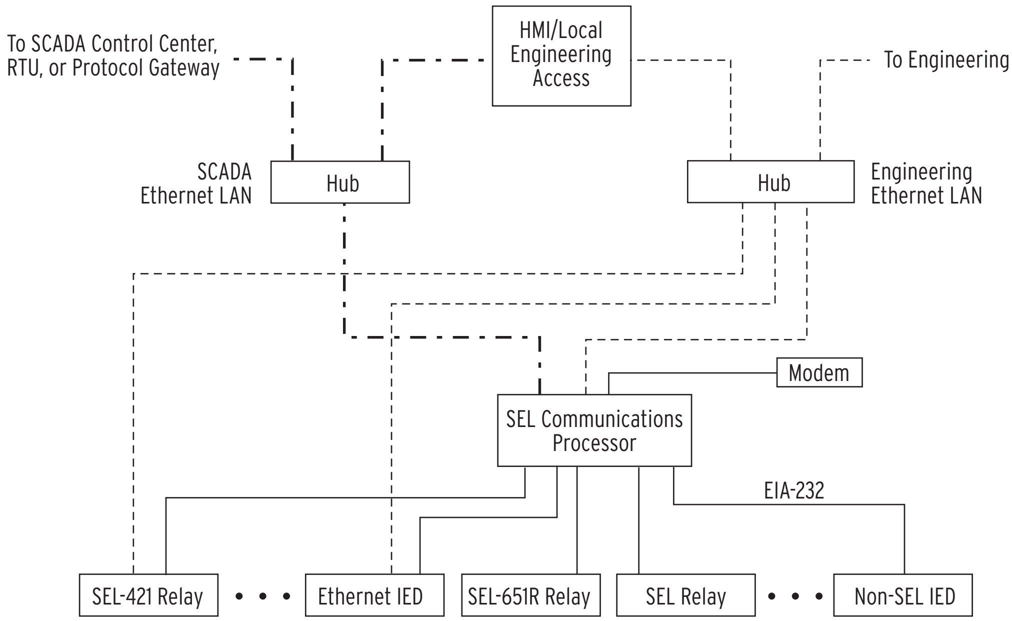

Figure C.3 Enhancing Multidrop Networks With SEL Communications Processors

In this example, the SEL Communications Processor provides the following enhancements when compared to a system that employs only the multidrop network:

- Ethernet access for IEDs with serial ports
- Backup engineering access through the dial-in modem
- IRIG-B time signal distribution to all station IEDs
- Integration of IEDs without Ethernet
- Single point of access for real-time data for SCADA, HMI, and other uses
- Significant cost savings by use of existing IEDs with serial ports

Control Points

The SEL Communications Processor can pass control messages, called Fast Operate messages, to the SEL-651R.

When Fast Operate functions are enabled, the SEL Communications Processor automatically sends messages to the relay in response to changes in remote bits RB1–RB16 or breaker bits BR1–BR4 on the corresponding SEL Communications Processor port. For example, if you set RB1 on Port 1 in the SEL Communications Processor, it automatically sets RB01 in the SEL-651R connected to that serial port. *Table C.4* shows the relationship between the SEL Communications Processor Remote Bits and the SEL-651R Remote Bits.

Follow these steps to enable Fast Operate messages that set or clear remote bits or breaker bits.

Step 1. Set the FASTOP setting equal to Y in the SEL-651R port settings for the port connected to the SEL Communications Processor.

The SEL-651R breaker jumper must be in the proper position; see *Table 2.4*.

Step 2. Enable Fast Operate messages in the communications processor by setting the auto-message setting SEND_OPER equal to Y.

Step 3. Toggle the corresponding Set and Clear elements SRB1–16, CRB1–16, SBR1–4, and CBR1–4.

To pulse, instead of set or clear, remote bits, set auto-message setting SEND_OPER equal to YP instead of Y. Note that SEND_OPER equal to YP applies to remote bits only; breaker bit operation is the same for both SEND_OPER = Y and SEND_OPER = YP.

Table C.4 Remote Bit Correspondence to the SEL-651R

Remote Bit in SEL Communications Processor:	Corresponding SEL-651R Relay Word Bit:
RB1	RB01
RB2	RB02
RB3	RB03
RB4	RB04
...	...
RB15	RB15
RB16	RB16
(NA)	RB17
...	...
(NA)	RB32

Fast Operate breaker bits operate differently from remote bits. For example, when you set BR1 on Serial Port 1 of the SEL Communications Processor, the SEL Communications Processor sends a message to the SEL-651R that asserts the open command bit OC3 for one processing interval. Likewise, if you clear BR1, the SEL Communications Processor sends a message to the SEL-651R that asserts the close command bit CC3 for one processing interval.

Table C.5 shows how the breaker bits in the SEL Communications Processor are mapped to the Open Command and Close Command Relay Word bits in the SEL-651R. For three-phase tripping and closing applications, use BR1 only. Use any of BR1–BR4 for single-phase trip and close applications.

The factory settings for the SEL-651R only use the OC3 and CC3 Relay Word bits—see *Figure 5.1*, *Figure 5.2*, *Figure 6.1*, and *Figure 6.2*.

Table C.5 Breaker Bit Correspondence to the SEL-651R

Breaker Bits in SEL Communications Processor:	Corresponding SEL-651R Relay Word bit:	
	When BRn is set:	When BRn is cleared:
BR1	Pulse OC3	Pulse CC3
BR2	Pulse OCA	Pulse CCA
BR3	Pulse OCB	Pulse CCB
BR4	Pulse OCC	Pulse CCC

See *OPEN Command (Open Breaker) on page 10.32*, and *CLOSE Command (Close Breaker) on page 10.16*, for more information on the Open and Close Command Relay Word bits in the SEL-651R.

SEL Communications Processor Example

This example demonstrates some of the data and control points available in the SEL Communications Processor when you connect an SEL-651R. The physical configuration used in this example is shown in *Figure C.4*.

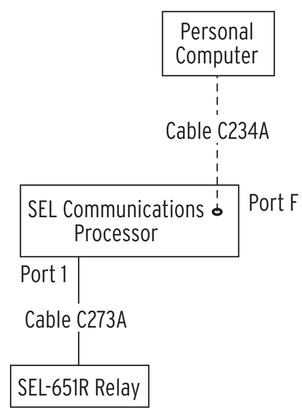

Figure C.4 Example SEL Relay and SEL Communications Processor Configuration

Table C.6 shows the Port 1 settings for the SEL Communications Processor.

Table C.6 SEL Communications Processor Port 1 Settings

Setting Name	Setting	Description
DEVICE	S	Connected device is an SEL device
CONFIG	Y	Allow autoconfiguration for this device
PORTID	“Relay 1”	Name of connected relay[a]
BAUD	19200	Channel speed of 19200 bits per second[a]
DATABIT	8	Eight data bits[a]
STOPBIT	1	One stop bit
PARITY	N	No parity
RTS_CTS	Y	Hardware flow control enabled
TIMEOUT	5	Idle timeout that terminates transparent connections of 5 minutes

[a] Automatically collected by the SEL Communications Processor during autoconfiguration.

Data Collection

Table C.7 lists the automatic messages that are available in the SEL-651R.

Table C.7 SEL Communications Processor Data Collection Auto-Messages

Message	Data Collected
20METER	Power system metering data
20DEMAND	Demand and peak demand metering data
20TARGET	Selected Relay Word bit elements
20HISTORY	History Command (ASCII)
20STATUS	Status Command (ASCII)
20EVENT	Standard 4 sample/cycle event report (data only)
20EVENTS	Standard 4 sample/cycle event report (data with settings)
20EVENTL	Long 32 sample/cycle event report (data with settings)

Table C.8 shows the auto-message (Set A) settings for the SEL Communications Processor. In this example the SEL Communications Processor is configured to collect metering and target data from the SEL-651R via the three automatic messages: 20TARGET, 20METER, and 20DEMAND.

Table C.8 SEL Communications Processor Port 1 Automatic Messaging Settings

Setting Name	Setting	Description
AUTOBUF	Y	Save unsolicited messages
STARTUP	"ACC\nOTTER\n"	Automatically log-in at Access Level 1
SEND_OPER	Y	Send Fast Operate messages for remote bit and breaker bit control
REC_SER	N	Automatic sequential event recorder data collection disabled
NOCONN	NA	No SELOGIC control equation entered to selectively block connections to this port
MSG_CNT	3	Three auto-messages
ISSUE1	P00:00:01.0	Issue Message 1 every second
MESG1	20METER	Collect metering data
ISSUE2	P00:00:01.0	Issue Message 2 every second
MESG2	20TARGET	Collect Relay Word bit data
ISSUE3	P00:01:00.0	Issue Message 3 every minute
MESG3	20DEMAND	Collect demand metering data
ARCH_EN	N	Archive memory disabled
USER	0	No USER region registers reserved

Table C.9 shows the map of regions in the SEL Communications Processor for data collected from the SEL-651R in the example.

Table C.9 SEL Communications Processor Port 1 Region Map

Region	Data Collection Message Type	Region Name	Description
D1	Binary	METER	Relay metering data
D2	Binary	TARGET	Relay Word bit data
D3	Binary	DEMAND	Demand metering data
D4–D8	n/a	n/a	Unused
A1–A3	n/a	n/a	Unused
USER	n/a	n/a	Unused

SEL-651R Metering Data

Table C.10 shows the list of meter data available in the SEL Communications Processor and the location and data type for the memory area within D1 (Data Region 1). The type field indicates the data type and size. The type "int" is a 16-bit integer. The type "float" is a 32-bit IEEE floating point number.

Table C.10 Communications Processor METER Region Map (Sheet 1 of 2)

Item	Starting Address	Type
_YEAR	2000h	int
DAY_OF_YEAR	2001h	int
TIME(ms)	2002h	int[2]
MONTH	2004h	char
DATE	2005h	char
YEAR	2006h	char
HOUR	2007h	char
MIN	2008h	char
SECONDS	2009h	char
MSEC	200Ah	int
IA(A)	200Bh	float[2]
IB(A)	200Fh	float[2]
IC(A)	2013h	float[2]
IN(A)	2017h	float[2]
VA1(V)[VAY][a]	201Bh	float[2]
VB1(V)[VBY][a]	201Fh	float[2]
VC1(V)[VCY][a]	2023h	float[2]
VA2(V)[VAZ][a]	2027h	float[2]
VB2(V)[VBZ][a]	202Bh	float[2]
VC2(V)[VCZ][a]	202Fh	float[2]
FREQ(Hz)	2033h	float[2]
IAB(A)	2037h	float[2]
IBC(A)	203Bh	float[2]
ICA(A)	203Fh	float[2]
VAB(V)[b]	2043h	float[2]
VBC(V)[b]	2047h	float[2]
VCA(V)[b]	204Bh	float[2]

Table C.10 Communications Processor METER Region Map (Sheet 2 of 2)

Item	Starting Address	Type
PA(MW)[MWA][a][b]	204Fh	float
QA(MVAR)[MVARA][a][b]	2051h	float
PB(MW)[MWB][a][b]	2053h	float
QB(MVAR)[MVARB][a][b]	2055h	float
PC(MW)[MWC][a][b]	2057h	float
QC(MVAR)[MVARC][a][b]	2059h	float
P(MW)[MW3P][a][b]	205Bh	float
Q(MVAR)[MVAR3P][a][b]	205Dh	float
I0(A)	205Fh	float[2]
I1(A)	2063h	float[2]
I2(A)	2067h	float[2]
V0(V)[b]	206Bh	float[2]
V1(V)[b]	206Fh	float[2]
V2(V)[b]	2073h	float[2]

[a] Quantities in brackets are the labels by which the SEL-651R identifies there meter data items.
[b] Calculated in the communications processor using voltage values defined by SEL-651R Global Setting VSELECT.

Relay Word Bit Information

Table C.11 lists the Relay Word bit data available in the SEL Communications Processor for the memory area within D2 (Data Region 2).

Table C.11 Communications Processor TARGET Region

Address	Relay Word Bits (in Bits 7–0)							
	7	6	5	4	3	2	1	0
2804h	*	*	*	STSET	*	*	*	*
2805h	See Table F.1, Row 0							
2806h	See Table F.1, Row 1							
2807h	See Table F.1, Row 2							
2808h	See Table F.1, Row 3							
2809h	See Table F.1, Row 4							
280Ah	See Table F.1, Row 5							
280Bh	See Table F.1, Row 6							
280Ch	See Table F.1, Row 7							
280Dh	See Table F.1, Row 8							
280Eh	See Table F.1, Row 9							
280Fh	See Table F.1, Row 10							
2810h	See Table F.1, Row 11							
. . .	. . .							
2868h	See Table F.1, Row 99							

SEL-651R Demand Data

Table C.12 shows the list of demand data available in the SEL Communications Processor and the location and data type for the memory areas within D3 (Data Region 3). The type field indicates the data type and size. The type “int” is a 16-bit integer. The type “float” is a 32-bit IEEE floating point number.

Table C.12 Communications Processor DEMAND Region Map

Item	Starting Address	Type
_YEAR	3000h	int
DAY_OF_YEAR	3001h	int
TIME(ms)	3002h	int[2]
MONTH	3004h	char
DATE	3005h	char
YEAR	3006h	char
HOUR	3007h	char
MIN	3008h	char
SECONDS	3009h	char
MSEC	300Ah	int
IA(A)	300Bh	float
IB(A)	300Dh	float
IC(A)	300Fh	float
IG(A)	3011h	float
IN(A)	3013h	float
3I2(A)	3015h	float
PA1(MW)	3017h	float
PB1(MW)	3019h	float
PC1(MW)	301Bh	float
P1(MW)	301Dh	float
QA1(MVAR)	301Fh	float
QB1(MVAR)	3021h	float
QC1(MVAR)	3023h	float
Q1(MVAR)	3025h	float
PA2(MW)	3027h	float
PB2(MW)	3029h	float
PC2(MW)	302Bh	float
P2(MW)	302Dh	float
QA2(MVAR)	302Fh	float
QB2(MVAR)	3031h	float
QC2(MVAR)	3033h	float
Q2(MVAR)	3035h	float

Appendix D

MIRRORED BITS Communications

Overview

MIRRORED BITS® communications is a direct relay-to-relay communications protocol, which allows protective relays to exchange information quickly and securely, and with minimal expense. Use MIRRORED BITS communications for remote control and remote sensing or communications-assisted protection schemes.

SEL products support several variations of MIRRORED BITS communications protocols. Through port settings, you can set the SEL-651R Recloser Control for compatible operation with SEL-300 series relays, SEL-400 series relays, SEL-600 series relays, the SEL-2505 Remote I/O Modules, and the SEL-2100 Logic Processors. These devices use MIRRORED BITS communications to exchange the states of eight logic bits.

The PROTO = MB*c* option (*c* = A or B) is provided for compatibility with older SEL products that only support this version of MIRRORED BITS. Use PROTO = MB8*c* if each relay supports this MIRRORED BITS version. Use the PROTO = MBT*c* option if your application includes Pulsar MBT9600 modems.

SEL Application Guide *AG2002-23*, *Applying Two* SEL-*351S Relays to Provide Automatic Source Transfer for Critical Loads*, provides an example of how to use MIRRORED BITS in the SEL-351S Relay. These same principles may be used with the SEL-651R.

Figure D.1 shows this example with the SEL-651R.

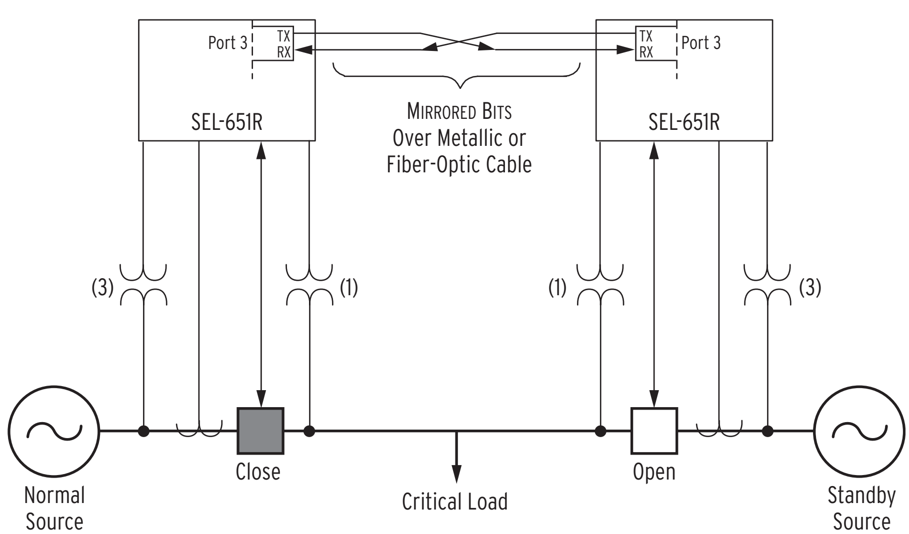

Figure D.1 Automatic Source Transfer Application

Communications Channels and Logical Data Channels

The SEL-651R supports two MIRRORED BITS communications channels, designated A and B. Use the port setting PROTO to assign one of the MIRRORED BITS communications channels to a serial port; PROTO := MBA for MIRRORED BITS communications Channel A or PROTO := MBB for MIRRORED BITS communications Channel B.

Transmitted bits include TMB1A–TMB8A and TMB1B–TMB8B. The last letter (A or B) designates with which channel the bits are associated. These bits are controlled by SELOGIC® control equations. Received bits include RMB1A–RMB8A and RMB1B–RMB8B. You can use received bits as operands in SELOGIC control equations. The channel status bits are ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, and LBOKB. You can also use these bits as operands in SELOGIC control equations. Use the **COM** command for additional channel status information.

Within each MIRRORED BITS communications message for a given channel (A or B), there are eight logical data channels (1–8). In operation compatible with other SEL products, you can use the eight logical data channels for TMB1 through TMB8, as shown in *Figure D.2*.

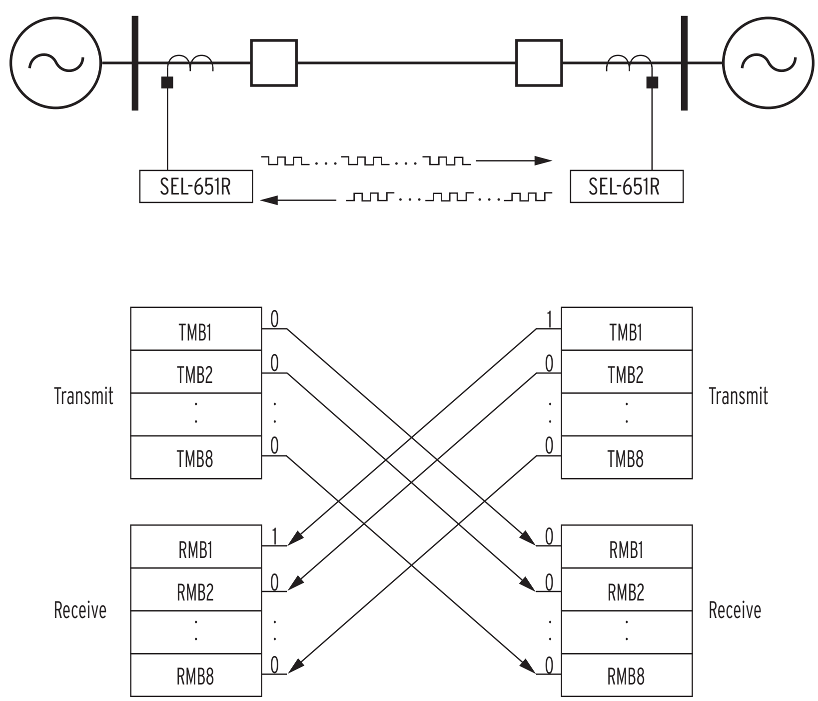

Figure D.2 Relay-to-Relay Logic Communication

Operation

Message Transmission

Depending on the settings, the SEL-651R transmits a MIRRORED BITS communications message every 1/8 to 1/2 of an electrical cycle (see *Table D.2*). Each message contains the most recent values of the transmit bits. All messages are transmitted without idle bits between characters. Idle bits are allowed between messages.

Message Reception

When the devices are synchronized and the MIRRORED BITS communications channel is in a normal state, the relay decodes and checks each received message. If the message is valid, the relay sends each received logic bit (RMB*nc*, where *n* = 1–8, *c* = A or B) to the corresponding pickup and dropout security counters, that in turn set or clear the RMB*nc* relay element bits.

Message Decoding and Integrity Checks

The relay provides indication of the status of each MIRRORED BITS communications channel, with element bits ROKA and ROKB. During normal operation, the relay sets the ROK*c* bit. The relay clears the bit upon detecting any of the following conditions:

- Parity, framing, or overrun errors.
- Receive data redundancy error.
- Receive message identification error.
- No message received in the time three messages have been sent.

The relay will assert ROK*c* only after successful synchronization as described below and two consecutive messages pass all of the data checks described above. After ROK*c* is reasserted, received data may be delayed while passing through the security counters described below.

NOTE: When MIRRORED BITS serial port settings are changed, the received MIRRORED BITS reset to zero regardless of the RXDFLT setting.

While ROK*c* is not set, the relay does not transfer new RMB data to the pickup-dropout security counters described below. Instead, the relay sends one of the user-definable default values to the security counter inputs. For each RMB*n*, specify the default value with setting RXDFLT, as follows:

- 1
- 0
- X (to use the last valid value)

Pickup/dropout security counters supervise the transfer of received data to RMB1*c*–RMB8*c*. Set these counters between 1 (allow every occurrence to pass) and at least 8 (require eight consecutive occurrences to pass). The pickup and dropout security count settings are separate.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that the counter uses units of “counted received messages,” instead of time. An SEL-651R communicating with another SEL-651R sends and receives MIRRORED BITS messages four times per power system cycle. Therefore, a security counter set to two counts will delay a bit by about 1/2 power system cycle. You must consider the impact of the security counter settings in the receiving device to determine the channel timing performance.

Things become slightly more complicated when two relays of different processing rates are connected via MIRRORED BITS (for instance, an SEL-321 talking to an SEL-651R). The SEL-321 processes power system information each 1/8 power system cycle but processes the pickup/dropout security counters as messages are received. Because the SEL-321 is receiving messages from the SEL-651R, it will receive a message each 1/4 cycle processing interval. So, a counter set to two will again delay a bit by about 1/2 cycle. However, in that same example, a security counter set to two on the SEL-651R will delay a bit by 1/4 cycle, because the SEL-651R is receiving new MIRRORED BITS messages each 1/8 cycle from the SEL-321.

Channel Synchronization

When an SEL-651R detects a communications error, it deasserts ROKA or ROKB. If a node detects two consecutive communications errors, it transmits an attention message, which includes its TXID setting.

When a node receives an attention message, it checks to see if its TXID is included.

If its own TXID is included and at least one other TXID is included, the node transmits data.

If its own TXID is not included, the node deasserts ROK*c*, includes its TXID in the attention message, and transmits the new attention message.

If its own TXID is the only TXID included, the relay assumes the message is corrupted unless the loopback mode has been enabled. If loopback is not enabled, the node deasserts ROK*c* and transmits the attention message with its TXID included. If loopback is enabled, the relay transmits data.

In summary, when a node detects two consecutive errors, it transmits attention until it receives an attention with its own TXID included. If three or four relays are connected in a ring topology, then the attention message will go all the way around the loop, and eventually will be received by the originating node. It will then be killed and data transmission will resume. This method of synchronization allows the relays to determine reliably which byte is the first byte of the message. It also forces mis-synchronized UARTs to become re-synchronized. On the down side, this method takes down the entire loop for a receive error at any node in the loop. This decreases availability. It also makes one-way communications impossible.

Loopback Testing

Use the **LOOP** command to enable loopback testing. While in loopback mode, ROK*c* is deasserted, and LBOK*c* asserts and deasserts based on the received data checks.

Channel Monitoring

Based on the results of data checks described above, the relay will collect information regarding the 255 most recent communications errors. Each record contains at least the following fields:

- Dropout Time/Date
- Pickup Time/Date
- Time elapsed during dropout
- Reason for dropout (see *Message Decoding and Integrity Checks*)

Use the **COMM** command to generate a long or summary report of the communications errors.

There is a single record for each outage, but an outage can evolve. For example, the initial cause could be a data disagreement, but framing errors can extend the outage. If the channel is presently down, the **COMM** record will only show the initial cause, but the **COMM** summary will display the present cause of failure.

When the duration of an outage on Channel A or B exceeds a user-definable threshold, the relay will assert a user-accessible flag, RBADA or RBADB.

When channel unavailability exceeds a user-settable threshold, the relay will assert a user accessible flag, hereafter called CBAD*c*.

MIRRORED BITS Protocol for the Pulsar 9600 Baud Modem

To use a Pulsar MBT-9600 modem, set setting PROTO = MBTA or MBTB to enable the MIRRORED BITS communications protocol Channel A or B respectively on this port. Either of these setting options hides setting SPEED and forces it to 9600, hides setting PARITY and forces it to a value of O, and hides setting RTSCTS and forces it to a value of N. The relay also injects a delay (idle time) of 3 ms between messages. The SEL-651R port settings associated with MIRRORED BITS communications are shown in *Table D.1*.

With one of these options set, the relay will transmit a message every 1/2 power system cycle and the relay will deassert the RTS signal on the EIA-232 connector. Also, the relay will monitor the CTS signal on the EIA-232 connector, which the modem will deassert if the channel has too many errors. The modem uses the relay RTS signal to determine whether the new or old MIRRORED BITS protocol is in use.

Settings

The SEL-651R port settings associated with MIRRORED BITS communications are shown in *Table D.1*. Set PROTO = MBA to enable the MIRRORED BITS communications protocol Channel A on this port. Set PROTO = MBB to enable the MIRRORED BITS communications protocol Channel B on this port.

Table D.1 MIRRORED BITS (Sheet 1 of 2)

Name	Description	Range	Default
PROTO	Protocol	SEL, DNP, MBA, MBB, MB8A, MB8B, MBTA, MBTB	SEL (Need to set to one of the MB_ values for MIRRORED BITS communications)
SPEED	Baud Rate	300, 1200, 2400, 4800, 9600, 19200, 38400	9600 (see *Table D.2*)
TXID	MIRRORED BITS Transmit Identifier	1–4	2
RXID	MIRRORED BITS Receive Identifier	1–4	1
RBADPU	MIRRORED BITS RX Bad Pickup Time	1–10000 s	60
CBADPU	PPM MIRRORED BITS Channel Bad Pickup	1–10000 s	1000
RXDFLT	MIRRORED BITS Receive Default State	8 character string of 1s, 0s, or *X*s	XXXXXXXX
RMB1PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB1DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB2PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB2DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB3PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB3DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB4PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB4DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB5PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1

Table D.1 MIRRORED BITS (Sheet 2 of 2)

Name	Description	Range	Default
RMB5DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB6PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB6DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB7PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB7DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB8PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB8DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1

As a function of the settings for SPEED, the message transmission periods are shown in *Table D.2*.

Table D.2 Message Transmission Periods

SPEED	SEL-321	SEL-651R
38400	1 message per 1/8 cycle	1 message per 1/4 cycle
19200	1 message per 1/8 cycle	1 message per 1/4 cycle
9600	1 message per 1/4 cycle	1 message per 1/4 cycle
4800	1 message per 1/2 cycle	1 message per 1/2 cycle

Use the RBADPU setting to determine how long a channel error must last before the relay element RBADA is asserted. RBADA is deasserted when the channel error is corrected. RBADPU is accurate to ±1 second.

Use the CBADPU setting to determine the ratio of channel down time to the total channel time before the relay element CBADA is asserted. The times used in the calculation are those that are available in the **COMM** records. See the *COMMUNICATIONS Command on page 10.17* for a description of the **COMM** records.

Set the RXID of the local relay to match the TXID of the remote relay. For example, in the three-terminal case, where Relay X transmits to Relay Y, Relay Y transmits to Relay Z, and Relay Z transmits to Relay X:

	TXID	RXID
Relay X	1	3
Relay Y	2	1
Relay Z	3	2

NOTE: When MIRRORED BITS serial port settings are changed, the received MIRRORED BITS reset to zero regardless of the RXDFLT setting.

Use the RXDFLT setting to determine the default state the MIRRORED BITS should use in place of received data if an error condition is detected. The setting is a mask of 1s, 0s and/or *X*s, for RMB1A–RMB8A, where *X* represents the most recently received valid value.

Supervise the transfer of received data (or default data) to RMB1A–RMB8A with the MIRRORED BITS pickup and dropout security counters. Set the pickup and dropout counters individually for each bit.

Appendix E
DNP3 Communications

The SEL-651R Recloser Control provides a DNP3 (Distributed Network Protocol) Level 2 Slave interface for direct network connections to the relay. This section covers the following topics:

- ➤ Introduction to DNP3
- ➤ DNP3 in the SEL-651R
- ➤ DNP3 Documentation, Object Tables, and Data Maps

Introduction to DNP3

A SCADA (Supervisory Control and Data Acquisition) manufacturer developed DNP3 from the lower layers of IEC 60870-5. DNP3 was designed for use in telecontrol applications. The protocol has become popular for both local substation data collection and telecontrol. DNP is one of the protocols included in the IEEE® Recommended Practice for Data Communication between Remote Terminal Units and Intelligent Electronic Devices in a Substation.

The DNP User's Group maintains and publishes DNP standards. See the DNP User's Group website, www.dnp.org, for more information on DNP standards, implementers of DNP, and tools for working with DNP.

DNP3 Specifications

DNP3 is a protocol with many features and many ways to accomplish tasks. DNP3 is defined in a series of specifications known as the Basic 4. A companion specification called the Subset Definitions simplifies DNP3 implementation by providing three standard interoperable implementation levels. The levels are listed in *Table E.1*.

Table E.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

Each level is a proper superset of the next lower-numbered level. A higher subset level device can act as a master to a lower subset level device. For example, a typical SCADA master is a Level 3 device and can poll a Level 2 or Level 1 device by using only the data types and functions that the lower-level device uses. A lower-level device can also poll a higher-level device. For example, a Level 1 device can poll a Level 3 device, but the Level 1 device can only access the features and data available in Level 1.

In addition to the Basic 4 and the Subset Definitions, the protocol is further refined by conformance requirements, optional features, and a series of technical bulletins. The technical bulletins supplement the specifications with discussion and examples of specific features of DNP.

Data Handling

Objects

DNP3 uses a system of data references called objects, which the Basic 4 standard object library defines. Each subset level specification requires a minimum implementation of object types and also recommends several optional object types. Object types are commonly referred to as objects. DNP 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 DNP 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 has three variations: 0, 1, and 2. Use Variation 0 to request the default variation. Variation 1 is used to specify binary input values only and Variation 2 is used 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 DNP message exchanges except unsolicited data. DNP terminology describes all points from the perspective of the master. Binary points for control that move from the master to the remote are called Binary Outputs, while binary status points within the remote are called Binary Inputs.

Function Codes

Each DNP message includes a function code. Each object has a limited set of function codes that a master may 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 E.2*.

Table E.2 Selected DNP3 Function Codes

Function Code	Function	Description
1	Read	Request data from the remote
2	Write	Send data to the remote
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. DNP masters use qualifier codes to compose the shortest, most concise message possible when requesting points from a DNP remote.

For example, the qualifier code 01 specifies that the request for points will include 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, that specifies points in the range 4 to 16.

Access Methods

DNP has many features that help it obtain maximum possible message efficiency. Requests are sent with the least number of bytes using special objects, variations, and qualifiers that reduce the message size. Other features eliminate the continual exchange of data values that are not changing. These features optimize use of bandwidth and maximize performance over any speed connection.

DNP event data collection eliminates the need to use bandwidth to transmit values that have not changed. Event data are records of when observed measurements changed. For binary points, the remote device (DNP slave) logs changes from logical 1 to logical 0 and from logical 0 to logical 1. For analog points, the remote device logs changes that exceed a dead band. DNP remote devices collect event data in a buffer that the master can either request or the relay can send to the master without a request message. Data sent from the remote to the master without a polling request are called unsolicited data.

DNP 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 remotes 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.

DNP also supports static polling, simple polling of the present value of data points within the remote. By combining event data, unsolicited polling, and static polling, you can operate your system in one of the four access methods shown in *Table E.3*.

The access methods listed in *Table E.3* are in order of increasing communication efficiency. With various tradeoffs, each method is less demanding of communication bandwidth than the previous one. For example, unsolicited report-by-exception consumes less communication bandwidth because of the elimination of polling messages from the master required by polled report-by-exception. You must also consider overall system size and the volume of data communication expected in order to properly evaluate which access method provides optimum performance for your application.

Table E.3 DNP 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	Remote 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

DNP masters use Object 12 control relay output block to perform DNP binary control operations. The control relay output block has both a trip/close selection and a code selection. The trip/close selection allows a single DNP 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 DNP master implementations.

The control relay output block code selection specifies either a latch or pulse operation on the point. In many cases, DNP remotes have only a limited subset of the possible combinations of the code field. Sometimes, DNP remotes assign special operation characteristics to the latch and pulse selections. *Table E.16* and *Table E.17* describe control point operation for the SEL-651R.

Conformance Testing

In addition to the protocol specifications, the DNP User's 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 remote will be fully interoperable (work together properly for all implemented features). Conformance testing does help to standardize the testing procedure and move the DNP implementers toward a higher level of interoperability. The SEL-651R is certified as having passed DNP3 Level 2 Slave conformance tests by a third-party organization, and the conformance certificate is on file at SEL and listed on the DNP User's Group website (www.dnp.org).

Data Link Layer Operation

DNP employs a three-layer version of the seven-layer OSI (Open Systems Interconnect) 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 DNP device. While this feature helps you recognize a failed device or failed communications link quickly, it also adds significant overhead to the DNP conversation. Consider for your individual application whether you require this link integrity function at the expense of overall system speed and performance.

The DNP 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 will reduce connection throughput further, possibly preventing the system from operating properly.

Network Medium Contention

When more than one device requires access to a single 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 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 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 due to data collisions.

DNP3 in the SEL-651R

The SEL-651R is a DNP3 Level 2 remote (slave) device. Additional implementation documentation describing DNP in the relay is in *DNP3 Communications on page E.1*.

Data Access

NOTE: Because unsolicited messaging only operates properly in some situations, for maximum performance and minimum risk of configuration problems, use the polled report-by-exception access method. Configure the master to perform at least 10 event polls for every integrity poll.

You can use any of the data access methods listed in *Table E.4*. *Table E.4* also lists the SEL-651R DNP3 settings. You must configure the DNP master for the data access method you select.

Table E.4 DNP Access Methods

Access Method	Master Polling	SEL-651R Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECL-ASSA, ECLASSV to 0; UNSOL to No
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLASSC, ECL-ASSA, ECLASSV to the desired event class; UNSOL to No
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently; mainly relies on unsolicited messages	Set ECLASSB, ECLASSC, ECL-ASSA, ECLASSV to the desired event class; set UNSOL to Yes and PUNSOL to Yes or No
Quiescent	Class 0, 1, 2, 3 never; relies completely on unsolicited messages	Set ECLASSB, ECLASSC, ECL-ASSA, ECLASSV to the desired event class; set UNSOL and PUN-SOL to Yes.

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table E.4*, you must make a selection for the PUNSOL setting. This setting enables or disables unsolicited data reporting at power up. If your master can send the DNP message to enable unsolicited reporting from the SEL-651R, you should set PUNSOL to No.

While automatic unsolicited data transmission on power up is convenient, problems can result if your 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 relay will resend the data until it is acknowledged. On a large system, or in systems where the processing power of the master is limited, you may have problems when several relays simultaneously begin sending data and waiting for acknowledgement messages.

The SEL-651R 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 *Configurable Data Mapping on page E.11*). 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 (NUMEVE1 and AGEEVE1 settings) so that changes to these points will be sent to the master quickly. You might then place low priority data in event class 2 with higher thresholds.

If the SEL-651R does not receive an Application Confirm in response to unsolicited data, it will wait for ETIMEO seconds and then repeat the unsolicited message. In order to prevent clogging of the network with unsolicited data retries, the SEL-651R uses the URETRY and UTIMEO settings to increase retry time when the number of retries set in URETRY is exceeded. After URETRY has been exceeded, the SEL-651R pauses UTIMEO seconds and then transmits the unsolicited data again. *Figure E.1* provides an example with URETRY = 2.

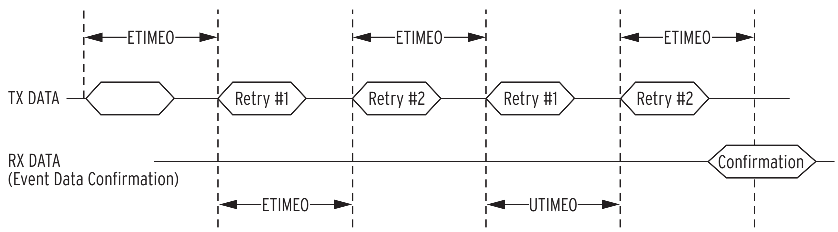

Figure E.1 Application Confirmation Timing With URETRY = 2

When UTIMEO is set to OFF the SEL-651R hangs-up the phone and re-dials instead of extending the delay to UTIMEO seconds. If the SEL-651R does not receive an Application Confirm in response to unsolicited data, it will wait for ETIMEO seconds and then repeat the unsolicited message. When the number of retries exceeds URETRY, the SEL-651R will hang-up the phone and wait 10 • ETIMEO seconds, then it will redial a phone number. When PH_NUM1 and PH_NUM2 are both populated, the SEL-651R will alternate between the two phone numbers each time it redials, otherwise it will redial PH_NUM1.

Collision Avoidance

If your application uses unsolicited reporting, 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.

The relay 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-651R pauses for a random delay between the settings MAXDLY and MINDLY when it detects a carrier through data on the receive line or the CTS pin. If you use the settings of 0.10 seconds for MAXDLY and 0.05 seconds for MINDLY, the SEL-651R will insert a random delay of 50 to 100 ms (milliseconds) between the end of carrier detection and the start of data transmission (see *Figure E.2*).

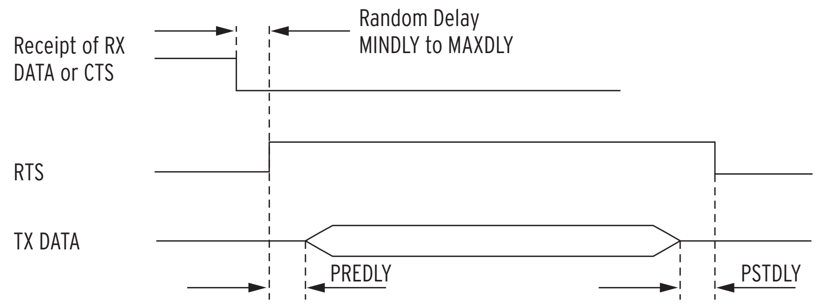

Figure E.2 Message Transmission Timing

Transmission Control

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 PREDLY and POSTDLY settings to provide a delay between RTS signal control and data transmission (see *Figure E.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 will avoid data loss resulting from data transmission beginning at the same time as RTS signal assertion.

Event Data

DNP event data objects contain change-of-state and time-stamp information that the SEL-651R collects and stores in a buffer. You can configure the SEL-651R 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 ECLASSB, ECLASSC, ECLASSA, and ECLASSV you can set the event class for binary, counter, analog and virtual terminal. You can use the classes as a simple priority system for collecting event data. The relay does not treat data of different classes differently with respect to message scanning, but the relay does allow the master to perform independent class polls.

NOTE: Most RTUs that act as substation DNP masters perform an event poll that collects event data of all classes simultaneously. Confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the SEL-651R.

For event data collection you must also consider and enter appropriate settings for dead band and scaling operation on analog points shown in *Table E.6*. You can either set and use default dead band and scaling according to data type or use a custom data map to select dead bands on a point-by-point basis. See *Configurable Data Mapping on page E.11* for a discussion of how to set scaling and dead-band operation on a point-by-point basis. Dead bands for analog inputs can be modified at run-time by writing to object 34.

The settings ANADBA, ANADBV, and ANADBM control default dead-band operation for the specified data type. Because DNP 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 13. 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.

Set the default analog value scaling with the DECPLA, DECPLV, and DECPLM settings. Application of event reporting dead bands occurs after scaling in the DECPLA, DECPLV, and DECPLM. For example, if you set

DECPLA to 2 and ANADBA 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 relay to report a new event value.

The relay uses the NUMEVE*n* and AGEEVE*n* settings to decide when to send unsolicited data to the master. The relay sends an unsolicited report when the total number of events accumulated in the event buffer for class *n* reaches NUMEVE*n*. The relay also sends an unsolicited report if the age of the oldest event in the class *n* buffer exceeds AGEEVE*n*. The SEL-651R has the buffer capacities listed in *Table E.5*.

Table E.5 SEL-651R Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	256
Counters	128

All event data, whether sent unsolicited or in response to a class poll, must be confirmed by the master within Port Setting ETIMEO amount of time. The ETIMEO timer begins at the transmission of the event from the SEL-651R, so the setting should be long enough to account for the data transmission as well as the response from the master. Otherwise, a new class poll will repeat the event data as if it had not received a confirmation message.

Binary Controls

The SEL-651R provides more than one way to control individual points within the relay. The relay maps incoming control points either to remote bits within the relay or to internal command bits that cause circuit breaker operations. *Table E.16* and *Table E.17* list control points and control methods available in the SEL-651R.

A DNP technical bulletin *(Control Relay Output Block Minimum Implementation 9701-002)* recommends that you use one point per Object 12, control block output relay. 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 DNP message to specify operation of the points shown in *Control Point Operation on page E.30*.

Time Synchronization

The accuracy of DNP time synchronization is insufficient for most protection and oscillography needs. DNP time synchronization provides backup time synchronization in the event the relay loses primary synchronization through the IRIG-B input. Enable time synchronization with the TIMERQ setting and use Object 50, Variation 1, and Object 52, Variation 2, to set the time via a DNP master.

By default, the SEL-651R accepts and ignores time set requests (TIMERQ=I). (This mode allows the SEL-651R to use a high accuracy, IRIG, time source, but still interoperate with DNP masters that send time synchronization messages.) It can be set to request time synchronization periodically by setting the TIMERQ setting to the desired period. It can also be set to not request, but accept time synchronization (TIMERQ=M).

Modem Support

The SEL-651R DNP implementation includes modem support. Your DNP master can dial-in to the SEL-651R and establish a DNP3 connection. The SEL-651R can automatically dial out and deliver unsolicited DNP event data. When the relay dials out, it waits for the "CONNECT" message from the local modem and for assertion of the relay CTS line before continuing the DNP transaction. This requires a connection from the modem DCD to the relay CTS line.

NOTE: Contact SEL for information on serial cable configurations and requirements for connecting your SEL-651R to other devices.

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.

Either connect the modem to a computer and configure it before connecting it to the relay, or program the appropriate modem setup string in the modem startup string setting MSTR. Use the PH_NUM1 setting to set the phone number that you want the relay to call. The relay automatically will send the ATDT modem dial command and then the contents of the PH_NUM1 setting when dialing the modem. PH_NUM1 is a text setting that must conform to the AT modem command set dialing string standard. Use a comma (,) for a pause of four seconds. You may need to include a nine to reach an outside line or a one if the number requires long distance access. You can also insert other special codes your telephone service provider designates for block call waiting and other telephone line features.

The SEL-651R supports the use of two phone numbers for its modem support. This can be extremely useful where a communications link is unreliable, or is likely to become very congested (i.e., many devices reporting to the same phone number). If the second phone number is enabled, the SEL-651R will attempt to make a connection on the primary phone number (PH_NUM1). If the connection attempt is unsuccessful, the SEL-651R will retry for a set number of times (RETRY1). If no connection is accomplished within the set number of retries, the control will then attempt to connect via the second phone number (PH_NUM2). Connection via the second phone number (PH_NUM2) will be attempted for a set number of retries (RETRY2). If, after the set number of retries, no connection has been made, the SEL-651R will revert to the first phone number (PH_NUM1), and the process will repeat. When PH_NUM2 is set to OFF, the SEL-651R will continue connection attempts using the first phone number (PH_NUM1).

DNP Settings

The DNP protocol settings that become available when you select DNP on a serial port are shown in *Table E.6*. The DNP protocol settings are in the port settings for the port that you select for the DNP protocol. You can use DNP on serial ports, Port 1–Port 3, but you can only enable DNP on one port at a time.

Table E.6 SEL-651R Port DNP Protocol Settings (Sheet 1 of 3)

Name	Description	Range	Default
DNPADR	DNP address	0–65534	0
REPADR	DNP address to which the relay reports unsolicited data	0–65534	1
ECLASSB	Class for binary event data	0–3	1
ECLASSC	Class for counter event data	0–3	OFF
ECLASSA	Class for analog event data	0–3	2
ECLASSV	Class for virtual terminal response data	0–3	3
DECPLA	Current value scaling	0–3	1
DECPLV	Voltage value scaling	0–3	1
DECPLM	Miscellaneous data scaling	0–3	1
TIMERQ	Time-set request interval	I, M, 1–32767	I
STIMEO	Select/operate time-out	0.0–60.0 seconds	1.0

Table E.6 SEL-651R Port DNP Protocol Settings (Sheet 2 of 3)

Name	Description	Range	Default
DRETRY	Data link retries	OFF, 1–15	OFF
DTIMEO	Data link time-out; hidden	0.0–5.0 seconds	1.0
MINDLY	Minimum delay from DCD to TX	0.00–1.00 seconds	0.05
MAXDLY	Maximum delay from DCD to TX	0.00–1.00 seconds	0.10
PREDLY	Settle time from RTS on to TX; Off disables PSTDLY	OFF, 0.00–30.00 seconds	0.00
PSTDLY	Settle time from TX to RTS off; hidden if PREDLY set to Off	0.00–30.00 seconds	0.00
ANADBA	Analog reporting dead band for current	0–32767	100
ANADBV	Analog reporting dead band for voltages	0–32767	100
ANADBM	Analog reporting dead band for miscellaneous analogs	0–32767	100
EVELOCK	Event summary lock period	0–1000 seconds	0
ETIMEO	Event data confirmation time-out	1–50 seconds	5
UNSOL	Enable unsolicited reporting; hidden and set to N if ECLASSB, ECLASSC, ECLASSA, and ECLASSV set to Off	Y, N	N
PUNSOL	Enable unsolicited reporting at power up; hidden if UNSOL set to N	Y, N	N
NUMEVE1	Number of Class 1 Events to Transmit On	1–200	10
AGEEVE1	Oldest Class 1 Event to Tx On	0.0–99999.0 seconds	2.0
NUMEVE2	Number of Class 2 Events to Transmit On	1–200	10
AGEEVE2	Oldest Class 2 Event to Tx On	0.0–99999.0 seconds	2.0
NUMEVE3	Number of Class 3 Events to Transmit On	1–200	10
AGEEVE3	Oldest Class 3 Event to Tx On	0.0–99999.0 seconds	2.0
URETRY	Maximum number of retries before changing the retry period to UTIMEO.	2–10	3
UTIMEO	Period at which to retry unsolicited responses after URETRY attempts.	1–5000	60
MODEM	Modem connected to port	Y, N	N
MSTR	Modem startup string; hidden if MODEM set to N	Up to 30 characters	"E0X0& D0S0=4"
PH_NUM1	Phone number 1 for unsolicited reporting dial-out; hidden if MODEM set to N or UNSOL set to N	Up to 30 characters	""
PH_NUM2	Phone number 2 for unsolicited reporting dial-out; hidden if MODEM set to N or UNSOL set to N	Up to 30 characters	""
RETRY1	Retry attempts for Phone Number 1 dial-out	1–20	5
RETRY2	Retry attempts for Phone Number 2 dial-out	1–20	5

Table E.6 SEL-651R Port DNP Protocol Settings (Sheet 3 of 3)

Name	Description	Range	Default
MDTIME	Time to attempt dial	5–300 seconds	60
MDRET	Time between dial-out attempts	5–3600 seconds	120

Configurable Data Mapping

One of the most powerful features of the SEL-651R implementation is the ability to remap DNP data with per-point scaling and dead bands. Remapping is the process of selecting data from the reference map and organizing it into a smaller data set optimized for your application. The default map is an optimized map.

Use the **DNP** command to view or change the DNP data map settings shown in *Table E.7*.

Table E.7 SEL-651R DNP Map Settings

Name	Description	Range	Default
Binary Inputs	Enter Off, Default Map, or a list of indices for the binary inputs (1 & 2)	Off, Index List Default Map	Default Map
Binary Outputs	Enter Off, Default Map, or a list of indices for the binary outputs (10 & 12)	Off, Index List Default Map	Default Map
Counters	Enter Off, Default Map, or a list of indices for the counters (20 & 22)	Off, Index List Default Map	Default Map
Analog Inputs	Enter Off, Default Map, or a list of indices for the analog inputs (30 & 32)	Off, Index List Default Map	Default Map
Analog Outputs	Enter Off, Default Map, or a list of indices for the analog outputs (40 & 41)	Off, Index List Default Map	Default Map

View all DNP maps in terms of reference map indices by entering **DNP <Enter>** as shown in *Figure E.3*.

```
=>>DNP <Enter>
Binary Inputs = 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26  \
                27 28 29 30 31 173 174 175 344 345 346 347 348 349 350 351  \
                352 353 354 355 356 357 358 359 361 362 375 377 408 409  \
                410 411 412 413 414 415 416 417 418 419 420 421 422 423  \
                424 425 426 427 428 429 430 431 432 433 434 435 436 437  \
                438 439 662 663 1616 1617 1618 1619 1636 1637 1638 1639  \
                1640 1641 1642 1643
Binary Outputs = 0 1 2 3 4 5 6 7 8 0 10 11 12 13 14 15 16 17 40
Counters = 0:1 1:1 2:1 3:1 4:1 5:1 6:1 7:1
Analog Inputs = 0 2 4 6 34 36 38 40 42 44 46 87 91 95 104 105 112 113 120  \
                121 166 167 168
Analog Outputs = 0

=>>
```

Figure E.3 DNP Command

Scaling factors allow you to overcome the limitations imposed by the integer nature of Objects 30 and 32. For example, the relay rounds a value of 11.4 amps to 11 amps. Use the scaling to include decimal point values by multiplying by a number larger than one. If you use 10 as a scaling factor, 11.4 amps will be transmitted as 114. You must divide the value by 10 in the master device 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. If you have a value that can reach 157834 you cannot send it using DNP 16-bit analog object variations. Use a scaling factor of 0.1 so that the maximum value reported is 15783. You must multiply the value by 10 in the master to see a value of 157830. You will lose some precision as the last digit is rounded in the scaling process, but you can transmit the scaled value using standard DNP Objects 30 and 32.

Change the DNP analog input map with per-point scaling, dead band, and class by entering **DNP AI <Enter>**. The semicolon (;) is used as a scaling prefix, the colon (:) is used as a dead-band prefix, and C is used as a class prefix. Per-point scaling, dead-band, and class entries are not required. Class scaling (DECPLA, DECPLV, and DECPLM), dead-band (ANADBA, ANADBV, and ANADBM), and class (ECLASSA) settings are applied to all indices that do not have per-point entries. Unlike the per-point scaling, described above, the class-level scaling is defined in terms of decimal place shifts. This means, select 0 to multiply by 1, 1 for 10, 2 for 100, or 3 for 1000. The backward slash (\) is used to continue entries that take more than one line. An example of entering a new map with per-point scaling, dead bands, and classes is shown in *Figure E.4*.

If it is important to you that tight data coherency be maintained (i.e., all data read of a certain type was sampled or calculated at the same time) then you should group this data together within your custom map. For example, if you want all the currents to be coherent, you should group points 0, 2, 4, and 6 together in the custom map. If points are not grouped together, they might not come from the same data sample.

Consider a case where you want to set the map as shown in the following table.

Desired Point Index	Description	Ref. Point Index (from Table E.12)	Scaling	Deadband	Event Class
0	IA magnitude	0	default	default	default
1	IB magnitude	2	default	default	default
2	IC magnitude	4	default	default	default
3	IN magnitude	6	default	default	none
4	Three-phase MWHr in	112	5	default	default
5	A-phase Demand MW in	128	0.2	default	2
6	B-phase MVARhr out	117	default	10	default
7	IA angle	1	1	15	3

To set-up this map, use the **DNP AI** command as shown below.

```
=>>DNP AI <Enter>

Enter the new DNP Analog Input map
0 2 4 6C0 112;5 128;0.2C2 117:10 1;1:15C3 <Enter>

=>>
```

Figure E.4 DNP AI Command

Use the **DNP BO** command to change the binary output map as shown in *Figure E.5*. **DNP AO** and **DNP BI** operate in a similar manner, but you can use per-point classes with DNP BI.

```
=>>DNP BO <Enter>

Enter the new DNP Binary Output map
0 1 2 3 4 5 6 7 <Enter>

Save Changes (Y/N)? Y <Enter>

=>>
```

Figure E.5 DNP BO Command

Change the DNP counter map with per-point dead bands and classes by entering **DNP C <Enter>**. These settings are entered in a manner similar to entering analog input settings.

Testing

Use the **TEST DNP** command to test the data mapping from the relay to your DNP master. You can use the **TEST DNP** command to force DNP values by object and index number. Although the relay reports forced values to the DNP host, these values do not affect protection processing or other protocol interfaces on the SEL-651R. The **TEST DNP** command operates by object and index number, so it works equally well with custom mapping and the default DNP map.

When you are using the **TEST DNP** command to test DNP operation, the Relay Word bit TESTDNP will be asserted to indicate that test mode is active. The DNP status bit will also show forced status for any object variations that include status.

Troubleshooting

The SEL-651R tracks DNP communications operations and makes them available through the STA D report and the front-panel. You can use this information to check many aspects of DNP operation.

If you suspect that there is a problem getting information from a DNP master to the SEL-651R, check the receive portion of the DNP communications statistics. The date and time of the last received message will give you an indication of the last time a message was successfully received by the SEL-651R. You can also watch the byte, frame, and fragment counters to see that they are increasing as data are received. If these receipt statistics are not as you expect, then there is probably some problem in the communication media from the master to the SEL-651R, or in the configuration of the master or the SEL-651R.

If you determine that the SEL-651R is receiving messages, but you suspect that messages are not coming back to your master, check the send portion of the DNP communications statistics. From these you can tell when the SEL-651R last transmitted and also see how many bytes, frames, and fragments it is transmitting, over time. If these appear reasonable, but your master is not receiving messages, there is probably a problem in the communication media from the SEL-651R to the master, or in the configuration of the master or the SEL-651R.

DNP3 Documentation

Device Profile

Table E.8 contains the standard DNP3 device profile information. Rather than checkboxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

Table E.8 SEL-651R DNP3 Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-651R Recloser Control
Highest DNP request level	Level 2
Highest DNP response level	Level 2
Device function	Slave
Notable objects, functions, and/or qualifiers supported	Virtual Terminal, Analog Dead-band Objects (object 34)
Maximum data link frame size transmitted/received (octets)	292
Maximum data link retries	Configurable, range 0–15
Requires data link layer confirmation	Configurable by setting
Maximum application fragment size transmitted/received (octets)	2048
Maximum application layer retries	None
Requires application layer confirmation	When reporting Event Data
Data link confirm time-out	Configurable
Complete application fragment time-out	None
Application confirm time-out	Configurable
Complete Application response time-out	None
Executes control WRITE binary outputs	Always
Executes control SELECT/OPERATE	Always
Executes control DIRECT OPERATE	Always
Executes control DIRECT OPERATE-NO ACK	Always
Executes control count greater than 1	Never
Executes control Pulse On	Always
Executes control Pulse Off	Always
Executes control Latch Off	Always
Executes control Latch Off	Always
Executes control Queue	Never
Executes control Clear Queue	Never
Reports binary input change events when no specific variation requested	Only time-tagged
Reports time-tagged binary input change events when no specific variation requested	Binary Input change with time
Sends unsolicited responses	Configurable with unsolicited message enable settings. Increases retry time (configurable) when a maximum retry setting is exceeded.

Table E.8 SEL-651R DNP3 Device Profile (Sheet 2 of 2)

Parameter	Value
Sends static data in unsolicited responses	Never
Default counter object/variation	Object 20, Variation 6
Counter roll-over	16 bits
Sends multifragment responses	No

In response to the delay measurement function code, the SEL-651R will return a time delay accurate to within 20 milliseconds.

Object List

Table E.9 lists the objects and variations with supported function codes and qualifier codes available in the SEL-651R. The list of supported objects conforms to the format laid out in the DNP specifications and includes both supported and unsupported objects. 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 E.9 SEL-651R DNP 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]
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				
12	3	Pattern Mask				
20	0	Binary Counter—All Variations	1	0, 1, 6, 7, 8, 17, 28		
20	1	32-Bit Binary Counter				
20	2	16-Bit Binary Counter				

Table E.9 SEL-651R DNP Object List (Sheet 2 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	6[e]	16-Bit Binary Counter Without Flag	1	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				
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				

Table E.9 SEL-651R DNP 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]
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 Frozen Delta Counter Event With Time				
23	8	16-Bit Frozen Delta Counter Event With Time				
30	0	Analog Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
30	1	32-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	2	16-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	4[e]	16-Bit Analog Input Without Flag	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				

Table E.9 SEL-651R DNP Object List (Sheet 4 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
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				
31	5	32-Bit Frozen Analog Input Without Flag				
31	6	16-Bit Frozen Analog Input Without Flag				
32	0	Analog Change Event—All Variations	1	6, 7, 8		
32	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32	2[e]	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28
32	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	4	16-Bit 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				
34	1	32-Bit Analog Dead-Band Setting	1, 2	0, 1, 6, 7, 8, 17, 28		0, 1, 17, 28
34	2	16-Bit Analog Dead-Band Setting	1, 2	0, 1, 6, 7, 8, 17, 28		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
41	0	Analog Output Block—All Variations				
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request

NOTE: In installations where a DNP Master is communicating via Ethernet and an Ethernet-to-serial conversion occurs to the SEL-651R, the master may attempt to set time with an Object 50 Variation 3 Last Recorded Time. The SEL-651R does not support Variation 2 or Variation 3. Ensure that the DNP Master sends Variation 0 or Variation 1 to write the Date and Time.

Table E.9 SEL-651R DNP 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]
41	2	16-Bit 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
50	2	Time and Date With Interval				
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO	07, quantity=1			
52	0	Time Delay—All Variations				
52	1	Time Delay, Coarse				
52	2	Time Delay, Fine	129	07, quantity=1		
60	0	All Classes of Data	1, 20, 21	6		
60	1	Class 0 Data	1	6	129	0, 1
60	2	Class 1 Data	1, 20, 21	6, 7, 8	129	17, 28
60	3	Class 2 Data	1, 20, 21	6, 7, 8	129	17, 28
60	4	Class 3 Data	1, 20, 21	6, 7, 8	129	17, 28
70	1	File Identifier				
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				
112	all	Virtual Terminal Output Block	2	6	129	

Table E.9 SEL-651R DNP 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	1	6	129, 130	17, 28
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

Table E.10 lists the amount of event data the SEL-651R can store. If more events occur than these limits, then some event data will be lost.

Table E.10 Event Data Buffer Limits

Event Data Type	Maximum Number of Events
Binary Inputs (object 2)	1024
Counter (object 22)	128
Analog Inputs (object 32)	256
Virtual Terminal (object 113)	30

Default Data Map

NOTE: Dead-band changes via Object 34 are stored in nonvolatile memory. Make sure to reissue the Object 34 dead bands after a warm (**HIS C**) or cold start (power cycle).

Table E.11 shows the SEL-651R default data map. The default map is a subset of the reference map to reduce the response time. Use the custom DNP mapping functions to create the map required for your application.

Table E.11 SEL-651R DNP3 Default Data Map (Sheet 1 of 2)

Object	Default Index	Reference Index	Description
01,02			Relay Word bits, see *Table F.1* and *Table F.2*.
01,02	00–01	006–007	EN, TRIPLED
01,02	02–25	008–031	TLED_01–TLED_24
01,02	26–29	151–148	52AA, 52AB, 52AC, 52A3P
01,02	30–34	311, 305, 308, 307, 318	PWR_SRC1, BTFAIL, CHRGG, DISCHG, TCCAP
01,02	35–46	288–293, 296–301	PB01_LED–PB12_LED
01,02	47–78	344–375	LT01–LT32
01,02	79–80	639, 638	SALARM, HALARM
01,02	81–83	1616–1618	Diagnostics
10,12	00–15	00–15	Remote bits RB01–RB16.
10,12	16	16	Pulse Open Breaker OC3 (3 pole)
10,12	17	17	Pulse Close Breaker CC3 (3 pole)

Table E.11 SEL-651R DNP3 Default Data Map (Sheet 2 of 2)

Object	Default Index	Reference Index	Description
10,12	18	40	Reset front panel targets
20,22	00	00	Active settings group (Read)
20,22	01	01	Internal breaker trips—Phase A
20,22	02	02	Internal breaker trips—Phase B
20,22	03	03	Internal breaker trips—Phase C
20,22	04	04	External breaker trips—Phase A
20,22	05	05	External breaker trips—Phase B
20,22	06	06	External breaker trips—Phase C
20,22	07	07	Reserved
30,32,34	00	00	IA magnitude
30,32,34	01	02	IB magnitude
30,32,34	02	04	IC magnitude
30,32,34	03	06	IN magnitude
30,32,34	04	34	IG [IN or 3I0] magnitude
30,32,34	05	36	VAY magnitude (kV)
30,32,34	06	38	VBY magnitude (kV)
30,32,34	07	40	VCY magnitude (kV)
30,32,34	08	42	VAZ magnitude (kV)
30,32,34	09	44	VBZ magnitude (kV)
30,32,34	10	46	VCZ magnitude (kV)
30,32,34	11	87	MW three-phase
30,32,34	12	91	MVAR three-phase
30,32,34	13	95	Power factor three-phase
30,32,34	14	104	Frequency (In 1/100ths of a hertz)
30,32,34	15	105	Temperature (In 1/100ths of a degree C)
30,32,34	16,17	112,113	Energy—three-phase MWhr in and out
30,32,34	18,19	120,121	Energy—three-phase MVARhr in and out
30,32,34	20–22	166–168	Breaker Contact Wear percentage—Phase A, Phase B, Phase C

Reference Data Map

Table E.12 shows the SEL-651R reference data map. The reference map makes a wide range of data in the relay available. If your DNP3 master does Class 0 polls (polls of all present value points), a reference map response will be quite large. Use the default map or use the custom DNP mapping functions of the SEL-651R to reduce the data map to the points that your application requires.

NOTE: Dead-band changes via Object 34 are stored in nonvolatile memory. Make sure to reissue the Object 34 dead bands after a warm (**STA C**) or cold start (power cycle).

The relay scales analog values by the indicated settings or fixed scaling indicated in the description. Analog dead bands for event reporting use the indicated settings, or ANADBM if you have specified no setting.

Table E.12 DNP3 Reference Data Map (Sheet 1 of 6)

Object	Index	Description
01,02	000–799 (000–999 for SEL-651R-1 only)	Relay Word bits; *Table F.1*.
	800–999 (1000–1199 for SEL-651R-1 only)	SER indices are derived from SER trigger settings SER1 through SER4. These indices are consecutively numbered based on actual elements within SER1 and continuing with actual elements within SER2, SER3, and SER4. For example, if SER1 has 4 elements, SER2 has 3 elements, SER3 has 2 elements, and SER4 has 1 element the indices would be as follows with an offset of 800 (1000 for SEL-651R-1 only): 00 — SER1, element 1 01 — SER1, element 2 02 — SER1, element 3 03 — SER1, element 4 04 — SER2, element 1 05 — SER2, element 2 06 — SER2, element 3 07 — SER3, element 1 08 — SER3, element 2 09 — SER4, element 1
01,02	1200–1599	Reserved
01,02	1600–1615	Relay front panel targets; product specific meaning
01,02	1616	Relay disabled
01,02	1617	Relay diagnostic failure
01,02	1618	Relay diagnostic warning
01,02	1619	Unread event available
01,02	1620	Settings change or relay restart
01,02	1621–1623	Reserved for future status points
01,02	1624–1631	Reserved
01,02	1632–1635	Power factor leading for A, B, C, and three-phase
01,02	1636–1643	Relay front panel targets (17–24); product specific meaning
01,02	1644	Reserved
10,12	00–15	Remote bits RB01–RB16
10,12	16	Pulse Open Breaker OC3 (Breaker 1, 3 pole)
10,12	17	Pulse Close Breaker CC3 (Breaker 1, 3 pole)
10,12	18	Pulse Open command OCA (Breaker 1 Phase A)
10,12	19	Pulse Close command CCA (Breaker 1 Phase A)
10,12	20	Pulse Open command OCB (Breaker 1 Phase B)
10,12	21	Pulse Close command CCB (Breaker 1 Phase B)
10,12	22	Pulse Open command OCC (Breaker 1 Phase C)
10,12	23	Pulse Close command CCC (Breaker 1 Phase C)
10,12	24–31	Remote bit pairs RB01–RB16
10,12	32	Open/Close pair OC3 & CC3 (Breaker 1, 3 pole)
10,12	33	Open/Close pair OCA & CCA (Breaker 1, Phase A)

NOTE: Object 12 Trip/Close pair operation is shown in Table E.16 and code selection operation is shown in Table E.17.

Table E.12 DNP3 Reference Data Map (Sheet 2 of 6)

Object	Index	Description
10,12	34	Open/Close pair OCB & CCB (Breaker 1, Phase B)
10,12	35	Open/Close pair OCC & CCC (Breaker 1, Phase C)
10,12	36	Reset demands
10,12	37	Reset demand peaks
10,12	38	Reset energies
10,12	39	Reset breaker monitor
10,12	40	Reset front panel targets
10,12	41	Single-Event Summary
10,12	42	Reset min/max metering
10,12	43	Reserved
10,12	44–59	Remote bits RB17–RB32
10,12	60–67	Remote bit pairs RB17–RB32
10,12	68	Load next event
20,22	00	Active settings group (Read)
20,22	01	Internal breaker trips—Phase A
20,22	02	Internal breaker trips—Phase B
20,22	03	Internal breaker trips—Phase C
20,22	04	External breaker trips—Phase A
20,22	05	External breaker trips—Phase B
20,22	06	External breaker trips—Phase C
20,22	07–10	Reserved
20,22	11–26	SELOGIC counters 1–16
30,32,34	00,01[a]	IA magnitude and angle
30,32,34	02,03[a]	IB magnitude and angle
30,32,34	04,05[a]	IC magnitude and angle
30,32,34	06,07[a]	IN magnitude and angle
30,32,34	08–33	Reserved
30,32,34	34, 35[a]	IG [IN or 3I0] magnitude and angle
30,32,34	36,37[b]	VAY magnitude (kV) and angle
30,32,34	38,39[b]	VBY magnitude (kV) and angle
30,32,34	40,41[b]	VCY magnitude (kV) and angle
30,32,34	42,43[b]	VAZ magnitude (kV) and angle
30,32,34	44,45[b]	VBZ magnitude (kV) and angle
30,32,34	46,47[b]	VCZ magnitude (kV) and angle
30,32,34	48,49[a]	3I0 magnitude and angle
30,32,34	50,51[a]	I1 magnitude and angle
30,32,34	52,53[a]	3I2 magnitude and angle
30,32,34	54–71	Reserved
30,32,34	72,73[b]	3V0Y magnitude (kV) and angle
30,32,34	74,75[b]	V1Y magnitude (kV) and angle
30,32,34	76,77[b]	V2Y magnitude (kV) and angle

Table E.12 DNP3 Reference Data Map (Sheet 3 of 6)

Object	Index	Description
30,32,34	78,79[b]	3V0Z magnitude (kV) and angle
30,32,34	80,81[b]	V1Z magnitude (kV) and angle
30,32,34	82,83[b]	V2Z magnitude (kV) and angle
30,32,34	84–87[c]	MW A, B, C, and three-phase
30,32,34	88–91[c]	MVAR A, B, C, and three-phase
30,32,34	92–95[c]	Power factor A, B, C, and three-phase
30,32,34	96–103	Reserved
30,32,34	104[c]	Frequency (In 1/100ths of a hertz)
30,32,34	105[c]	Temperature (In 1/100ths of a degree C)
30,32,34	106,107[c]	Energy—A-phase MWhr in and out
30,32,34	108,109[c]	Energy—B-phase MWhr in and out
30,32,34	110,111[c]	Energy—C-phase MWhr in and out
30,32,34	112,113[c]	Energy—three-phase MWhr in and out
30,32,34	114,115[c]	Energy—A-phase MVARhr in and out
30,32,34	116,117[c]	Energy—B-phase MVARhr in and out
30,32,34	118,119[c]	Energy—C-phase MVARhr in and out
30,32,34	120,121[c]	Energy—three-phase MVARhr in and out
30,32,34	122–126[a]	Demand—IA, IB, IC, IG [IN or 3I0], and 3I2 magnitudes
30,32,34	127[a]	Demand—IN magnitude
30,32,34	128–131[c]	Demand—A, B, C, and three-phase demand MW in
30,32,34	132–135[c]	Demand—A, B, C, and three-phase demand MVAR in
30,32,34	136–139[c]	Demand—A, B, C, and three-phase demand MW out
30,32,34	140–143[c]	Demand—A, B, C, and three-phase demand MVAR out
30,32,34	144–148[a]	Peak Demand—IA, IB, IC, IG [IN or 3I0], and 3I2 magnitudes
30,32,34	149[a]	Peak Demand—IN magnitude
30,32,34	150–153[c]	Peak Demand—A, B, C, and three-phase peak demand MW in
30,32,34	154–157[c]	Peak Demand—A, B, C, and three-phase peak demand MVAR in
30,32,34	158–161[c]	Peak Demand—A, B, C, and three-phase peak demand MW out
30,32,34	162–165[c]	Peak Demand—A, B, C, and three-phase peak demand MVAR out
30,32,34	166–168[c]	Breaker Contact Wear percentage—Phase A, Phase B, Phase C
30,32,34	169–175	Reserved for other breaker information
30	176[d]	Fault Type; see *Table E.13* and *Table E.14* for definition
30	177[d]	Fault targets (corresponding to rows 0 and 1 of Relay Word)
30	178[d]	Fault location
30	179	Reserved
30	180[d]	Fault frequency

Table E.12 DNP3 Reference Data Map (Sheet 4 of 6)

Object	Index	Description
30	181[d]	Fault settings group
30	182[d]	Fault recloser shot counter
30	183	Reserved
30	184–186[d]	Fault time in DNP format (high, middle, and low 16 bits)
30	187–190[a]	Fault Current—Phase A, Phase B, Phase C, Ground
30	191[a]	Fault Current—Negative Sequence
30	192[d]	Fault targets (corresponding to rows 2 and 3 of Relay Word)
30	193–195	Reserved for additional fault information
30	196	Reserved
30,32,34	197–200[c]	MVA A, B, C, and three-phase
30,32,34	201–204[c]	Demand—MVA A, B, C, and three-phase
30,32,34	205–208[c]	Peak Demand—MVA A, B, C, and three-phase
30,32,34	209–213[a]	Min—IA, IB, IC, IN, IG [IN or 3I0] magnitudes
30,32,34	214–219[b]	Min—VAY, VBY, VCY, VAZ, VBZ, and VCZ magnitudes (kV)
30,32,34	220–222[c]	Reserved
30,32,34	223[c]	Min—MW three-phase
30,32,34	224–226[c]	Reserved
30,32,34	227[c]	Min—MVAR three-phase
30,32,34	228–230[c]	Reserved
30,32,34	231[c]	Min—MVA three-phase
30,32,34	232–236[a]	Max—IA, IB, IC, IN, IG [IN or 3I0] magnitudes
30,32,34	237–242[b]	Max—VAY, VBY, VCY, VAZ, VBZ, and VCZ magnitudes (kV)
30,32,34	243–245[c]	Reserved
30,32,34	246[c]	Max—MW three-phase
30,32,34	247–249[c]	Reserved
30,32,34	250[c]	Max—MVAR three-phase
30,32,34	251–253[c]	Reserved
30,32,34	254[c]	Max—MVA three-phase
30,32,34	255–258[a]	RMS—IA, IB, IC, IN magnitudes
30,32,34	259–264[b]	RMS—VAY, VBY, VCY, VAZ, VBZ, and VCZ magnitudes (kV)
30,32,34	265–268[c]	RMS—MW A, B, C and three-phase
30,32,34	269–272[c]	Reserved
30,32,34	273–276[c]	Reserved
30,32,34	277–289	Reserved
30,32,34	290–293[a]	THD—IA, IB, IC, IN (percent)
30,32,34	294–299[b]	THD—VAY, VBY, VCY, VAZ, VBZ, and VCZ (percent)
30,32,34	300[a]	Harmonics—IA Fundamental
30,32,34	301–314[c]	Harmonics—IA (2nd ... 15th as percent of fundamental)

Table E.12 DNP3 Reference Data Map (Sheet 5 of 6)

Object	Index	Description
30,32,34	315[a]	Harmonics—IB Fundamental
30,32,34	316–329[c]	Harmonics—IB (2nd ... 15th as percent of fundamental)
30,32,34	330[a]	Harmonics—IC Fundamental
30,32,34	331–344[c]	Harmonics—IC (2nd ... 15th as percent of fundamental)
30,32,34	345[a]	Harmonics—IN Fundamental
30,32,34	346–359[c]	Harmonics—IN (2nd ... 15th as percent of fundamental)
30,32,34	360	Harmonics—Reserved for future
30,32,34	361–374	Harmonics—Reserved for future
30,32,34	375	Harmonics—Reserved for future
30,32,34	376–389	Harmonics—Reserved for future
30,32,34	390[b]	Harmonics—VAY Fundamental (kV)
30,32,34	391–404[c]	Harmonics—VAY (2nd ... 15th as percent of fundamental)
30,32,34	405[b]	Harmonics—VBY Fundamental (kV)
30,32,34	406–419[c]	Harmonics—VBY (2nd ... 15th as percent of fundamental)
30,32,34	420[b]	Harmonics—VCY Fundamental (kV)
30,32,34	421–434[c]	Harmonics—VCY (2nd ... 15th as percent of fundamental)
30,32,34	435[b]	Harmonics—VAZ Fundamental (kV)
30,32,34	436–449[c]	Harmonics—VAZ (2nd ... 15th as percent of fundamental)
30,32,34	450[b]	Harmonics—VBZ Fundamental (kV)
30,32,34	451–464[c]	Harmonics—VBZ (2nd ... 15th as percent of fundamental)
30,32,34	465[b]	Harmonics—VCZ Fundamental (kV)
30,32,34	466–479[c]	Harmonics—VCZ (2nd ... 15th as percent of fundamental)
30,32,34	480[a]	51PJP setting in secondary units
30,32,34	481[a]	51PKP setting in secondary units
30,32,34	482[a]	51G1JP setting in secondary units
30,32,34	483[a]	51G1KP setting in secondary units
30,32,34	484[a]	51G2JP setting in secondary units
30,32,34	485[a]	51G2KP setting in secondary units
30,32,34	486[a]	51QJP setting in secondary units
30,32,34	487[a]	51QKP setting in secondary units
30,32,34	488[a]	51AJP setting in secondary units
30,32,34	489[a]	51AKP setting in secondary units
30,32,34	490[a]	51BJP setting in secondary units
30,32,34	491[a]	51BKP setting in secondary units
30,32,34	492[a]	51CJP setting in secondary units
30,32,34	493[a]	51CKP setting in secondary units
30,32,34	494[c]	+5 Volt Power Supply (PB5_PS)
30,32,34	495[c]	+5 Volt Reg. Power Supply (P5VREG)

Table E.12 DNP3 Reference Data Map (Sheet 6 of 6)

Object	Index	Description
30,32,34	496[c]	–5 Volt Reg. Power Supply (N5VREG)
30,32,34	497[c]	+12 Volt Power Supply (P12VPS)
30,32,34	498[c]	–12 Volt Power Supply (N12VPS)
30,32,34	499[c]	+15 Volt Power Supply (P15VPS)
30,32,34	500[c]	–15 Volt Power Supply (N15VPS)
30,32,34	501[c]	+2.5 Volt Power Supply (2.5VRG)
30,32,34	502[c]	+3.3 Volt Power Supply (3.3VRG)
30,32,34	503[c]	+5 Volt VT/CT Power Supply (P5VTPS)
30,32,34	504[c]	–5 Volt VT/CT Power Supply (N5VTPS)
30,32,34	505[c]	Control Temperature (TEMP)
30,32,34	506[c]	Charger mode (CMODE), see *Table E.15* for definitions
30,32,34	507[c]	Battery voltage (VBAT)
30,32,34	508[c]	Battery current (IBAT)
30,32,34	509[c]	Reserved
30,32,34	510[c]	Input Power Bus Voltage (INPBV)
30,32,34	511[c]	12V AUX Power (12VAUX)
30,32,34	512[c]	Trip/Close Cap. Voltage (TCCAPV)
30,32,34	513–515	Reserved
30,32,34	516–518[a]	Internal Trip Accumulated Current—Phase A, Phase B, Phase C
30,32,34	519–521[a]	External Trip Accumulated Current—Phase A, Phase B, Phase C
30,32,34	522–525[a]	Involved Phase Count—Phase A, Phase B, Phase C, Ground
30,32,34	526	Relay Firmware revision number
30,32,34	527	DNP Client Address (REPADR)
30,32,34	528	Lowest 4 digits of the relay serial number
30,32,34	529	Middle 4 digits of the relay serial number
30,32,34	530	Upper 4 digits of the relay serial number
40,41	00	Active settings group (Write)
50	N/A	Time and date
60	N/A	Class data
80	N/A	Internal indications
112	0	Virtual Terminal Output Block
113	0	Virtual Terminal Event Data

[a] Default current scaling DECPLA on magnitudes and angles multiplied by 100. Dead band ANADBA on magnitudes and ANADBM on angles.
[b] Default voltage scaling DECPLV on magnitudes and angles multiplied by 100. Dead band ANADBV on magnitudes and ANADBM on angles.
[c] Default miscellaneous scaling DECPLM and dead band ANADBM.
[d] No scaling.

The Relay Word bits mapped into Objects 1 and 2 (Indices 000–799 [000–999 for SEL-651R-1]) are shown in *Table F.1*. The table lists eight bits in each row and the index range for each row. To determine the index for a specific point, add the Relay Word bit number (0 to 7) to the first number in the range listed in the first column. For example, the index of TLED_4 is 12 (the bit number, 4, plus the first number in the range, 8).

Use indices 800–999 (1000–1199 for SEL-651R-1) and the corresponding SER settings to track each change of bits in the Relay Word and provide SER quality time stamps via DNP. Event reporting for indices 0–799 (0–999 for SEL-651R-1) uses a slower, less accurate time-stamping mechanism, but this reporting operates for all points within the range without additional configuration.

Fault summary information (Fault Type, Targets, Location, Frequency, Settings Group, and Recloser Shot Counter) are available through Object 30. Any new trip event (TRIPA, TRIPB, TRIPC, or TRIP3P) is latched into these event registers. The event registers will be locked (they will not update) for time EVELOCK. The event registers are cleared by an assertion of the TRGTR Relay Word bit.

Object 30, Fault Type, is a 16-bit composite value, where the upper byte value indicates an event cause as shown in *Table E.13* and the lower byte indicates a fault type as shown in *Table E.14*. Both the upper and lower bytes are a composite sum of the applicable values. For example, an AG fault that causes a trip and an event report would be reported as 0C09x, where the upper byte is a decimal 12 (indicating a trip and event report) and the lower byte is a 9 (indicating an A-phase-to-ground fault).

Table E.13 Object 30, Fault Type Upper Byte—Event Cause

Byte Value	Description
1	Trigger command
4	Trip element
8	Event report element

Table E.14 Object 30, Fault Type Lower Byte—Fault Type

Byte Value	Description
0	Indeterminate
1	A-phase
2	B-phase
4	C-phase
8	Ground

Use *Table E.15* to determine the charger mode (CMODE).

Table E.15 Object 30, CMODE

CMODE Value	Description
0	Shutdown
1	Startup
2	Constant Current Charge
3	Fast Charge
4	Float Charge
5	Discharge
6	Bad Battery

Table E.15 Object 30, CMODE

CMODE Value	Description
7	Capacitor Charging
8	Battery Test

Reading Relay Events

The SEL-651R provides protective relay event history information in one of two modes: Single-Event or Multiple-Event mode. The default mode is Single-Event. The relay will also enter Single-Event mode if a control is sent to the Single-Event binary output point. It will initiate multiple-event mode if a control is sent to a load-event binary output point. Multiple-Event mode supports first-in, first-out (FIFO) and last-in, first-out (LIFO) data access.

Single-Event mode provides the most recent tripping event to the event summary area. In Single-Event mode, any new trip event (TRIPA, TRIPB, TRIPC, or TRIP3P, but not ER and not TRIG) causes event data to be latched into the event registers and made available in the DNP fault summary area (analog points 176 through 195, Table E.12). The relay shall ignore any subsequent events for EVELOCK (port setting) time. The event registers will be cleared on a rising edge of the TRGTR Relay Word bit. The relay element EVELOCK is set when a fault is triggered and reset when EVELOCK time expires.

Multi-Event mode shall be initiated if a Load Event control is operated. In multiple-event mode, an event is loaded into the event registers when a control point is pulsed. The order that events are loaded depends on the binary output point controlled—Load-Event LIFO Mode or Load-Event FIFO Mode.

To use Multiple-Event FIFO Mode, the master should monitor binary input point 1619 (Unread Event Available, *Table E.12*), which will be asserted when there is an unread relay event summary. To read the oldest relay event summary, the master should pulse-on binary output point 68 (Load-Event FIFO Mode, see *Table E.17*). This will load the relay event summary analogs (points 176 through 195, *Table E.12*) with information from the oldest relay event summary, discarding the values from the previous load.

After reading the analogs, the master should again check binary input point 1619, which will be asserted if another unread relay event summary is available. The master should continue to be asserted if another unread relay event summary is available. The master should continue this monitor-pulse on-read events process until binary input point 1619 deasserts. If the master attempts to load values by pulsing binary output point 68 with binary input point 1619 deasserted, the relay event summary analogs (points 176 through 195) will be filled with zeroes. With the FIFO method, the relay event summaries will always be collected in chronological order.

Similarly, to use Multiple-Event LIFO Mode, the master should also monitor binary input point 1619 (Unread Event Available), which will be asserted when there is an unread relay summary. To read the newest relay event summary, the master should pulse-off binary output point 68 (Load-Event LIFO Mode, see *Table E.17*). This will load the relay event summary analogs (points 176 through 195) with information from the newest relay event summary discarding the values from the previous load. After reading the events, the master should check binary input points 1619 and pulse-off binary output point 68, if it is asserted, to read the next newest event. The master should continue to process until binary input point 1619 deasserts. If the master attempts to load values by pulsing binary output point 68 with binary input point 1619 deasserted, the relay event summary analogs (points 176 through 195) will be filled with zeroes. Note that events will be in chronological order if no new events have occurred, the most recent event will always be in the event registers if the load-event control point is pulsed after an event, and events will always be out of order if new events occur before all of the previous events have been read.

Control Point Operation

Use the Trip and Close operations with Object 12 control relay output block command messages to operate the points shown in *Table E.16*. Pulse operations provide a pulse with a duration of one protection processing interval. Because the SEL-651R allows only one control bit to be pulsed at a time, send consecutive control bits in consecutive messages.

Table E.16 Object 12 Trip/Close Pair Operation (Sheet 1 of 2)

Index	Close	Trip
0–15	Set RB01–RB16	Clear RB01–RB16
16	Open OC3	No action
17	Close CC3	No action
18	Open OCA	No action
19	Close CCA	No action
20	Open OCB	No action
21	Close CCB	No action
22	Open OCC	No action
23	Close CCC	No action
24	Pulse RB2	Pulse RB1
25	Pulse RB4	Pulse RB3
26	Pulse RB6	Pulse RB5
27	Pulse RB8	Pulse RB7
28	Pulse RB10	Pulse RB9
29	Pulse RB12	Pulse RB11
30	Pulse RB14	Pulse RB13
31	Pulse RB16	Pulse RB15
32	Pulse CC3,	Pulse OC3
33	Pulse CCA	Pulse OCA
34	Pulse CCB	Pulse OCB
35	Pulse CCC	Pulse OCC
36	Reset demands	Reset demands
37	Reset demand peaks	Reset demand peaks
38	Reset energy metering	Reset energy metering
39	Reset breaker monitor	Reset breaker monitor
40	Reset front panel targets	Reset front panel targets
41	Single-Event	Single-Event
42	Reset min/max metering	Reset min/max metering
43	Reserved	Reserved
44–59	Set RB17–RB32	Clear RB17–RB32
60	Pulse RB18	Pulse RB17

Table E.16 Object 12 Trip/Close Pair Operation (Sheet 2 of 2)

Index	Close	Trip
61	Pulse RB20	Pulse RB19
62	Pulse RB22	Pulse RB21
63	Pulse RB24	Pulse RB23
64	Pulse RB26	Pulse RB25
65	Pulse RB28	Pulse RB27
66	Pulse RB30	Pulse RB29
67	Pulse RB32	Pulse RB31
68	Load-Event FIFO Mode	Load-Event LIFO Mode

The SEL-651R assigns some special operations to the code portion of the control relay output block command. The special operations are shown in *Table E.17*. Pulse operations provide a pulse duration of one protection-processing interval.

Table E.17 Object 12 Code Selection Operation (Sheet 1 of 2)

Index	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
0–15	Set RB01–RB16	Clear RB01–RB16	Pulse RB01–RB16	Clear RB01–RB16
16	Pulse OC3	No action	Pulse OC3	No action
17	Pulse CC3	No action	Pulse CC3	No action
18	Pulse OCA	No action	Pulse OCA	No action
19	Pulse CCA	No action	Pulse CCA	No action
20	Pulse OCB	No action	Pulse OCB	No action
21	Pulse CCB	No action	Pulse CCB	No action
22	Pulse OCC	No action	Pulse OCC	No action
23	Pulse CCC	No action	Pulse CCC	No action
24	Pulse RB2	Pulse RB1	Pulse RB2	Pulse RB1
25	Pulse RB4	Pulse RB3	Pulse RB4	Pulse RB3
26	Pulse RB6	Pulse RB5	Pulse RB6	Pulse RB5
27	Pulse RB8	Pulse RB7	Pulse RB8	Pulse RB7
28	Pulse RB10	Pulse RB9	Pulse RB10	Pulse RB9
29	Pulse RB12	Pulse RB11	Pulse RB12	Pulse RB11
30	Pulse RB14	Pulse RB13	Pulse RB14	Pulse RB13
31	Pulse RB16	Pulse RB15	Pulse RB16	Pulse RB15
32	Pulse CC3	Pulse OC3	Pulse CC3	Pulse OC3
33	Pulse CCA	Pulse OCA	Pulse CCA	Pulse OCA
34	Pulse CCB	Pulse OCB	Pulse CCB	Pulse OCB
35	Pulse CCC	Pulse OCC	Pulse CCC	Pulse OCC
36	Reset demands	No action	Reset demands	No action
37	Reset demand peaks	No action	Reset demand peaks	No action
38	Reset energy metering	No action	Reset energy metering	No action

Table E.17 Object 12 Code Selection Operation (Sheet 2 of 2)

Index	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
39	Reset breaker monitor	No action	Reset breaker monitor	No action
40	Reset front panel targets	No action	Reset front panel targets	No action
41	Single-Event	No action	Single-Event	No action
42	Reset min/max metering	No action	Reset min/max metering	No action
43	Reserved	Reserved	Reserved	Reserved
44–59	Set RB17–RB32	Clear RB17–RB32	Pulse RB17–RB32	Clear RB17–RB32
60	Pulse RB18	Pulse RB17	Pulse RB18	Pulse RB17
61	Pulse RB20	Pulse RB19	Pulse RB20	Pulse RB19
62	Pulse RB22	Pulse RB21	Pulse RB22	Pulse RB21
63	Pulse RB24	Pulse RB23	Pulse RB24	Pulse RB23
64	Pulse RB26	Pulse RB25	Pulse RB26	Pulse RB25
65	Pulse RB28	Pulse RB27	Pulse RB28	Pulse RB27
66	Pulse RB30	Pulse RB29	Pulse RB30	Pulse RB29
67	Pulse RB32	Pulse RB31	Pulse RB32	Pulse RB31
68	Load-Event FIFO Mode	Load-Event LIFO Mode	Load-Event FIFO Mode	Load-Event LIFO Mode

Appendix F
Relay Word Bits

Relay Word bits show the status of functions within the relay. The bits are available via communications protocols and the front panel.

Any Relay Word bit can be used in SELOGIC® control equations (see *Section 7: SELOGIC Control Equation Programming*) and the Sequential Events Recorder (SER) trigger list settings (see *Section 12: Analyzing Events*).

Use *Table F.1* for an overview of what bits are available and their row number. You can display the bits with either the row number (**TAR *row_number***) or the bit name (**TAR *bit_name***).

Table F.2 provides an alphanumeric listing of the Relay Word bits that includes a description of each bit.

Use the DNP index range of *Table F.1* to determine the correspondence between the Relay Word bits and their Object 1, 2 index.

Table F.1 lists eight bits in each row and the index range for each row. To determine the index for a specific point, add the Relay Word bit number (0 to 7) to the first number in the range listed in the first column. For example, the index of TLED_04 is 11 (the bit number, 3, plus the first number in the range, 8).

Table F.1 Relay Word Bit Mapping (Sheet 1 of 5)

Row	DNP Index Range	Relay Word Bits[a]							
		7	6	5	4	3	2	1	0
Enable and Target Bits (see Section 5 and Section 11)									
0	7–0	EN	TRIPLED	*	*	*	*	*	*
1	15–8	TLED_08	TLED_07	TLED_06	TLED_05	TLED_04	TLED_03	TLED_02	TLED_01
2	23–16	TLED_16	TLED_15	TLED_14	TLED_13	TLED_12	TLED_11	TLED_10	TLED_09
3	31–24	TLED_24	TLED_23	TLED_22	TLED_21	TLED_20	TLED_19	TLED_18	TLED_17
Instantaneous Overcurrent Elements (see Section 4)									
4	39–32	50A1	50B1	50C1	50P1	50A2	50B2	50C2	50P2
5	47–40	50A3	50B3	50C3	50P3	50A4	50B4	50C4	50P4
6	55–48	50G1	50G2	50G3	50G4	50Q1	50Q2	50Q3	50Q4
7	63–56	50N1	50N2	50N3	50N4	50A	50B	50C	50P32
8	71–64	50P5	50P6	50G5	50G6	50Q5	50Q6	50N5	50N6
9	79–72	50LA	50LB	50LC	50L	50GF	50GR	50QF	50QR

Table F.1 Relay Word Bit Mapping (Sheet 2 of 5)

Row	DNP Index Range	Relay Word Bits[a] 7	6	5	4	3	2	1	0
Inverse-Time Overcurrent Elements (see Section 4)									
10	87–80	51AS	51AR	51A	51AT	51BS	51BR	51B	51BT
11	95–88	51CS	51CR	51C	51CT	51PS	51PR	51P	51PT
12	103–96	51G1S	51G1R	51G1	51G1T	51G2S	51G2R	51G2	51G2T
13	111–104	51QS	51QR	51Q	51QT	*	*	*	*
Definite-Time Overcurrent Elements (see Section 4)									
14	119–112	50A1T	50B1T	50C1T	50P1T	50A2T	50B2T	50C2T	50P2T
15	127–120	50A3T	50B3T	50C3T	50P3T	50A4T	50B4T	50C4T	50P4T
16	135–128	50G1T	50G2T	50G3T	50G4T	50Q1T	50Q2T	50Q3T	50Q4T
17	143–136	50N1T	50N2T	50N3T	50N4T	*	*	*	*
Breaker Status, Loss-of-Potential, Ground Switch, Fault Identification, and Load Encroachment (see Section 4 and Section 5)									
18	151–144	52AA	52AB	52AC	52A3P	SPOA	SPOB	SPOC	SPO
19	159–152	V1GOOD	LOP	VPOLV	GNDSW	FSA	FSB	FSC	3PO
20	167–160	*	*	*	*	PHASE_A	PHASE_B	PHASE_C	*
21	175–168	ZLOUT	ZLIN	ZLOAD	*	FAULT	SPE	SW1	*
Voltage Elements (see Section 4)									
22	183–176	27YA1	27YB1	27YC1	27YA2	27YB2	27YC2	59YA1	59YB1
23	191–184	59YC1	59YA2	59YB2	59YC2	27YAB1	27YBC1	27YCA1	59YAB1
24	199–192	59YBC1	59YCA1	59YN1	59YN2	59YQ1	59YV1	3P27Y	3P59Y
25	207–200	*	*	*	*	*	*	*	VSELY
26	215–208	27ZA1	27ZB1	27ZC1	27ZA2	27ZB2	27ZC2	59ZA1	59ZB1
27	223–216	59ZC1	59ZA2	59ZB2	59ZC2	27ZAB1	27ZBC1	27ZCA1	59ZAB1
28	231–224	59ZBC1	59ZCA1	59ZN1	59ZN2	59ZQ1	59ZV1	3P27Z	3P59Z
29	239–232	*	*	*	*	*	*	*	VSELZ
Synchronism-Check and Frequency Elements (see Section 4)									
30	247–240	SF	25A1	25A2	SFAST	SSLOW	*	59VS	59VP
31	255–248	81D1	81D2	81D3	81D4	81D5	81D6	*	*
32	263–256	81D1T	81D2T	81D3T	81D4T	81D5T	81D6T	27B81	*
Digital Inputs (see Section 7)									
33	271–264	*	IN107[b]	IN106[b]	IN105[b]	IN104[b]	IN103[b]	IN102[b]	IN101[b]
34	279–272	*	*	IN206	IN205	IN204	IN203	IN202	IN201
35	287–280	*	*	*	*	*	*	*	*
Pushbutton LEDs (see Section 7 and Section 11)									
36	295–288	*	*	PB06_LED	PB05_LED	PB04_LED	PB03_LED	PB02_LED	PB01_LED
37	303–296	*	*	PB12_LED	PB11_LED	PB10_LED	PB09_LED	PB08_LED	PB07_LED
Power Supply, Battery Charger and Recloser Interface (see Section 2, Section 7, and Section 8)									
38	311–304	PWR_SRC1	*	*	CHRGG	DISCHG	DTFAIL	BTFAIL	TOSLP
39	319–312	*	TCCAP	XS_TRIP1	XS_TRIP2	XS_TRIP3	XS_CLOS1	XS_CLOS2	XS_CLOS3

Table F.1 Relay Word Bit Mapping (Sheet 3 of 5)

Row	DNP Index Range	Relay Word Bits[a] 7	6	5	4	3	2	1	0
Local, Breaker Operate, and Latch Bits (see Section 7, Section 10, Section 11, and Appendix C)									
40	327–320	LB01	LB02	LB03	LB04	LB05	LB06	LB07	LB08
41	335–328	LB09	LB10	LB11	LB12	LB13	LB14	LB15	LB16
42	343–336	CCA	CCB	CCC	CC3	OCA	OCB	OCC	OC3
43	351–344	LT01	LT02	LT03	LT04	LT05	LT06	LT07	LT08
44	359–352	LT09	LT10	LT11	LT12	LT13	LT14	LT15	LT16
45	367–360	LT17	LT18	LT19	LT20	LT21	LT22	LT23	LT24
46	375–368	LT25	LT26	LT27	LT28	LT29	LT30	LT31	LT32
SELogic Variables/Timers (see Section 7)									
47	383–376	SV01	SV02	SV03	SV04	SV01T	SV02T	SV03T	SV04T
48	391–384	SV05	SV06	SV07	SV08	SV05T	SV06T	SV07T	SV08T
49	399–392	SV09	SV10	SV11	SV12	SV09T	SV10T	SV11T	SV12T
50	407–400	SV13	SV14	SV15	SV16	SV13T	SV14T	SV15T	SV16T
51	415–408	SV17	SV18	SV19	SV20	SV17T	SV18T	SV19T	SV20T
52	423–416	SV21	SV22	SV23	SV24	SV21T	SV22T	SV23T	SV24T
53	431–424	SV25	SV26	SV27	SV28	SV25T	SV26T	SV27T	SV28T
54	439–432	SV29	SV30	SV31	SV32	SV29T	SV30T	SV31T	SV32T
55	447–440	SV33	SV34	SV35	SV36	SV33T	SV34T	SV35T	SV36T
56	455–448	SV37	SV38	SV39	SV40	SV37T	SV38T	SV39T	SV40T
57	463–456	SV41	SV42	SV43	SV44	SV41T	SV42T	SV43T	SV44T
58	471–464	SV45	SV46	SV47	SV48	SV45T	SV46T	SV47T	SV48T
SELogic Counters (see Section 7)									
59	479–472	SC01QU	SC02QU	SC03QU	SC04QU	SC05QU	SC06QU	SC07QU	SC08QU
60	487–480	SC01QD	SC02QD	SC03QD	SC04QD	SC05QD	SC06QD	SC07QD	SC08QD
61	495–488	SC09QU	SC10QU	SC11QU	SC12QU	SC13QU	SC14QU	SC15QU	SC16QU
62	503–496	SC09QD	SC10QD	SC11QD	SC12QD	SC13QD	SC14QD	SC15QD	SC16QD
Reclosing Relays (see Section 6)									
63	511–504	79RS3P	79CY3P	79LO3P	SH03P	SH13P	SH23P	SH33P	SH43P
64	519–512	79RSA	79CYA	79LOA	SH0A	SH1A	SH2A	SH3A	SH4A
65	527–520	79RSB	79CYB	79LOB	SH0B	SH1B	SH2B	SH3B	SH4B
66	535–528	79RSC	79CYC	79LOC	SH0C	SH1C	SH2C	SH3C	SH4C
67	543–536	CLOSEA	CLOSEB	CLOSEC	CLOSE3P	CFA	CFB	CFC	CF3P
68	551–544	RCSFA	RCSFB	RCSFC	RCSF3P	OPTMNA	OPTMNB	OPTMNC	OPTMN3P
69	559–552	RSTMNA	RSTMNB	RSTMNC	RSTMN3P	ULCLA	ULCLB	ULCLC	ULCL3P
Tripping Elements, Target Latch Control, and Directional Control (see Section 4 and Section 5)									
70	567–560	SOTFE	SOTFT	TRGTR	*	TRIPA	TRIPB	TRIPC	TRIP3P
71	575–568	32QE	32QGE	32VE	*	F32Q	R32Q	F32QG	R32QG
72	583–576	F32V	R32V	F32P	R32P	*	*	*	*
73	591–584	32QF	32QR	32GF	32GR	32PF	32PR	*	*

Table F.1 Relay Word Bit Mapping (Sheet 4 of 5)

Row	DNP Index Range	Relay Word Bits[a]							
		7	6	5	4	3	2	1	0
Breaker Monitor, Demand Elements (see Section 8)									
74	599–592	BCWA	BCWB	BCWC	BCW	PDEM	NDEM	GDEM	QDEM
Digital Outputs (see Section 7)									
75	607–600	OUT108[b]	OUT107[b]	OUT106[b]	OUT105[b]	OUT104[b]	OUT103[b]	OUT102[b]	OUT101[b]
76	615–608	OUT202	OUT201	RCCL3X	RCTR3X	RCCL2X	RCTR2X	RCCL1X	RCTR1X
77	623–616	*	*	*	*	*	*	*	*
Setting Group Bits, Alarms, and Analog Scaling (see Section 7 and Section 13)									
78	631–624	SG1	SG2	SG3	SG4	SG5	SG6	*	TESTDNP
Row 78 for SEL-651R-1									
78	631–624	SG1	SG2	SG3	SG4	SG5	SG6	SG7	SG8
79	639–632	SALARM	HALARM	*	IRIGOK	INMET	ICMET	IBMET	IAMET
Mirrored Bits (see Appendix D)									
80	647–640	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
81	655–648	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
82	663–656	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
83	671–664	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
84	679–672	LBOKA	CBADA	RBADA	ROKA	LBOKB	CBADB	RBADB	ROKB
Voltage Sag/Swell/Interruption Elements (see Section 4)									
85	687–680	SAGA	SAGB	SAGC	SAG3P	SWA	SWB	SWC	SW3P
86	695–688	*	*	*	*	*	*	*	*
87	703–696	INTA	INTB	INTC	INT3P	*	*	*	*
Row 87 for SEL-651R-1									
87	703–696	INTA	INTB	INTC	INT3P	*	*	*	TESTDNP
Power Elements (see Section 4)									
88	711–704	*	*	*	3PWR1	*	*	*	3PWR2
89	719–712	*	*	*	3PWR3	*	*	*	3PWR4
Operator Controls (see Section 11)									
90	727–720	*	*	PB06	PB05	PB04	PB03	PB02	PB01
91	735–728	*	*	PB06_PUL	PB05_PUL	PB04_PUL	PB03_PUL	PB02_PUL	PB01_PUL
92	743–736	*	*	PB12	PB11	PB10	PB09	PB08	PB07
93	751–744	*	*	PB12_PUL	PB11_PUL	PB10_PUL	PB09_PUL	PB08_PUL	PB07_PUL
Remote Bits (see Section 10 and Appendix C)									
94	759–752	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
95	767–760	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
96	775–768	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
97	783–776	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
98	791–784	*	*	*	*	*	*	*	*
99	799–792	*	*	*	*	*	*	*	*

Table F.1 Relay Word Bit Mapping (Sheet 5 of 5)

Row	DNP Index Range	Relay Word Bits[a]							
		7	6	5	4	3	2	1	0
SELOGIC Variables/Timers for SEL-651R-1									
98	791–784	SV49	SV50	SV51	SV52	SV49T	SV50T	SV51T	SV52T
99	799–792	SV53	SV54	SV55	SV56	SV53T	SV54T	SV55T	SV56T
100	807–800	SV57	SV58	SV59	SV60	SV57T	SV58T	SV59T	SV60T
101	815–808	SV61	SV62	SV63	SV64	SV61T	SV62T	SV63T	SV64T
102	823–816	*	*	*	*	*	*	*	*
103	831–824	*	*	*	*	*	*	*	*

[a] An asterisk (*) denotes "reserved for future use."
[b] IN101–IN107 and OUT101–OUT108 are displayed only if the extra I/O is ordered.

Table F.2 Alphabetic List of Relay Word Bits (Sheet 1 of 7)

Name	Definition	Relay Word Bit Row (Table F.1)
*	Reserved	
25A1, 25A2	Synchronism-check elements	30
27B81	Undervoltage element for frequency element blocking	32
27YA1, 27YA2	A-phase undervoltage elements, Y-terminal	22
27YAB1	AB-phase-to-phase undervoltage element, Y-terminal	23
27YB1, 27YB2	B-phase undervoltage elements, Y-terminal	22
27YBC1	BC-phase-to-phase undervoltage element, Y-terminal	23
27YC1, 27YC2	C-phase undervoltage elements, Y-terminal	22
27YCA1	CA-phase-to-phase undervoltage, Y-terminal	23
27ZA1, 27ZA2	A-phase undervoltage elements, Z-terminal	26
27ZAB1	AB-phase-to-phase undervoltage element, Z-terminal	27
27ZB1, 27ZB2	B-phase undervoltage elements, Z-terminal	26
27ZBC1	BC-phase-to-phase undervoltage element, Z-terminal	27
27ZC1, 27ZC2	C-phase undervoltage elements, Z-terminal	26
27ZCA1	CA-phase-to-phase undervoltage element, Z-terminal	27
32GF	Forward directional control for ground overcurrent elements	73
32GR	Reverse directional control for ground overcurrent elements	73
32PF	Forward directional control for phase overcurrent elements	73
32PR	Reverse directional control for phase overcurrent elements	73
32QE	Enable for negative-sequence voltage-polarized directional element	71
32QF	Forward directional control for negative-sequence overcurrent elements	73
32QGE	Enable for negative-sequence voltage-polarized directional element (for ground)	71
32QR	Reverse directional control for negative-sequence overcurrent elements	73
32VE	Enable for zero-sequence voltage-polarized directional element	71
3P27Y	Three-phase undervoltage element, Y-terminal = 27YA1 AND 27YB1 AND 27YC1	24
3P27Z	Three-phase undervoltage element, Z-terminal = 27ZA1 AND 27ZB1 AND 27ZC1	28

Table F.2 Alphabetic List of Relay Word Bits (Sheet 2 of 7)

Name	Definition	Relay Word Bit Row (Table F.1)
3P59Y	Three-phase overvoltage element, Y-terminal = 59YA1 AND 59YB1 AND 59YC1	24
3P59Z	Three-phase overvoltage element, Z-terminal = 59ZA1 AND 59ZB1 AND 59ZC1	28
3PO	Three-pole open condition	19
3PWR1–3PWR4	Three-phase power elements, 1 through 4	88, 89
50A	A-phase instantaneous overcurrent element = 50A1 OR 50A2 OR 50A3 OR 50A4	7
50A1–50A4	Level 1 through Level 4 A-phase instantaneous overcurrent elements	4, 5
50A1T–50A4T	Level 1 through Level 4 A-phase definite time-overcurrent elements	14, 15
50B	B-phase instantaneous overcurrent element = 50B1 OR 50B2 OR 50B3 OR 50B4	7
50B1–50B4	Level 1 through Level 4 B-phase instantaneous overcurrent elements	4, 5
50B1T–50B4T	Level 1 through Level 4 B-phase definite time-overcurrent elements	14, 15
50C	C-phase instantaneous overcurrent element = 50C1 OR 50C2 OR 50C3 OR 50C4	7
50C1–50C4	Level 1 through Level 4 C-phase instantaneous overcurrent elements	4, 5
50C1T–50C4T	Level 1 through Level 4 C-phase definite time-overcurrent elements	14, 15
50G1–50G6	Level 1 through Level 6 ground instantaneous overcurrent elements	6, 8
50G1T–50G4T	Level 1 through Level 4 ground definite time-overcurrent elements	16
50GF	Forward direction ground overcurrent threshold exceeded	9
50GR	Reverse direction ground overcurrent threshold exceeded	9
50L	Phase instantaneous overcurrent element for load detection = 50LA OR 50LB OR 50LC	9
50LA	A-phase instantaneous overcurrent element for load detection	9
50LB	B-phase instantaneous overcurrent element for load detection	9
50LC	C-phase instantaneous overcurrent element for load detection	9
50N1–50N6	Level 1 through Level 6 neutral instantaneous overcurrent elements	7, 8
50N1T–50N4T	Level 1 through Level 4 neutral definite time-overcurrent elements	17
50P1–50P6	Level 1 through Level 6 phase instantaneous overcurrent elements	4, 5, 8
50P1T–50P4T	Level 1 through Level 4 phase definite time-overcurrent elements	14, 15
50P32	Three-phase overcurrent threshold exceeded for phase directional element	7
50Q1–50Q6	Level 1 through Level 6 negative-sequence instantaneous overcurrent elements	6, 8
50Q1T–50Q4T	Level 1 through Level 4 negative-sequence definite time-overcurrent elements	16
50QF	Forward direction negative-sequence overcurrent threshold exceeded	9
50QR	Reverse direction negative-sequence overcurrent threshold exceeded	9
51A	A-phase time-overcurrent element picked up	10
51AR	A-phase time-overcurrent element reset	10
51AS	A-phase time-overcurrent element, J/K setting indication[a]	10
51AT	A-phase time-overcurrent element timed-out	10
51B	B-phase time-overcurrent element picked-up	10
51BR	B-phase time-overcurrent element reset	10
51BS	B-phase time-overcurrent element, J/K setting indication[a]	10
51BT	B-phase time-overcurrent element timed-out	10
51C	C-phase time-overcurrent element picked-up	11
51CR	C-phase time-overcurrent element reset	11

Table F.2 Alphabetic List of Relay Word Bits (Sheet 3 of 7)

Name	Definition	Relay Word Bit Row (Table F.1)
51CS	C-phase time-overcurrent element, J/K setting indication[a]	11
51CT	C-phase time-overcurrent element timed-out	11
51G1	#1 Ground time-overcurrent element picked-up	12
51G1R	#1 Ground time-overcurrent element reset	12
51G1S	#1 Ground time-overcurrent element, J/K setting indication[a]	12
51G1T	#1 Ground time-overcurrent element timed-out	12
51G2	#2 Ground time-overcurrent element picked-up	12
51G2R	#2 Ground time-overcurrent element reset	12
51G2S	#2 Ground time-overcurrent element, J/K setting indication[a]	12
51G2T	#2 Ground time-overcurrent element timed-out	12
51P	Maximum-phase time-overcurrent element picked-up	11
51PR	Maximum-phase time-overcurrent element reset	11
51PS	Maximum-phase time-overcurrent element, J/K setting indication[a]	11
51PT	Maximum-phase time-overcurrent element timed-out	11
51Q	Negative-sequence time-overcurrent element picked-up	13
51QR	Negative-sequence time-overcurrent element reset	13
51QS	Negative-sequence time-overcurrent element, J/K setting indication[a]	13
51QT	Negative-sequence time-overcurrent element timed-out	13
52A3P	Circuit breaker status	18
52AA, 52AB, 52AC	A, B, or C-phase circuit breaker status (available when setting BKTYP := 1)	18
59VP	Healthy voltage V_P for synchronism check	30
59VS	Healthy voltage V_S for synchronism check	30
59YA1, 59YA2	A-phase overvoltage elements, Y-terminal	22, 23
59YAB1	AB-phase-to-phase overvoltage element, Y-terminal	23
59YB1, 59YB2	B-phase overvoltage elements, Y-terminal	22, 23
59YBC1	BC-phase-to-phase overvoltage element, Y-terminal	24
59YC1, 59YC2	C-phase overvoltage elements, Y-terminal	23
59YCA1	CA-phase-to-phase overvoltage element, Y-terminal	24
59YN1, 59YN2	Zero-sequence overvoltage elements, Y-terminal	24
59YQ1	Negative-sequence overvoltage element, Y-terminal	24
59YV1	Positive-sequence overvoltage element, Y-terminal	24
59ZA1, 59ZA2	A-phase overvoltage elements, Z-terminal	26
59ZAB1	AB-phase-to-phase overvoltage element, Z-terminal	27
59ZB1, 59ZB2	B-phase overvoltage elements, Z-terminal	26, 27
59ZBC1	BC-phase-to-phase overvoltage element, Z-terminal	28
59ZC1, 59ZC2	C-phase overvoltage elements, Z-terminal	27
59ZCA1	CA-phase-to-phase overvoltage element, Z-terminal	28
59ZN1, 59ZN2	Zero-sequence overvoltage elements, Z-terminal	28
59ZQ1	Negative-sequence overvoltage element, Z-terminal	28
59ZV1	Positive-sequence overvoltage elements, Z-terminal	28

Table F.2 Alphabetic List of Relay Word Bits (Sheet 4 of 7)

Name	Definition	Relay Word Bit Row (Table F.1)
79CY3P	Reclosing relay in the Reclose Cycle State (available when setting ESPB := N)	63
79CYA, 79CYB, 79CYC	A, B, or C-phase reclosing relay in the Reclose Cycle State (available when setting ESPB := Y)	64–66
79LO3P	Reclosing relay in the Lockout State (available when setting ESPB := N)	63
79LOA, 79LOB, 79LOC	A, B, or C-phase reclosing relay in the Lockout State (available when setting ESPB := Y)	64–66
79RS3P	Reclosing relay in the Reset State (available when setting ESPB := N)	63
79RSA, 79RSB, 79RSC	A, B, or C-phase reclosing relay in the Reset State (available when setting ESPB := Y)	64–66
81D1–81D6	Level 1 through Level 6 instantaneous frequency elements (for testing only)	31
81D1T–81D6T	Level 1 through Level 6 definite-time frequency elements	32
BCW	Any contact wear has reached 100% wear level = BCWA OR BCWB OR BCWC	74
BCWA	A-phase breaker contact wear has reached 100% wear level	74
BCWB	B-phase breaker contact wear has reached 100% wear level	74
BCWC	C-phase breaker contact wear has reached 100% wear level	74
BTFAIL	Battery failure	38
CBADA, CBADB	MIRRORED BITS® channel unavailability over threshold, Channels A and B	84
CC3	Asserts for one processing interval for **CLOSE** command execution	42
CCA	Asserts for one processing interval for **CLOSE A** command execution	42
CCB	Asserts for one processing interval for **CLOSE B** command execution	42
CCC	Asserts for one processing interval for **CLOSE C** command execution	42
CF3P	Close Failure condition (available when setting ESPB := N)	67
CFA, CFB, CFC	A, B, or C-phase Close Failure condition (available when setting ESPB := Y)	67
CHRGG	Battery is charging	38
CLOSE3P	Close logic output asserted (available when setting ESPB := N)	67
CLOSEA, CLOSEB, CLOSEC	A, B, or C-phase close logic output asserted (available when setting ESPB := Y)	67
DISCHG	Battery is discharging	38
DTFAIL	Battery failed discharge test	38
EN	Enabled LED. Asserts when relay enabled.	0
F32P	Forward positive-sequence voltage-polarized directional element	72
F32Q	Forward negative-sequence voltage-polarized directional element	71
F32QG	Forward negative-sequence voltage-polarized directional element (for ground)	71
F32V	Forward zero-sequence voltage-polarized directional element	72
FAULT	Output of SELOGIC control equation FAULT	21
FSA, FSB, FSC	Fault identification logic outputs (used in targeting)	19
GDEM	Ground demand current element	74
GNDSW	Ground Switch (Ground elements operating off of channel IN when asserted)	19
HALARM	Hardware Alarm (diagnostic alarms)	79
IAMET, IBMET, ICMET	Channel IA, IB, or IC operating from high-gain channel	79

Table F.2 Alphabetic List of Relay Word Bits (Sheet 5 of 7)

Name	Definition	Relay Word Bit Row (Table F.1)
IN101–IN107	Optoisolated inputs IN101 through IN107, asserted (optional inputs)	33
IN201–IN206	Status inputs IN201 through IN206, asserted	34
INMET	Channel IN operating from high-gain channel	79
INT3P	Three-phase voltage interruption element = INTA AND INTB AND INTC	87
INTA, INTB, INTC	A, B, or C-phase voltage interruption elements	87
IRIGOK	IRIG time source signal detected	79
LB01–LB16	Local Bits 01 through 16, asserted	40, 41
LBOKA, LBOKB	MIRRORED BITS channel looped back OK, Channels A and B	84
LOP	Loss-of-potential	19
LT01–LT32	Latch bits 01 through 32, asserted	43–46
NDEM	Neutral demand current element (available when EGNDSW := N)	74
OC3	Asserts for one processing interval for **OPEN** command execution	42
OCA	Asserts for one processing interval for **OPEN A** command execution	42
OCB	Asserts for one processing interval for **OPEN B** command execution	42
OCC	Asserts for one processing interval for **OPEN C** command execution	42
OPTMN3P	Reclosing relay open interval timer is timing (available when setting ESPB := N)	68
OPTMNA, OPTMNB, OPTMNC	A, B, or C-phase reclosing relay open interval timer is timing (available when setting ESPB := Y)	68
OUT101–OUT108	Output contacts OUT101 through OUT108, asserted (optional outputs)	75
OUT201–OUT202	Output contact OUT201 or OUT202, asserted	76
PB01_LED–PB12_LED	Operator control pushbutton LEDs 01 through 12. Driven by associated SELOGIC front-panel settings PB01_LED–PB12_LED.	36, 37
PB01_PUL–PB12_PUL	Operator control pushbutton 01 through 12, momentarily pulsed (one processing interval assertion when button is first pressed)	91, 93
PB01–PB12	Operator control pushbuttons 01 through 12 (asserted when button is being pressed)	90, 92
PDEM	Maximum-phase demand current element	74
PHASE_A, PHASE_B, PHASE_C	A, B, or C-phase target logic output	20
PWR_SRC1	Recloser control power supply is operating from external power source (e.g., 120 Vac)	38
QDEM	Negative-sequence demand current element	74
R32P	Reverse positive-sequence voltage-polarized directional element	72
R32Q	Reverse negative-sequence voltage-polarized directional element	71
R32QG	Reverse negative-sequence voltage-polarized directional element (for ground)	71
R32V	Reverse zero-sequence voltage-polarized directional element	72
RB01–RB32	Remote bits 01 through 32, asserted	94–97
RBADA, RBADB	MIRRORED BITS outage duration over threshold, Channels A and B	84
RCCL1X	Pole 1 recloser close output asserted	76
RCCL2X	Pole 2 recloser close output asserted (only available for single-phase reclosers)	76
RCCL3X	Pole 3 recloser close output asserted (only available for single-phase reclosers)	76
RCSF3P	Reclose supervision failure, asserts for one processing interval (available when setting ESPB := N)	68

Table F.2 Alphabetic List of Relay Word Bits (Sheet 6 of 7)

Name	Definition	Relay Word Bit Row (Table F.1)
RCSFA, RCSFB, RCSFC	A, B, or C-phase reclose supervision failure, asserts for one processing interval (available when setting ESPB := Y)	68
RCTR1X	Pole 1 recloser trip output asserted	76
RCTR2X	Pole 2 recloser trip output asserted (only available for single-phase reclosers)	76
RCTR3X	Pole 3 recloser trip output asserted (only available for single-phase reclosers)	76
RMB1A–RMB8A	Received MIRRORED BITS 1 through 8, channel A	80
RMB1B–RMB8B	Received MIRRORED BITS 1 through 8, channel B	82
ROKA, ROKB	MIRRORED BITS received data OK, Channels A and B	84
RSTMN3P	Reclosing relay reset timer is timing (available when setting ESPB := N)	69
RSTMNA, RSTMNB, RSTMNC	A, B, or C-phase reclosing relay reset timer is timing (available when setting ESPB := Y)	69
SAG3P	Three-phase voltage interruption element = SAGA AND SAGB AND SAGC	85
SAGA, SAGB, SAGC	A, B, or C-phase voltage interruption elements	85
SALARM	Software Alarm (momentary assertion during group and active setting changes)	79
SC01QD–SC16QD	SELOGIC Counters 01 through 16, asserted when counter = 0	60, 62
SC01QU–SC16QU	SELOGIC Counters 01 through 16, asserted when counter = Preset value	59, 61
SF	Synchronism-check element, slip frequency less than setting 25SF	30
SFAST	Synchronism-check element, V_P frequency greater than V_S frequency ($f_P > f_S$).	30
SG1–SG6	Setting group indication, group 1 through 6, asserted for active group	78
SG1–SG8	Setting group indication, group 1 through 8, asserted for active group (SEL-651R-1 only)	78
SH03P	Reclosing relay shot counter = 0 (available when setting ESPB := N)	63
SH0A	A, B, or C-phase reclosing relay shot counter = 0 (available when setting ESPB := Y)	64–66
SH13P	Reclosing relay shot counter = 1 (available when setting ESPB := N)	63
SH1A, SH1B, SH1C	A, B, or C-phase reclosing relay shot counter = 1 (available when setting ESPB := Y)	64–66
SH23P	Reclosing relay shot counter = 2 (available when setting ESPB := N)	63
SH2A, SH2B, SH2C	A, B, or C-phase reclosing relay shot counter = 2 (available when setting ESPB := Y)	64–66
SH33P	Reclosing relay shot counter = 3 (available when setting ESPB := N)	63
SH3A, SH3B, SH3C	A, B, or C-phase reclosing relay shot counter = 3 (available when setting ESPB := Y)	64–66
SH43P	Reclosing relay shot counter = 4 (available when setting ESPB := N)	63
SH4A, SH4B, SH4C	A, B, or C-phase reclosing relay shot counter = 4 (available when setting ESPB := Y)	64–66
SOTFE	Switch-onto-fault enable logic output	70
SOTFT	Switch-onto-fault trip	70
SPE	Single-phase mode enabled (asserted when setting ESPB := Y)	21
SPO	Single pole/phase open condition	18
SPOA, SPOB, SPOC	Phase A, B, or C single pole/phase open conditions	18
SSLOW	Synchronism-check element, V_P frequency less than or equal to V_S frequency ($f_P <= f_S$)	30
SV01–SV48	SELOGIC variables 01 through 48. Associated timers (below) are picked-up when variable is asserted	47–58
SV01T–SV48T	SELOGIC timers 01 through 48, timed-out when asserted	47–58
SV49–SV64	SELOGIC variables 49 through 64. Associated timers (below) are picked-up when variable is asserted (SEL-651R-1 only)	98–101

Table F.2 Alphabetic List of Relay Word Bits (Sheet 7 of 7)

Name	Definition	Relay Word Bit Row (Table F.1)
SV49T–SV64T	SELOGIC timers 49 through 64, timed-out when asserted (SEL-651R-1 only)	98–101
SW1	Recloser status “Switch 1” derived from inputs. Only operative for Traditional Retrofit reclosers. Otherwise, it evaluates to logical 0. See *Factory 52A Settings Example (Traditional Retrofit Recloser) on page 6.4* for more information.	21
SW3P	Three-phase voltage swell element = SWA AND SWB AND SWC	85
SWA, SWB, SWC	A, B, or C-phase voltage swell elements	85
TCCAP	Recloser interface trip and close capacitor fully charged	39
TESTDNP	Indicates override of some DNP data	78 87 (SEL-651R-1 only)
TLED_01–TLED_24	Target LEDs 01 through 24. Asserted when LED illuminated.	1–3
TMB1A–TMB8A	Transmit MIRRORED BITS 1 through 8, channel A	81
TMB1B–TMB8B	Transmit MIRRORED BITS 1 through 8, channel B	83
TOSLP	To Sleep. Asserts for last minute of control operation on battery power.	38
TRGTR	Target Reset, button or command (asserts for one processing interval)	70
TRIP3P	Trip logic output asserted (available when setting ESPB := N)	70
TRIPA, TRIPB, TRIPC	Phase A, B, or C trip logic output asserted (available when setting ESPB := Y)	70
TRIPLED	Trip target LED. Asserted when LED illuminated.	0
ULCL3P	Unlatch close condition. Driven by associated SELOGIC group setting ULCL3P.	69
ULCLA, ULCLB, ULCLC	Phase A, B, or C unlatch close condition. Driven by associated SELOGIC group settings ULCLA, ULCLB, or ULCLC.	69
V1GOOD	Positive-sequence voltage greater than setting VNOM • 0.85	19
VPOLV	Positive-sequence polarization voltage valid	19
VSELY	VY voltage inputs selected (asserts when setting VSELECT := VY)	25
VSELZ	VZ voltage inputs selected (asserts when setting VSELECT := VZ)	29
XS_CLOS1, XS_CLOS2, XS_CLOS3	Pole 1, 2, or 3: excessive close operations detected. (Available for single-phase reclosers only)	39
XS_TRIP1, XS_TRIP2, XS_TRIP3	Pole 1, 2, or 3: excessive trip operations detected. (Available for single-phase reclosers only)	39
ZLIN	Load encroachment “load in” element	21
ZLOAD	Load encroachment element = ZLIN OR ZLOUT	21
ZLOUT	Load encroachment “load out” element	21

[a] Time overcurrent elements (51A, 51B, 52C, 51P, 51G1, 51G2, 51Q) have two sets of settings (pickup, curve, time dial, electromechanical reset, constant time adder, and minimum response time), called J and K. Only one of these sets is operative at any time for each 51 element, as indicated by the 51_S Relay Word bit, which is deasserted when J settings are in use, asserted when K settings are in use. The same output Relay Word bits (51_, 51_R, 51_T) are used, regardless of the J/K selection.

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Appendix G
Analog Quantities

The SEL-651R Recloser Control contains several analog quantities that can be used for more than one function.

Analog quantities are typically generated and used by a primary function, such as metering, and selected quantities are made available for one or more supplemental functions, such as the load profile recorder.

SEL-651R analog quantities are generated by the following:

- Metering functions (see *Section 8: Metering and Monitoring*)
- Recloser/breaker monitor (see *Section 8: Metering and Monitoring*)
- Self-Test diagnostics (see *Section 13: Testing and Troubleshooting*)
- DNP Communications Statistics (see *Appendix E: DNP3 Communications*)
- Relay settings (see *Section 9: Settings*)
- System date and time (see *Section 10: Communications*)
- SELOGIC counters (see *Section 7: SELOGIC Control Equation Programming*)
- Reclosing relay logic (see *Section 6: Close and Reclose Logic*)

See *Table G.1* for a list of analog quantities that can be used in display points (see *Section 11: Front-Panel Operations*) and load profile (see *Section 8: Metering and Monitoring*).

See *Table 7.2* for a list of analog quantities that can be used in analog comparisons in SELOGIC® control equations.

Table G.1 Analog Quantities (Sheet 1 of 4)

Label	Description	Units	Display Points	Load Profile
Fundamental Metering				
IA, IB, IC	Phase (A, B, C) Current Magnitudes	A pri	x	x
IN	Neutral (channel IN) Current Magnitude	A pri	x	x
IG	Ground Current Magnitude[a]	A pri	x	x
3I0, I1, 3I2	Sequence Current Magnitudes	A pri	x	x
VAY, VBY, VCY VAZ, VBZ, VCZ	Phase (A, B, C) Voltage Magnitudes for Y- and Z-terminals	kV	x	x
VABY, VBCY, VCAY VABZ, VBCZ, VCAZ	Phase-to-Phase (AB, BC, CA) Voltage Magnitudes for Y- and Z-terminals	kV	x	x
V1Y, V2Y, 3V0Y V1Z, V2Z, 3V0Z	Positive-, Negative-, and Zero-Sequence Voltage Magnitudes for Y- and Z-terminals	kV	x	x

Table G.1 Analog Quantities (Sheet 2 of 4)

Label	Description	Units	Display Points	Load Profile
MVAA, MVAB, MVAC	Phase (A, B, C) Apparent Power	MVA	x	x
MVA3	Three-Phase Apparent Power	MVA	x	x
MWA, MWB, MWC	Phase (A, B, C) Real Power	MW	x	x
MW3	Three-Phase Real Power	MW	x	x
MVARA, MVARB, MVARC	Phase (A, B, C) Reactive Power	MVAR	x	x
MVAR3	Three-Phase Reactive Power	MVAR	x	x
PFA, PFB, PFC	Phase (A, B, C) Power Factor	per unit	x	x
PF3	Three-Phase Power Factor	per unit	x	x
LDPFA, LDPFB, LDPFC	Phase (A, B, C) Power Factor Leading	0 or 1	x	x
LDPF3	Three-Phase Power Factor Leading	0 or 1	x	x
FREQ	Frequency	Hz	x	x
Demand Metering				
IADEM, IBDEM, ICDEM	Phase (A, B, C) Current Magnitudes	A pri	x	x
INDEM	Neutral (channel IN) Current Magnitude	A pri	x	x
IGDEM	Ground Current Magnitude[a]	A pri	x	x
3I2DEM	Negative-Sequence Current Magnitude	A pri	x	x
MVAAD, MVABD, MVACD	Phase (A, B, C) Apparent Power	MVA	x	x
MVA3D	Three-Phase Apparent Power	MVA	x	x
MWADI, MWBDI, MWCDI	Phase (A, B, C) Real Power In	MW	x	x
MW3DI	Three-Phase Real Power In	MW	x	x
MWADO, MWBDO, MWCDO	Phase (A, B, C) Real Power Out	MW	x	x
MW3DO	Three-Phase Real Power Out	MW	x	x
MVRADI, MVRBDI, MVRCDI	Phase (A, B, C) Reactive Power In	MVAR	x	x
MVR3DI	Three-Phase Reactive Power In	MVAR	x	x
MVRADO, MVRBDO, MVRCDO	Phase (A, B, C) Reactive Power Out	MVAR	x	x
MVR3DO	Three-Phase Reactive Power Out	MVAR	x	x
Peak (Demand) Metering				
IAPK, IBPK, ICPK	Phase (A, B, C) Current Magnitudes	A pri	x	
INPK	Neutral (channel IN) Current Magnitude	A pri	x	
IGPK	Ground Current Magnitude[a]	A pri	x	
3I2PK	Negative-Sequence Current Magnitude	A pri	x	
MVAAP, MVABP, MVACP	Phase (A, B, C) Apparent Power	MVA	x	
MVA3P	Three-Phase Apparent Power	MVA	x	
MWAPI, MWBPI, MWCPI	Phase (A, B, C) Real Power In	MW	x	
MW3PI	Three-Phase Real Power In	MW	x	
MWAPO, MWBPO MWCPO	Phase (A, B, C) Real Power Out	MW	x	
MW3PO	Three-Phase Real Power Out	MW	x	
MVRAPI, MVRBPI MVRCPI	Phase (A, B, C) Reactive Power In	MVARh	x	
MVR3PI	Three-Phase Reactive Power In	MVARh	x	

Table G.1 Analog Quantities (Sheet 3 of 4)

Label	Description	Units	Display Points	Load Profile
MVRAPO, MVRBPO, MVRCPO	Phase (A, B, C) Reactive Power Out	MVARh	x	
MVR3PO	Three-Phase Reactive Power Out	MVARh	x	
Energy Metering				
MWHAI, MWHBI, MWHCI	Phase (A, B, C) Real Energy In	MWh	x	x
MWH3I	Three-Phase Real Energy In	MWh	x	x
MWHAO, MWHBO, MWHCO	Phase (A, B, C) Real Energy Out	MWh	x	x
MWH3O	Three-Phase Real Energy Out	MWh	x	x
MVRHAI, MVRHBI, MVRHCI	Phase (A, B, C) Reactive Energy In	MVARh	x	x
MVRH3I	Three-Phase Reactive Energy In	MVARh	x	x
MVRHAO, MVRHBO, MVRHCO	Phase (A, B, C) Reactive Energy Out	MVARh	x	x
MVRH3O	Three-Phase Reactive Energy Out	MVARh	x	x
RMS Metering				
IAR, IBR, ICR	Phase (A, B, C) RMS Current	A pri	x	x
INR	Neutral (channel IN) RMS Current	A pri	x	x
VAYR, VBYR, VCYR, VAZR, VBZR, VCZR	Phase (A, B, C) RMS Voltage for Y- and Z-terminals	kV	x	x
MWAR, MWBR, MWCR	Phase (A, B, C) Average Real Power	MW	x	x
MW3R	Three-Phase Average Real Power	MW	x	x
Harmonics Metering				
IAHT, IBHT, ICHT	Phase (A, B, C) Current THD	%	x	x
INHT	Neutral (channel IN) Current THD	%	x	x
VAYHT, VBYHT, VCYHT, VAZHT, VBZHT, VCZHT,	Phase (A, B, C) Voltage THD for Y- and Z-terminals	%	x	x
Breaker Monitor				
BRKDAT	Last Reset Date and Time		x	
INTTA, INTTB, INTTC	Phase (A, B, C) Internal Trip Counter		x	
INTIA, INTIB, INTIC	Phase (A, B, C) Internal Trip Accumulated Current	kA	x	
EXTTA, EXTTB, EXTTC	Phase (A, B, C) External Trip Counter		x	
EXTIA, EXTIB, EXTIC	Phase (A, B, C) External Trip Accumulated Current	kA	x	
APHTR, BPHTR, CPHTR	Phase (A, B, C) Involvement Counter		x	
GNDCTR	Ground Involvement Counter		x	
WEARA, WEARB, WEARC	Phase (A, B, C) Breaker Wear Percentage	%	x	
Diagnostics				
TEMP	Temperature	Deg C	x	
VBAT	Battery Voltage	Vdc	x	x
IBAT	Battery Current (negative indicates discharge)	Adc	x	
TCCAPV	Trip/Close Capacitor Voltage	Vdc	x	
DNP Communications Statistics				
DBYTER	DNP Bytes Received	Bytes	x	
DBYTES	DNP Bytes Transmitted	Bytes	x	
DFRAMR	DNP Frames Received	Frames	x	

Table G.1 Analog Quantities (Sheet 4 of 4)

Label	Description	Units	Display Points	Load Profile
DFRAMS	DNP Frames Transmitted	Frames	x	
DFRAGR	DNP Fragments Received	Fragments	x	
DFRAGS	DNP Fragments Transmitted	Fragments	x	
DLRCVD	Date/Time of last received DNP message	Date/time	x	
DLSENT	Date/Time of last transmitted DNP message	Date/time	x	
DLRSET	Date/Time of last reset of DNP communications statistics	Date/time	x	
Pickup Settings, 51[b]				
51PJP, 51PKP	Maximum-phase Time-Overcurrent Element (J, K) Pickup	A sec	x	
51AJP, 51BJP, 51CJP 51AKP, 51BKP, 51CKP	Phase (A, B, C) Time-Overcurrent Element (J, K) Pickup	A sec	x	
51G1JP, 51G1KP	Ground (#1) Time-Overcurrent Element (J, K) Pickup	A sec	x	
51G2JP, 51G2KP	Ground (#2) Time-Overcurrent Element (J, K) Pickup	A sec	x	
51QJP, 51QKP	Negative-Sequence Time-Overcurrent Element (J, K) Pickup	A sec	x	
Curve Settings 51[b] (SEL-651R-1 only)				
51PJC, 51PKC	Maximum-phase Time-Overcurrent Element (J, K) Curve	Curve	x	
51AJC, 51BJC, 51CJC 51AKC, 51BKC, 51CKC	Phase (A, B, C) Time-Overcurrent Element (J, K) Curve	Curve	x	
51G1JC, 51G1KC	Ground (#1) Time-Overcurrent Element (J, K) Curve	Curve	x	
51G2JC, 51G2KC	Ground (#2) Time-Overcurrent Element (J, K) Curve	Curve	x	
51QJC, 51QKC	Negative-Sequence Time-Overcurrent Element (J, K) Curve	Curve	x	
Time Dial Settings, 51[b] (SEL-651R-1 only)				
51PJTD, 51PKTD	Maximum-phase Time-Overcurrent Element (J, K) Time Dial	Time Dial	x	
51AJTD, 51BJTD, 51CJTD 51AKTD, 51BKTD, 51CKTD	Phase (A, B, C) Time-Overcurrent Element (J, K) Time Dial	Time Dial	x	
51G1JTD, 51G1KTD	Ground (#1) Time-Overcurrent Element (J, K) Time Dial	Time Dial	x	
51G2JTD, 51G2KTD	Ground (#2) Time-Overcurrent Element (J, K) Time Dial	Time Dial	x	
51QJTD, 51QKTD	Negative-Sequence Time-Overcurrent Element (J, K) Time Dial	Time Dial	x	

[a] When global setting EGNDSW := Y, the metering ground current quantity IG automatically switches between 3I0 and IN, depending on the magnitude of the measured ground current. The metering IG quantity (A primary) is based on the IN channel for small signals, and it is based on the 3I0 quantity for larger signals.
When global setting EGNDSW := N, the ground current quantity IG is always based on 3I0 = IA + IB + IC (in A primary).
See Ground Switch Option on page 8.3 for more details.

[b] The time-overcurrent elements have two sets of settings, called J and K. Only one of these sets is operative at any time. J/K selection is controlled by the 51_SW SELOGIC group setting for each of the 51_ elements.

Appendix H
Fast SER Protocol (SEL-651R-1 Only)

Introduction

This appendix describes special binary Fast Sequential Events Recorder (SER) messages that are not included in *Section 10: Communications* of this instruction manual. Devices with embedded processing capability can use these messages to enable and accept unsolicited binary Fast SER messages from the SEL-651R Relay.

SEL relays and communications processors have two separate data streams that share the same serial port. The normal serial interface consists of ASCII character commands and reports that are intelligible to people using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information, and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering or SER data. To exploit this feature, the device connected to the other end of the link requires software that uses the separate data streams. The binary commands and ASCII commands can also be accessed by a device that does not interleave the data streams.

Make Sequential Events Recorder (SER) Settings With Care

The relay triggers a row in the Sequential Events Recorder (SER) event report for any change of state in any one of the elements listed in the SER1, SER2, or SER3 trigger settings. Nonvolatile memory is used to store the latest 1000 rows of the SER event report so they can be retained during power loss. The nonvolatile memory is rated for a finite number of "writes." Exceeding the limit can result in an EEPROM self-test failure. *An average of six state change every minute can be made for a 25-year relay service life*.

Recommended Message Usage

Use the following sequence of commands to enable unsolicited binary Fast SER messaging in the SEL-651R:

Step 1. On initial connection, send the **SNS** command to retrieve and store the ASCII names for the digital I/O points assigned to trigger SER records.

The order of the ASCII names matches the point indices in the unsolicited binary Fast SER messages. Send the “Enable Unsolicited Fast SER Data Transfer” message to enable the SEL-651R to transmit unsolicited binary Fast SER messages.

Step 2. When SER records are triggered in the SEL-651R, the relay responds with an unsolicited binary Fast SER message. If this message has a valid checksum, it must be acknowledged by sending an acknowledge message with the same response number as contained in the original message. The relay will wait approximately 100 ms to 500 ms to receive an acknowledge message, at which time the relay will resend the same unsolicited Fast SER message with the same response number.

Step 3. Upon receiving an acknowledge message with a matching response number, the relay increments the response number, and continues to send and seek acknowledgment for unsolicited Fast SER messages, if additional SER records are available. When the response number reaches three it wraps around to zero on the next increment.

Functions and Function Codes

In the messages shown below, all numbers are in hexadecimal unless otherwise noted.

01-Function Code: Enable Unsolicited Fast SER Data Transfer, Sent From Master to Relay

Upon power-up, the SEL-651R disables it own unsolicited transmissions. This function enables the SEL-651R to begin sending unsolicited data to the device which sent the enable message, if the SEL-651R has such data to transfer. The message format for function code 01 is shown in *Table H.1*.

Table H.1 Function Code 01 Message Format (Sheet 1 of 2)

Data	Description
A546	Message header
12	Message length in bytes (18 decimal)
0000000000	Five bytes reserved for future use as a routing address
YY	Status byte (LSB = 1 indicates an acknowledge is requested)
01	Function code
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 00, 01...).
18	Function to enable (18-unsolicited SER messages)
0000	Reserved for future use as function code data

Table H.1 Function Code 01 Message Format (Sheet 2 of 2)

Data	Description
nn	Maximum number of SER records per message, 01–20 hex
cccc	Two byte CRC-16 check code for message

The SEL-651R verifies the message by checking the header, length, function code, and enabled function code against the expected values. It also checks the entire message against the CRC-16 field. If any of the checks fail, except the function code or the function to enable, the message is ignored.

If an acknowledge is requested as indicated by the least significant bit of the status byte, the relay transmits an acknowledge message with the same response number received in the enable message.

The *nn* field is used to set the maximum number of SER records per message. The relay checks for SER records approximately every 500 ms. If there are new records available, the relay immediately creates a new unsolicited Fast SER message and transmits it. If there are more than *nn* new records available, or if the first and last record are separated by more than 16 seconds, the relay will break the transmission into multiple messages so that no message contains more than *nn* records, and the first and last record of each message are separated by no more than 16 seconds.

If the function to enable is not 18 or the function code is not recognized, the relay responds with an acknowledge message containing a response code 01 (function code unrecognized), and no functions are enabled. If the SER triggers are disabled (SER1, SER2, and SER3 are all set to NA), the unsolicited Fast SER messages are still enabled, but the only SER records generated are due to settings changes, and power being applied to the relay. If the SER1, SER2, or SER3 settings are subsequently changed to any non-NA value and SER entries are triggered, unsolicited SER messages will be generated with the new SER records.

02-Function Code: Disable Unsolicited Fast SER Data Transfer, Sent From Master to Relay

This function disables the SEL-651R from transferring unsolicited data. The message format for function code 02 is shown in *Table H.2*.

Table H.2 Function Code 02 Message Format

Data	Description
A546	Message header
10	Message length (16 decimal)
0000000000	Five bytes reserved for future use as a routing address.
YY	Status byte (LSB = 1 indicates an acknowledge is requested)
02	Function code
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 01, 02...)
18	Function to disable (18 = Unsolicited SER)
00	Reserved for future use as function code data
cccc	Two byte CRC-16 check code for message

The SEL-651R verifies the message by checking the header, length, function code, and disabled function code against the expected values, and checks the entire message against the CRC-16 field. If any of the checks fail, except the function code or the function to disable, the message is ignored.

If an acknowledge is requested as indicated by the least significant bit of the status byte, the relay transmits an acknowledge message with the same response number received in the enable message.

If the function to disable is not 18 or the function code is not recognized, the relay responds with an acknowledge message containing the response code 01 (function code unrecognized) and no functions are disabled.

18-Function: Unsolicited Fast SER Response, Sent From Relay to Master

The function 18 is used for the transmission of unsolicited Fast Sequential Events Recorder (SER) data from the SEL-651R. This function code is also passed as data in the “Enable Unsolicited Data Transfer” and the “Disable Unsolicited Data Transfer” messages to indicate which type of unsolicited data should be enabled or disabled. The message format for function code 18 is shown in *Table H.3*.

Table H.3 Function Code 18 Message Format (Sheet 1 of 2)

Data	Description
A546	Message header
ZZ	Message length (Up to 34 + 4 · *nn* decimal, where *nn* is the maximum number of SER records allowed per message as indicated in the “Enable Unsolicited Data Transfer” message.)
0000000000	Five bytes reserved for future use as a routing address.
YY	Status Byte (01 = need acknowledgment; 03 = settings changed and need acknowledgment. If YY=03, the master should re-read the SNS data because the element index list may have changed.)
18	Function code
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 01, 02...)
00000000	Four bytes reserved for future use as a return routing address.
dddd	Two-byte day of year (1–366)
yyyy	Two-byte, four-digit year (e.g., 1999 or 07CF hex)
mmmmmmmm	Four-byte time of day in milliseconds since midnight
XX	1st element index (match with the response to the **SNS** command; 00 for 1st element, 01 for second element, and so on)
uuuuuu	Three-byte time tag offset of 1st element in microseconds since time indicated in the time of day field.
XX	2nd element index
uuuuuu	Three-byte time tag offset of 2nd element in microseconds since time indicated in the time of day field.
.	
.	
.	
xx	Last element index
uuuuuu	Three-byte time tag offset of last element in microseconds since time indicated in the time of day field.

Table H.3 Function Code 18 Message Format (Sheet 2 of 2)

Data	Description
FFFFFFFE	Four-byte end-of-records flag
ssssssss	Packed four-byte element status for up to 32 elements (LSB for the 1st element)
cccc	Two-byte CRC-16 checkcode for message

If the relay determines that SER records have been lost, it sends a message with the following format:

Data	Description
A546	Message header
22	Message length (34 decimal)
0000000000	Five bytes reserved for future use as a routing address.
YY	Status Byte (01 = need acknowledgement; 03 = settings changed and need acknowledgement)
18	Function code
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 00, 01, ...)
00000000	Four bytes reserved for future use as a return routing address.
dddd	Two-byte day of year (1–366) of overflow message generation
yyyy	Two-byte, four-digit year (e.g., 1999 or 07CF hex) of overflow message generation.
mmmmmmmm	Four-byte time of day in milliseconds since midnight
FFFFFFFE	Four-byte end-of-records flag
00000000	Element status (unused)
cccc	Two byte CRC-16 checkcode for message

Acknowledge Message Sent from Master to Relay, and From Relay to Master

The acknowledge message is constructed and transmitted for every received message which contains a status byte with the LSB set (except another acknowledge message), and which passes all other checks, including the CRC. The acknowledge message format is shown in *Table H.4*.

Table H.4 Acknowledge Message Format

Data	Description
A546	Message header
0E	Message length (14 decimal)
0000000000	Five bytes reserved for future use as a routing address.
00	Status byte (always 00)
XX	Function code, echo of acknowledged function code with MSB set.
RR	Response code (see below)
XX	Response number (XX = 00, 01, 02, 03, 00, 01, ...) must match response number from message being acknowledged.)
cccc	Two byte CRC-16 checkcode for message

The SEL-651R supports the following response codes:

Table H.5 SEL-651R Response Codes

RR	Response
00	Success
01	Function code not recognized

Examples

1. Successful acknowledge for "Enable Unsolicited Fast SER Data Transfer" message from a relay with at least one of SER1, SER2, or SER3 not set to NA:

   A5 46 0E 00 00 00 00 00 00 81 00 XX cc cc

   (XX is as same as the Response Number in the "Enable Unsolicited Data Transfer" message to which it responds)

2. Unsuccessful acknowledge for "Enable Unsolicited Fast SER Data Transfer" message from a relay with all of SER1, SER2, and SER3 set to NA:

   A5 46 0E 00 00 00 00 00 00 81 02 XX cc cc

   (XX is as same as the response number in the "Enable Unsolicited Data Transfer" message to which it responds.)

3. Disable Unsolicited Fast SER Data Transfer message, acknowledge requested:

   A5 46 10 00 00 00 00 00 01 02 C0 XX 18 00 cc cc

   (XX = 0, 1, 2, 3)

4. Successful acknowledge from the relay for the "Disable Unsolicited Fast SER Data Transfer" message:

   A5 46 0E 00 00 00 00 00 00 82 00 XX cc cc

   (XX is as same as the response number in the "Disable Unsolicited Fast SER Data Transfer" message to which it responds.)

5. Successful acknowledge message from the master for an unsolicited Fast SER message:

   A5 46 0E 00 00 00 00 00 00 98 00 XX cccc

   (XX is as same as the response number in the unsolicited Fast SER message to which it responds.)

Notes:

Once the relay receives an acknowledge with response code 00 from the master, it will clear the settings changed bit (bit 1) in its status byte, if that bit is asserted, and it will clear the settings changed bit in fast meter, if that bit is asserted.

An element index of FE indicates that the SER record is due to power up. An element index of FF indicates that the SER record is due to setting change. An element index of FD indicates that the element identified in this SER record is no longer in the SER trigger settings.

When the relay sends an SER message packet, it will put a sequential number (0, 1, 2, 3, 0, 1, ...) into the response number. If the relay does not receive an acknowledge from the master before approximately 500 mS, the relay will resend the same message packet with the same response number until it receives an acknowledge message with that response number. For the next SER message, the relay will increment the response number (it will wrap around to zero from three).

A single Fast SER message packet from the relay can have a maximum number 32 records and the data may span a time period of no more than 16 seconds. The master may limit the number records in a packet with the third byte of function code data in the “Enable Unsolicited Data Transfer” message (function code 01). The relay may generate an SER packet that with less than the requested number of records, if the record time stamps span more than 16 seconds.

The relay always requests acknowledgment in unsolicited Fast SER messages (LSB of the status byte is set).

Unsolicited Fast SER messages can be enabled on multiple ports simultaneously.

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Glossary

AC Ripple — The peak-to-peak ac component of a signal or waveform. In the station dc battery system, monitoring ac ripple provides an indication of whether the substation battery charger has failed.

ACSELERATOR QuickSet® SEL-5030 — A Windows®-based program that simplifies settings and provides analysis support.

Active Settings Group — The settings group that the SEL-651R is presently using from among six settings groups available in the relay.

Analog Quantities — Variables represented by such fluctuating measurable quantities as temperature, frequency, current, and voltage.

AND Operator — Logical AND. An operator in Boolean SELOGIC® control equations that requires fulfillment of conditions on both sides of the operator before the equation is true.

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 the following:

25	Synchronism-Check Element
27	Undervoltage Element
50	Overcurrent Element
51	Inverse Time-Overcurrent Element
52	AC Circuit Breaker
59	Overvoltage Element
69	Permissive Control Device (e.g., permit/block circuit breaker closing)
79	Reclosing Relay
81	Frequency Element

These numbers are frequently used within a suffix letter to further designate their application. The suffix letters used in this instruction manual include the following:

P	Phase Element
G	Ground Element
N	Neutral Element
Q	Negative-Sequence (3I2) Element

Anti-Aliasing Filter — A low pass filter that blocks frequencies too high for the given sampling rate to accurately reproduce.

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: $S = P + jQ$. This is power at the fundamental frequency only; no harmonics are included in this quantity.

ASCII Abbreviation for American Standard Code for Information Interchange. Defines a standard set of text characters. The SEL-651R uses ASCII text characters to communicate, using front- and rear-panel EIA-232 serial ports on the relay and through virtual serial ports.

ASCII Terminal A terminal without built-in logic or local processing capability that can only send and receive information.

Assert To activate. To fulfill the logic or electrical requirements needed to operate a device. To set a logic condition to the true state (logical 1) of that condition. To apply a closed contact to an SEL-651R input. To close a normally open output contact. To open a normally closed output contact.

AT Modem Command Set Dialing String Standard The command language standard that Hayes Microcomputer Products, Inc. developed to control auto-dial modems from an ASCII terminal (usually EIA-232 connected) or a PC (personal computer) containing software allowing emulation of such a terminal.

Autoconfiguration The ability to determine relay type, model number, metering capability, port ID, baud rate, passwords, relay elements, and other information that an IED (e.g., SEL-2020/2030/2032 Communications Processor) needs to automatically communicate with relays.

Automatic Messages Messages including status failure and status warning messages that the relay generates at the serial ports and displays automatically on the front-panel LCD.

Automatic Reclose Automatic closing of a circuit breaker after a breaker trip by a protective relay.

Boolean Logic Statements Statements consisting of variables that behave according to Boolean logic operators, such as AND, NOT, and OR.

Breaker Auxiliary Contact An 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 and 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.

Contact Input See Control Input.

Contact Output See Control Output.

Control Input Relay input for monitoring the state of external circuits. Connects auxiliary relay and circuit breaker contacts to the control inputs.

Control Output Relay output that affects the state of other equipment. Connects control outputs to circuit breaker trip and close coils, breaker failure auxiliary relays, communications-assisted tripping circuits, and SCADA systems.

Coordination Timer A timer that delays an overreaching element so that a downstream device has time to operate.

Counter Variable or device such as a register or storage location that either records or represents the number of times an event occurs.

Deadband The range of variation an analog quantity can traverse before causing a response.

Deassert To deactivate. To remove the logic or electrical requirements needed to operate a device. To clear a logic condition to its false state (logical 0). To open the circuit or open the contacts across an SEL-651R input. To open a normally open output contact. To close a normally closed output contact.

Debounce Time The time that masks the period when relay contacts continue to move after closing; debounce time covers this indeterminate state.

Default Data Map The default map of objects and indices that the SEL-651R uses in DNP protocol.

Demand Meter A measuring function that calculates a rolling average or thermal average of instantaneous measurements over time.

DNP (Distributed Network Protocol) Manufacturer-developed, hardware-independent communications protocol.

Dropout Time The time measured from the removal of an input signal until the output signal deasserts. You can set the time, in the case of a logic variable timer, or the dropout time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element dropout time.

DTE Devices Data terminal equipment (computers, terminals, printers, relays, etc.).

EIA-232 Electrical definition for point-to-point serial data communications interfaces, based on the standard EIA/TIA-232. Formerly known as RS-232.

ESD (Electrostatic Discharge) The sudden transfer of charge between objects at different potentials caused by direct contact or induced by an electrostatic field.

Event History A quick look at recent relay activity that includes a standard report header; event number, date, time, and type; fault location; maximum fault phase current; active group at the trigger instant; 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 ASCII **TRI** 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 location, time source, recloser shot counter, currents, and sequence currents. The relay sends an event report summary (if auto messaging is enabled) to the relay serial port a few seconds after an event.

Fast Meter SEL binary serial port command used to collect metering data with SEL relays.

Fast Operate SEL binary serial port command used to perform control with SEL relays.

FET Field Effect Transistor.

Firmware The nonvolatile program stored in the relay that defines relay operation.

Flash Memory A type of nonvolatile relay memory used for storing large blocks of nonvolatile data.

Function Code A code that defines how you manipulate an object in DNP3 protocol.

Fundamental Frequency The component of the measured electrical signal with a frequency equal to the normal electrical system frequency, usually 50 Hz or 60 Hz. Generally used to differentiate between the normal system frequency and any harmonic frequencies present.

Global Settings General settings including those for breaker type, date format, phase rotation, nominal system frequency, enables, control inputs, settings group selection, and current and voltage source selection.

GUI Graphical user interface.

HMI Human machine interface.

Local Bits The Relay Word bit outputs of local control switches that you access through the SEL-651R front panel. Local control switches replace traditional panel mounted control switches.

Lockout Relay An auxiliary relay that prevents operation of associated devices until it is reset either electrically or manually.

Logical 0 A false logic condition, dropped out element, or deasserted control input or control output.

Logical 1 A true logic condition, picked up element, or asserted control input or control output.

Maximum/Minimum Meter Type of meter data presented by the SEL-651R that includes a record of the maximum and minimum of each value, along with the date and time that each maximum and minimum occurred.

Mechanical Operating Time Time between trip initiation or close initiation and the change in status of an associated circuit breaker auxiliary 52A normally open contacts.

MIRRORED BITS® Communications Patented relay-to-relay communications protocol that sends internal logic status, encoded in a digital message, from one relay to the other. Eliminates the need for some communications hardware.

Nonvolatile Memory Relay memory that persists over time to maintain the contained data even when the relay is de-energized.

NOT Operator A logical operator that produces the inverse value.

OR Operator Logical OR. A Boolean SELOGIC control equation operator that compares two Boolean values and yields either a logical 1 if either compared Boolean value is logical 1 or a logical 0 if both compared Boolean values are logical 0.

Parentheses Operator Math operator. Use paired parentheses to control the execution of operations in a SELOGIC control equation.

PC Personal computer.

Peak Demand Metering Maximum demand and a time stamp for phase currents, negative-sequence and zero-sequence currents, and powers. The SEL-651R stores peak demand values and the date and time these occurred to nonvolatile storage once per day, overwriting the previously stored value if the new value is larger. Should the relay lose control power, the relay restores the peak demand information saved at 23:50 hours on the previous day.

Phase Rotation The sequence of voltage or current phasors in a multiphase electrical system. In an ABC phase rotation system, the B-phase voltage lags the A-phase voltage by 120°, and the C-phase voltage lags B-phase voltage by 120°. In an ACB phase rotation system, the C-phase voltage lags the A-phase voltage by 120°, and the B-phase voltage lags the C-phase voltage by 120°.

Phase Selection Ability of the relay to determine the faulted phase or phases.

R_TRIG Rising-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a rising edge.

Relay Word Bit A single relay element or logic result. A Relay Word bit can equal either logical 1 or logical 0. Logical 1 represents a true logic condition, picked up element, or asserted control input or control output. Logical 0 represents a false logic condition, dropped out element, or deasserted control input or control output. Use Relay Word bits in SELOGIC control equations.

RTU Remote Terminal Unit.

RXD Received data.

SCADA Supervisory control and data acquisition.

Self-Test A function that verifies the correct operation of a critical device subsystem and indicates detection of an out-of-tolerance condition. The SEL-651R has self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC Control Equation A relay setting that allows you to control a relay function (such as a control output) using a logical combination of relay element outputs and fixed logic outputs.

SELOGIC Expression Builder A rules-based editor within the ACSELERATOR QuickSet software for programming SELOGIC control equations.

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 list that you set in the relay. SER provides a useful way to determine the order and timing of events of a relay operation.

SER Sequential Events Recorder or the relay serial port command to request a report of the latest 1000 sequential events.

Shot Counter A counter that records the number of times a reclosing relay (dev. 79) attempts to close a circuit breaker.

Single-Phase Trip A circuit breaker trip operation that occurs when one pole of the three poles of a circuit breaker opens independently of the other poles.

Status Failure A severe out-of-tolerance internal operating condition. The relay issues a status failure message and enters a protection-disabled state.

Status Warning Out-of-tolerance internal operating conditions that do not compromise relay protection, yet are beyond expected limits. The relay issues a status warning message and continues to operate.

Three-Phase Trip A circuit breaker operation that occurs when the circuit breaker opens all three poles at the same time.

Torque Control A method of using one relay element to supervise the operation of another.

Total Clearing Time The time interval from the beginning of a fault condition to final interruption of the circuit.

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SEL-651R Recloser Control Command Summary

Command	Access Level and Prompt	Description
2ACCESS	1 =>	Go to Access Level 2.
ACCESS	0 =	Go to Access Level 1.
BACCESS	1 =>	Go to Access Level B (Breaker/Recloser).
BNAMES	0 =	ASCII names of all relay status bits in Compressed ASCII format (Fast Meter).
BREAKER	1 =>	Display breaker/recloser contact wear report.
BREAKER R	B ==>	Reset breaker/recloser contact wear and trip operation counters.
BREAKER W	B ==>	Preload breaker/recloser contact wear and trip operation counters.
BTT	B ==>	Display latest battery load test results and time remaining until next discharge test.
BTT NOW	B ==>	Initiate battery load test immediately.
CAL	2 =>>	Enter Access Level C. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level C password. Access Level C is reserved for SEL use only.
CASCII	0 =>	Display the Compressed ASCII configuration message.
CEVENT *n*	1 =>	Display the Compressed ASCII version of the **EVENT** command for event *n*.
CHISTORY	1 =>	Display the Compressed ASCII version of the **HISTORY** command.
CLOSE, CLOSE A, CLOSE B, CLOSE C	B ==>	Close the recloser or circuit breaker (momentarily assert Relay Word bit CC3, CCA, CCB, or CCC).
COM C	1 =>	Clear/reset communications buffer data.
COM *n date1 date2*	1 =>	Show a MIRRORED BITS® communications summary for events occurring between dates *date1* and *date2* on channel *n* (where *n* = A or B).
COM *n* L	1 =>	Show a MIRRORED BITS long format communications summary report for all events on channel *n*.
COM *n row1 row2*	1 =>	Show a MIRRORED BITS communications summary report for events *row1* through *row2* on channel *n*.
CONTROL *nn*	2 =>>	Set, clear, or pulse internal remote bit *nn* (*nn* is the Remote Bit number from 01–32). The control will respond with **CONTROL RB*nn***. Reply with the following: **SRB *nn*** To set Remote Bit *nn* (assert RB*nn*). **CRB *nn*** To clear Remote Bit *nn* (deassert RB*nn*). **PRB *nn*** To pulse Remote Bit *nn* (assert RB*nn* for 1/4 cycle).
COPY *m n*	2 =>>	Copy settings and logic equations from settings group *m* to settings group *n*.
COUNTER *k*	1 =>	Show the SELOGIC® counter values. Enter *k* for repeat count.
CSTATUS	1 =>	Display the Compressed ASCII version of the **STATUS** command.
CSUMMARY *n*	1 =>	Display the Compressed ASCII version of the summary auto-message for event *n*.
DATE	1 =>	Show date.
DATE *date*	1 =>	Enter date in accordance with Date Format setting DATE_F = MDY, YMD, or DMY.
DNAMES	=	ASCII names of all Relay Word bits in Compressed ASCII format (Fast Meter).
DNP	1 =>	Show DNP map settings.

Command	Access Level and Prompt	Description
DNP *n*	2 =>>	Modify DNP map settings.
EVENT C *n*	1 =>	Show compressed event report number *n* for use with SEL-5601 Analytic Assistant.
EVENT L *n*	1 =>	Show event report number *n* with 1/32-cycle resolution.
EVENT *n*	1 =>	Show event report number *n* with 1/4-cycle resolution.
EVENT R *n*	1 =>	Show raw event report number *n* with 1/32-cycle resolution.
FILE DIR|READ|SHO|	1 =>	Transfer data from the recloser control to a PC.
FILE WRITE	2 =>>	Transfer settings files from a PC to the recloser control.
GROUP	1 =>	Display active settings group number.
GROUP *n*	B ==>	Change active settings group to settings group *n* (*n* = 1–6; *n* = 1–8 for SEL-651R-1).
HISTORY C	1 =>	Clear the brief summary and corresponding event reports.
HISTORY *n*	1 =>	Show brief summary of the *n* latest event reports.
ID	0 =>	Display the firmware id, user id, device code, part number, and configuration information.
IRIG	1 =>	Force synchronization of internal control clock to IRIG-B time-code input.
L_D	2 =>>	Download firmware to the recloser control.
LDP *date1 date2*	1 =>	Show rows in the Load Profile report from dates *date1* to *date2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY, YMD, or DMY).
LDP *row1 row2*	1 =>	Show rows *row1* through *row2* in the Load Profile report.
LDP C	1 =>	Clear the Load Profile Report.
LDP D	1 =>	Show the maximum number of days data can be collected.
LOOPBACK c t	2 =>>	Set MIRRORED BITS channel c to loopback.
LOOPBACK c t DATA	2 =>>	Set MIRRORED BITS channel c to loopback and pass input data to receive data as in non-loopback mode.
LOOPBACK c R	2 =>>	Cease MIRRORED BITS channel c loopback.
METER D	1 =>	Display demand and peak demand data. Select **MET RD** or **MET RP** to reset.
METER E	1 =>	Display energy metering data. Select **MET RE** to reset.
METER H	1 =>	Display THD and harmonic metering data.
METER *k*	1 =>	Display fundamental (instantaneous) metering data. Enter *k* for repeat count.
METER M	1 =>	Display maximum/minimum metering data. Select **MET RM** to reset.
METER RMS	1 =>	Display RMS metering data.
METER RD	1 =>	Reset demand metering data.
METER RE	1 =>	Reset energy metering data.
METER RM	1 =>	Reset maximum metering data
METER RP	1 =>	Reset peak demand metering data.
OPEN, OPEN A, OPEN B, OPEN C	B ==>	Open the recloser or circuit breaker (momentarily assert Relay Word bit CO3, OCA, OCB, or OCC).
PAS 1 *xxxxxx*	2 =>>	Change Access Level 1 password to *xxxxxx*.
PAS 2 *xxxxxx*	2 =>>	Change Access Level 2 password to *xxxxxx*.
PAS B *xxxxxx*	2 =>>	Change Access Level B password to *xxxxxx*.
PAS C *xxxxxx*	2 =>>	Change Access Level C password to *xxxxxx*.
PULSE OUT*nnn s*	B ==>	Pulse output contact OUT*nnn* [*nnn* = 201, 202 (all models); 101–108 (models with extra I/O)] for *s* (1–30) seconds. Parameter OUT*nnn* must be specified; *s* defaults to 1 if not specified.

Command	Access Level and Prompt	Description
QUIT	0 =	Reduce access level to Access Level 0 (exit relay control).
R_S	2 =>	Restore the factory default setting and passwords and reboot the relay (only available if there is a diagnostic failure).
SER C	1 =>	Clear/reset recently SER records.
SER *date1 date2*	1 =>	Show rows in the Sequential Events Recorder (SER) event report from dates *date1* to *date2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY, YMD, or DMY).
SER *row1 row2*	1 =>	Show rows *row1* through *row2* in the Sequential Events Recorder (SER) event report.
SET F	2 =>>	Change front-panel settings.
SET G	2 =>>	Change global settings.
SET L *n*	2 =>>	Change SELOGIC control equation settings for settings group *n* (*n* = 1–6; *n* = 1–8 for SEL-651R-1).
SET *n*	2 =>>	Change "regular" settings for settings group *n* (*n* = 1–6; *n* = 1–8 for SEL-651R-1).
SET P *n*	2 =>>	Change port settings for port *n* (*n* = 1, 2, 3, F).
SET R	2 =>>	Change report settings.
SHOW F	1 =>	Show front-panel settings.
SHOW G	1 =>	Show global settings.
SHOW L *n*	1 =>	Show SELOGIC control equation settings for settings group *n* (*n* = 1–6; *n* = 1–8 for SEL-651R-1).
SHOW *n*	1 =>	Show "regular" settings for settings group *n* (*n* = 1–6; *n* = 1–8 for SEL-651R-1).
SHOW P *n*	1 =>	Show port settings for port *n* (*n* = 1, 2, 3, F).
SHOW R	1 =>	Show report settings.
SSI	1 =>	Show the Voltage Sag, Swell, Interruption report.
SSI C	1 =>	Clear the Voltage Sag, Swell, Interruption report from nonvolatile memory.
SSI *date 1 date 2*	1 =>	Show the Voltage Sag, Swell, Interruption report between *date 1* and *date 2*.
SSI R	1 =>	Reset the Voltage Sag, Swell, Interruption recorder logic and clear the Vbase value.
SSI *row 1 row 2*	1 =>	Show the Voltage Sag, Swell, Interruption report between *row 1* and *row 2*.
SSI T	1 =>	Manually trigger the Voltage Sag, Swell, Interruption recorder
STATUS C	2 =>>	Clear status warning or failure and reboot the recloser control.
STATUS D	1 =>	Show DNP communications statistics.
STATUS *k*	1 =>	Show recloser control self-test status. Enter *k* for repeat count (defaults to 1).
STATUS RD	2 =>>	Reset DNP communications statistics.
STATUS S	1 =>	Display the memory and execution utilization for the SELOGIC control equations.
TARGET *n k*	1 =>	Display relay elements for a row in the Relay Word table. If *n* is a row number from the Relay Word table, display row *n*. If *n* is an element name, display the row containing element *n*. Enter *k* for repeat count.
TARGET R	1 =>	Reset the front-panel tripping targets.
TEST DNP	1 =>	Display DNP test data values.
TEST DNP OFF	B ==>	Remove all DNP test data.
TEST DNP *c n m*	B ==>	Assign DNP test value of *m* to point *n* within group *c* (A for analog input, B for binary input, C for counter).
TIME	1 =>	Show or set time (24-hour time). Show the present time by entering **TIME**. Set the present time by entering **TIME xx:xx:xx**.

Command	Access Level and Prompt	Description
TRIGGER	1 =>	Trigger an event report.
VERSION	1 =>	Show firmware version and options.

Key Stroke Commands

Key Stroke	Description	Key Stroke When Using SET Command	Description
<Ctrl+Q>	Sends **XON** command to restart communications port output previously halted by XOFF.	**<Enter>**	Retains setting and moves on to next setting.
<Ctrl+S>	Sends **XOFF** command to pause communications port output.	^ **<Enter>**	Returns to previous setting.
<Ctrl+X>	Sends **CANCEL** command to abort current command and return to current access level prompt.	< **<Enter>**	Returns to previous setting section.
		> **<Enter>**	Skips to next setting section.
		END <Enter>	Exits setting editing session, then prompts user to save settings.
		<Ctrl+X>	Aborts setting editing session without saving changes.

SEL-651R Recloser Control Command Summary

Command	Access Level and Prompt	Description
2ACCESS	1 =>	Go to Access Level 2.
ACCESS	0 =	Go to Access Level 1.
BACCESS	1 =>	Go to Access Level B (Breaker/Recloser).
BNAMES	0 =	ASCII names of all relay status bits in Compressed ASCII format (Fast Meter).
BREAKER	1 =>	Display breaker/recloser contact wear report.
BREAKER R	B ==>	Reset breaker/recloser contact wear and trip operation counters.
BREAKER W	B ==>	Preload breaker/recloser contact wear and trip operation counters.
BTT	B ==>	Display latest battery load test results and time remaining until next discharge test.
BTT NOW	B ==>	Initiate battery load test immediately.
CAL	2 =>>	Enter Access Level C. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level C password. Access Level C is reserved for SEL use only.
CASCII	0 =>	Display the Compressed ASCII configuration message.
CEVENT *n*	1 =>	Display the Compressed ASCII version of the **EVENT** command for event *n*.
CHISTORY	1 =>	Display the Compressed ASCII version of the **HISTORY** command.
CLOSE, CLOSE A, CLOSE B, CLOSE C	B ==>	Close the recloser or circuit breaker (momentarily assert Relay Word bit CC3, CCA, CCB, or CCC).
COM C	1 =>	Clear/reset communications buffer data.
COM *n date1 date2*	1 =>	Show a MIRRORED BITS® communications summary for events occurring between dates *date1* and *date2* on channel *n* (where *n* = A or B).
COM *n* L	1 =>	Show a MIRRORED BITS long format communications summary report for all events on channel *n*.
COM *n row1 row2*	1 =>	Show a MIRRORED BITS communications summary report for events *row1* through *row2* on channel *n*.
CONTROL *nn*	2 =>>	Set, clear, or pulse internal remote bit *nn* (*nn* is the Remote Bit number from 01–32). The control will respond with **CONTROL RB*nn***. Reply with the following: **SRB *nn*** To set Remote Bit *nn* (assert RB*nn*). **CRB *nn*** To clear Remote Bit *nn* (deassert RB*nn*). **PRB *nn*** To pulse Remote Bit *nn* (assert RB*nn* for 1/4 cycle).
COPY *m n*	2 =>>	Copy settings and logic equations from settings group *m* to settings group *n*.
COUNTER *k*	1 =>	Show the SELOGIC® counter values. Enter *k* for repeat count.
CSTATUS	1 =>	Display the Compressed ASCII version of the **STATUS** command.
CSUMMARY *n*	1 =>	Display the Compressed ASCII version of the summary auto-message for event *n*.
DATE	1 =>	Show date.
DATE *date*	1 =>	Enter date in accordance with Date Format setting DATE_F = MDY, YMD, or DMY.
DNAMES	=	ASCII names of all Relay Word bits in Compressed ASCII format (Fast Meter).
DNP	1 =>	Show DNP map settings.

Command	Access Level and Prompt	Description
DNP *n*	2 =>>	Modify DNP map settings.
EVENT C *n*	1 =>	Show compressed event report number *n* for use with SEL-5601 Analytic Assistant.
EVENT L *n*	1 =>	Show event report number *n* with 1/32-cycle resolution.
EVENT *n*	1 =>	Show event report number *n* with 1/4-cycle resolution.
EVENT R *n*	1 =>	Show raw event report number *n* with 1/32-cycle resolution.
FILE DIR|READ|SHO|	1 =>	Transfer data from the recloser control to a PC.
FILE WRITE	2 =>>	Transfer settings files from a PC to the recloser control.
GROUP	1 =>	Display active settings group number.
GROUP *n*	B ==>	Change active settings group to settings group *n* (*n* = 1–6; *n* = 1–8 for SEL-651R-1).
HISTORY C	1 =>	Clear the brief summary and corresponding event reports.
HISTORY *n*	1 =>	Show brief summary of the *n* latest event reports.
ID	0 =>	Display the firmware id, user id, device code, part number, and configuration information.
IRIG	1 =>	Force synchronization of internal control clock to IRIG-B time-code input.
L_D	2 =>>	Download firmware to the recloser control.
LDP *date1 date2*	1 =>	Show rows in the Load Profile report from dates *date1* to *date2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY, YMD, or DMY).
LDP *row1 row2*	1 =>	Show rows *row1* through *row2* in the Load Profile report.
LDP C	1 =>	Clear the Load Profile Report.
LDP D	1 =>	Show the maximum number of days data can be collected.
LOOPBACK c t	2 =>>	Set MIRRORED BITS channel c to loopback.
LOOPBACK c t DATA	2 =>>	Set MIRRORED BITS channel c to loopback and pass input data to receive data as in non-loopback mode.
LOOPBACK c R	2 =>>	Cease MIRRORED BITS channel c loopback.
METER D	1 =>	Display demand and peak demand data. Select **MET RD** or **MET RP** to reset.
METER E	1 =>	Display energy metering data. Select **MET RE** to reset.
METER H	1 =>	Display THD and harmonic metering data.
METER *k*	1 =>	Display fundamental (instantaneous) metering data. Enter *k* for repeat count.
METER M	1 =>	Display maximum/minimum metering data. Select **MET RM** to reset.
METER RMS	1 =>	Display RMS metering data.
METER RD	1 =>	Reset demand metering data.
METER RE	1 =>	Reset energy metering data.
METER RM	1 =>	Reset maximum metering data
METER RP	1 =>	Reset peak demand metering data.
OPEN, OPEN A, OPEN B, OPEN C	B ==>	Open the recloser or circuit breaker (momentarily assert Relay Word bit CO3, OCA, OCB, or OCC).
PAS 1 *xxxxxx*	2 =>>	Change Access Level 1 password to *xxxxxx*.
PAS 2 *xxxxxx*	2 =>>	Change Access Level 2 password to *xxxxxx*.
PAS B *xxxxxx*	2 =>>	Change Access Level B password to *xxxxxx*.
PAS C *xxxxxx*	2 =>>	Change Access Level C password to *xxxxxx*.
PULSE OUT*nnn s*	B ==>	Pulse output contact OUT*nnn* [*nnn* = 201, 202 (all models); 101–108 (models with extra I/O)] for *s* (1–30) seconds. Parameter OUT*nnn* must be specified; *s* defaults to 1 if not specified.

Command	Access Level and Prompt	Description
QUIT	0 =	Reduce access level to Access Level 0 (exit relay control).
R_S	2 =>	Restore the factory default setting and passwords and reboot the relay (only available if there is a diagnostic failure).
SER C	1 =>	Clear/reset recently SER records.
SER *date1 date2*	1 =>	Show rows in the Sequential Events Recorder (SER) event report from dates *date1* to *date2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY, YMD, or DMY).
SER *row1 row2*	1 =>	Show rows *row1* through *row2* in the Sequential Events Recorder (SER) event report.
SET F	2 =>>	Change front-panel settings.
SET G	2 =>>	Change global settings.
SET L *n*	2 =>>	Change SELOGIC control equation settings for settings group *n* (*n* = 1–6; *n* = 1–8 for SEL-651R-1).
SET *n*	2 =>>	Change “regular” settings for settings group *n* (*n* = 1–6; *n* = 1–8 for SEL-651R-1).
SET P *n*	2 =>>	Change port settings for port *n* (*n* = 1, 2, 3, F).
SET R	2 =>>	Change report settings.
SHOW F	1 =>	Show front-panel settings.
SHOW G	1 =>	Show global settings.
SHOW L *n*	1 =>	Show SELOGIC control equation settings for settings group *n* (*n* = 1–6; *n* = 1–8 for SEL-651R-1).
SHOW *n*	1 =>	Show “regular” settings for settings group *n* (*n* = 1–6; *n* = 1–8 for SEL-651R-1).
SHOW P *n*	1 =>	Show port settings for port *n* (*n* = 1, 2, 3, F).
SHOW R	1 =>	Show report settings.
SSI	1 =>	Show the Voltage Sag, Swell, Interruption report.
SSI C	1 =>	Clear the Voltage Sag, Swell, Interruption report from nonvolatile memory.
SSI *date 1 date 2*	1 =>	Show the Voltage Sag, Swell, Interruption report between *date 1* and *date 2*.
SSI R	1 =>	Reset the Voltage Sag, Swell, Interruption recorder logic and clear the Vbase value.
SSI *row 1 row 2*	1 =>	Show the Voltage Sag, Swell, Interruption report between *row 1* and *row 2*.
SSI T	1 =>	Manually trigger the Voltage Sag, Swell, Interruption recorder
STATUS C	2 =>>	Clear status warning or failure and reboot the recloser control.
STATUS D	1 =>	Show DNP communications statistics.
STATUS *k*	1 =>	Show recloser control self-test status. Enter *k* for repeat count (defaults to 1).
STATUS RD	2 =>>	Reset DNP communications statistics.
STATUS S	1 =>	Display the memory and execution utilization for the SELOGIC control equations.
TARGET *n k*	1 =>	Display relay elements for a row in the Relay Word table. If *n* is a row number from the Relay Word table, display row *n*. If *n* is an element name, display the row containing element *n*. Enter *k* for repeat count.
TARGET R	1 =>	Reset the front-panel tripping targets.
TEST DNP	1 =>	Display DNP test data values.
TEST DNP OFF	B ==>	Remove all DNP test data.
TEST DNP *c n m*	B ==>	Assign DNP test value of *m* to point *n* within group *c* (A for analog input, B for binary input, C for counter).
TIME	1 =>	Show or set time (24-hour time). Show the present time by entering **TIME**. Set the present time by entering **TIME xx:xx:xx**.

Command	Access Level and Prompt	Description
TRIGGER	1 =>	Trigger an event report.
VERSION	1 =>	Show firmware version and options.

Key Stroke Commands

Key Stroke	Description	Key Stroke When Using SET Command	Description
<Ctrl+Q>	Sends **XON** command to restart communications port output previously halted by XOFF.	**<Enter>**	Retains setting and moves on to next setting.
<Ctrl+S>	Sends **XOFF** command to pause communications port output.	^ **<Enter>**	Returns to previous setting.
<Ctrl+X>	Sends **CANCEL** command to abort current command and return to current access level prompt.	< **<Enter>**	Returns to previous setting section.
		> **<Enter>**	Skips to next setting section.
		END <Enter>	Exits setting editing session, then prompts user to save settings.
		<Ctrl+X>	Aborts setting editing session without saving changes.