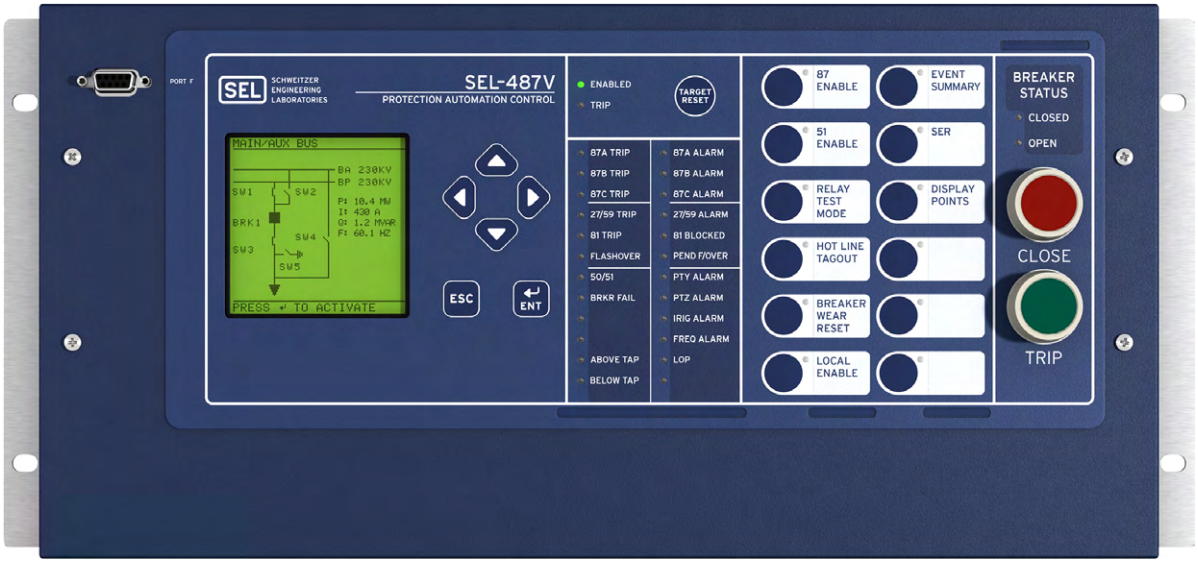
SEL-487V Capacitor Protection and Control System

Capacitor Bank Protection, Automation, and Control



Key Features and Benefits

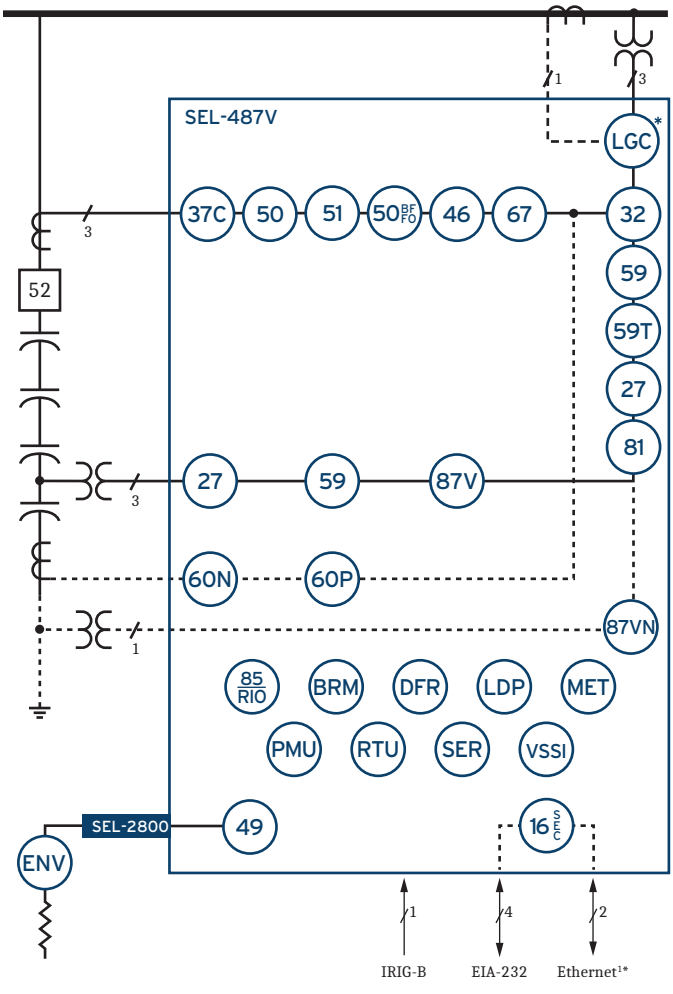
The SEL-487V Capacitor Bank Protection and Control System integrates voltage or reactive power control for grounded and ungrounded capacitor banks with full automation and protection in one device.

- **Grounded and Ungrounded Bank Protection.** The SEL-487V provides sensitive voltage differential or current unbalance protection with compensation adjustment. Use the compensation adjustment to zero out small unbalances that are natural in the bank, as well as instrument transformer errors. Instantaneous and time-overcurrent elements and voltage elements provide additional protection for the capacitor bank. The SEL-487V provides breaker failure protection for the capacitor bank breaker by using high-speed (less than one cycle) open-pole detection logic that reduces coordination times for critical breaker failure applications.
- **Control.** You can use the SEL-487V-1 control functions to maintain system voltage and VAR or power factor (PF) levels. The control functions include auto/manual and local/remote control capabilities with control instability detection for alarm or blocking of control operations. Implement the time-of-day control feature to synchronize capacitor bank insertion with peak VAR demand periods for any weekday or weekend period. Automatically sequence as many as three capacitor bank stages by using the universal sequencing control. This control provides sequencing based upon accumulated operating time, an analog quantity, or a fixed order.
- **Faulted-Phase and Section Identification Logic.** The patented faulted-phase and section identification logic reduces the time needed to identify faulted capacitor bank units. This logic automatically determines the phase (A, B, C) and section (top/bottom or left/right) where the faulty capacitor bank unit is located.
- **Simple Application-Based Settings.** You can use the recommended capacitor bank protection elements in the SEL-487V that are based on the capacitor bank nameplate and configuration settings. The relay selects from differential voltage, differential neutral voltage, neutral current unbalance, and phase current unbalance protection.

- **Simple Settings Assistance.** The Capacitor Bank Assistant software simplifies settings calculations for grounded wye capacitor bank applications. This software runs as a tool within ACSELERATOR QuickSet® SEL-5030 Software. QuickSet and Capacitor Bank Assistant are available at no charge from SEL.
- **Comprehensive Metering.** Improve system load profiles by using built-in, high-accuracy metering functions. PF and VAR measurements optimize capacitor bank operation. Minimize equipment needs with full metering capabilities including rms, maximum/minimum, demand/peak, energy, and instantaneous values.
- **Harmonic Metering.** The relay provides individual harmonic content from fundamental through the 15th harmonic for all current and voltage channels. Total Harmonic Distortion is provided as a percentage of the fundamental.
- **Auxiliary Trip/Close Pushbuttons.** You can use the optional pushbuttons that are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.
- **Directional Elements.** You can use the phase and ground directional elements with voltage polarization.
- **Breaker Failure.** High-speed (less than one cycle) open-pole detection logic reduces coordination times for critical breaker failure applications. Apply the relay to supply breaker failure protection for all supported breakers. Logic for breaker failure retrip and initiation of transfer tripping is included.
- **IEC 60255-149 Compliant Thermal Model.** The relay can provide a configurable thermal model for the protection of a wide variety of devices. This function can activate a control action or issue an alarm or trip when equipment overheats as a result of adverse operation conditions. A separate resistance temperature detector (RTD) module is required for this application.
- **Ethernet Access.** The optional Ethernet card grants access to all relay functions. Use IEC 61850 Manufacturing Message Specification (MMS) or DNP3 protocol directly to interconnect with automation systems. You can also connect to DNP3 networks through a communications processor. Use File Transfer Protocol (FTP) for high-speed data collection. Connect to substation or corporate LANs to transmit synchrophasors by using TCP or UDP internet protocols.
- **Serial Data Communication.** The relay can communicate serial data through SEL ASCII, SEL Fast Message, SEL Fast Operate, MIRRORED BITS®, and DNP3 protocols. Synchrophasor data are provided in either SEL Fast Message or IEEE C37.118 format.
- **Automation.** The enhanced automation features include programmable elements for local control, remote control, protection latching, and automation latching. Local metering on the large front-panel LCD eliminates the need for separate panel meters. Serial and Ethernet links efficiently transmit key information, including metering data, protection element and control I/O status, synchrophasor data, IEC 61850 GOOSE messages, Sequential Events Recorder (SER) reports, breaker monitoring, relay summary event reports, and time synchronization. Apply expanded SELOGIC® control equations with math and comparison functions in control applications. Incorporate as many as 1000 lines of automation logic to accelerate and improve control actions.
- **Synchrophasors.** You can make informed load dispatch decisions based on actual real-time phasor measurements from relays across your power system. Record streaming synchrophasor data from the relay for system-wide disturbance recording. Control the power system by using local and remote synchrophasor data.
- **Breaker and Battery Monitoring.** You can schedule breaker maintenance when accumulated breaker duty (independently monitored for each pole) indicates possible excess contact wear. The relay records electrical and mechanical operating times for both the last operation and the average of operations since function reset. An alarm contact provides notification of substation battery voltage problems even if voltage is low only during trip or close operations.
- **Six Independent Settings Groups.** The relay includes group logic to adjust settings for different operating conditions, such as station maintenance, seasonal operations, emergency contingencies, loading, source changes, and adjacent relay settings changes. Select the active group settings by control input, command, or other programmable conditions.
- **Parallel Redundancy Protocol (PRP).** PRP provides seamless recovery from any single Ethernet network failure. The Ethernet network and all traffic are fully duplicated with both copies operating in parallel.
- **IEC 61850 Operating Modes.** The relay supports IEC 61850 standard operating modes such as Test, Blocked, On, and Off.
- **Digital Relay-to-Relay Communications.** MIRRORED BITS communications can monitor internal element conditions between bays within a station, or between stations, using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel.
- **Sequential Events Recorder (SER).** The SER records the last 1000 events, including setting changes, startups, and selectable logic elements.

- **Oscillography and Event Reporting.** The relay records voltages, currents, and internal logic points at a sampling rate as fast as 8 kHz. Offline phasor and harmonic-analysis features allow investigation of bay and system performance. Time-tag binary COMTRADE event reports with high-accuracy time stamping for accuracy better than 10 µs.
- **Digitally Signed Upgrades.** The relay supports upgrading the relay firmware with a digitally signed upgrade file. The digitally signed portion of the upgrade file helps ensure firmware and device authenticity after it is sent over a serial connection.
- **Increased Security.** The relay divides control and settings into seven relay access levels; the relay has separate breaker, protection, automation, and output access levels, among others. Set unique passwords for each access level.
- **Rules-Based Settings Editor.** You can communicate with and set the relay by using an ASCII terminal or use QuickSet to configure the relay and analyze fault records with relay element response. Use as many as 200 aliases to rename any digital or analog quantity in the relay.

Functional Overview



ANSI NUMBERS/ACRONYMS AND FUNCTIONS	
27	Undervoltage (Phase, Bank)
32	Directional Power
37C	Undercurrent
46	Phase Current Unbalance
49	IEC 60255-Compliant Thermal Model
50BF	Breaker Failure Overcurrent
50FO	Breaker Flashover Overcurrent
50	Overcurrent (Phase, Zero- Sequence, and Negative-Sequence)
51	Time-Overcurrent (Phase, Zero- Sequence, and Negative-Sequence)
59	Overvoltage (Phase, Zero- Sequence, and Negative-Sequence, and Bank)
59T	IEC 60871-1 Inverse-Time Overvoltage Element
60N	Neutral Current Unbalance
60P	Phase Current Unbalance
67	Directional Overcurrent (Phase, Zero-Sequence, and Negative-Sequence)
81	Frequency (Over, Under, ROCOF)
85 RIO	SEL Mirrored Bits Communications
87V	Phase (Tapped) Voltage Differential
87VN	Neutral Voltage Differential

ADDITIONAL FUNCTIONS	
16 SEC	Access Security (Serial, Ethernet)
BRM	Breaker Wear Monitor
DFR	Event Reports
ENV	SEL-2600 RTD Module*
LDP	Load Data Profiling
LGC	Capacitor Bank Control (PF, VAR, Voltage)*
MET	High-Accuracy Metering
PMU	Synchrophasors
RTU	Remote Terminal Unit
SER	Sequential Events Recorder
VSSI	Voltage Sag, Swell, Interruption Monitoring

[1] Copper or Fiber Optic * Optional Feature

Figure 1 Functional Overview

Protection Features

Phase Voltage Differential Elements

The SEL-487V provides three phase voltage differential elements. Use these elements to measure voltage differences between bus or line phase voltages and the tapped voltage of the grounded wye capacitor bank. Each phase voltage differential element includes a differential voltage-nulling algorithm, referred to as the KSET function. Issue a **KSET** command to the relay via serial or Telnet communications. Once received by the relay, the **KSET** command acts to zero out any existing voltage differential. The KSET function provides a means for removing small voltage differential levels because of variations in individual capacitor elements from manufacturing or from PT measurement error.

Each phase differential element includes three levels of detection, each with its own definite-time delay, as well as a low-set alarm level, trip pickup level, and high-level trip pickup.

Use the phase differential elements to detect variations in capacitor bank impedance because of loss of individual capacitor elements, an entire capacitor can, or an entire group of capacitor cans.

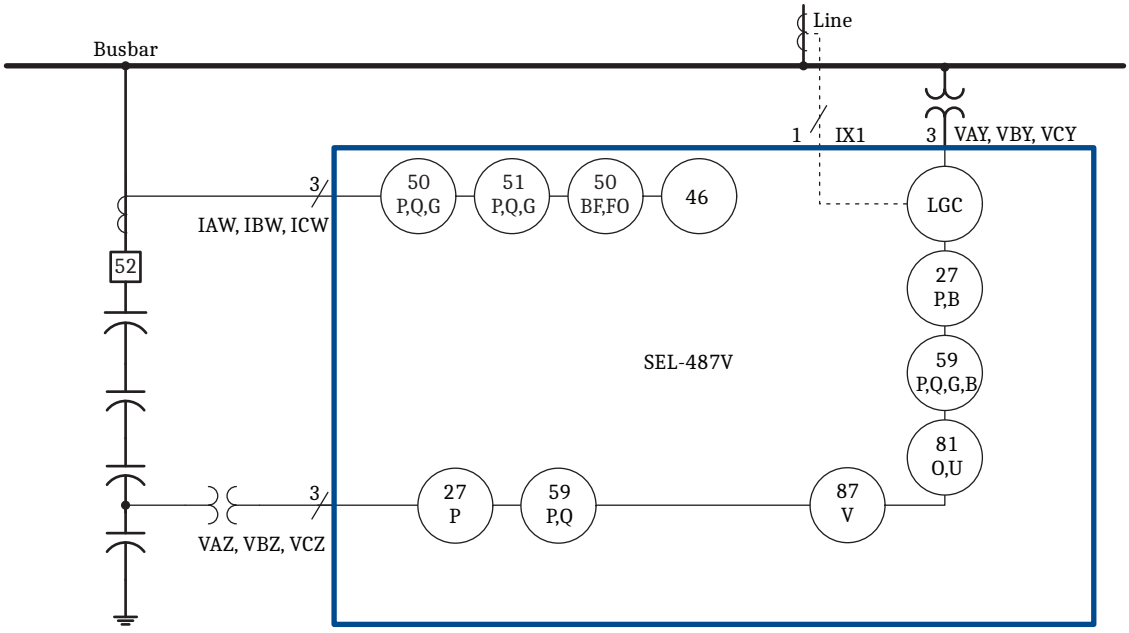


Figure 2 Phase Voltage Differential One-Line Diagram

Neutral Voltage Differential Elements

The SEL-487V provides three neutral voltage differential elements to protect as many as three ungrounded wye capacitor banks. The neutral voltage differential elements of the SEL-487V calculate zero-sequence voltage from the three-phase potential inputs provided from the line or bus. The zero-sequence voltage is then compared to the zero-sequence voltage measured by a PT connected between the capacitor bank neutral and ground. As with the phase differential elements, the neutral voltage differential element uses a KSET nulling function to eliminate differential voltage caused by manufacturing tolerances of the capacitor bank and voltage measurement devices. Sensitive measurement of the inputs allows as little as 30 mV of differential voltage to be detected.

Each neutral voltage differential element includes three pickup levels with independent definite-time delay. The three levels provide alarm, trip, and catastrophic failure protection for the capacitor bank.

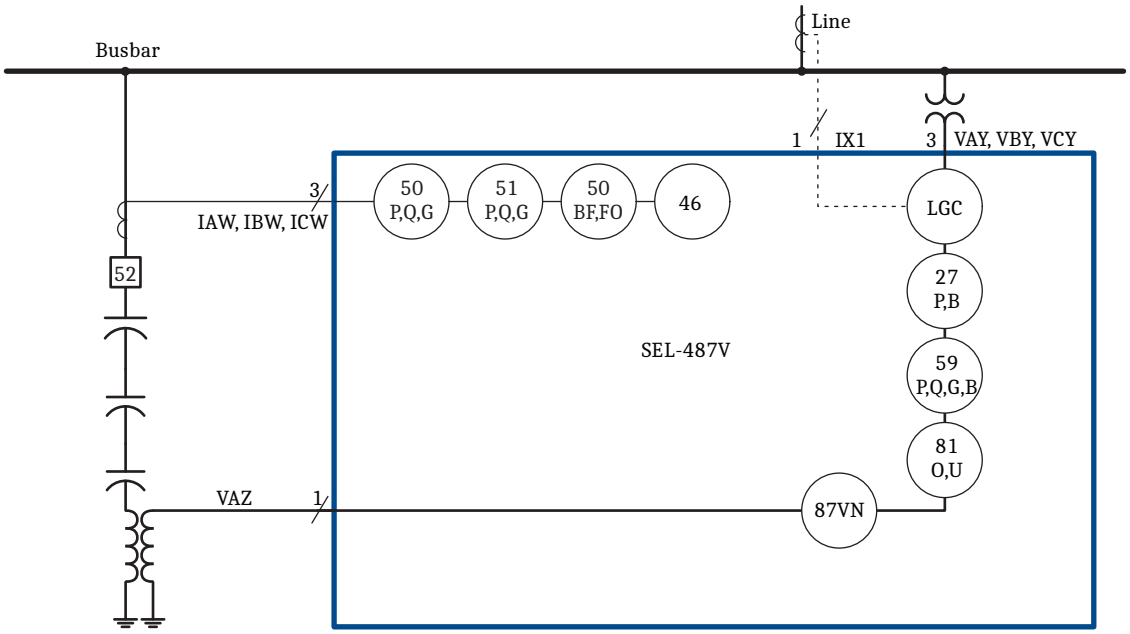


Figure 3 Neutral Voltage Differential One-Line Diagram

Phase Current Unbalance Elements

The SEL-487V protects grounded and ungrounded double-wye capacitor bank applications with phase current unbalance detection. The SEL-487V provides three independent phase current unbalance elements with KSET nulling functions. The phase unbalance elements use the positive-sequence current as a reference to enhance sensitivity and provide a directional indication. Fault direction is indicated based upon the polarity of the phase current transformer connection to the relay.

Each phase current unbalance element includes three pickup levels, with independent definite-time delay.

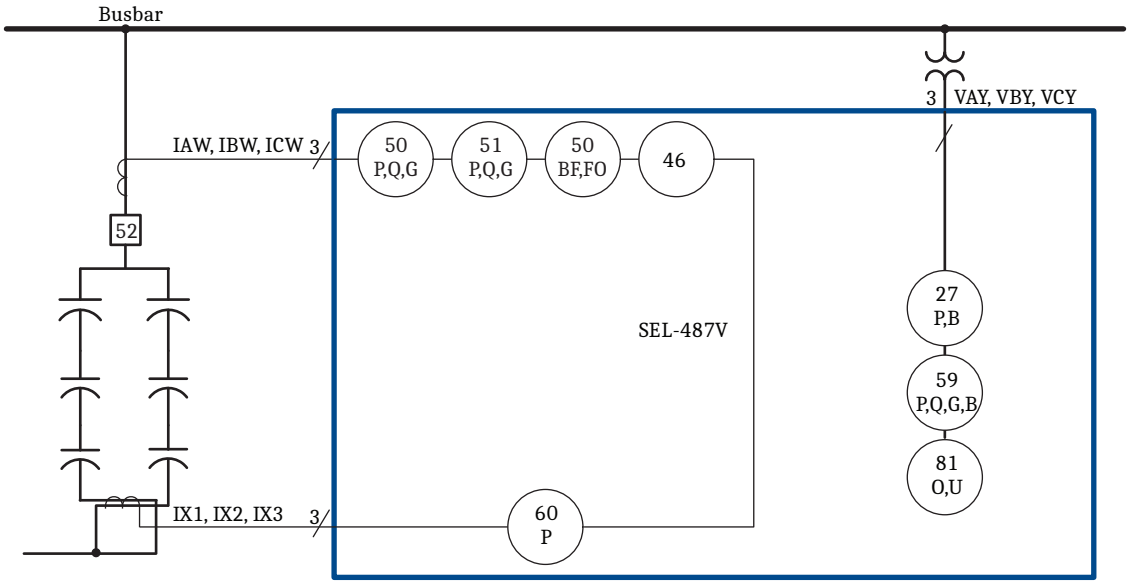


Figure 4 Phase Current Unbalance One-Line Diagram

Neutral Current Unbalance Elements

Protect ungrounded capacitor bank configurations with the SEL-487V neutral current unbalance elements. The SEL-487V provides three elements to protect as many as three parallel capacitor banks. Each element includes with three levels of pickup with definite-time delay.

Issue the **KSET** command via the relay serial port or through a Telnet session to provide KSET nulling for each neutral current element.

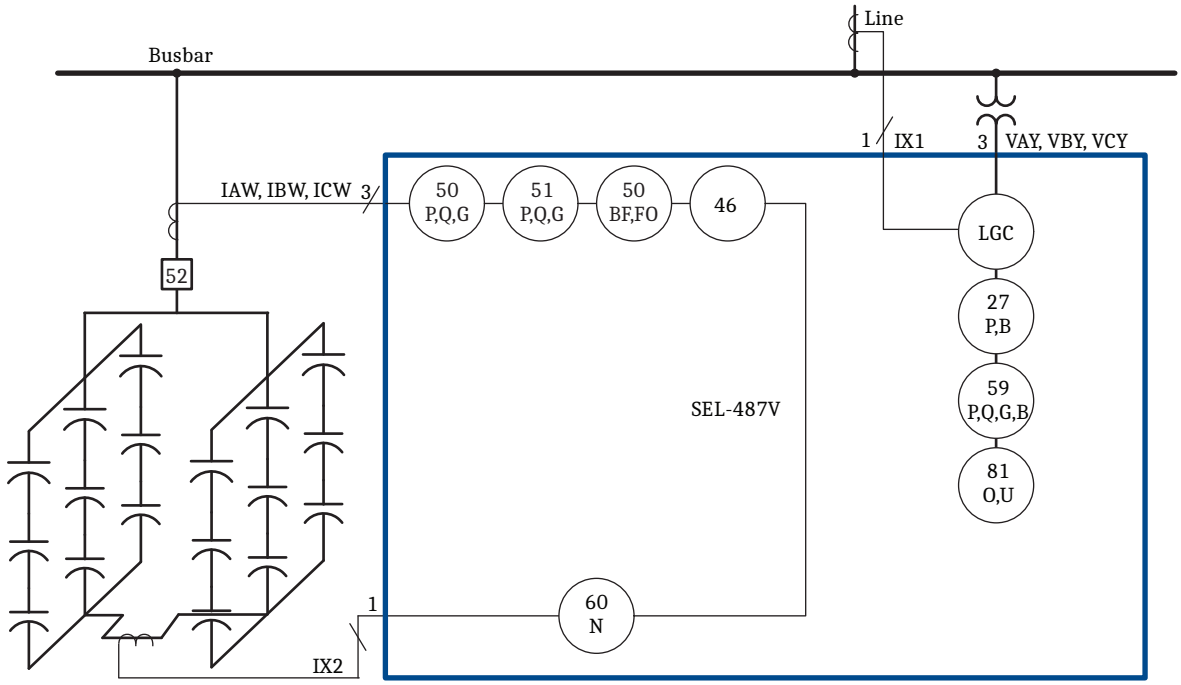


Figure 5 Neutral Current Unbalance One-Line Diagram

Faulted-Phase and Section Identification Logic

The SEL-487V makes sensitive measurements of the magnitude and phase angle of differential quantities generated by the failure of fuses or elements within the capacitor bank. The SEL-487V uses these measurements to automatically determine the faulted phase (A, B, C) and section (top, bottom or left, right) in grounded and ungrounded capacitor bank applications. Use the faulted-phase and section identification logic to provide local or remote indication of the problem area within the capacitor bank so that fault location identification times are reduced. The faulted-phase and section identification logic is processed each time a differential alarm, trip, or high-set element asserts.

Undercurrent Elements

The relay includes six undercurrent elements, each with two levels, for a total of 12 undercurrent outputs for detecting loss of load conditions. All 12 elements provide both instantaneous and time-delayed outputs. You can use SELOGIC control equations to switch the 12 elements in or out of service.

Inverse-Time Overvoltage Elements

Six inverse-time overvoltage elements are provided, and are designed to meet the IEC 60871-1:2005 standard for maximum allowable overvoltage for capacitor banks in service. Selectable operating quantities provide flexibility for the input to the inverse-time overvoltage elements, and the built-in logic tracks overvoltage duration with respect to operating time.

Current Unbalance

The SEL-487V uses the average three-phase terminal current on the W current terminals to calculate the percentage difference between the individual phase current and the terminal average current. If the percentage difference is greater than the set pickup value, the phase unbalance element asserts. To prevent this element from asserting during fault conditions and after a terminal circuit breaker has closed, the final terminal unbalance out-

put (46*n*P) is supervised by using current, fault detectors, and the open-phase detection logic. The current unbalance logic is blocked from operating if any of the following conditions is true:

- The mean terminal current is less than 5 percent or greater than 200 percent of I nominal (I_{NOM} = 1 A or 5 A)
- The FAULT Relay Word is asserted
- The circuit breaker has been closed (open-phase detection element has deasserted for a settable dropout period)

Thermal Overload Protection

The SEL-487V provides three independent thermal elements that conform to the IEC 60255-149 standard for thermal overload protection of a variety of devices, including in-line reactors used to limit capacitor bank switching transients.

Ambient temperature measurements for the thermal model are provided using the SEL-2600 RTD Module.

Backup Protection

Add reliability and dependability by providing independent backup protection without increasing relay count. The SEL-487V can provide primary differential voltage or current unbalance protection with backup voltage and overcurrent protection on the capacitor bank.

Breaker Control

The SEL-487V contains analog voltage inputs for multiple sources and control inputs to indicate both breaker and disconnect position, as well as the logic required to provide breaker control. This includes separate monitoring functions, as well as separate elements for tripping and closing the breaker. All analog values are monitored on a per-phase basis to allow station control access to complete information for individual components of the system.

Automatic Voltage Control

Configure as many as three independent automatic voltage control elements to operate by using power factor, VAR, or voltage control feedback. *Figure 6–Figure 8* show the deadband characteristics of these control functions. Alternatively, the SEL-487V can control capacitor banks based on the time of day and the day of the week.

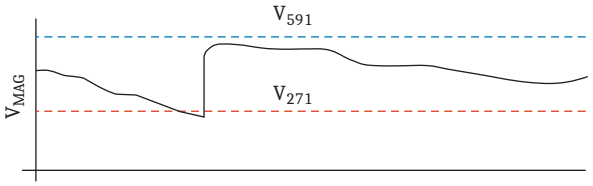


Figure 6 Voltage Control Deadband Characteristics

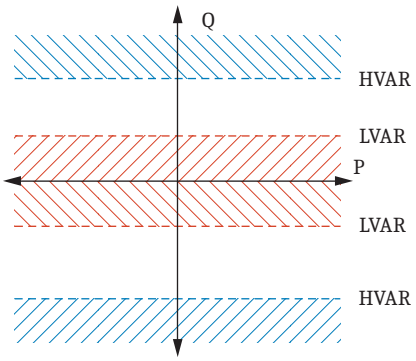


Figure 7 VAR Control Deadband Characteristics

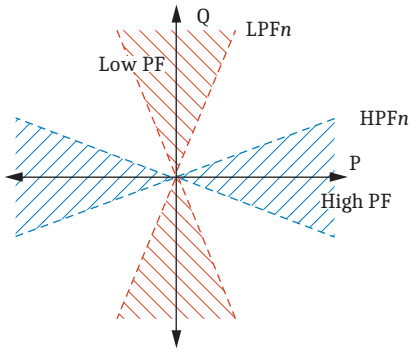


Figure 8 PF Control Deadband Characteristics

Universal Sequencer

The Universal Sequencer provides for the automatic sequencing of as many as three capacitor bank stages, as shown in *Figure 9*. The Universal Sequencer accumulates either time in service or an analog quantity and prioritizes bank insertion to the bank with the lowest accumulated value. Bank removal can prioritize banks with the highest or lowest accumulated value or by a predetermined sequence.

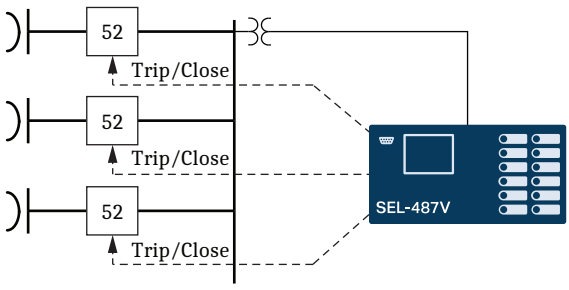


Figure 9 Universal Sequencer Capacitor Bank Staging

Additional Features

One-Line Bay Diagrams

The SEL-487V provides dynamic one-line bay diagrams on the front-panel screen with disconnect and breaker control capabilities for predefined user-selectable bay types. The relay can control as many as ten disconnects and a single breaker, depending on the one-line diagram selected. Operate disconnects and the breaker with ASCII commands, SELOGIC control equations, Fast Operate messages, and from the one-line diagram. The one-line diagram includes user-configurable apparatus labels and as many as six user-definable analog quantities.

The SEL-487V offers a variety of preconfigured one-line diagrams for common bus and capacitor bank configurations. Once a one-line diagram is selected, you can customize the names for all of the disconnect switches, capacitor bank, buses, and breaker. Most one-line diagrams contain analog display points. You can set these display points to any of the available analog quantities with labels, units, and scaling. The SEL-487V updates these values along with the breakers and switch position in real time to give instant status and complete control of a bay.

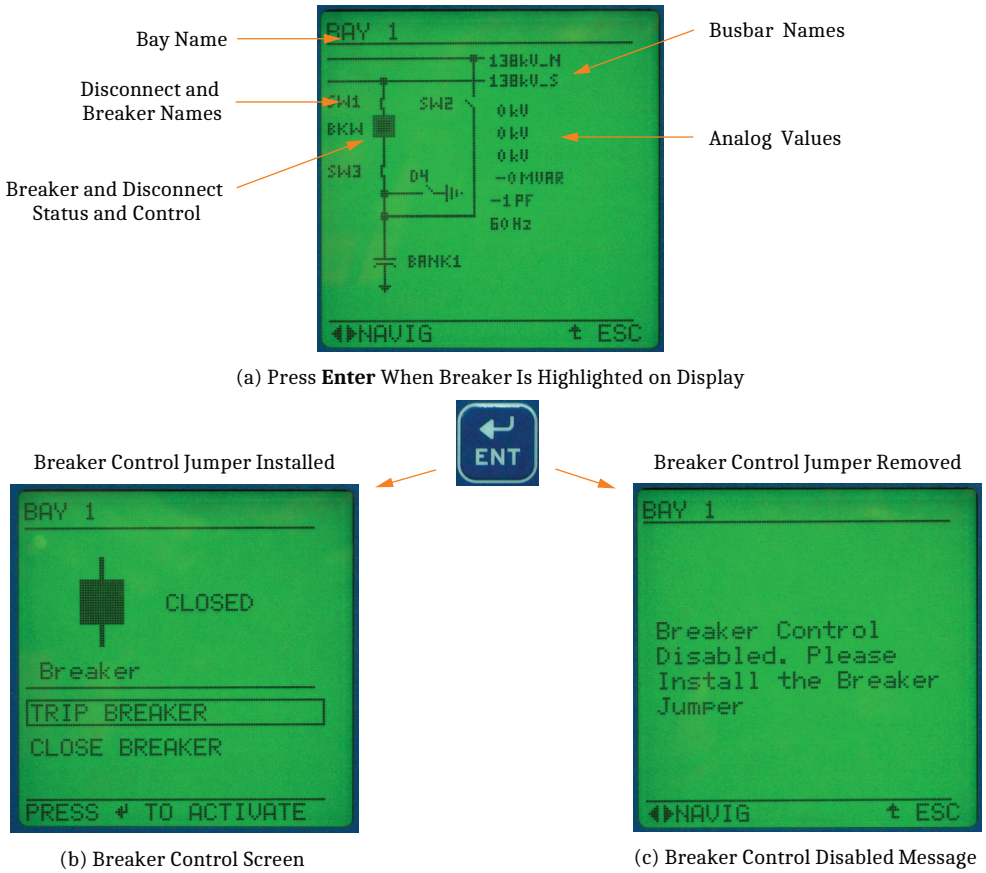
Programmable interlocks help prevent operators from incorrectly opening or closing switches or breakers. The SEL-487V not only prevents the operator from making an incorrect control decision but can notify and/or alarm upon initiation of an incorrect operation.

Circuit Breaker Operations From the Front Panel

Select the one-line diagram from the Bay settings. Additional settings for defining labels and analog quantities are also found in the Bay settings of the relay. One-line diagrams are composed of the following:

- Bay names and bay labels
- Busbar and busbar labels
- Breaker and breaker labels
- Capacitor bank labels
- Disconnect switches and disconnect switch labels
- Analog display points

Figure 10 shows the breaker control screens available when the **ENT** pushbutton is pressed with the circuit breaker highlighted as shown in *Figure 10(a)*. After pressing the **ENT** pushbutton with the breaker highlighted and the LOCAL Relay Word bit asserted, the breaker control screen in *Figure 10(b)* appears. After entering the screen in *Figure 10(b)*, the relay performs the circuit breaker operations as outlined in the *SEL-487V Instruction Manual*. If the LOCAL Relay Word bit does not assert when you press the **ENT** pushbutton, the screen in *Figure 10(c)* appears for 3 seconds, then the relay displays the screen in *Figure 10(a)* again.



(a) Press **Enter** When Breaker Is Highlighted on Display

(b) Breaker Control Screen

(c) Breaker Control Disabled Message

Figure 10 Screens for Circuit Breaker Selection

QuickSet Relay Settings Interface

There are two ways to enter relay settings with the QuickSet settings interface. The standard style settings appear in the traditional form under the relay form. QuickSet also provides an interactive relay setting entry method. The interactive method works by selecting the one-line diagram labels. This action automatically displays all the settings for the device selected. This method provides an easy way of organizing and verifying all settings associated with the device.

Figure 11 illustrates the interactive relay settings form in QuickSet. Select an apparatus in the one-line diagram and a form with apparatus-specific settings appears.

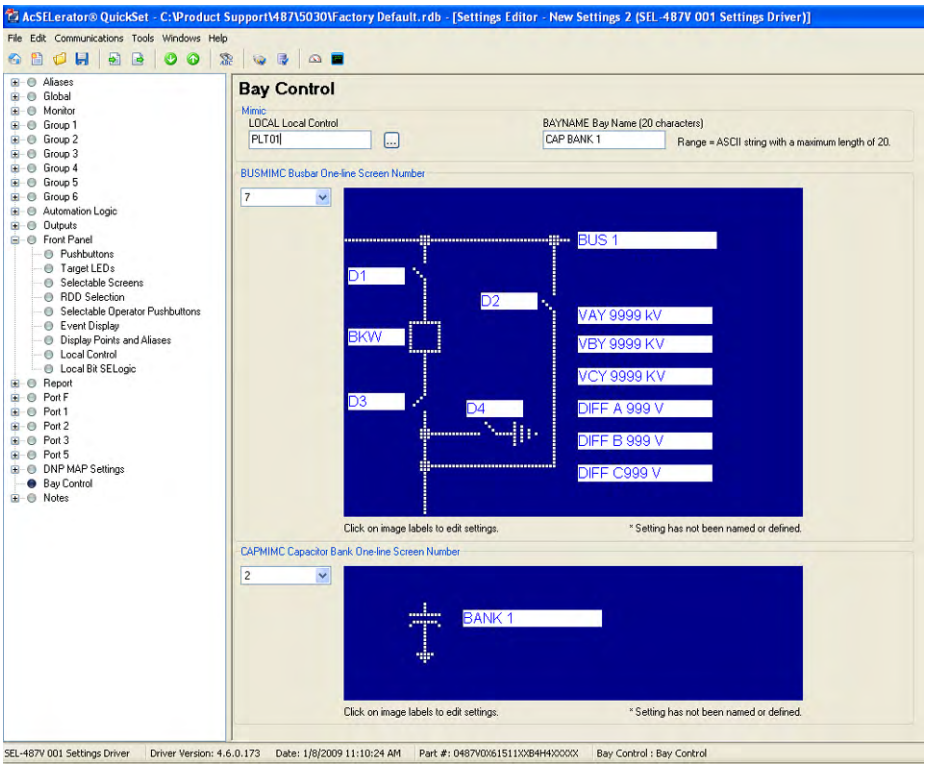


Figure 11 Interactive Relay Settings Form

QuickSet Templates

Use the fully licensed version of QuickSet to create custom views of settings, called Design Templates, to reduce complexity, decrease the chance of errors, and increase productivity.

- ➤ Lock and hide unused settings
- ➤ Lock settings to match your standard for protection, I/O assignment, communication, and SELOGIC control equations
- ➤ Enforce settings limits narrower than the device settings
- ➤ Define input variables based on the equipment nameplate or manufacturer's terminology or scaling and calculate settings from these "friendlier" inputs
- ➤ Use settings comments to guide users and explain design reasoning

Capacitor Bank Assistant

Use the Capacitor Bank Assistant, included in QuickSet, to analyze the impact of failed capacitor bank components. The Capacitor Bank Assistant applies the standard analysis techniques provided by IEEE C37.99, *IEEE Guide for the Protection of Shunt Capacitor Banks*. Input nameplate ratings and other capacitor bank parameters to calculate relevant voltages or neutral current after failure and use this data to develop relay settings.

Front-Panel Display

The LCD shows event, metering, settings, and relay self-test status information. The target LEDs display relay target information as described in *Figure 12*.

The LCD is controlled by the navigation pushbuttons (*Figure 13*), automatic messages the relay generates, and user-programmed analog and digital display points. The rotating display scrolls through the bay screen, alarm points, display points, and metering screens. Each display remains for a user-programmed time (1–15 s) before the display continues scrolling. Any message generated by the relay because of an alarm condition takes precedence over the rotating display.

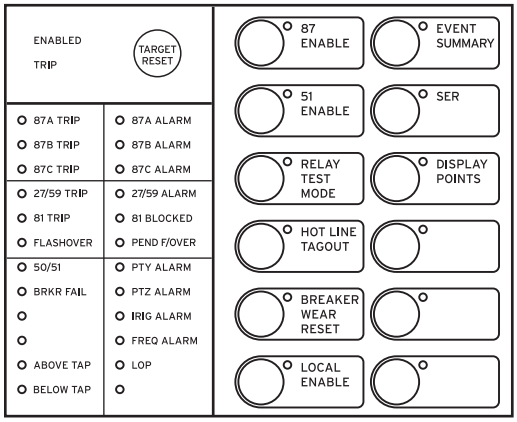


Figure 12 Factory-Default Status and Trip Target LEDs (12 Pushbutton, 24 Target Option)

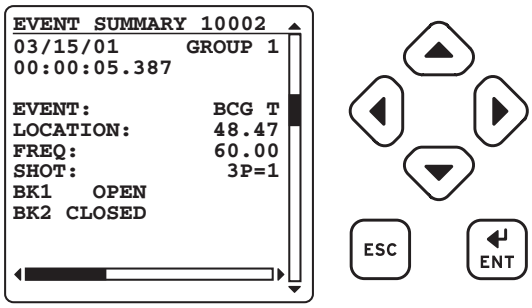


Figure 13 Front-Panel Display and Pushbuttons

Figure 12 and *Figure 13* show close-up views of the front panel of the SEL-487V. The front panel includes a 128 x 128 pixel, 3" x 3" LCD screen, LED target indicators, and pushbuttons with indicating LEDs for local control functions. The asserted and deasserted colors for the LEDs are programmable. Configure any of the direct-acting pushbuttons to navigate directly to an HMI menu item, such as events, bay display, alarm points, display points, or the SER.

Status and Trip Target LEDs

The SEL-487V includes programmable status and trip target LEDs, as well as programmable direct-action control pushbuttons/LEDs on the front panel. *Figure 12* shows these targets.

The SEL-487V features a versatile front panel that you can customize to fit your needs. Use SELOGIC control equations and slide-in configurable front-panel labels to change the function and identification of target LEDs and operator control pushbuttons and LEDs. The blank slide-in label set is included with the SEL-487V. You can use templates supplied with the relay or hand label supplied blank labels and print label sets from a printer.

Advanced Display Points

Create custom screens showing metering values, special text messages, or a mix of analog and status information. *Figure 14* shows an example of how you can use display points to show circuit breaker information and current metering. You can create as many as 96 display points. All display points occupy only one line on the display at all times. The height of the line is programmable as either single or double (see *Figure 14*). These screens become part of the autoscrolling display when the front panel times out.

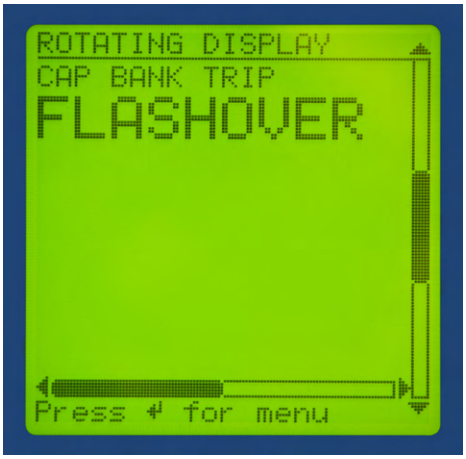


Figure 14 Sample Display Points Screen

Alarm Points

You can display messages on the SEL-487V front-panel LCD that indicates alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

Figure 15 shows a sample alarm points screen. The relay can display as many as 66 alarm points. The relay automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. You can configure the alarm points message and trigger it either immediately by using inputs, communications, or conditionally by using powerful SELOGIC control equations. The asterisk next to the alarm point indicates an active alarm. Use the front-panel navigation pushbuttons to clear inactive alarms.

Figure 15 Sample Alarm Points Screen

Auxiliary Trip/Close Pushbuttons and Indicating LEDs

Optional auxiliary trip and close pushbuttons (see *Figure 19*) and indicating LEDs allow breaker control independent of the relay. The auxiliary trip/close pushbuttons are electrically separate from the relay, operating even if the relay is turned off.

The auxiliary trip/close pushbuttons incorporate an arc suppression circuit for interrupting dc trip or close current. To use these pushbuttons with ac trip or close circuits, disable the arc suppression for either pushbutton by changing jumpers inside the SEL-487V. The operating voltage ranges of the breaker **CLOSED** and breaker **OPEN** indicating LEDs are also jumper-selectable.

Control Inputs and Outputs

The SEL-487V includes five independent and two common inputs, two Form A and three Form C standard interrupting outputs, and three Form A high-current interrupting outputs. The following additional I/O boards are currently available:

- Eight independent inputs, 13 standard Form A, and two standard Form C contact outputs.
- Eight independent inputs and eight high-speed, high-current interrupting Form A contact outputs.
- Eight independent inputs, 13 high-current interrupting Form A outputs, and two standard Form C contact outputs.
- Twenty-four inputs, six high-speed outputs, and two standard Form A contact outputs.

Assign the control inputs for control functions, monitoring logic, and general indication. You can use SELOGIC control equations to program each control output. You can add one board to the 4U chassis and two additional I/O boards to the 5U chassis.

Communications Features

See *Specifications* on page 22 for specific supported protocols.

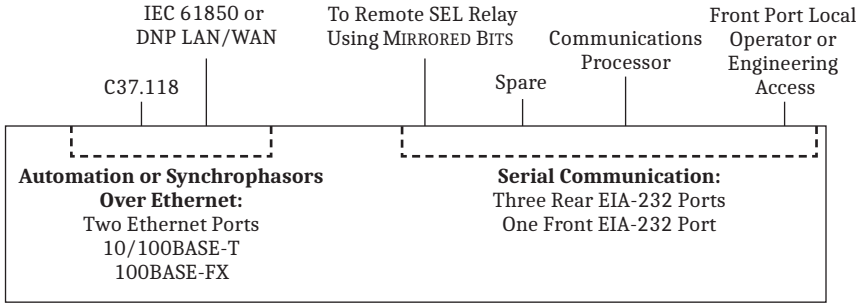


Figure 16 System Functional Overview

The relay offers the following communications features:

- Four independent EIA-232 serial ports.
- Access to event history, relay status, and meter information from the communications ports.
- Password-controlled settings management and automation features.
- SCADA interface capability, including FTP, IEC 61850 Edition 2.1, DNP3 LAN/WAN (via Ethernet), and DNP3 (via serial port). The relay does not require special communications software. You only need ASCII terminals, printing terminals, or a computer supplied with terminal emulation and a serial communications port.
- Synchrophasor data at 60 message-per-second data format.

Ethernet Card

Use popular Telnet applications for easy terminal communications with SEL relays and other devices. Transfer data at high speeds for fast file uploads. The Ethernet card communicates using FTP applications for easy and fast file transfers.

Communicate with SCADA by DNP3 and other substation IEDs by using IEC 61850 Manufacturing Message Specification (MMS) and GOOSE messaging.

Choose Ethernet connection media options for primary and standby connections:

- 10/100BASE-T twisted pair network
- 100BASE FX fiber-optic network

Telnet and FTP

Use Telnet to access relay settings, metering, and event reports remotely by using the ASCII interface. Use FTP to transfer settings files to and from the relay via the high-speed Ethernet port.

DNP3 LAN/WAN

DNP3 LAN/WAN provides the relay with DNP3 Level 2 Outstation functionality over Ethernet. Configure DNP3 data maps for use with specific DNP3 masters.

SNTP Time Synchronization

Use SNTP to synchronize relays to as little as ±1 ms with no time source delay. Use SNTP as a primary time source, or as a backup to a higher accuracy time input to the relay.

PRP

Use PRP to provide seamless recovery from any single Ethernet network failure, in accordance with IEC 62439-3. The Ethernet network and all traffic are fully duplicated with both copies operating in parallel.

HTTP Web Server

The relay can serve read-only webpages displaying certain settings, metering, and status reports. As many as four users can access the embedded HTTP server simultaneously.

IEC 61850 Ethernet Communications

IEC 61850 Ethernet-based communication protocols provide interoperability between intelligent devices within the substation. Standardized logical nodes allow interconnection of intelligent devices from different manufacturers for monitoring and control of the substation.

Eliminate system RTUs by streaming monitor and control information from the intelligent devices directly to remote SCADA client devices.

You can order the relay with IEC 61850 protocol for relay monitor and control functions, including:

- As many as 128 incoming GOOSE messages. You can use the incoming GOOSE messages to control as many as 256 control bits in the relay with <3 ms latency from device to device depending on network design. These messages provide binary control inputs to the relay for high-speed control functions and monitoring.
- As many as eight outgoing GOOSE messages. Configure outgoing GOOSE messages for Boolean or analog data such as high-speed control and monitoring of external breakers, switches, and other devices. Boolean data are provided with <3 ms latency from device to device depending on network design.
- IEC 61850 Data Server. The relay equipped with embedded IEC 61850 Ethernet protocol provides data according to predefined logical node objects. Each relay supports as many as seven simultaneous MMS client sessions, with support to association-based and indexed reports. Relevant Relay Word bits are available within the logical node data, so status of relay elements, inputs, outputs, or SELOGIC control equations can be monitored.
- As many as 256 virtual bits. Configure the virtual bits within GOOSE messaging to represent a variety of Boolean values available within the relay. These bits that the relay receives are available for use in SELOGIC control equations.
- As many as 64 remote analog outputs. Assign the remote analog outputs to virtually any analog quantity available in the relay. You can also use SELOGIC math variables to develop custom analog quantities for assignment as remote analog outputs. Remote analog outputs that use GOOSE messages provide peer-to-peer transmission of analog data. Each relay can receive as many as 256 remote analog inputs and use those inputs as analog quantities within SELOGIC control equations.
- IEC 61850 standard operating modes. The relay supports Test, Blocked, On, and Off. The relay also supports Simulation mode for added flexibility.

MMS File Services

This service of IEC 61850 MMS provides support for file transfers completely within an MMS session. All relay files that can be transferred via FTP can also be transferred via MMS file services.

MMS Authentication

When enabled via a setting in the Configured IED Description (CID) file, the relay requires authentication from any client requesting to initiate an MMS session.

Architect Software

Use ACSELERATOR Architect SEL-5032 Software to manage the IEC 61850 configuration for devices on the network. This Windows-based software provides easy-to-use displays for identifying and binding IEC 61850 network data among logical nodes that use IEC 61850-compliant CID files. Architect uses CID files to describe the data available in each relay.

Serial Communications

MIRRORED BITS Communications

The SEL patented MIRRORED BITS technology provides bidirectional relay-to-relay digital communication.

Figure 17 shows two relays with SEL-2815 Fiber-Optic Transceivers that use MIRRORED BITS communications. MIRRORED BITS communications can operate simultaneously on any two serial ports. This bidirectional digital communication creates additional outputs (transmitted MIRRORED BITS) and additional inputs (received MIRRORED BITS) for each serial port operating in the MIRRORED BITS communications mode.

Communicated information can include digital, analog, and virtual terminal data. Virtual terminal allows operator access to remote relays through the local relay. You can use this MIRRORED BITS protocol to transfer information between stations to enhance coordination and achieve faster tripping.

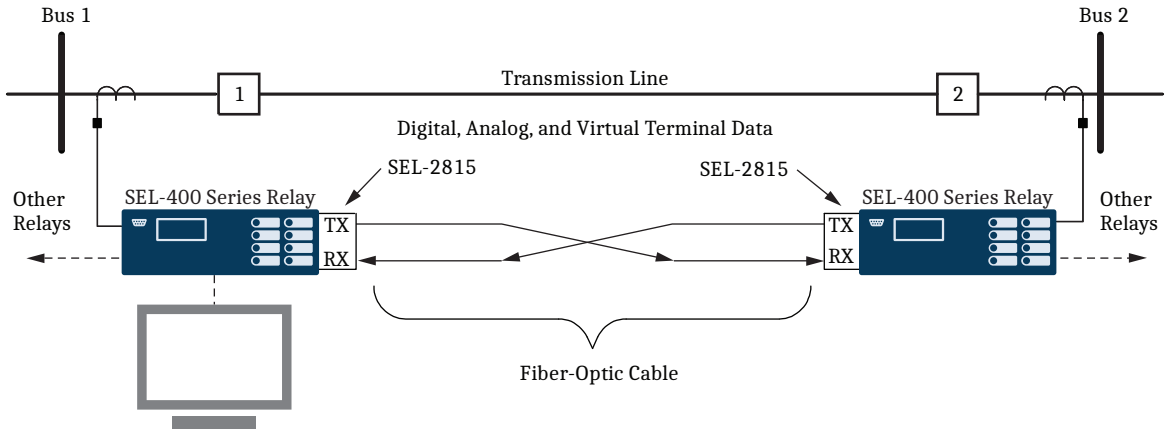


Figure 17 Integral Communication Provides Secure Protection, Monitoring, and Control as Well as Terminal Access to Both Relays Through One Connection

Open Communications Protocols

The relay does not require special communications software. ASCII terminals, printing terminals, or a computer supplied with terminal emulation and a serial communications port are all that is required. *Table 1* lists a brief description of the terminal protocols.

Table 1 Open Communications Protocol (Sheet 1 of 2)

Type	Description
ASCII	Plain-language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.
Compressed ASCII	Comma-delimited ASCII data reports. Allows external devices to obtain bay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Extended Fast Meter, Fast Operate, and Fast SER	Binary protocol for machine-to-machine communications. Quickly updates communications processors, RTUs, and other substation devices with metering information, bay element, I/O status, time-tags, open and close commands, and summary event reports. Data are checksum protected. Binary and ASCII protocols operate simultaneously over the same communications lines so that control operator metering information is not lost while a technician is transferring an event report.
Ymodem	Support for reading event, settings, and oscillography files.

Table 1 Open Communications Protocol (Sheet 2 of 2)

Type	Description
Optional DNP3 Level 2 Outstation	DNP with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and settings groups.
IEEE C37.118	Phasor measurement protocol.
MIRRORED BITS	SEL protocol for exchanging digital and analog information among SEL relays and for use as low-speed terminal connection.
IEC 61850	Ethernet-based international standard for interoperability between intelligent devices in a substation.
PRP	PRP provides redundant Ethernet network capabilities for seamless operation in the event of loss to one network.
SNTP	Ethernet-based SNTP for time synchronization among relays.
FTP and Telnet	Use Telnet to establish a terminal-to-relay connection over Ethernet. Use FTP to move files in and out of the relay over Ethernet.

Automation

Flexible Control Logic and Integration Features

Use the control logic to perform the following:

- ➤ Replace traditional panel control switches
- ➤ Eliminate remote terminal unit (RTU)-to-bay wiring
- ➤ Replace traditional latching relays
- ➤ Replace traditional indicating panel lights

Eliminate traditional panel control switches with 32 local control points. Set, clear, or pulse local control points with the front-panel pushbuttons and display. Program the local control points to implement your control scheme via SELOGIC control equations. Use the local control points for such functions as trip testing, enabling/disabling reclosing, and tripping/closing circuit breakers.

Eliminate RTU-to-bay wiring with 32 remote control points per relay. Set, clear, or pulse remote control points via serial port commands. Incorporate the remote control points into your control scheme via SELOGIC control equations. Use remote control points for SCADA-type control operations (e.g., trip, close, settings group selection).

Replace traditional latching relays for such functions as remote control enable with 64 latching control points. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the latch control points via control inputs, remote control points, local control points, or any programmable logic condition. The relay retains the states of the latch control points after turning on following a power interruption.

Replace traditional indicating panel lights and switches with as many as 24 latching target LEDs and as many as 12 programmable pushbuttons with LEDs. Define custom messages (i.e., `BREAKER OPEN`, `BREAKER CLOSED`, `RECLOSER ENABLED`) to report power system or relay conditions on the large format LCD. Control displayed messages with SELOGIC control equations by driving the LCD via any logic point in the relay.

SELOGIC Control Equations With Expanded Capabilities and Aliases

Expanded SELOGIC control equations put relay logic in the hands of the engineer. Assign inputs to suit your application, logically combine selected bay elements for various control functions, and assign outputs to your logic functions.

Programming SELOGIC control equations consists of combining relay elements, inputs, and outputs with SELOGIC control equation operators (*Table 2*). Any element in the Relay Word can be used in these equations. For complex or unique applications, these expanded SELOGIC functions allow superior flexibility.

Table 2 SELOGIC Control Equation Operators (Sheet 1 of 2)

Operator Type	Operators	Comments
Boolean	AND, OR, NOT	Allows combination of measuring units.
Edge Detection	F_TRIG, R_TRIG	Operates at the change of state of an internal function.
Comparison	>, >=, =, <=, <, < >	
Arithmetic	+, –, *, /	Uses traditional math functions for analog quantities in an easily programmable equation.

Table 2 SELOGIC Control Equation Operators (Sheet 2 of 2)

Operator Type	Operators	Comments
Numerical	ABS, SIN, COS, LN, EXP, SQRT, LOG	
Precedence Control	( )	Allows multiple and nested sets of parentheses.
Comment	#, (* *)	Provides for easy documentation of control and protection logic.

Use the relay alias capability to assign more meaningful names to analog and Boolean quantities. This improves the readability of customized programming. Use as many as 200 aliases to rename any digital or analog quantity. The following is an example of possible applications of SELOGIC control equations that use aliases.

```
=>>SET T <Enter>
1: PMV01,THETA
```

(assign the alias "THETA" to math variable PMV01)

```
2: PMV02,TAN
```

(assign the alias "TAN" to math variable PMV02)

```
=>>SET L <Enter>
1: # CALCULATE THE TANGENT OF THETA
2: TAN:=SIN(THETA)/COS(THETA)
```

(use the aliases in an equation)

Add programmable control functions to your relay and automation systems. New functions and capabilities enable using analog values in conditional logic statements. The following are examples of possible applications of SELOGIC control equations with expanded capabilities.

- Emulate a motor-driven reclose timer, including stall, reset, and drive-to-lockout conditions.
- Scale analog values for SCADA retrieval.
- Initiate remedial action sequence based on load flow before fault conditions.
- Interlock breakers and disconnect switches.
- Restrict breaker tripping in excessive duty situations without additional relays.
- Hold momentary change-of-state conditions for SCADA polling.

Metering and Monitoring

Access a range of useful information in the relay with the metering function. Metered quantities include fundamental primary and secondary current and voltage magnitudes and angles for each terminal. RMS voltage and current metering is also provided. Fundamental phase and real and reactive power, per-phase voltage magnitude, angle, and frequency are displayed in the metering report for applications that use the relay voltage inputs.

Table 3 Metering Capabilities (Sheet 1 of 2)

Capabilities	Description
Instantaneous Quantities	
Fundamental Voltages $V_{A, B, C}$ (Y, Z), 3V0, V1, 3V2	Voltages measured at the fundamental frequency of the power system.
RMS Voltages $V_{A, B, C}$ (Y, Z), Vϕϕ	RMS voltages include fundamental plus all measurable harmonics.
Fundamental Currents $I_{A, B, C}$ (W, X), 3I0, I1, 3I2	Currents measured at the fundamental frequency of the power system.
RMS Currents $I_{A, B, C}$ (W, X)	RMS currents include fundamental plus all measurable harmonics.
Power Metering Quantities	
$S_{A, B, C}$, $P_{A, B, C}$, $Q_{A, B, C}$ (W, X) $S_{3\phi}$, $P_{3\phi}$, $Q_{3\phi}$ (W, X) Power Factor	Power quantities calculated using fundamental voltage and current measurements (S = MVA, P = MW, Q = MVAR).
Harmonic Metering Quantities	
$I_{A, B, C}$ (W, X) $V_{A, B, C}$ (Y, Z)	Harmonics 1–15 for all currents and voltages

Table 3 Metering Capabilities (Sheet 2 of 2)

Capabilities	Description
RTD Metering Quantities	
As many as 12 temperature measurements	Available from connected SEL-2600 RTD Module
Unbalance Metering Quantities	
DVA, DVB, DVC	Phase differential voltage magnitude for each phase
DVG1, DVG2, DVG3	Ground differential voltage magnitude for each of three elements
60KIX1, 60KIX1, 60KIX3	Unbalance current magnitude for each of three elements
Synchrophasors	
Voltages (Primary Magnitude, Angle) $V_{A, B, C}$ (Y, Z), V1	Primary phase quantities (kV) for each of the six voltage sources available
Currents (Primary Magnitude, Angle) $I_{A, B, C}$ (W, X), I1	Primary phase quantities (A) for each of the six current sources available
Frequency FREQ ROCOF	 Frequency (Hz) as measured by frequency source potential inputs Rate-of-change of frequency (Hz/s)

Voltage Sag, Swell, Interruption Records

The SEL-487V can perform automatic voltage disturbance monitoring for three-phase systems. The sag, swell, interruption (SSI) recorder uses the SSI Relay Word bits to determine when to start (trigger) and when to stop recording. The SSI recorder uses nonvolatile memory, so de-energizing the relay will not erase any stored SSI data.

The recorded data are available through the SSI report, which includes date, time, current, voltage, and voltage sag, swell, interruption (VSSI) element status during voltage disturbances, as determined by programmable settings VINT, VSAG, and VSWELL. When the relay is recording a disturbance, entries are automatically added to the SSI report at one of four rates, depending on the length of the disturbance:

- Once per quarter cycle
- Once per cycle
- Once per 64 cycles
- Once per day

Event Reporting and SER

Event reports and SER features simplify post-fault analysis and help improve your understanding of both simple and complex protective scheme operations. These features also aid in testing and troubleshooting relay settings and protective schemes.

Oscillography and Event Reporting

In response to a user-selected internal or external trigger, the voltage, current, and element status information contained in each event report confirms relay, scheme, and system performance for every fault. The relay provides sampling rates as fast as 8 kHz for analog quantities in a COMTRADE file format, as well as eight-sample-per-cycle and four-sample-per-cycle event reports. The relay stores as much as 3 seconds of 8 kHz event data. The relay supports inclusion of user-configurable analogs in the events. Reports are stored in nonvolatile memory. Relay settings operational in the relay at the time of the event are appended to each event report.

Each relay provides event reports for analysis with software such as SEL-5601-2 SYNCHROWAVE® Event Software. With SYNCHROWAVE Event, you can display events from several relays to make the fault analysis easier and more meaningful. Because the different relays time-stamp the events with values from their individual clocks, be sure to time synchronize the relay with an IRIG-B clock input to use this feature.

Event Summary

Each time the relay generates a standard event report, it also generates a corresponding event summary. This is a concise description of an event that includes the following information:

- Relay/terminal identification
- Event date and time
- Event type
- Event number
- Time source

- ➤ Active settings group
- ➤ Targets asserted during the fault
- ➤ Current magnitudes and angles for each terminal
- ➤ Pre-fault and fault calculated zero- and negative-sequence currents
- ➤ Voltage magnitudes and angles
- ➤ Voltage differential magnitudes and angles
- ➤ Fault location
- ➤ Breaker status (open/close)

With an appropriate setting, the relay sends an event summary in ASCII text automatically to one or more serial ports each time an event report is triggered.

SER

Use this feature to gain a broad perspective of relay element operation. Items that trigger an SER entry are selectable and can include as many as 250 monitoring points, such as I/O change-of-state and element pickup/dropout. The relay SER stores the latest 1000 events.

Analog Signal Profiling

The relay provides analog signal profiling for as many as 20 analog quantities. Select any analog quantity measured or calculated by the relay for analog signal profiling. You can select signal sampling rates of 1, 5, 15, 30, and 60 minutes through settings. The analog signal profile report provides a comma-separated variable (CSV) list that you can load into any spreadsheet or database for analysis and graphical display.

SELOGIC enable/disable functions can start and stop signal profiling based on Boolean or analog comparison conditions.

Substation Battery Monitor for DC Quality Assurance

The relay measures and reports the substation battery voltage for one battery system. The battery monitor supports programmable threshold comparators and associated logic provides alarm and control for one battery and charger. The relay also provides dual ground detection.

Monitor dc system status alarms with an SEL communications processor and trigger messages, telephone calls, or other actions.

The measured dc voltage is reported in the METER display via serial port communications, on the LCD, and in the event report. Use the event report data to see an oscillographic display of the battery voltage. Monitor the substation battery voltage drops during trip, close, and other control operations.

Breaker Contact Wear Monitoring

Circuit breakers experience mechanical and electrical wear during each operation. Effective scheduling of breaker maintenance takes into account the manufacturer's published data of contact wear versus interruption levels and operation count.

- ➤ Every time the breaker trips, the relay integrates interrupted current. When the result of this integration exceeds the threshold set by the breaker wear curve (*Figure 18*), the relay can alarm via an output contact or the optional front-panel display. With this information, you can schedule breaker maintenance in a timely, economical fashion.
- ➤ The relay monitors last and average mechanical and electrical interruption time per pole. You can easily determine if operating time is increasing beyond reasonable tolerance and then schedule proactive breaker maintenance. You can activate an alarm point if operation time exceeds a preset value.

The relay also monitors breaker motor run time, pole discrepancy, and breaker inactivity.

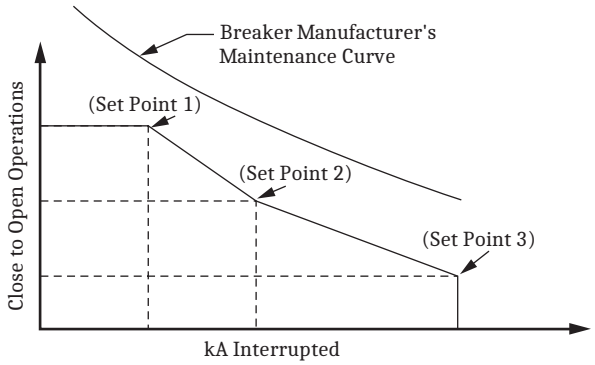


Figure 18 Breaker Contact Wear Curve and Settings

Diagrams and Dimensions

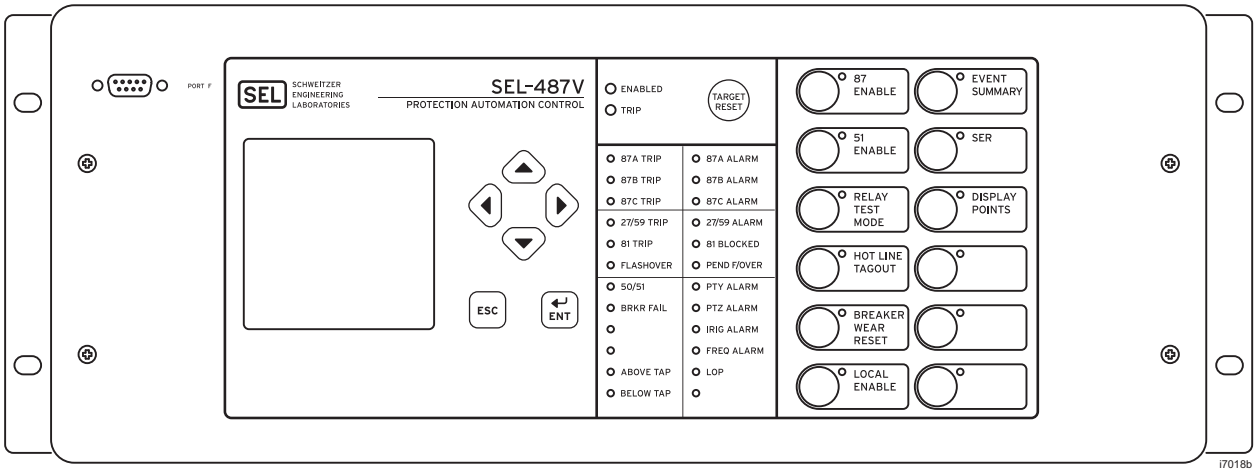


Figure 19 4U Front Panel, Rack-Mount Option

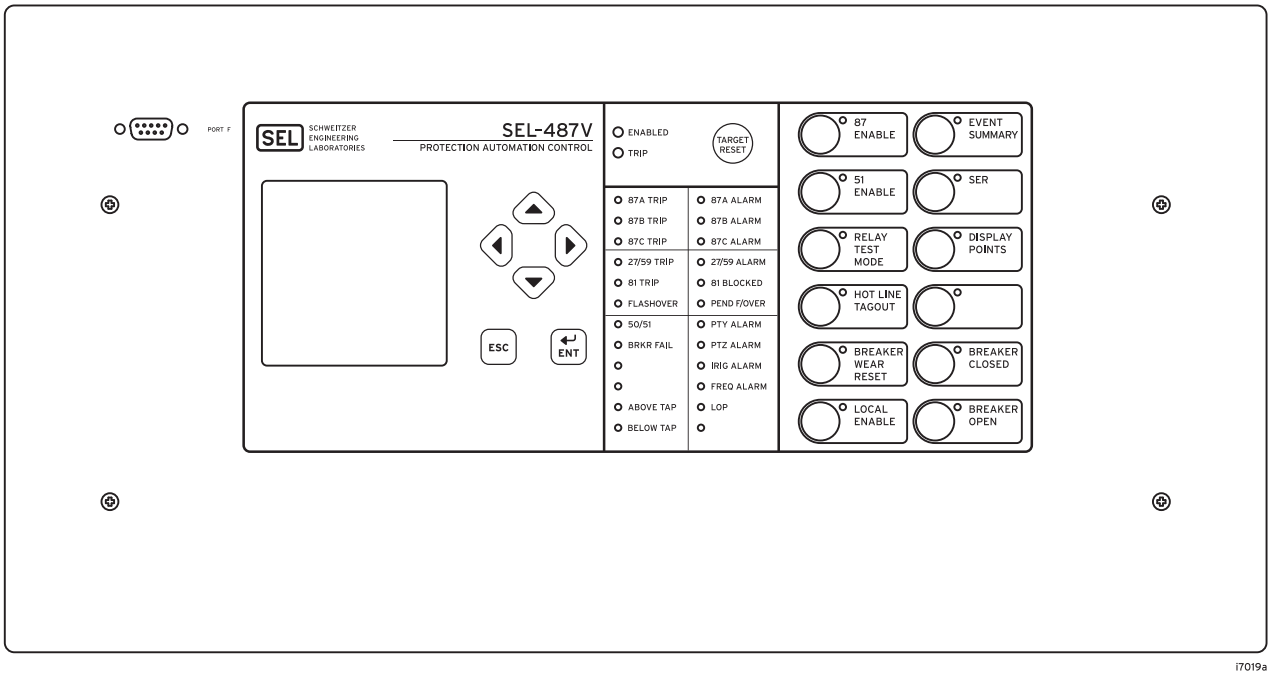


Figure 20 5U Front Panel, Panel-Mount Option

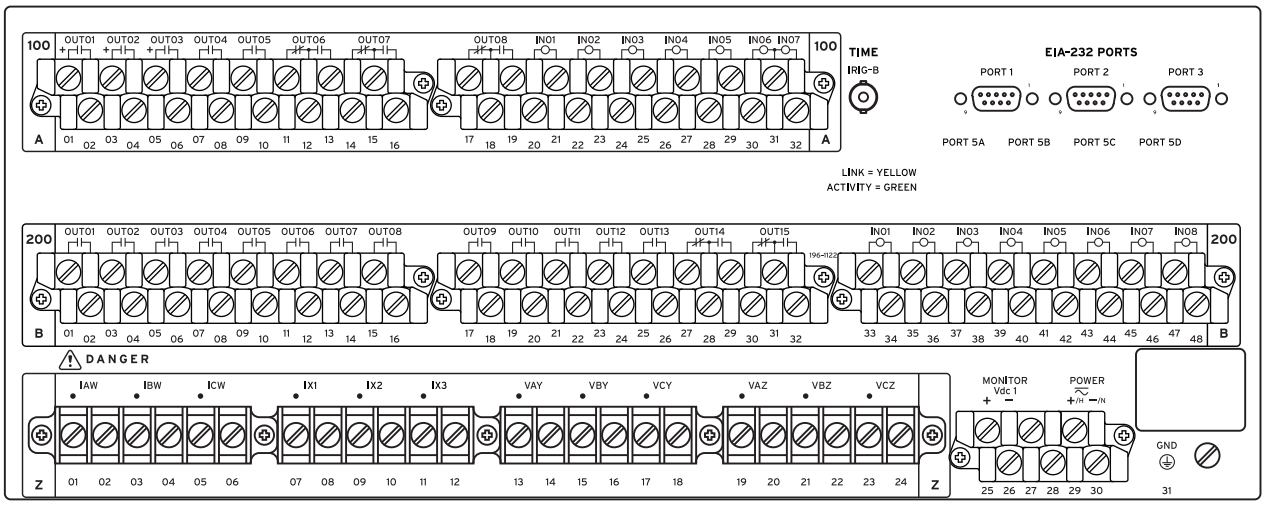


Figure 21 4U Rear Panel, Main Board, Terminal Block Option, One (INT2) I/O Board Option

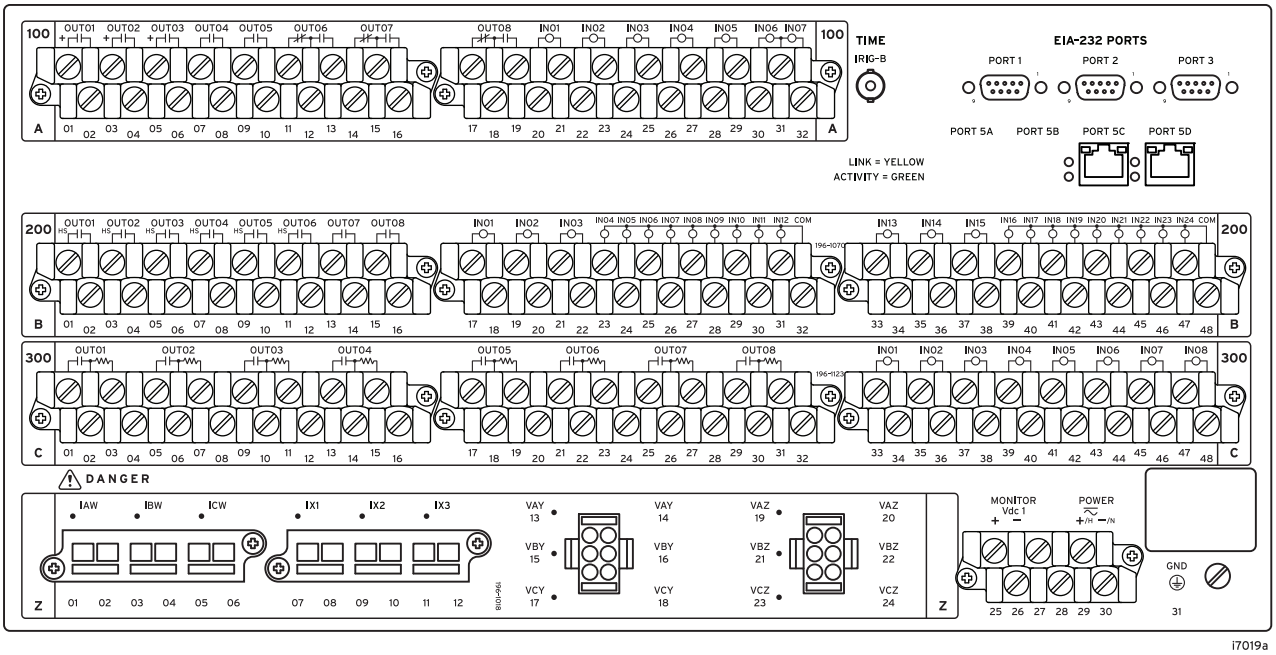
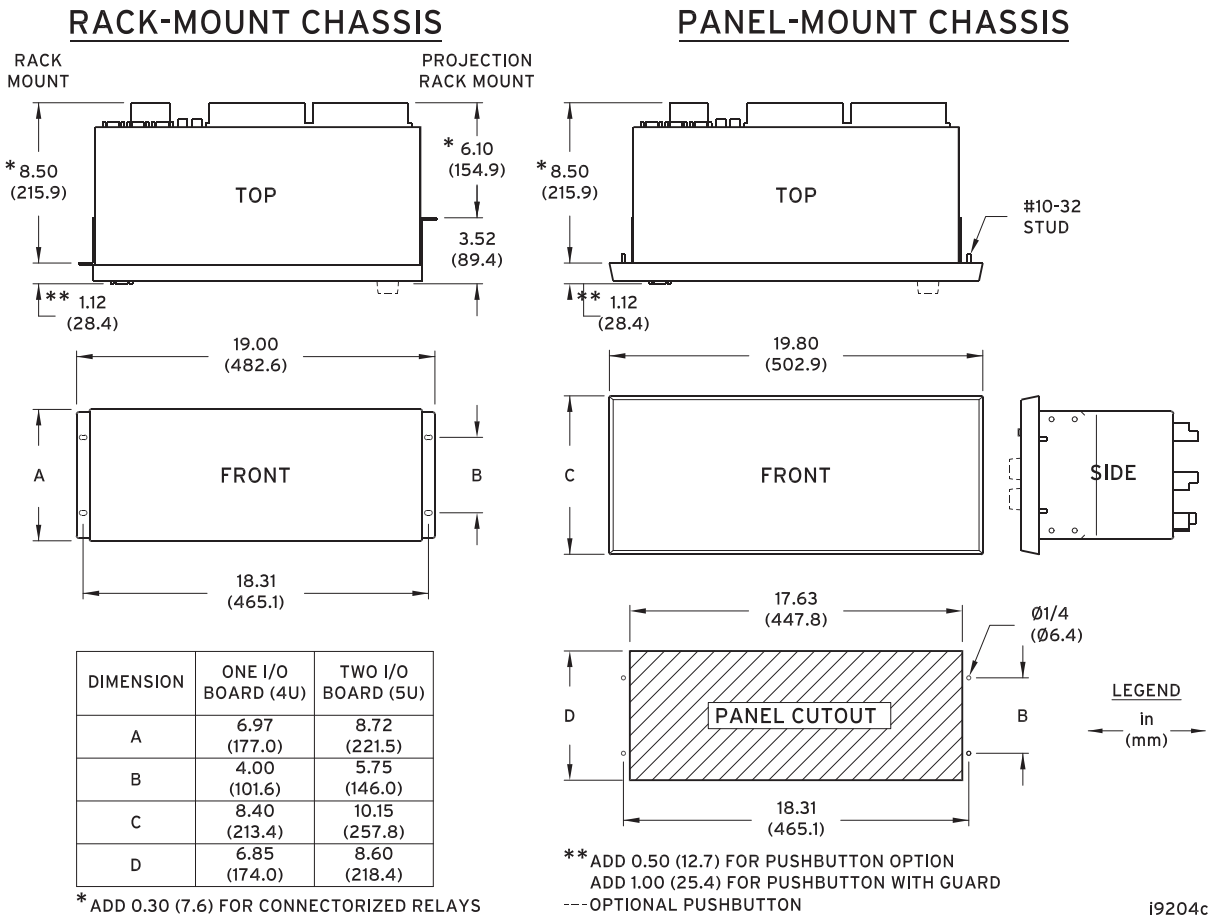


Figure 22 5U Rear Panel, Main Board, Connectorized Option, Two (One INT3, One INT8) I/O Board Option



DIMENSION	ONE I/O BOARD (4U)	TWO I/O BOARD (5U)
A	6.97 (177.0)	8.72 (221.5)
B	4.00 (101.6)	5.75 (146.0)
C	8.40 (213.4)	10.15 (257.8)
D	6.85 (174.0)	8.60 (218.4)

Figure 23 Dimensions for Rack- and Panel-Mount Models (Horizontal Mounting Shown; Dimensions Also Apply to Vertical Mounting)

Models and Options

Depending on the number of interface boards, the SEL-487V is available in either 4U (one interface board) or 5U (two interface boards) sizes (U is one rack unit in height—44.45 mm [1.75 in]). Select I/O boards from a choice of four interface boards. Each board is designed to provide a wide range of input and output combinations to tailor the relay for your specific application. If your application requires more I/O, add contact I/O with the SEL-2505/ SEL-2506 Remote I/O Module.

Firmware Options

Order the SEL-487V with standard firmware or add automatic voltage control and VSSI reporting functions.

- Standard firmware (SEL-487V-0)
- Standard firmware plus automatic voltage control and VSSI reporting (SEL-487V-1)

Current Channel Options

Select the CT secondary current for either set of current input channels from 1 A or 5 A (all three inputs 1 A or 5 A). Order the current channels for the SEL-487V in any one of the following four configurations:

- 1 A W current channels, 1 A X current channels
- 5 A W current channels, 5 A X current channels
- 5 A W current channels, 1 A X current channels
- 1 A W current channels, 5 A X current channels

Interface Board (I/O) Options

Select from four interface boards to provide flexibility with the diverse I/O requirements when installing the SEL-487V at power plants, transmission, and distribution networks. You can install the interface boards in any combination in the relay. *Table 4* provides I/O information about the main board and the four interface boards.

Table 4 Main Board and Interface Board Information

Board Name	Inputs	Description	Outputs	Description
Main	5	Optoisolated, independent, level-sensitive	3	High-current interrupting, Form A
	2	Optoisolated, common, level-sensitive		
			2	Standard Form A
			3	Standard Form C
INT2	8	Optoisolated, independent, level-sensitive	13	Standard Form A
			2	Standard Form C
INT3	18	Two sets of 9 common optoisolated, level-sensitive	4	High-current interrupting Form A outputs
	6	Optoisolated, independent, level-sensitive		
INT4	18	Two sets of 9 common optoisolated, level-sensitive	6	High-speed, high-current interrupting, Form A
	6	Optoisolated, independent, level-sensitive	2	Standard Form A
INT7	8	Optoisolated, independent, level-sensitive	13	High-current interrupting, Form A
			2	Standard Form C
INT8	8	Optoisolated, independent, level-sensitive	8	High-speed, high-current interrupting, Form A

- Voltage ranges for the inputs on the main board as well as for the inputs on the four interface boards
  - 48 Vdc
  - 110 Vdc
  - 125 Vdc
  - 220 Vdc
  - 250 Vdc
- Power supply options
  - 48–125 Vdc or 110–120 Vac
  - 125–250 Vdc or 110–240 Vac
- Communications cards option
  - Ethernet card with combinations of 10/100BASE-T and 100BASE-FX media connections on each of the two ports
- Communications protocols
  - (SEL ASCII, SEL Compressed ASCII, SEL Fast Messaging [SEL Fast Meter, SEL Fast Operate, SEL Fast SER, SEL Fast Message Synchrophasor], IEEE C37.118 Synchrophasor, Ymodem File Transfer, Enhanced MIRRORED BITS, DNP3 LAN/WAN, DNP3 Level 2 Outstation, Serial, HTTP server (read-only), PRP, FTP (ordering option), Telnet (ordering option), IEC 61850 Edition 2.1 (ordering option)

Contact the SEL factory or your local Technical Service Center for particular part number and ordering information (see *Technical Support* on page 30). You can also view the latest part number and ordering information on the SEL website at selinc.com.

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

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

UL Listed to U.S. and Canadian safety standards (File E212775; NRGU, NRGU7)

CE Mark

General

AC Current Input (Secondary Circuit)

Sampling Rate: 8 kHz

Note: Current transformers are Measurement Category II.

Current Rating (With DC Offset at X/R = 10, 1.5 cycles)

1 A Nominal: 18.2 A

5 A Nominal: 91 A

Continuous Thermal Rating

1 A Nominal: 3 A
4 A (+55°C)

5 A Nominal: 15 A
20 A (+55°C)

Saturation Current (Linear) Rating

1 A Nominal:	20 A
5 A Nominal:	100 A

A/D Current Limit

Note: Signal clipping may occur beyond this limit.

1 A Nominal:	49.5 A
5 A Nominal:	247.5 A

One-Second Thermal Rating

1 A Nominal:	100 A
5 A Nominal:	500 A

One-Cycle Thermal Rating

1 A Nominal:	250 A peak
5 A Nominal:	1250 A peak

Burden Rating

1 A Nominal:	≤0.1 VA at 1 A
5 A Nominal:	≤0.5 VA at 5 A

AC Voltage Inputs

Three-phase, four-wire (wye) connections are supported.

Rated Voltage Range:	55–250 V_{LN}
Operational Voltage Range:	0–300 V_{LN}
Ten-Second Thermal Rating:	600 Vac
Burden:	≤0.1 VA @ 125 V

Frequency and Rotation

Nominal Frequency	
Rating:	50 ± 5 Hz 60 ± 5 Hz
Phase Rotation:	ABC or ACB
Frequency Tracking Range:	40–65 Hz <40 Hz = 40 Hz >65 Hz = 65 Hz
Maximum Slew Rate:	15 Hz/s

Power Supply

48–125 Vdc or 110–120 Vac

Rated Voltage:	48–125 Vdc, 110–120 Vac
Operational Voltage Range:	38–140 Vdc 85–140 Vac
Rated Frequency:	50/60 Hz
Operational Frequency Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-26:2013
Interruption:	14 ms at 48 Vdc, 160 ms at 125 Vdc per IEC 60255-26:2013
Burden:	<35 W, <90 VA

125–250 Vdc or 110–240 Vac

Rated Voltage:	125–250 Vdc, 110–240 Vac
Operational Voltage Range:	85–300 Vdc 85–264 Vac
Rated Frequency:	50/60 Hz
Operational Frequency Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-26:2013
Interruption:	46 ms at 125 Vdc, 250 ms at 250 Vdc per IEC 60255-26:2013
Burden:	<35 W, <90 VA

Control Outputs

Note: IEEE C37.90-2005 and IEC 60255-27:2013

Update Rate:	1/8 cycle
Make (Short Duration Contact Current):	30 Adc 1,000 operations at 250 Vdc 2,000 operations at 125 Vdc
Limiting Making Capacity:	1000 W at 250 Vdc (L/R = 40 ms)
Mechanical Endurance:	10,000 operations

Standard

Rated Voltage:	48–250 Vdc 110–240 Vrms
Operational Voltage Range:	0–300 Vdc 0–264 Vrms
Operating Time:	Pickup ≤6 ms (resistive load) Dropout ≤6 ms (resistive load)
Short-Time Thermal Withstand:	50 A for 1 s
Continuous Contact Current:	6 A at 70°C 4 A at 85°C
Contact Protection:	MOV protection across open contacts 264 Vrms continuous voltage 300 Vdc continuous voltage
Limiting Breaking Capacity/Electrical Endurance:	10,000 operations 10 operations in 4 seconds, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break L/R = 40 ms (DC) PF = 0.4 (AC)
48 Vdc	0.63 Adc	0.63 Adc
125 Vdc	0.30 Adc	0.30 Adc
250 Vdc	0.20 Adc	0.20 Adc
110 Vrms	0.30 Arms	0.30 Arms
240 Vrms	0.20 Arms	0.20 Arms

Hybrid (High-Current Interrupting)

Rated Voltage:	48–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time:	Pickup ≤6 ms (resistive load) Dropout ≤6 ms (resistive load)
Short-Time Thermal Withstand:	50 Adc for 1 s
Continuous Contact Current:	6 Adc at 70°C 4 Adc at 85°C
Contact Protection:	MOV protection across open contacts 300 Vdc continuous voltage
Limiting Breaking Capacity/Electrical Endurance:	10,000 operations 4 operations in 1 second, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break
48 Vdc	10 Adc	10 Adc (L/R = 40 ms)
125 Vdc	10 Adc	10 Adc (L/R = 40 ms)
250 Vdc	10 Adc	10 Adc (L/R = 20 ms)

Note: Do not use hybrid control outputs to switch ac control signals. These outputs are polarity-dependent.

Fast Hybrid (High-Speed High-Current Interrupting)

Rated Voltage:	48–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time:	Pickup ≤10 µs (resistive load) Dropout ≤8 ms (resistive load)

Short-Time Thermal Withstand: 50 Adc for 1 s

Continuous Contact Current: 6 Adc at 70°C
4 Adc at 85°C

Contact Protection: MOV protection across open contacts
300 Vdc continuous voltage

Limiting Breaking Capacity/Electrical Endurance: 10,000 operations
4 operations in 1 second, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break
48 Vdc	10 Adc	10 Adc (L/R = 40 ms)
125 Vdc	10 Adc	10 Adc (L/R = 40 ms)
250 Vdc	10 Adc	10 Adc (L/R = 20 ms)

Note: Do not use hybrid control outputs to switch ac control signals.

Control Inputs Optoisolated (Use With AC or DC Signals)

General

Sampling Rate: 2 kHz

Main Board: 5 inputs with no shared terminals
2 inputs with shared terminals

INT2, INT7, and INT8 Interface Boards: 8 inputs with no shared terminals

INT3 and INT4: 6 inputs with no shared terminals
18 inputs with shared terminals (2 groups of 9 inputs, with each group sharing one terminal)

Voltage Options: 48, 110, 125, 220, 250 V

DC Thresholds (Dropout Thresholds Indicate Level-Sensitive Option)

48 Vdc: Pickup 38.4–60.0 Vdc; Dropout <28.8 Vdc

110 Vdc: Pickup 88.0–132.0 Vdc; Dropout <66.0 Vdc

125 Vdc: Pickup 105–150 Vdc; Dropout <75 Vdc

220 Vdc: Pickup 176–264 Vdc; Dropout <132 Vdc

250 Vdc: Pickup 200–300 Vdc; Dropout <150 Vdc

Current Draw: 5 mA at nominal voltage; 8 mA at 110 V option

Rated Frequency: 50 ± 5 Hz, 60 ± 5 Hz

AC Thresholds (Ratings Met Only When Recommended Control Input Settings Are Used—See *Table 2.1*)

48 Vac: Pickup 32.8–60.0 Vac rms; Dropout <20.3 Vac rms

110 Vac: Pickup 75.1–132.0 Vac rms; Dropout <46.6 Vac rms

125 Vac: Pickup 89.6–150.0 Vac rms; Dropout <53.0 Vac rms

220 Vac: Pickup 150.3–264.0 Vac rms; Dropout <93.2 Vac rms

250 Vac: Pickup 170.6–264.0 Vac rms; Dropout <106 Vac rms

Current Draw: <5 mA at nominal voltage
<8 mA at 110 V option

Auxiliary Breaker Control Pushbuttons

Quantity: 2

Pushbutton Functions: One (1) pushbutton shall be provided to open the breaker.
One (1) pushbutton shall be provided to close the breaker.

Resistive DC or AC Outputs With Arc Suppression Disabled:

Make: 30 A

Carry: 6 A continuous carry

1 s Rating: 50 A

MOV Protection (Maximum Voltage): 250 Vac/330 Vdc

Breaking Capacity (10,000 Operations):

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

High Interrupt DC Outputs With Arc Suppression Enabled:

Make: 30 A

Carry: 6 A continuous carry

1 s Rating: 50 A

MOV Protection: 330 Vdc/130 J

Breaking Capacity (10,000 Operations):

48 V	10 A	L/R = 40 ms
125 V	10 A	L/R = 40 ms
250 V	10 A	L/R = 20 ms

Breaker Open/Closed LEDs:

48 Vdc: on for 30–60 Vdc;
125 Vdc: on for 80–150 Vdc; 96–144 Vac
250 Vdc: on for 150–300 Vdc; 192–288 Vac

Note: With nominal control voltage applied, each LED draws 8 mA (max.). Jumpers may be set to 125 Vdc for 110 Vdc input and set to 250 Vdc for 220 Vdc input.
Note: Per IEC 60255-23:1994, using the simplified method of assessment.
Note: Make rating per IEEE C37.90-2005.
Note: Per IEC 61810-2:2005.

Communications Ports

EIA-232: 1 front and 3 rear

Serial Data Speed: 300–57600 bps

Communications Card Slot for Optional Ethernet Card

Ordering Options: 10/100BASE-T

Connector Type: RJ45

Ordering Option: 100BASE-FX Fiber-Optic

Connector Type: LC

Fiber Type: Multimode

Wavelength: 1300 nm

Source: LED

Min. TX Power: –19 dBm

Max. TX Power: –14 dBm

RX Sensitivity: –32 dBm

Sys. Gain: 13 dB

Time Inputs

IRIG-B Input–Serial Port 1

Input: Demodulated IRIG-B

Rated I/O Voltage: 5 Vdc

Operating Voltage Range: 0–8 Vdc

Logic High Threshold: ≥ 2.8 Vdc

Logic Low Threshold: ≤0.8 Vdc

Input Impedance: 2.5 kΩ

IRIG-B Input–BNC Connector

Input: Demodulated IRIG-B

Rated I/O Voltage: 5 Vdc

Operating Voltage Range: 0–8 Vdc

Logic High Threshold: ≥ 2.2 Vdc

Logic Low Threshold: ≤0.8 Vdc

Input Impedance: >1 kΩ

Dielectric Test Voltage: 0.5 kVac

Operating Temperature

–40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20°C and above +70°C. Stated temperature ranges not applicable to UL applications.

Humidity

5% to 95% without condensation

Weight (Maximum)

3U Rack Unit: 8.00 kg (17.5 lb)

4U Rack Unit: 9.8 kg (21.5 lb)

5U Rack Unit: 11.6 kg (25.5 lb)

Terminal Connection

Rear Screw-Terminal Tightening Torque, #8 Ring Lug

Minimum: 1.0 Nm (9 in-lb)

Maximum: 2.0 Nm (18 in-lb)

User terminals and stranded copper wire should have a minimum temperature rating of 105°C. Ring terminals are recommended.

Wire Size and Insulation

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. You can use the following table as a guide in selecting wire sizes. The grounding conductor should be as short as possible and sized equal to or greater than any other conductor connected to the device, unless otherwise required by local or national wiring regulations.

Connection Type	Min. Wire Size	Max. Wire Size
Grounding (Earthing) Connection	14 AWG (2.5 mm^2)	N/A
Current Connection	16 AWG (1.5 mm^2)	10 AWG (5.3 mm^2)
Potential (Voltage) Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Contact I/O	18 AWG (0.8 mm^2)	10 AWG (5.3 mm^2)
Other Connection	18 AWG (0.8 mm^2)	10 AWG (5.3 mm^2)

Type Tests

Installation Requirements

Overvoltage Category: 3

Pollution Degree: 2

Safety

Product Standards: IEC 60255-27:2013
IEEE C37.90-2005
21 CFR 1040.10

Dielectric Strength: IEC 60255-27:2013, Section 10.6.4.3
2.5 kVac, 50/60 Hz for 1 min: Analog Inputs, Contact Outputs, Digital Inputs
3.6 kVdc for 1 min: Power Supply, Battery Monitors
2.2 kVdc for 1 min: IRIG-B
1.1 kVdc for 1 min: Ethernet

Impulse Withstand: IEC 60255-27:2013, Section 10.6.4.2
IEEE C37.90-2005
Common Mode:
±1.0 kV: Ethernet
±2.5 kV: IRIG-B
±5.0 kV: All other ports
Differential Mode:
0 kV: Analog Inputs, Ethernet, IRIG-B, Digital Inputs
±5.0 kV: Standard Contact Outputs, Power Supply Battery Monitors
+5.0 kV: Hybrid Contact Outputs

Insulation Resistance: IEC 60255-27:2013, Section 10.6.4.4
>100 MΩ @ 500 Vdc

Protective Bonding: IEC 60255-27:2013, Section 10.6.4.5.2
<0.1 Ω @ 12 Vdc, 30 A for 1 min

Ingress Protection: IEC 60529:2001 + CRGD:2003
IEC 60255-27:2013
IP30 for front and rear panel
IP10 for rear terminals with installation of ring lug
IP40 for front panel with installation of serial port cover
IP52 for front panel with installation of dust protection accessory

Max Temperature of Parts and Materials: IEC 60255-27:2013, Section 7.3

Flammability of Insulating Materials: IEC 60255-27:2013, Section 7.6
Compliant

Electromagnetic (EMC) Immunity

Product Standards: IEC 60255-26:2013
IEC 60255-27:2013
IEEE C37.90-2005

Surge Withstand Capability (SWC): IEC 61000-4-18:2006 + A:2010
IEEE C37.90.1-2012
Slow Damped Oscillatory, Common and Differential Mode:
±1.0 kV
±2.5 kV
Fast Transient, Common and Differential Mode:
±4.0 kV

Electrostatic Discharge (ESD): IEC 61000-4-2:2008
IEEE C37.90.3-2001
Contact:
±8 kV
Air Discharge:
±15 kV

Radiated RF Immunity: IEEE C37.90.2-2004
IEC 61000-4-3:2006 + A1:2007 + A2:2010
20 V/m (>35 V/m, 80% AM, 1 kHz)
Sweep: 80 MHz to 1 GHz
Spot: 80, 160, 450, 900 MHz
10 V/m (>15 V/m, 80% AM, 1 kHz)
Sweep: 80 MHz to 1 GHz
Sweep: 1.4 GHz to 2.7 GHz
Spot: 80, 160, 380, 450, 900, 1850, 2150 MHz

Electrical Fast Transient Burst (EFTB): IEC 61000-4-4:2012
Zone A:
±2 kV: Communication ports
±4 kV: All other ports

Surge Immunity: IEC 61000-4-5:2005
Zone A:
±2 kV_{L-L}
±4 kV_{L-E}
±4 kV: communication ports (Ethernet)
Note: Cables connected to EIA-422, G.703, EIA-232, and IRIG-B communications ports shall be less than 10 m in length for Zone A compliance.
Zone B:
±1 kV_{L-L}: 24–48 Vdc power supply
±2 kV_{L-E}: 24–48 Vdc power supply
±2 kV: communication ports (except Ethernet)
Note: Cables connected to EIA-232 communications ports shall be less than 10 m in length for Zone B compliance.

Conducted Immunity:	IEC 61000-4-6:2013 20 V/m; (>35 V/m, 80% AM, 1 kHz) Sweep: 150 kHz–80 MHz Spot: 27, 68 MHz
Power Frequency Immunity (DC Inputs):	IEC 61000-4-16:2015 Zone A: Differential: 150 V_{RMS} Common Mode: 300 V_{RMS}
Power Frequency Magnetic Field:	IEC 61000-4-8:2009 Level 5: 100 A/m; ≥60 Seconds; 50/60 Hz 1000 A/m 1 to 3 Seconds; 50/60 Hz **Note:** 50G1P ≥0.05 (ESS = N, 1, 2) 50G1P ≥0.1 (ESS = 3, 4)
Power Supply Immunity:	IEC 61000-4-11:2004 IEC 61000-4-17:1999/A1:2001/A2:2008 IEC 61000-4-29:2000 AC Dips & Interruptions Ripple on DC Power Input DC Dips & Interruptions Gradual Shutdown/Startup (DC only) Discharge of Capacitors Slow Ramp Down/Up Reverse Polarity (DC only)
Damped Oscillatory Magnetic Field:	IEC 61000-4-10:2016 Level 5: 100 A/m

EMC Compatibility

Product Standards:	IEC 60255-26:2013
Emissions:	IEC 60255-26:2013, Section 7.1 Class A 47 CFR Part 15B Class A Canada ICES-001 (A) / NMB-001 (A)

Environmental

Product Standards:	IEC 60255-27:2013
Cold, Operational:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Cold, Storage:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Dry Heat, Operational:	IEC 60068-2-2:2007 Test Bd: 16 hours at +85°C
Dry Heat, Storage:	IEC 60068-2-2:2007 Test Bd: 16 hours at +85°C
Damp Heat, Cyclic:	IEC 60068-2-30:2005 Test Db: +25 °C to +55°C, 6 cycles (12 + 12-hour cycle), 95% RH
Damp Heat, Steady State:	IEC 60068-2-78:2013 Severity: 93% RH, +40°C, 10 days
Cyclic Temperature:	IEC 60068-2-14:2009 Test Nb: –40°C to +80°C, 5 cycles
Vibration Resistance:	IEC 60255-21-1:1988 Class 2 Endurance, Class 2 Response
Shock Resistance:	IEC 60255-21-2:1988 Class 1 Shock Withstand, Class 1 Bump Withstand, Class 2 Shock Response
Seismic:	IEC 60255-21-3:1993 Class 2 Quake Response

Event Reports

High-Resolution Data

Rate:	8000 samples/second 4000 samples/second 2000 samples/second 1000 samples/second
Output Format:	Binary COMTRADE

Note: Per IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111-1999.

Event Reports

Length:	15/30 cycles
Maximum Duration:	Five records of 24 seconds each at 1000 samples/second
Resolution:	1/4 and 1/8 samples/cycle
Digital Inputs:	2 kHz

Event Summary

Storage:	100 summaries

Breaker History

Storage:	128 histories

Sequential Events Recorder

Storage:	1000 entries
Trigger Elements:	250 relay elements

Processing Specifications

AC Voltage and Current Inputs

8000 samples per second, 3 dB low-pass analog filter cut-off frequency at 646 Hz, ± 5%

Digital Filtering

Two-Cycle and Full-cycle cosine after low-pass analog filtering

Protection and Control Processing

4, 8, and 32 times per power system cycle

Control Points

32 remote bits
32 local control bits
32 latch bits in protection logic
32 latch bits in automation logic

Relay Element Pickup Ranges and Accuracies

Phase Voltage Differential Elements (87V)

Number of Elements:	3
Levels:	3 (Sensitive, Alarm, and Trip)
Pickup Range:	Magnitude: 0.1 V to 300.00 V
Pickup Accuracy, Steady-State:	±0.1% of set point
Maximum Pickup/Dropout Time:	2.5 cycles
Timers:	3 levels with individual timers for each level (0.00 to 6000.00 seconds with 0.01 second resolution)
Time-Delay Range:	0.00–64000 cycles
Time-Delay Accuracy:	±0.1% ± 4.2 ms at 60 Hz
Reset Time Range:	0.00–64000 cycles
Torque Control:	SELOGIC control equation
K Factor (Compensation) Range:	0.0000 to 1.9999 with 0.0001 resolution

Neutral Voltage Differential Elements (87VN)

Number of Elements:	3
Levels:	3 (Sensitive, Alarm, and Trip)
Pickup Range:	Magnitude: 0.1 V to 300.00 V Angle: –179.00 to 180.00 degrees
Pickup Accuracy, Steady-State:	±0.1% of set point
Maximum Pickup/Dropout Time:	2.5 cycles
Timers:	3 levels with individual timers for each level (0.00 to 6000.00 seconds with 0.01 second resolution)
Time-Delay Range:	0.00–64000 cycles

Time-Delay Accuracy:	±0.1% ± 4.2 ms at 60 Hz
Reset Time Range:	0.00–64000 cycles
Torque Control:	SELOGIC control equation
K Factor (Compensation) Range:	0.00 to 300.00 with 0.01 resolution

Phase Current Unbalance Elements (60P)

Number of Elements:	3
Pickup Range:	Magnitude: 0.005 to 20.00 per unit (I_{NOM})
Pickup Accuracy, Steady-State:	±0.001 per unit ± 10% of set point (0.005–0.05 per unit) ±0.01 per unit ± 3% of set point (0.05–20 per unit)
Maximum Pickup/Dropout Time:	2.5 cycles for I > 0.05 per unit 10 cycles for 0.002 < I < 0.05 per unit
Time-Delay Range:	0.00–16000 cycles
Reset Time Range:	0.00–16000 cycles
Time-Delay Accuracy:	±0.1% ± 4.2 ms at 60 Hz
Torque Control:	SELOGIC control equation

Neutral Current Unbalance Elements (60N)

Number of Elements:	3
Pickup Range:	Magnitude: 0.005 to 20.00 per unit (I_{NOM})
Pickup Accuracy, Steady-State:	±0.001 per unit ± 10% of set point (0.005–0.05 per unit) ±0.01 per unit ± 3% of set point (0.05–20 per unit)
Maximum Pickup/Dropout Time:	2.0 cycles for I > 0.05 per unit 10 cycles for 0.002 < I < 0.05 per unit
Time-Delay Range:	0.00–400.0 s
Reset Time Range:	0.00–400.00 s
Time-Delay Accuracy:	±0.1% ± 4.2 ms at 60 Hz
Torque Control:	SELOGIC control equation

Three-Phase Current Unbalance Elements (46)

Number of Elements:	3 (W current channels only)
Pickup Range:	0.00 to 2.00 per unit (I_{NOM})
Pickup Accuracy, Steady-State:	±1% of set point
Maximum Pickup/Dropout Time:	1.5 cycles
Time-Delay Range:	0.00–400.0 s
Time-Delay Accuracy:	±0.1% ± 4.2 ms at 60 Hz

Undercurrent Elements (37)

Number of Elements:	6
Levels:	2 (alarm and trip)
Pickup Range	Magnitude: OFF, 0.05 to 2 per unit (I_{NOM})
Pickup Accuracy, Steady-State:	±0.01 per unit ±3% of setpoint
Maximum Pickup/Dropout Time:	1.5 cycles
Timers:	Individual timers for each level
Time-Delay Range:	0.00–16000 cycles
Time-Delay Accuracy:	±0.1% ±4.2 ms at 60 Hz
Torque Control:	SELOGIC control equation

Open-Phase Detection Logic

Number of Elements:	3 (W current channels only)
Pickup Range	
1 A nominal:	0.05–1.00 A
5 A nominal:	0.25–5.00 A
Maximum Pickup/Dropout Time:	0.625 cycles

Instantaneous/Definite-Time Overcurrent Elements (50)

Phase- and Negative-Sequence, Ground-Residual Elements

Pickup Range	
5 A nominal:	0.25–100.00 A secondary, 0.01 A steps
1 A nominal:	0.05–20.00 A secondary, 0.01 A steps
Accuracy (Steady-State)	
5 A nominal:	±0.05 A plus ±3% of setting
1 A nominal:	±0.01 A plus ±3% of settings
Transient Overreach (phase and ground residual)	
5 A nominal:	±5% of setting, ± 0.10 A
1 A nominal:	±5% of setting, ± 0.02 A
Transient Overreach (negative-sequence)	
5 A nominal:	±6% of setting, ± 0.10 A
1 A nominal:	±6% of setting, ± 0.02 A
Time-Delay Range:	0.00–16000.00 cycles, 0.250 cycle steps
Timer Accuracy:	±0.250 cycle ± 0.1% of setting
Maximum Pickup/Dropout Time:	1.5 cycles

Adaptive-Time Overcurrent Elements (51)

Pickup Range (Adaptive within the range)	
5 A nominal:	0.25–16.00 A secondary, 0.01 A steps
1 A nominal:	0.05–3.20 A secondary, 0.01 A steps
Accuracy (Steady-State)	
5 A nominal:	±0.05 A ± 3% of setting
1 A nominal:	±0.01 A ± 3% of settings
Transient Overreach	
5 A nominal:	±5% of setting, ± 0.10 A
1 A nominal:	±5% of setting, ± 0.20 A
Time Dial Range (Adaptive within the range)	
U.S.:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Curve Timing Accuracy:	±1.50 cycles plus ±4% of curve time (for current between 2 and 30 multiples of pickup). Curves operate on definite-time for current greater than 30 multiples of pickup.
Reset:	1 power cycles or Electromechanical Reset Emulation time

Phase Under- and Overvoltage Elements

Based on maximum of the VA, VB, and VC phase voltages

Pickup Range:	0.25 V–300 V_{LN} in 0.01 steps
Accuracy:	±3% of setting, ± 0.5 V
Transient Overreach:	±5% of pickup
Maximum Delay:	1.5 cycles

Phase-to-Phase Under- and Overvoltage Elements

Elements based on maximum of the calculated phase-to-phase voltages

Pickup Range:	0.25–520 V_{LL} in 0.01 steps
Accuracy:	±3% of setting, ± 0.5 V
Transient Overreach:	±5% of pickup
Maximum Delay:	1.5 cycles

Sequence Under- and Overvoltage

Pickup Range:	0.25 V–300 V_{LN} in 0.01 steps
Pickup Accuracy, Steady State:	±5% of setting, ± 1 V

Pickup Accuracy, Transient Overreach:	±5%
Maximum Pickup/Dropout Time:	1.5 cycles

Under- and Overfrequency Elements (81)

Pickup Range:	20.01–79.99 Hz, 0.01 Hz steps
Accuracy, Steady-State Plus Transient:	±0.005 Hz for frequencies between 20 and 80 Hz
Maximum Pickup/Dropout Time:	3.0 cycles
Time-Delay Range:	0.04–400.0 s, 0.01 s increments
Time-Delay Accuracy:	±0.1% ± 0.0042 s
Pickup Range, Undervoltage Blocking:	20.00–200.00 V_{LN} (Wye)
Pickup Accuracy, Undervoltage Blocking:	±2% ± 2 V
Maximum Pickup/Dropout Time:	2.625 cycles

Rate-of-Change-of-Frequency Elements (81R)

Pickup Range:	0.10–14.95 Hz/s, 0.01 Hz/s steps
Accuracy:	±0.005 Hz/s for frequencies between 20.00 and 80.00 Hz
Pickup Range, Undervoltage Blocking:	20.00–200.00 V in 0.01 V steps
Pickup Accuracy, Undervoltage Blocking:	±3% of setting ±0.5 V
Time-Delay Range:	0.04–80.00 s, 0.01 s increment
Time-Delay Accuracy:	±0.1% ±0.0042 s
Maximum Pickup/Dropout Time:	3.75 cycles

Breaker Failure Instantaneous Overcurrent (50BF)

Setting Range	
5 A nominal:	0.50–50 A, 0.01 A steps
1 A nominal:	0.10–10.0 A, 0.01 A steps
Accuracy	
5 A nominal:	±0.05 A ± 3% of setting
1 A nominal:	±0.01 A ± 3% of settings
Transient Overreach	
5 A nominal:	±5%, ± 0.10 A
1 A nominal:	±5%, ± 0.02 A
Maximum Pickup Time:	1.5 cycles
Maximum Dropout Time:	Less than 1 cycle
Maximum Reset Time:	Less than 1 cycle
Timer Setting Range:	0–6000 cycles, 0.125 cycle steps
Time-Delay Accuracy:	±0.1% of setting ± 0.125 cycle

Directional Over- and Underpower Element

Pickup Range:	3-phase: OFF, 1–900 W (secondary) in 1 W steps Single phase: OFF, 0.30–900 W (secondary) in 0.1 W steps
Pickup Accuracy:	±3% of setting and ±5 W, power factor > ±0.5 at nominal frequency
Time-Delay Range:	0–16,000 cycles, 0.125 cycle increment
Time-Delay Accuracy:	±0.1% of setting, ± 0.125 cycle

Bay Control

Breakers:	1
Disconnects (Isolators):	10 (maximum)
Timers Setting Range:	1–99999 cycles, 1-cycle steps
Time-Delay Accuracy:	±0.1% of setting, ± 0.125 cycle

Station DC Battery System Monitor

Rated Voltage:	24–250 Vdc
Operational Voltage Range:	0–350 Vdc
Input Sampling Range:	2 kHz
Processing Rate:	1/8 cycle
Operating Time:	≤1.5 seconds (element dc ripple) ≤1.5 cycles (all elements but dc ripple)
Setting Range	
DC Settings:	1 Vdc steps (OFF, 15–300 Vdc)
AC Ripple Setting:	1 Vac steps (1–300 Vac)
Pickup Accuracy:	±10%, ± 2 Vdc (dc ripple) ±3%, ± 2 Vdc (all elements but dc ripple)

Metering Accuracies

All metering accuracies are based on an ambient temperature of 20°C and nominal frequency.

Absolute Phase Angle Accuracy:	IA, IB, and IC per terminal: ±0.5° (both 1 and 5 A) VA, VB, and VC per terminal: ±0.125°

Currents

Quantity: IA, IB, IC Per Terminal

I_{NOM} = 1 A

Magnitude Accuracy:	±0.2%, ± 0.8 mA
Phase Accuracy:	±0.2°
Current Range:	0.5–3.0

I_{NOM} = 5 A

Magnitude Accuracy:	±0.2%, ± 4.0 mA
Phase Accuracy:	±0.2°
Current Range:	2.5–15.0

Quantity: 3I0 (IG), I1 and 3I2 (Calculated) Per Terminal

I_{NOM} = 1 A

Magnitude Accuracy:	±0.3%, ± 0.8 mA
Phase Accuracy:	±0.3°
Current Range:	0.1–20.0

I_{NOM} = 5 A

Magnitude Accuracy:	±0.3%, ± 4.0 mA
Phase Accuracy:	±0.3°
Current Range:	0.5–100.0

Quantity: VA, VB, VC Per Terminal

Voltage Range:	5–33.5 V
Magnitude Accuracy:	±2.5% ± 1 V
Phase Accuracy:	±1.0°
Voltage Range:	33.5–300 V
Magnitude Accuracy:	±0.1%
Phase Accuracy:	±0.5°

Quantity: 3V0, V1, V2 Per Terminal

Voltage Range:	5–33.5 V
Magnitude Accuracy:	±2.5% ± 1 V
Phase Accuracy:	±1.0°
Voltage Range:	33.5–300 V
Magnitude Accuracy:	±0.1%
Phase Accuracy:	±0.5°

Quantity: VAB, VBC, VCA (Calculated, Per Terminal)

Voltage Range:	5–33.5 V
Magnitude Accuracy:	±2.5% ± 1 V
Phase Accuracy:	±1.0°
Voltage Range:	33.5–300 V
Magnitude Accuracy:	±0.1%
Phase Accuracy:	±0.5°

Quantity: MW (P), Per Phase (Wye), Three Phase (Wye) Per Terminal

Accuracy:	±1%
Range:	(0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (single phase)
Accuracy:	±0.7%
Range:	(0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (three phase)

Quantity: MVAR (Q), Per Phase (Wye), Three Phase (Wye) Per Terminal

Accuracy:	±1%
Range:	(0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (single phase)
Accuracy:	±0.7%
Range:	(0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (three phase)

Quantity: MVA (S), Per Phase (Wye), Three Phase (Wye) Per Terminal

Accuracy:	±1%
Range:	(0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (single phase)
Accuracy:	±0.7%
Range:	(0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (three phase)

Quantity: PF, Per Phase (Wye), 3-ϕ (Wye) Per Terminal

Accuracy:	±1%
Range:	(0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (single phase)
Accuracy:	±0.7%
Range:	(0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (three phase)

Frequency Accuracy

Accuracy:	0.01 Hz
Range:	40–65 Hz

Magnitude Accuracy

Accuracy:	±1%
Range:	40–65 Hz

Power Supply Voltage Range

100–275 Vdc

Accuracy:	±1%

RMS Metering

Voltage Metering Function:	VAY, VBY, VCY, VAZ, VBZ, VCZ (4-wire wye connected)
Range:	2–300 V (PT)
Magnitude Accuracy (at 20°C and Nominal Frequency):	±1.2%
Current Metering Function:	IAW, IBW, ICW
Range:	0.05–20.0 •I_{NOM} (I_{NOM} = 1 A, 5 A)
Magnitude Accuracy (at 20°C and Nominal Frequency):	±0.2% ± 0.5 mA

Unbalance Metering

Quantity:	Differential Voltage dVA, dVB, dVC, dVG1, dVG2, dVG3
Accuracy:	±1.0%
Range:	±0.01 V to ±100.00 V
Quantity:	Unbalance Current 60N/60P
Magnitude Accuracy:	±0.3%
Phase Accuracy:	±0.3°
Current Range:	at 0.001 to 5.000 • I_{NOM}

K Compensation Factors

Magnitude Accuracy:	±1.0% ± 0.002 • KSET
Phase Angle Accuracy:	±0.3°

Optional RTD Elements (RTD Temperature Measurement From SEL-2600 Series RTD Module)

12 RTD inputs via SEL-2600 Series RTD Module and SEL-2800 Fiber-Optic Transceiver

Monitor Ambient or Other Temperatures

PT 100, NI 100, NI 120, and CU 10 RTD-Types Supported, Field Selectable

Up to 500 m Fiber-Optic Cable to SEL-2600 Series RTD Module

Synchrophasors

Number of Synchrophasor Data Streams:	5
Number of Synchrophasors for Each Stream:	12 phase synchrophasors (6 voltage and 6 currents) 4 positive-sequence synchrophasors (2 voltage and 2 currents)
Number of User Analogs for Each Stream:	16 (any analog quantity)
Number of User Digitals for Each Stream:	64 (any Relay Word bit)
Synchrophasor Protocol:	IEEE C37.118-2005, SEL Fast Message (Legacy)
Synchrophasor Data Rate:	As many as 60 messages per second
Synchrophasor Accuracy:	
Voltage Accuracy:	±1% Total Vector Error (TVE) Range 30–150 V, f_{NOM} ±5 Hz
Current Accuracy:	±1% Total Vector Error (TVE) Range (0.1–20) • I_{NOM} A, f_{NOM} ±5 Hz
Synchrophasor Data Recording:	Records as much as 120 s IEEE C37.232-2011 File Naming Convention

Breaker Monitoring

Running Total of Interrupted Current (kA) per Pole:	±5% ± 0.02 • I_{NOM}
Percent kA Interrupted for Trip Operations:	±5%
Percent Breaker Wear per Pole:	±5%
Compressor/Motor Start and Run Time:	±1 day
Time Since Last Operation:	±1 day

Battery System Monitoring

Pickup Range:	15–300 Vdc, 1 Vdc steps
Pickup Accuracy:	±3% of setting, ± 2 Vdc (all elements except dc ripple) ±10% of setting, ± 2 Vdc (dc ripple element)
Maximum Pickup/Dropout Time:	±1.5 cycles (all elements except dc ripple) ±1.5 seconds (dc ripple element)
Sampling Rate:	1/8 cycle

Voltage Sag/Swell/Interruption Reporting

Pickup Range		
Sag:	10.00%–95.00%	
Swell:	105.00%–180.00%	
Interruption:	5.00%–95.00%	
Recording Rates and Duration		
Fast:	4 samples/cycle	4 cycle dur.
Medium:	1 sample/cycle	176 cycle dur.
Slow:	1 sample/64 cycles	4096 cycle dur.
Daily:	1 sample/day	Indefinite

Control Functions (SEL-487V-1)

Voltage Control

Deadband Range:	10.00–300.00 V sec.
Deadband Control Delay:	1–6000 s
Stall-Time Delay:	1–6000 s

Power Factor Control

Deadband Range:	0.01–0.99
Deadband Control Delay:	1–6000 s
Stall-Time Delay:	1–6000 s
Minimum Operating Power:	±1 W or ±1 VAR sec.

VAR Control

Deadband Range:	–1000.00 to +1000.00 VAR sec.
Deadband Control Delay:	1–6000 s
Stall-Time Delay:	1–6000 s
Minimum Operating Power:	±1 W or ±1 VAR sec.

Time-of-Day Control

Minimum Resolution:	±1 minute

Universal Sequencer

Accumulation Period:	1–9999 minutes
Resolution:	±1 minute
Accumulated Value:	0–2147483646
Resolution:	±1

Technical Support

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

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Notes

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