SEL-421-4, -5 Protection and Automation System

High-Speed Line Protection, Automation, and Control System

Major Features and Benefits

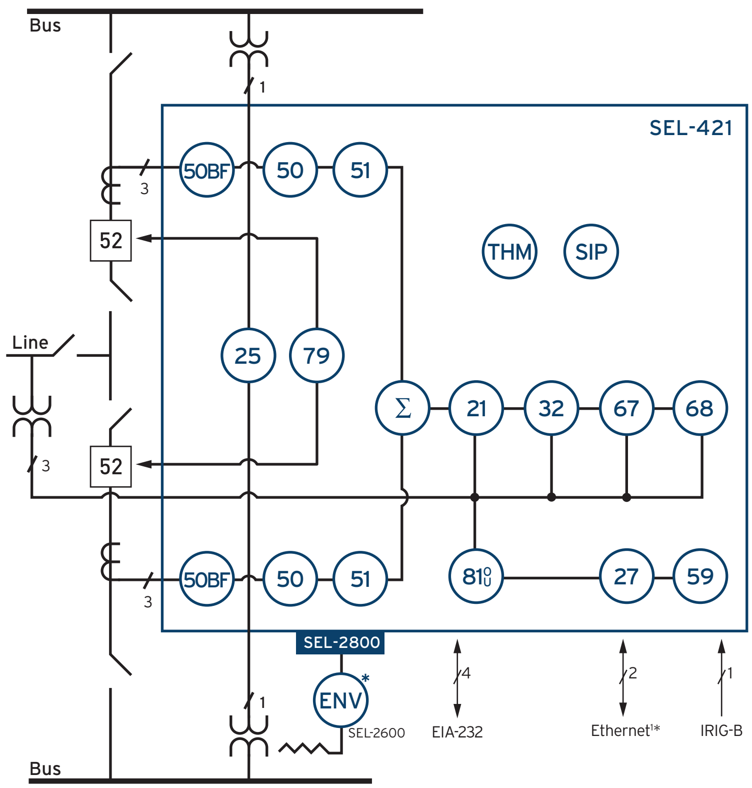
The SEL-421-4, -5 Protection, Automation, and Control System combines high-speed distance and directional protection with complete control for a two-breaker bay.

- **Protection.** Protect any transmission line by using a combination of five zones of phase- and ground-distance and directional overcurrent elements. Select Mho or Quadrilateral characteristics for any phase or ground-distance element. Use the optional high-speed elements and series compensation logic to optimize protection for critical lines or series-compensated lines. Use the ACSELERATOR QuickSet® SEL-5030 Software (a graphical user interface) to speed and simplify setting the relay. Patented Coupling Capacitor Voltage Transformer (CCVT) transient overreach logic enhances the security of Zone 1 distance elements. Best Choice Ground Directional Element® logic optimizes directional element performance and eliminates the need for many directional settings.
- **Automation.** Take advantage of enhanced automation features that include 32 programmable elements for local control, remote control, protection latching, and automation latching. Local metering on the large format front-panel Liquid Crystal Display (LCD) eliminates the need for separate panel meters. Use serial and Ethernet links to efficiently transmit key information, including metering data, protection element and control I/O status, IEEE C37.118 Synchrophasors, IEC 61850 GOOSE messages, Sequential Events Recorder (SER) reports, breaker monitor, relay summary event reports, and time synchronization. Use expanded SELOGIC® control equations with math and comparison functions in control applications. Incorporate as many as 1000 lines of automation logic (depending on the model) to speed and improve control actions.
- **Software-Invertible Polarities.** Invert individual or grouped CT and PT polarities to account for field wiring or zones of protection changes. CEV files and all metering and protection logic use the inverted polarities, whereas COMTRADE event reports do not use inverted polarities but rather record signals as applied to the relay.
- **Synchrophasors.** Make informed load dispatch decisions based on actual real-time phasor measurements from SEL-421 Relays across your

power system. Record streaming synchrophasor data from SEL-421 Relays for system-wide disturbance recording. Control the power system by using local and remote synchrophasor data.

- **Digital Relay-to-Relay Communications.** Use MIRRORED BITS® communications to monitor internal element conditions between relays within a station, or between stations, by using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel. Receive synchrophasor data from as many as two other devices transmitting IEEE C37.118-2005 format synchrophasors at rates as high as 60 messages per second. The SEL-421 time-correlates the data for use in SELOGIC control equations.
- **Primary Potential Redundancy.** Multiple voltage inputs to the SEL-421 provide primary input redundancy. Upon loss-of-potential (LOP) detection, the relay can use inputs from an electrically equivalent source connected to the relay. Protection remains in service without compromising security.
- **Parallel Redundancy Protocol (PRP).** This protocol is used 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.
- **Ethernet Access.** Access all relay functions with the optional Ethernet card. Interconnect with automation systems by using IEC 61850 or DNP3 protocol directly. Optionally 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 in the IEEE C37.118-2005 format through use of TCP or UDP Internet protocols.
- **Dual CT Input.** Combine currents within the relay from two sets of CTs for protection functions, but keep them separately available for monitoring and station integration applications.
- **Monitoring.** Schedule breaker maintenance when accumulated breaker duty (independently monitored for each pole of two circuit breakers) indicates possible excess contact wear. Electrical and mechanical operating times are recorded for both the last operation and the average of operations since function reset. Alarm contacts provide notification of substation battery voltage problems (two independent battery monitors) even if voltage is low only during trip or close operations.
- **Reclosing Control.** Incorporate programmable single-pole or three-pole trip and reclose of one or two breakers into an integrated substation control system. Synchronism and voltage checks from multiple sources provide complete bay control.
- **Breaker Failure.** Use high-speed (5/8-cycle) open-pole detection logic to reduce coordination times for critical breaker failure applications. Apply the SEL-421 to supply single and/or three-pole breaker failure for one or two breakers. Necessary logic for single-pole and three-pole breaker failure retrip and initiation of transfer tripping is included. Logic to use different delay settings for multiphase and single phase is included.
- **Out-of-Step Blocking and Tripping.** Select out-of-step blocking of distance elements or tripping on unstable power swings. Out-of-step detection does not require settings or system studies.
- **Switch-Onto-Fault and Stub Bus Protection.** Use disconnect status inputs and voltage elements to enable high-speed protection.
- **Fault Locator.** Efficiently dispatch line crews to quickly isolate line problems and restore service faster.
- **Oscillography.** Record voltages, currents, and internal logic points at as high as 8 kHz sampling rate. Phasor and harmonic analysis features allow investigation of relay and system performance.
- **Rules-Based Settings Editor.** In addition to communicating and setting the relay by using an ASCII terminal, use the PC-based QuickSet to configure the SEL-421 and analyze fault records with relay element response. View real-time phasors and harmonic levels.
- **Sequential Events Recorder (SER).** Record the last 1000 entries, including setting changes, power-ups, and selectable logic elements.
- **IEC 60255-Compliant Thermal Model.** Use the relay to provide a configurable thermal model for the protection of a wide variety of devices.
- **Comprehensive Metering.** Improve feeder loading by using built-in, high-accuracy metering functions. Use watt and VAR measurements to optimize feeder operation. Minimize equipment needs with full metering capabilities, including: rms, maximum/minimum, demand/peak, energy, and instantaneous values.
- **Auxiliary Trip/Close Pushbuttons.** These optional pushbuttons are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.
- **IEEE 1588, Precision Time Protocol.** The relay shall support Precision Time Protocol version 2 (PTPv2). PTP provides high-accuracy timing over an Ethernet network.
- **Time-Domain Link (TiDL) Technology.** The relay supports remote data acquisition through use of an SEL-2240 Axion®. The Axion provides remote analog and digital data over an IEC 61158 EtherCAT® TiDL network. This technology provides very low and deterministic latency over a fiber point-to-point architecture. The SEL-421 relay can receive fiber links from as many as eight Axion remote data acquisition nodes.

Functional Overview



ANSI NUMBERS/ACRONYMS AND FUNCTIONS	
21	Phase and Ground Distance
25	Synchronism Check
27	Undervoltage
32	Directional Power
50	Overcurrent
50BF	Dual Breaker Failure Overcurrent
51	Time-Overcurrent
59	Overvoltage
67	Directional Overcurrent
68	Out-of-Step Block/Trip
79	Single-/Three-Pole Reclosing
81 (O, U)	Over-/Underfrequency
85 RIO	SEL MIRRORED BITS Communications
DFR	Event Reports
ENV	SEL-2600*
HMI	Operator Interface
LGC	Expanded SELOGIC Control Equations
MET	High-Accuracy Metering
PMU	Synchrophasors
SER	Sequential Events Recorder
TiDL	Time-Domain Link Remote Data Acquisition

ADDITIONAL FUNCTIONS	
BRM	Breaker Wear Monitor
LDE	Load Encroachment
LOC	Fault Locator
SBM	Station Battery Monitor
SIP	Software-Invertible Polarities
THM	IEC 60255-Compliant Thermal Model

[1] Copper or Fiber Optic   * Optional Feature

Figure 1 Functional Diagram

Protection Features

The SEL-421 contains all the necessary protective elements and control logic to protect overhead transmission lines and underground cables (see *Figure 1*). The relay simultaneously measures five zones of phase and ground mho distance plus five zones of phase and ground quadrilateral distance. These distance elements, together with optional high-speed directional and faulted phase selection and high-speed distance elements, are applied in communications-assisted and step-distance protection schemes. You can further tailor the relay to your particular application through use of expanded SELOGIC control equations. Performance times of the high-speed and standard distance elements for a range of faults, locations, and source impedance ratios (SIR) are shown in *Figure 2*, *Figure 3*, *Figure 4* and *Figure 5*. As transmission systems are pushed to operational limits by both competitive and regulatory pressures, line protection must be able to adapt to changing conditions. The SEL-421 is easy to set and use for typical lines, while the high-speed and logic settings make it applicable for critical and hard-to-protect lines.

Subcycle Tripping Times Using Optional High-Speed Elements

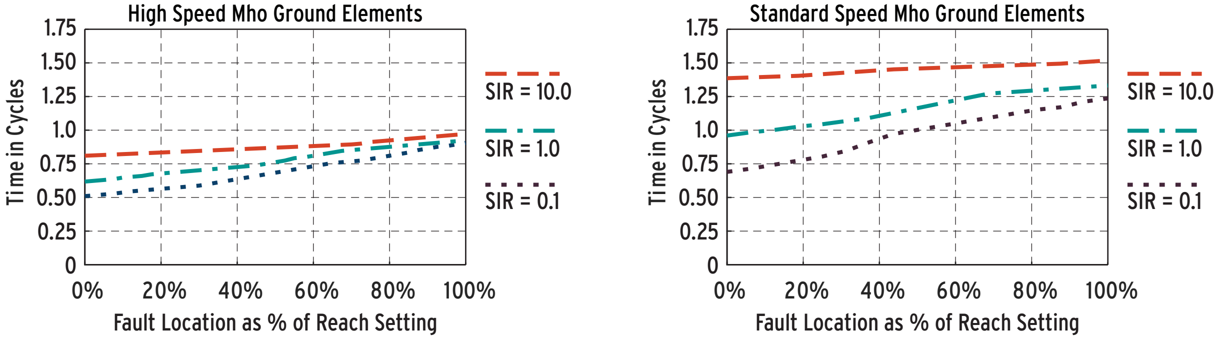


Figure 2 Mho Single-Phase-to-Ground Faults

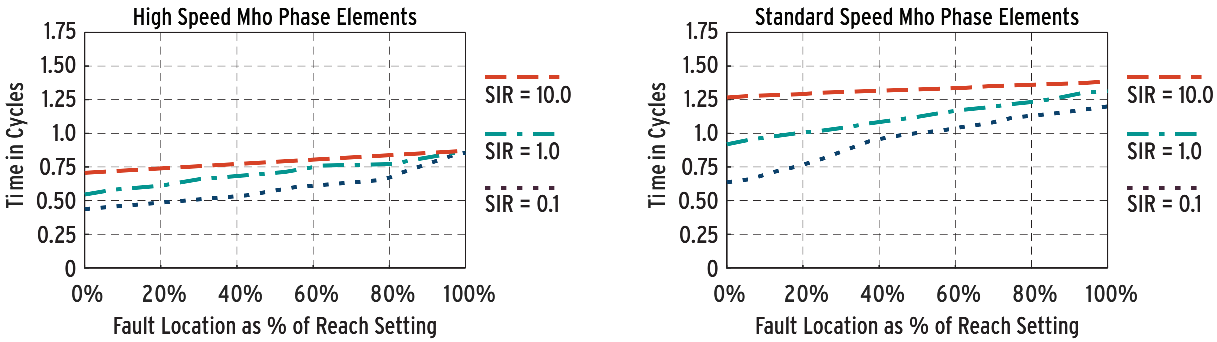


Figure 3 Mho Phase-to-Phase Faults

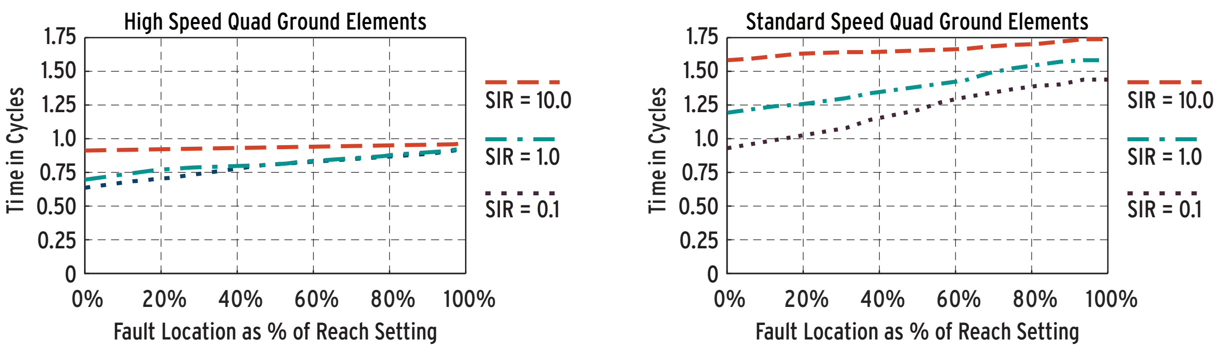


Figure 4 Quadrilateral Single-Phase-to-Ground Faults

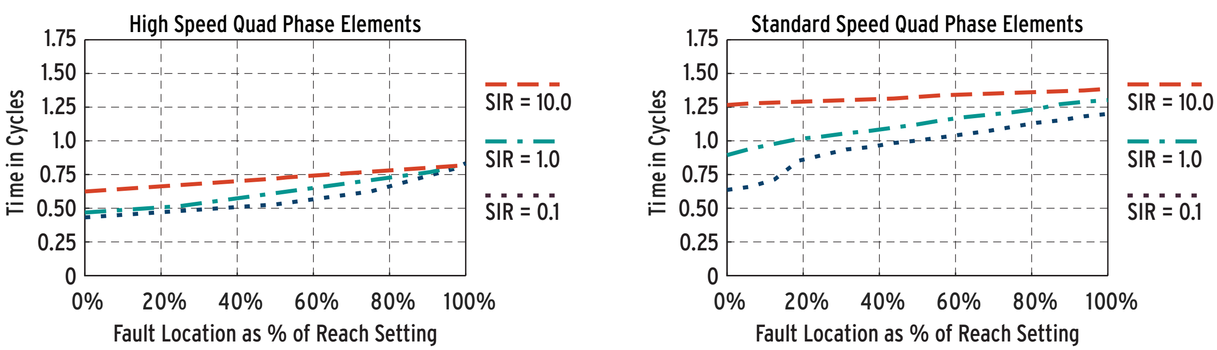


Figure 5 Quadrilateral Phase-to-Phase Faults

Mho Distance Elements

The SEL-421 uses mho characteristics for phase- and ground-distance protection. Two zones are fixed in the forward direction, and the remaining three zones can be set for either forward or reverse. All mho elements use positive-sequence memory polarization that expands the operating characteristic in proportion to the source impedance (*Figure 6*). This provides dependable, secure operation for close-in faults. The mho circle expands to the source impedance, Z_S, but this expansion never exceeds the set relay reach, Z_R.

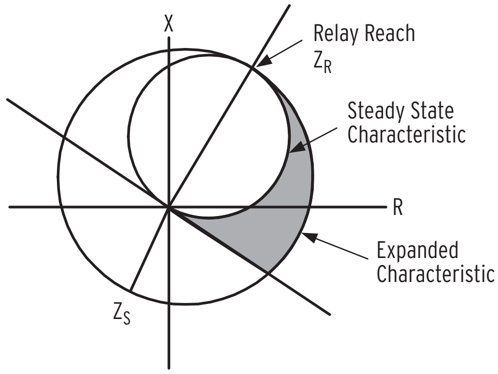


Figure 6 Mho Characteristic

As an optional addition to the standard distance elements, there are three zones (either three forward, or two forward and one reverse) of high-speed distance elements. These high-speed elements use voltage and current phasors derived from a fast half-cycle filter to provide subcycle tripping times. Settings are automatically associated with the standard element zone reach; no additional settings are required.

The SEL-421 includes optional series-compensated line logic and polarizing to prevent overreach of the Zone 1 distance element resulting from the series capacitor transient response.

Load-Encroachment Logic

Load-encroachment logic (*Figure 7*) prevents operation of the phase-distance elements under high load conditions. This unique SEL feature permits load to enter a predefined area of the phase-distance characteristic without causing a trip.

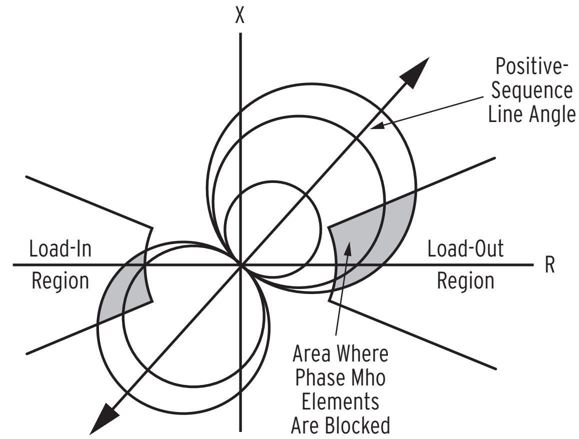


Figure 7 Load-Encroachment Logic

CCVT Transient Detection Logic

CCVT transient detection, once enabled, automatically prevents incorrect operation of the direct tripping (Zone 1) distance elements. The relay determines the Source Impedance Ratio (SIR), and a smoothness detection system acts to inhibit Zone 1 only for those conditions that indicate a CCVT transient exists. No user settings are required.

Phase and Ground Quadrilateral Distance Elements

The SEL-421 provides five zones of quadrilateral phase and ground-distance characteristics for improved fault and arc resistance coverage and reach-limiting action on short lines. The top line of the quadrilateral characteristic automatically tilts with load flow to avoid under- and overreaching. Available settings prevent overreaching of the quadrilateral characteristic from nonhomogeneous infeed. The mho and quadrilateral distance elements can be used separately, concurrently, or not at all.

Each of the distance elements has a specific reach setting. The ground-distance elements include three zero-sequence compensation factor settings (k01, k0R, and k0F) to calculate ground fault impedance accurately. Setting k01 adjusts the zero-sequence transmission line impedance for accurate measurement through use of positive-sequence quantities. Settings k0F and k0R account for forward and reverse zero-sequence mutual coupling between parallel transmission lines.

Directional Elements Increase Sensitivity and Security

The SEL-421 provides multiple directional elements to optimize security and sensitivity. Directional overcurrent elements provide increased sensitivity, complementing distance elements that provide well-controlled reach. Use ground and negative-sequence directional overcurrent elements to detect high-resistance faults when using communications-assisted tripping schemes.

The SEL-421 includes a number of directional elements for supervision of overcurrent elements and distance elements. The negative-sequence directional element uses the same patented principle proven in our SEL-321 Relay. This directional element can be applied in virtually any application, regardless of the amount of negative-sequence voltage available at the relay location.

Ground overcurrent elements are directionally controlled by three directional elements working together:

- Negative-sequence voltage-polarized directional element
- Zero-sequence voltage-polarized directional element
- Zero-sequence current-polarized directional element

Our patented Best Choice Ground Directional Element selects the best ground directional element for the system conditions and simplifies directional element settings. (You can override this automatic setting feature for special applications.)

Optional High-Speed Directional and Faulted Phase Selection (HSDPS) Element

In addition to standard directional elements, the SEL-421 optionally includes a HSDPS function through use of incremental voltage and current phasors. The incremental quantities are derived by comparing the measured signal to the same signal a short time earlier. The HSDPS provides directional and faulted phase selection outputs much faster than conventional algorithms and allows faster (less than one cycle) relay operation.

Communications-Assisted Tripping Schemes

The SEL-421 is the ideal relay for use in transmission pilot-based tripping schemes. Use MIRRORED BITS communications with SEL fiber-optic transceivers for 3–6 ms relay-to-relay transmission time. Among the schemes supported are the following:

- Permissive Overreaching Transfer Tripping (POTT) for two- or three-terminal lines
- Directional Comparison Unblocking (DCUB) for two- or three-terminal lines
- Directional Comparison Blocking (DCB)

Use the SEL control equation TRCOMM to program specific elements, combinations of elements, inputs, etc., to perform communications scheme tripping and other scheme functions. The logic readily accommodates the following conditions:

- Current reversals
- Breaker open at one terminal
- Weak-infeed conditions at one terminal
- Switch-onto-fault conditions

Step distance and time-overcurrent protection provide reliable backup operation should the channel be lost.

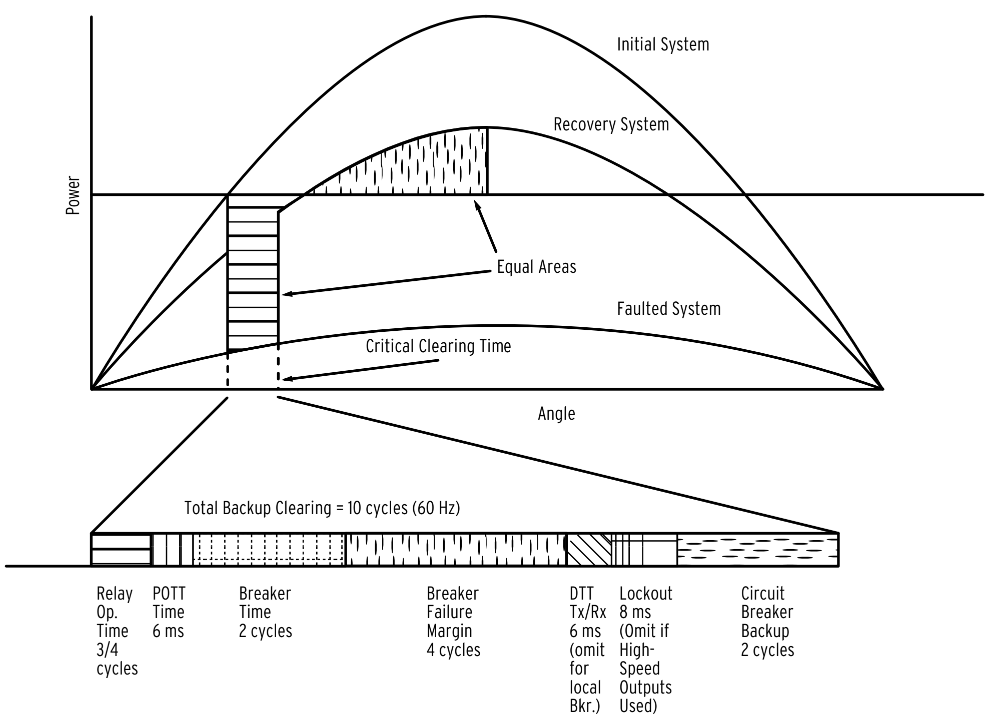


Figure 8 Combining high-speed tripping, MIRRORED BITS communications, and high-speed open-pole detection in the SEL-421 Relay provides for faster total clearing time.

Overcurrent Elements

The SEL-421 includes four phase, four negative-sequence, and four ground instantaneous overcurrent elements. The SEL-421 also includes three selectable operating quantity inverse-time overcurrent elements. You can select the operating quantities from the following:

|IA|, |IB|, |IC|, MAX(|IA|, |IB|, |IC|), |I1|, |3I2|, |IG|

The time-overcurrent curves (listed in *Table 1*) have two reset characteristic choices for each time-overcurrent element. One choice resets the elements if current drops below pickup for one cycle. The other choice emulates the reset characteristic of an electromechanical induction disc relay.

Table 1 Time-Overcurrent Curves

U.S.	IEC
Moderately Inverse	Standard Inverse
Inverse	Very Inverse
Very Inverse	Extremely Inverse
Extremely Inverse	Long-Time Inverse
Short-Time Inverse	Short-Time Inverse

Breaker Failure Protection

Incorporated into the SEL-421 is a full-function breaker failure system. Current can be individually monitored in two breakers. Single- and three-pole logic allows flexible operation. High-speed open-pole detection logic allows you to set the pickup current below minimum load, for sensitivity without sacrificing high-speed dropout. Even in cases with delayed current zero in the secondary of the CT caused by trapped flux, high-speed detection of circuit breaker opening is achieved. If breaker failure is initiated on all circuit breaker trips, this feature is essential. A 5/8-cycle reset reduces coordination times, improving stability.

Thermal Overload Protection

The SEL-421 supports three independent thermal elements that conform to the IEC 60255-149 standard. Use these elements to activate a control action or issue an alarm or trip when your equipment overheats as a result of adverse operating conditions.

The SEL-2600 RTD Module provides ambient temperature measurements for the thermal model.

Loss-of-Potential (LOP) Logic Supervises Directional Elements

The SEL-421 includes logic to detect a loss-of-potential caused by failures such as blown fuses, which can cause an incorrect operation in distance and directional elements. Simple settings configure the LOP logic to either block or force forward ground and phase directional elements under these conditions. The logic checks for a sudden change in positive-sequence voltage without a corresponding change in positive- or zero-sequence current. Tests and field experience show that this principle is very secure and is faster than the tripping elements.

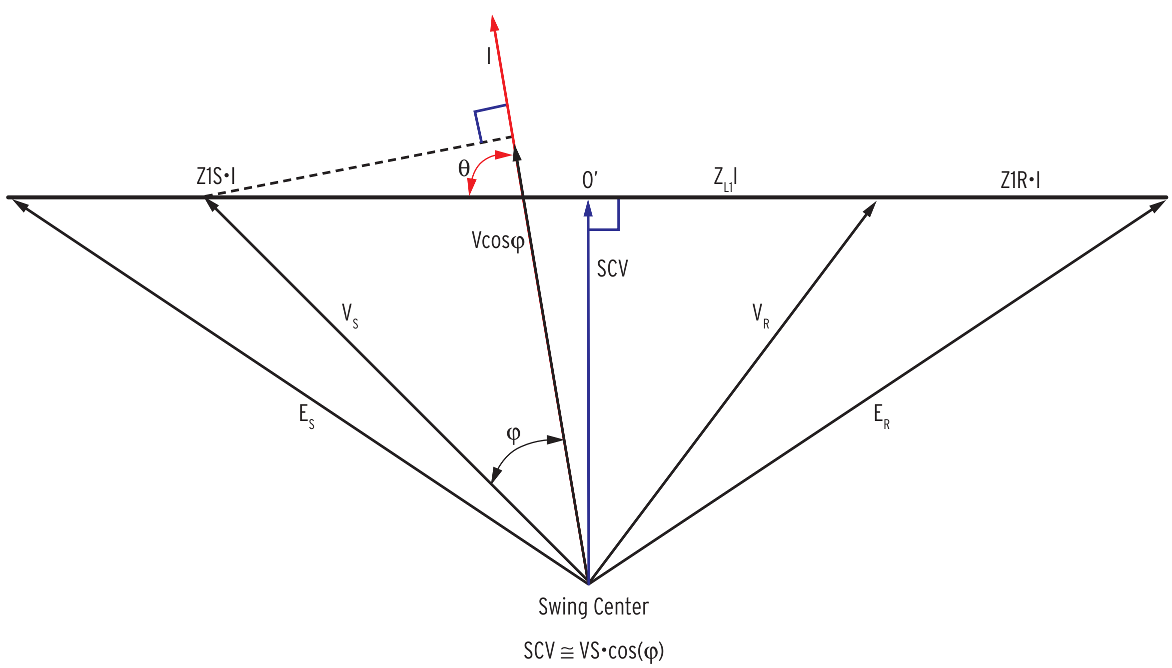


Figure 9 Applying VS to approximate the swing center voltage provides an accurate local quantity to detect power swings.

Out-of-Step Detection

The SEL-421 provides two different algorithms for out-of-step detection. One of the two schemes may be selected by the user.

The new zero setting method requires no system studies or any settings (other than enabling) for out-of-step functions. Using local voltage measurements (see *Figure 9*) to closely approximate the swing center voltage (SCV) allows the relay to use the rate-of-change of SCV to quantify the power swing condition.

Performance of the system has been verified for in-zone and out-of-zone fault conditions and all normal power swings.

The conventional out-of-step detection provides timers and blinders that are set outside any of the distance elements. A power swing is declared when an impedance locus travels through the blinders slower than a preset time.

Six Independent Settings Groups Increase Operation Flexibility

The relay stores six settings groups. Select the active settings group by control input, command, or other programmable conditions. Use these settings groups to cover a wide range of protection and control contingencies. Selectable settings groups make the SEL-421 ideal for applications requiring frequent settings changes and for adapting the protection to changing system conditions.

Selecting a group also selects logic settings. Program 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.

Combined Current for Protection Flexibility

In traditional relays, when protecting a line fed from two breakers, such as a breaker-and-a-half system or double-breaker system, you needed to combine the CT inputs before connecting these inputs to the relay. The SEL-421 can accept separate inputs from two separate CTs (these CTs can be a different ratio) and mathematically combine the currents. This allows collecting separate current metering and breaker monitor information for each breaker. Breaker monitoring functions for two breakers are done within one relay. Individual breaker currents allow for breaker failure functions on a per-breaker basis within the SEL-421. Breaker diagnostics are reported on a comparative basis allowing for advanced, proactive troubleshooting.

Control Inputs and Outputs

The basic SEL-421 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 input/output (I/O) boards are currently available.

- Eight independent inputs, 13 standard Form A and two standard Form C contact outputs.
- Eight independent inputs, 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 and two standard Form A contact outputs.

Assign the control inputs for control functions, monitoring logic, and general indication. Each control output is programmable by using SELOGIC control equations. No additional I/O boards can be added to the 3U chassis; however, one board can be added to the 4U chassis, and two additional I/O boards can be added to the 5U chassis. Order standard and additional I/O as either universal (15–265 Vdc settable pickup) or optoisolated type.

Multifunction Recloser With Flexible Applications

The SEL-421 includes both single-pole and three-pole trip and reclose functions, for either one or two breakers (*Figure 10*). Synchronism check is included for breaker control. Synchronizing and polarizing voltage inputs are fully programmable with Dead Line/Dead Bus closing logic as well as zero-closing-angle logic to minimize system stress upon reclosing. Program as many as two single-pole reclose attempts and four three-pole reclose attempts as well as combined single-/three-pole reclosing sequences. Select Leader and Follower breakers directly, or use a SELOGIC control equation to determine reclosing order based on system conditions. When coupled with independent-pole-operating circuit breakers, this reclosing system gives maximum flexibility for present system conditions and for future requirements to meet changing demands on your power system.

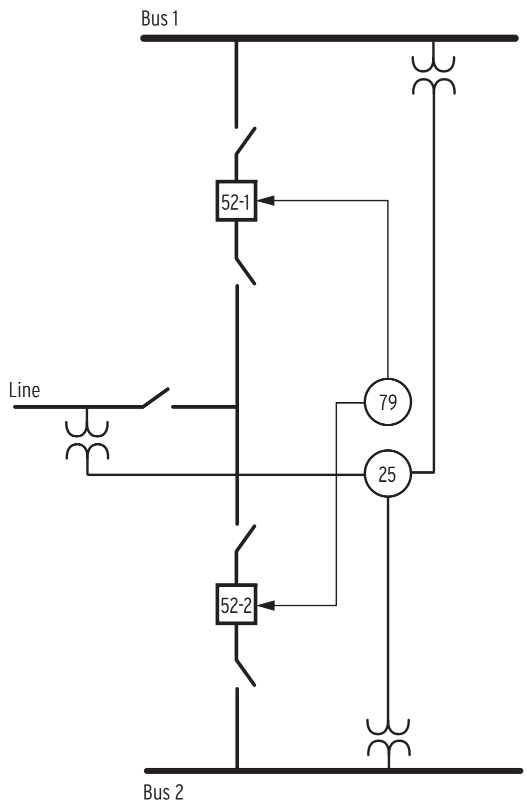


Figure 10 Two-Breaker Reclosing With Synchronism Check

Remote Voltage for Second Contingency Operation

An LOP condition within the relay can initiate a transfer of voltage information from another voltage source connected to the relay. The logic maintains normal protection operation of all directional elements in the relay with the LOP condition. You can program an LOP alarm contact to signal an operator that an error has occurred in the system to allow operator action to find and repair the faulty element.

Two-Breaker Control

The SEL-421 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 full control for two breakers. This includes separate monitoring functions as well as separate elements for tripping and closing the two breakers to allow for leader/follower operation or other desired control schemes. All analog values are monitored on a per-breaker basis to allow station control access to complete information for individual components of the system.

Voltage Elements

The SEL-421 provides six independent over- and undervoltage elements with two pickup levels. The first pickup level is provided with a definite-time delay. Choose from a wide range of fundamental and rms operating quantities for the Y and Z terminal voltage inputs. *Table 2* shows the voltage inputs available for use as operating quantities.

Table 2 Voltage Element Operating Quantities

Analog Quantity	Description
VA, VB, VC	L-N Phase Voltage
VNMAX, VNMIN	Neutral Voltage Min/Max
VAB, VBC, VCA	L-L Phase Voltage
VA–VN[a], VB–VN[a], VC–VN[a]	Phase Voltage with Neutral Voltage Subtracted
VPMAX, PVMIN	Phase Voltage Min/Max
V1[a], 3V2[a], 3V0[a]	Positive-, Negative-, Zero-Sequence

[a] Fundamental quantities only.

Frequency Elements

The SEL-421 provides six frequency elements, driven from either the Y or the Z potential transformers. Any of the six elements may be configured for over- or under-frequency. Each frequency element provides a pickup time-delay setting. The frequency elements are supervised by a programmable undervoltage element. The undervoltage element can be set to monitor either Y or Z potential inputs, and will block the assertion of the 81 element when the selected voltage input falls below a programmable undervoltage supervision threshold.

Functional Overview: System

The SEL-421 is a complete standalone protection, automation, and control device. It can also act as an integral part of a full station protection, control, and monitoring system. Each relay can be tied to a communications processor that integrates the individual unit protections for overall protection integration (*Figure 11*).

Backup protection such as the SEL-321 Relay or SEL-311 Relay can also be connected to an SEL communications processor (*Figure 11*). The SEL-421 has four serial ports that can be used for connection to a communications processor, ASCII terminal, fiber-optic transceiver, or PC.

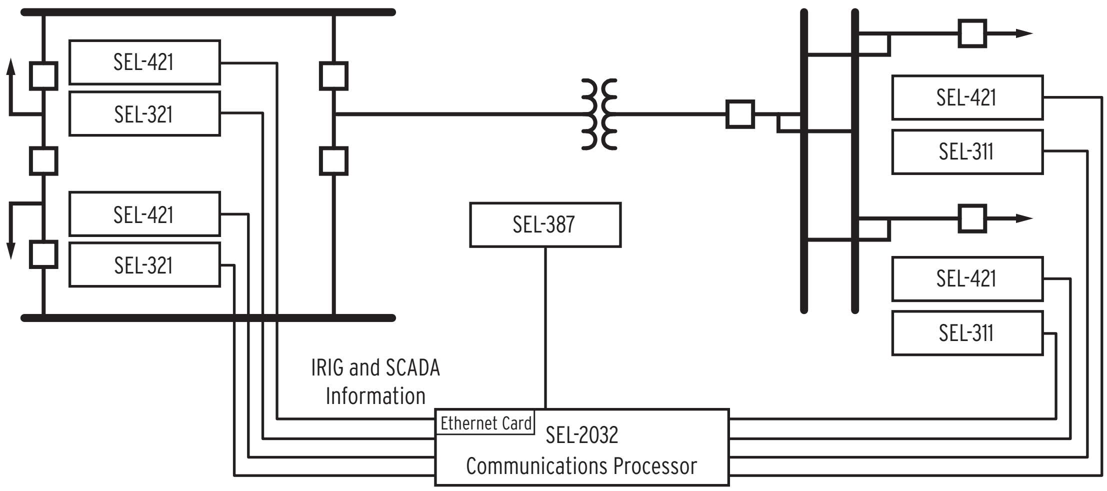


Figure 11 System Functional Overview

Network Connection and Integration

Connect the SEL-421 to Local Area Networks (LANs) by using the optional Ethernet card. The Ethernet card also allows connection of an SEL communications processor to a single or dual LAN (*Figure 12*). The integrated Ethernet card supports both copper and/or fiber connections with failover protection.

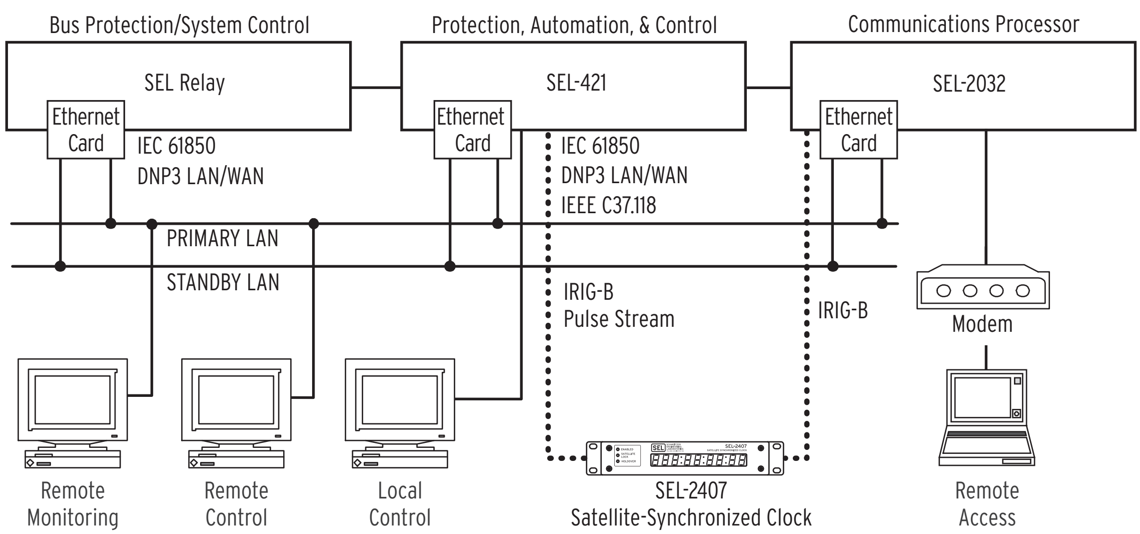


Figure 12 Network Connection and Integration

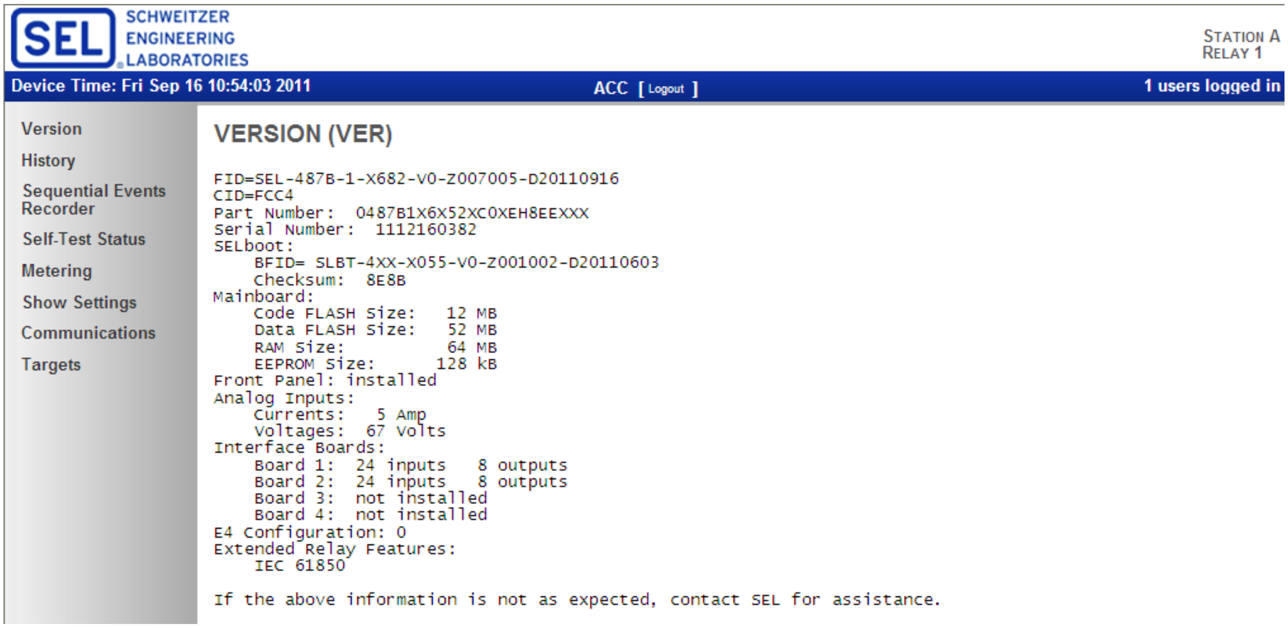


Figure 13 Typical Web Server Default Menu Screen

Ethernet Card

The optional Ethernet card mounts directly in the SEL-421. Use popular Telnet applications for easy terminal communications with SEL relays and other devices. Transfer data at high speeds (10 Mbps or 100 Mbps) for fast HMI updates and file uploads. The Ethernet card communicates using File Transfer Protocol (FTP) applications for easy and fast file transfers.

Provide Operations with situational awareness of the power system by using IEEE C37.118-2005 Standard for Synchrophasors for Power Systems. Communicate with SCADA and other substation IEDs through use of DNP3 or IEC 61850 Logical Nodes and GOOSE messaging.

Choose Ethernet connection media options for primary and stand-by connections:

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

Telnet and FTP

Order the SEL-421 with Ethernet communications and use the built-in Telnet and FTP (File Transfer Protocol) that come standard with Ethernet to enhance real communication sessions. Use Telnet to access relay settings, and metering and event reports remotely by using the ASCII interface. Transfer settings files to and from the relay via the high-speed Ethernet port by using FTP.

IEEE C37.118 Synchrophasors

The latest IEEE synchrophasor protocol provides a standard method for communicating synchronized phasor measurement data over Ethernet or serial media. The integrated Ethernet card in the SEL-421 provides two independent connections using either TCP/IP, UDP/IP, or a combination thereof. Each connection supports unicast data for serving data to a single client. The connections also receive data for control applications. Each data stream can support as many as 60 frames per second.

DNP3 LAN/WAN

The DNP3 LAN/WAN option provides the SEL-421 with DNP3 Level 2 Outstation functionality over Ethernet. Custom DNP3 data maps can be configured for use with specific DNP3 masters.

Precision Time Protocol (PTP)

An Ethernet card option with Ports 5A and 5B populated provides the ability for the SEL-421 to accept IEEE 1588 Precision Time Protocol, version 2 (PTPv2) for data time synchronization. Optional PTP support includes both the Default and Power System (C37.238-2011) PTP Profiles.

HTTP Web Server

When equipped with Ethernet communications, the relay can serve read-only webpages displaying certain settings, metering, and status reports (see *Figure 13*). As many as four users can access the embedded HTTP server simultaneously.

IEC 61850 Ethernet Communications

IEC 61850 Ethernet-based communications provide interoperability between intelligent devices within the substation. Logical nodes that use IEC 61850 allow standardized interconnection of intelligent devices from different manufacturers for monitoring and control of the substation. Reduce wiring between various manufacturers' devices and simplify operating logic with IEC 61850. Eliminate system RTUs by streaming monitoring and control information from the intelligent devices directly to remote SCADA client devices.

The SEL-421 can be ordered with embedded IEC 61850 protocol operating on 100 Mbps Ethernet. Use the IEC 61850 Ethernet protocol for relay monitoring and control functions, including the following.

➤ As many as 128 incoming GOOSE messages. The incoming GOOSE messages can be used to control as many as 256 control bits in the relay with <3 ms latency from device to device. These messages provide binary control inputs to the relay for high-speed control functions and monitoring.

➤ As many as 8 outgoing GOOSE messages. Outgoing GOOSE messages can be configured for Boolean or analog data. Boolean data are provided with <3 ms latency from device to device. Use outgoing GOOSE messages for high-speed control and monitoring of external breakers, switches, and other devices.

➤ IEC 61850 Data Server. The SEL-421 equipped with embedded IEC 61850 Ethernet protocol, provides data according to predefined logical node objects. As many as seven simultaneous client associations are supported by each relay. Relevant Relay Word bits are available within the logical node data, so status of relay elements, inputs, outputs, or SELOGIC equations can be monitored using the IEC 61850 data server provided in the relay.

Use the ACSELERATOR Architect® SEL-5032 Software to manage the logical node data for all IEC 68150 devices on the network. This Microsoft® Windows®-based software provides easy-to-use displays for identifying and binding IEC 61850 network data between logical nodes by using IEC 61850-compliant CID (Configured IED Description) files. CID files are used by Architect to describe the data that will be provided by the IEC 61850 logical node within each relay.

Metering and Monitoring

Complete Metering Capabilities

The SEL-421 provides extensive metering capabilities as listed in *Table 3*.

Table 3 Metering Capabilities (Sheet 1 of 2)

Capabilities	Description
Instantaneous Quantities	
Voltages $V_{A,B,C}$ (Y), $V_{A,B,C}$ (Z), Vϕϕ, 3V0, V1, 3V2	0–300 V with phase quantities for each of the six voltage sources available as a separate quantity.
Currents $I_{A,B,C}$ (W), $I_{A,B,C}$ (X) I_AL, I_BL, I_CL, (combined currents) IGL, I1L, 3I2L (combined currents)	Phase quantities for each of the two current sources available as a separate quantity or combined as line quantities.
Power/Energy Metering Quantities	
MW, MWh, MVAR, MVARh, MVA, PF, single-phase and three-phase	Available for each input set and as combined quantities for the line.
Demand/Peak Demand Metering	
$I_{A,B,C}$, $3I_2$, $3I_0$	Thermal or rolling interval demand and peak demand.
MW, MVAR, MVA, single-phase	Thermal or rolling interval demand and peak demand.
MW, MVAR, MVA, three-phase	Thermal or rolling interval demand and peak demand.

Table 3 Metering Capabilities (Sheet 2 of 2)

Capabilities	Description
Synchrophasors	
Voltages (Primary Magnitude, Angle) $V_{A,B,C}$ (Y), $V_{A,B,C}$ (Z)	Primary phase quantities (kV) for each of the six voltage sources available.
Currents (Primary Magnitude, Angle) $I_{A,B,C}$ (W), $I_{A,B,C}$ (X)	Primary phase quantities (A) for each of the six current sources available.
Frequency	
FREQ	Frequency (Hz) as measured by frequency source potential inputs.
dF/dT	Rate-of-change in frequency (Hz/s).

Event Reporting and Sequential Events Recorder (SER)

Event Reports and Sequential Events Recorder 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 protection schemes. Oscillograms are available in binary COMTRADE and ASCII COMTRADE formats.

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. Decide how much detail is necessary when an event report is triggered: 8 kHz, 4 kHz, 2 kHz, or 1 kHz resolution analog data. The relay stores from 5 seconds of data per fault at 1 kHz resolution to 2 seconds per fault at 8 kHz resolution. Reports are stored in nonvolatile memory. Relay settings operational in the relay at the time of the event are appended to each event report.

Event Summary

Each time the SEL-421 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
- Fault location
- Recloser shot count at time of trigger
- System frequency at time of trigger
- Phase voltages
- Fault type at time of trip
- Prefault, fault phase, and polarizing current levels
- Prefault and fault calculated zero- and negative-sequence currents
- Active group targets
- Status of all MIRRORED BITS channels
- Trip and close times of day
- Breaker status (open/close)

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

Sequential Events Recorder (SER)

Use this feature to gain a broad perspective of relay element operation. Items that trigger an SER entry are selectable and can include input/output change of state, element pickup/dropout, recloser state changes, etc. The relay SER stores the latest 1,000 entries.

High-Accuracy Timekeeping

Using high accuracy IRIG-B from a global positioning satellite clock, the SEL-421 can time-tag oscillography to within 10 µs accuracy. This high accuracy can be combined with the high sampling rate of the relay to synchronize data from across the system with an accuracy of better than 1/4 electrical degree. This allows examination of the power system state at given times, including load angles, system swings, and other system-wide events. Triggering can be via external signal (contact or communications port), set time, or system event. Optimal calibration of this feature requires a knowledge of primary input component (VT and CT) phase delay and error.

A high-accuracy C37.118 IRIG-B time-code input synchronizes the SEL-421 time to be within ±1 µs of the time-source input when the time-source input jitter is less than 500 ns and the time error is less than 1 µs. A convenient source for this time code is an SEL communications processor (via Serial Port 1 on the SEL-421).

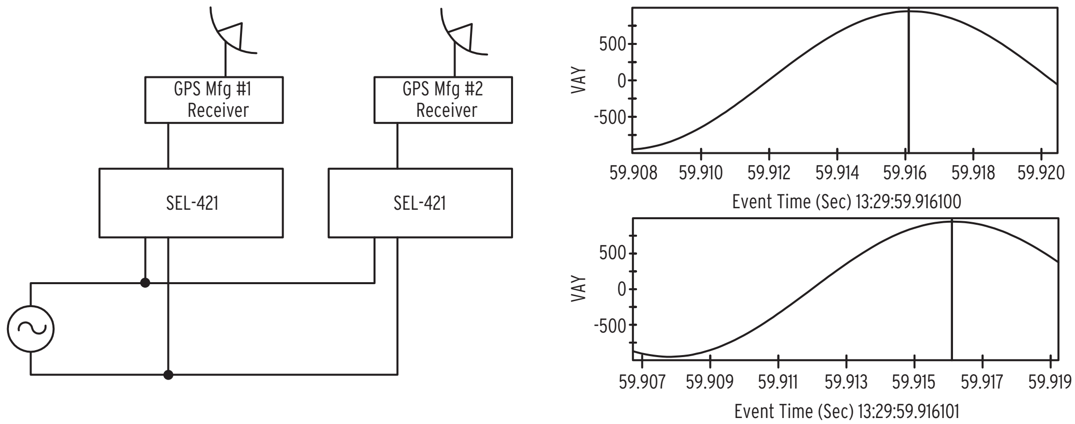


Figure 14 Actual data from back-to-back testing using two different manufacturers' time clocks. Voltage peak is measured to 1 microsecond accuracy in this example.

Precision Time Protocol (PTP) Time Synchronization

In addition to being able to use IRIG-B for high-accuracy timekeeping, the relay can use IEEE 1588 Precision Time Protocol, version 2 (PTPv2) to obtain time synchronization through the Ethernet network. When connected directly to a grandmaster clock providing PTP at 1-second synchronization intervals, the relay can be synchronized to an accuracy of ±100 ns. The relay can receive as many as 32 synchronization messages per second.

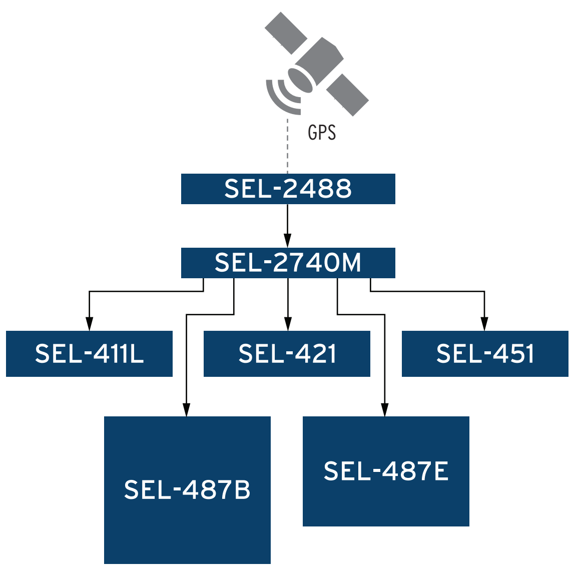


Figure 15 Example PTP Network

SNTP Time Synchronization

Use simple network time protocol (SNTP) to cost-effectively synchronize SEL-421 Relays equipped with Ethernet communication 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 IRIG-B time input to the relay.

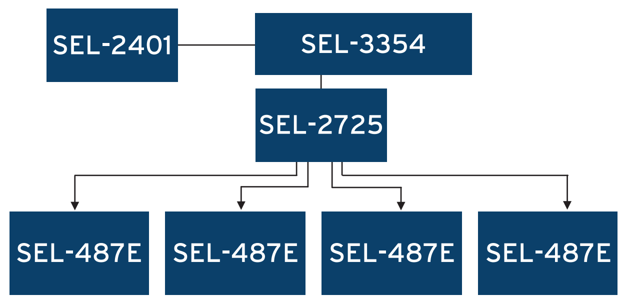


Figure 16 SNTP Diagram

Substation Battery Monitor for DC Quality Assurance

The SEL-421 measures and reports the substation battery voltage for two battery systems. Two sets of programmable threshold comparators and associated logic provide alarm and control of two separate batteries and chargers. The relay also provides dual ground detection. Monitor these thresholds 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 Monitor Feature Allows for Wear-Based Breaker Maintenance Scheduling

Circuit breakers experience mechanical and electrical wear at each operation. Effective scheduling of breaker maintenance takes into account the manufacturer's published data of contact wear versus interruption levels and operation count. The SEL-421 dual breaker monitor feature compares the breaker manufacturer's published data to the integrated actual interrupted current and number of operations.

- ➤ 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 17*), 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 to schedule proactive breaker maintenance. You can activate an alarm point if operation time goes beyond a preset value.

Breaker motor run time, pole scatter, pole discrepancy, and breaker inactivity are also monitored quantities.

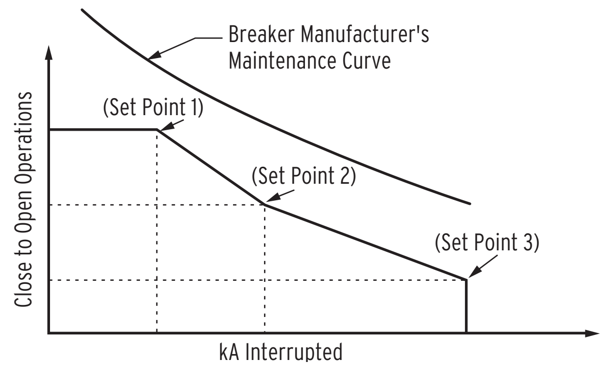


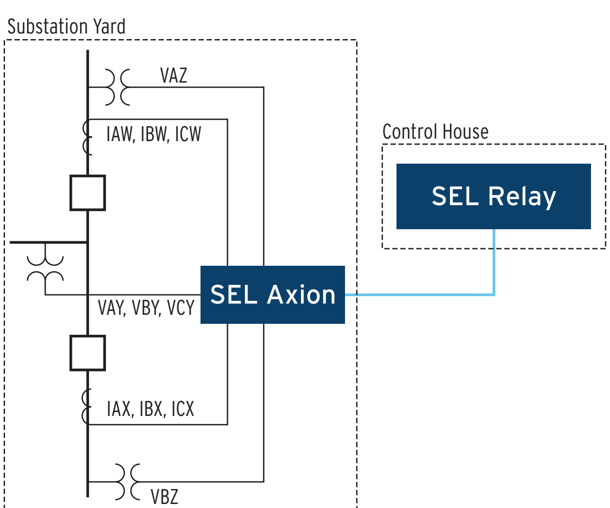
Figure 17 Breaker Contact Wear Curve and Settings

Automation

Time-Domain Link (TiDL) Technology

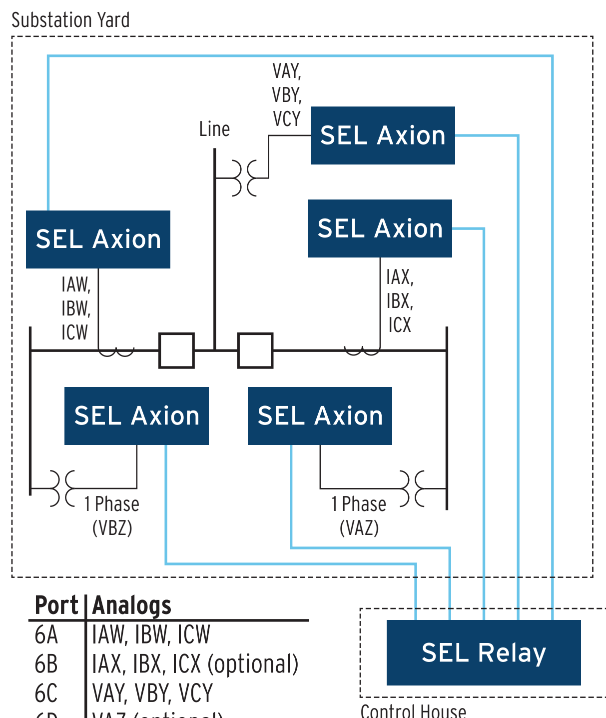
The SEL-421 supports remote data acquisition through use of an SEL Axion with a technology known as TiDL. The Axion provides remote analog and digital data over an IEC 61158 EtherCAT TiDL network. This technology provides very low and deterministic 1.5 ms latency over a point-to-point architecture. The SEL-421 Relay can receive as many as eight fiber links from as many as eight Axion remote data acquisition nodes (see *Figure 36*).

The relay supports a number of fixed topologies. The relay maps the voltage and current inputs from the Axion to existing analog quantities in the SEL-421 Relay based on the connected topology. This limits the number of settings and makes converting an existing system to TiDL easy. *Figure 18* and *Figure 19* show sample TiDL topologies. The SEL-421 Instruction Manual shows all supported topologies.



Port	Analogs
6A	IAW, IBW, ICW, VAY, VBY, VCY IAX, IBX, ICX, VAZ, VBZ, VCZ

Figure 18 Sample SEL-421 Topology #1



Port	Analogs
6A	IAW, IBW, ICW
6B	IAX, IBX, ICX (optional)
6C	VAY, VBY, VCY
6D	VAZ (optional)
6E	VBZ (optional)
6F	VCZ (optional)

Figure 19 Sample SEL-421 Topology #2

Flexible Control Logic and Integration Features

Use the SEL-421 control logic to do the following:

- ➤ Replace traditional panel control switches
- ➤ Eliminate RTU-to-relay 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-relay wiring with 32 remote control points. 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 32 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 latch control points retain states when the relay loses power.

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 which messages are displayed via SELOGIC control equations by driving the LCD display via any logic point in the relay.

Open Communications Protocols

The SEL-421 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 4* lists a synopsis of the terminal protocols.

Table 4 Open Communications Protocol

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 relay 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 communication. Quickly updates SEL-2032 Communications Processors, RTUs, and other substation devices with metering information, relay 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.
Optional DNP3 Level 2 Outstation	Distributed Network Protocol 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.
IEC 61850	Ethernet-based international standard for interoperability between intelligent devices in a substation.

Rules-Based Settings Editor

Use QuickSet to develop settings off-line. The system automatically checks interrelated settings and highlights out-of-range settings. Settings created off-line can be transferred by using a PC communications link with the SEL-421. The relay converts event reports to oscillograms with time-coordinated element assertion and phasor/sequence element diagrams. The QuickSet interface supports Windows 95, 98, 2000, and NT® operating systems. Open COMTRADE files from SEL and other products. Convert binary COMTRADE files to ASCII format for portability and ease of use. View real-time phasors and harmonic values.

QuickSet Templates

Use the fully licensed version of QuickSet to create custom views of settings, called Application Designs, 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, communications 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.

Table 5 SELOGIC Control Equation Operators

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

SELOGIC Control Equations With Expanded Capabilities and Aliases

Expanded SELOGIC control equations put relay logic in the hands of the protection engineer. Assign the relay inputs to suit your application, logically combine selected relay 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 5*). Any element in the Relay Word can be used in these equations. The SEL-421 is factory set for use without additional logic in most situations. For complex or unique applications, these expanded SELOGIC functions allow superior flexibility.

Use the new alias capability to assign more meaningful relay variable names. 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 using 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 protection and automation systems. New functions and capabilities enable use of 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 (refer to *Figure 20*).
- 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.
- Construct a compensated overvoltage element for open line overvoltage protection.
- Hold momentary change-of-state conditions for SCADA polling.

Provide a combination of frequency or rate-of-change-of-frequency functions.

Relay-to-Relay Digital Communication (MIRRORED BITS)

The SEL patented MIRRORED BITS technology provides bidirectional relay-to-relay digital communication (*Figure 21*). In the SEL-421, MIRRORED BITS can operate simultaneously on any two serial ports for three-terminal power system operation.

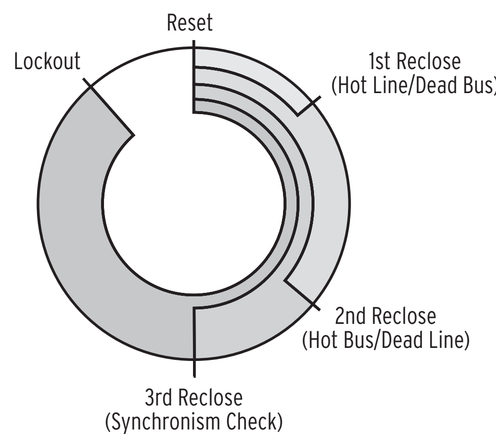


Figure 20 Motor-Driven Reclose Timer

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. These MIRRORED BITS can be used to transfer information between line terminals to enhance coordination and achieve faster tripping. MIRRORED BITS also help reduce total pilot scheme operating time by eliminating the need to close output contacts and debounce contact outputs. Use the dual-port MIRRORED BITS communications capabilities for high-speed communications-assisted schemes applied to three-terminal transmission lines.

Communication

The SEL-421 offers the following serial communication features:

- ➤ Four independent EIA-232 serial ports.
- ➤ Full access to event history, relay status, and meter information.
- ➤ Strong password protection for settings and group switching.
- ➤ DNP3 Level 2 Outstation
- ➤ Patented SEL Fast Message Interleaving of ASCII and binary data for SCADA communications, including access to SER, relay element targets, event data, and more.
- ➤ Communication of synchronized phasor-measurement data through use of either SEL Fast Messaging for Synchrophasors or IEEE C37.118-2005 Standard for Synchrophasors for Power Systems.

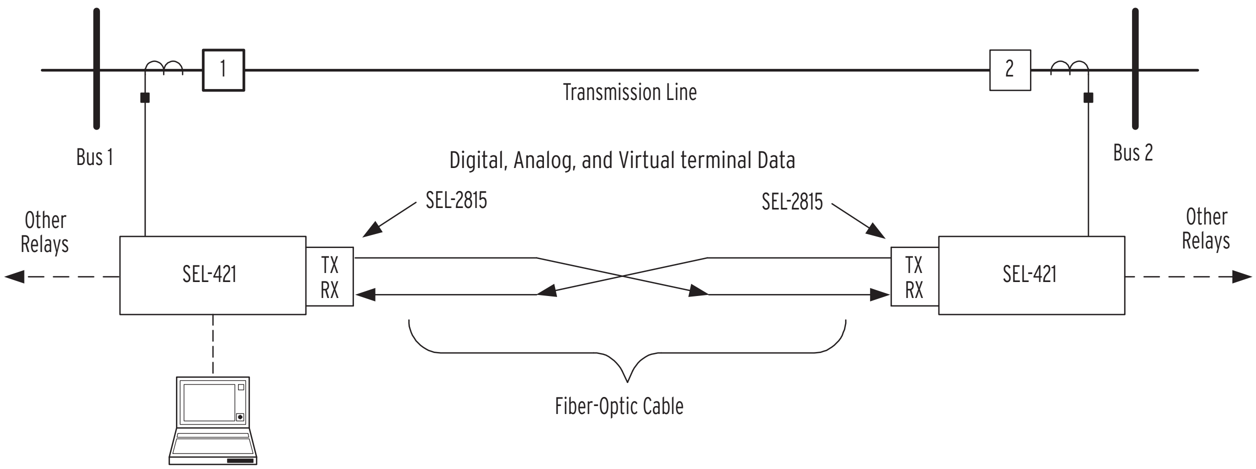


Figure 21 Integral communication provides secure protection, monitoring, and control, as well as terminal access to both relays through one connection.

Advanced Front-Panel Operation

Front-Panel Display

The liquid crystal display (LCD) shows event, metering, setting, and relay self-test status information. The target LEDs display relay target information as described in *Figure 22* and *Figure 23*, and explained in *Table 6*.

The LCD is controlled by the navigation pushbuttons (*Figure 24*), automatic messages the relay generates, and user-programmed analog and digital display points. The rotating display scrolls through alarm points, display points, and metering screens. If none are active, the relay scrolls through displays of the fundamental and rms metering screens. Each display remains for a user-programmed time (1–15 seconds) before the display continues scrolling. Any message generated by the relay because of an alarm condition takes precedence over the rotating display.

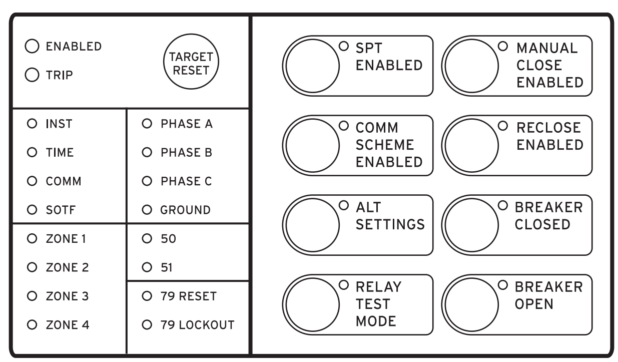


Figure 22 Factory-Default Status and Trip Target LEDs (8 Pushbutton, 16 Target LED Option)

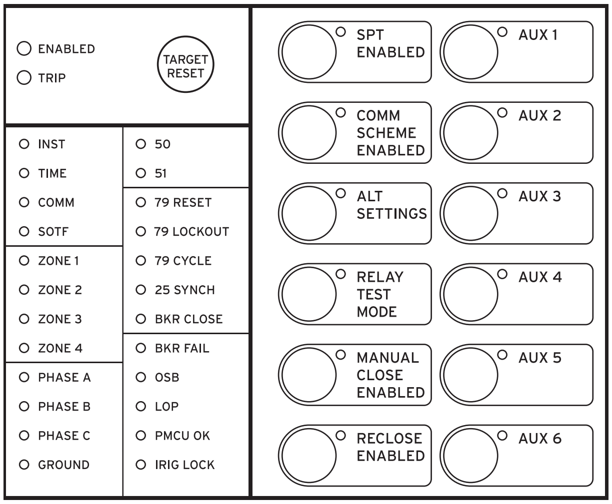


Figure 23 Factory-Default Status and Trip Target LEDs (12 Pushbutton, 24 Target LED Option)

Close-up views of the front panel of the SEL-421 are shown in *Figure 22*, *Figure 23*, and *Figure 24*. 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 any HMI menu item. Quickly view events, alarm points, display points, or the SER.

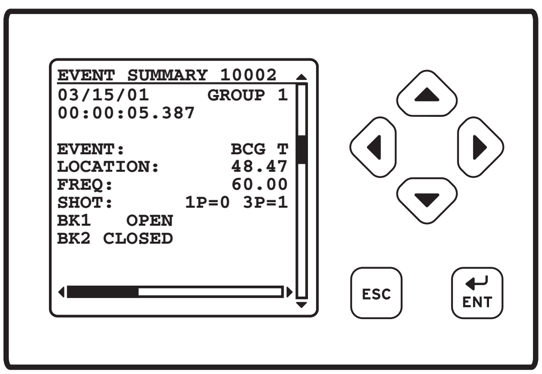


Figure 24 Factory-Default Front-Panel Display and Pushbuttons

Bay Control

The SEL-421 provides dynamic bay one-line diagrams on the front-panel screen with disconnect and breaker control capabilities for 25 predefined user-selectable bay types. Additional user-selectable bay types are available via the QuickSet interface that can be downloaded at selinc.com. The bay control is equipped to control as many as 10 disconnects and two breakers, depending on the one-line diagram selected. Certain one-line diagrams provide status for as many as three breakers and five disconnect switches. Operate disconnects and breakers 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.

One-Line Bay Diagrams

The SEL-421 bay control offers a variety of preconfigured one-line diagrams for common bus configurations. Once a one-line diagram is selected, the user has the ability to customize the names for all of the breakers, disconnect switches, and buses. Most one-line diagrams contain analog display points. These display points can be set to any of the available analog quantities with labels, units, and scaling. These values are updated real-time along with the breakers and switch position to give instant status and complete control of a bay. The diagrams below demonstrate some of the preconfigured bay arrangements available in the SEL-421.

The operator can see all valuable information on a bay before making a critical control decision. Programmable interlocks help prevent operators from incorrectly opening or closing switches or breakers. The SEL-421 will not only prevent the operator from making an incorrect control decision, but can notify and/or alarm when an incorrect operation is initiated.

Circuit Breaker Operations From the Front Panel

Figure 25–Figure 28 are examples of some of the selectable one-line diagrams in the SEL-421. The one-line diagram is selectable from the Bay settings. Additional settings for defining labels and analog quantities are also found in the Bay settings. One-line diagrams are composed of the following:

- Bay Names and Bay Labels
- Busbar and Busbar Labels
- Breaker and Breaker Labels
- Disconnect Switches and Disconnect Switch Labels
- Analog Display Points

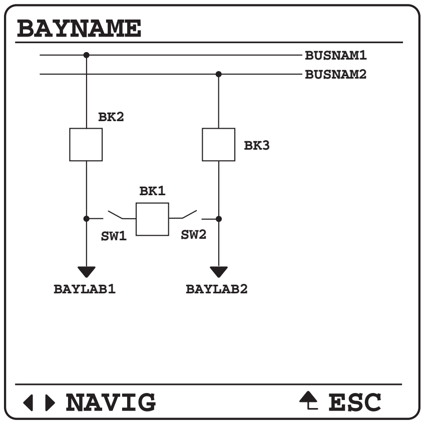


Figure 25 Breaker-and-a-Half

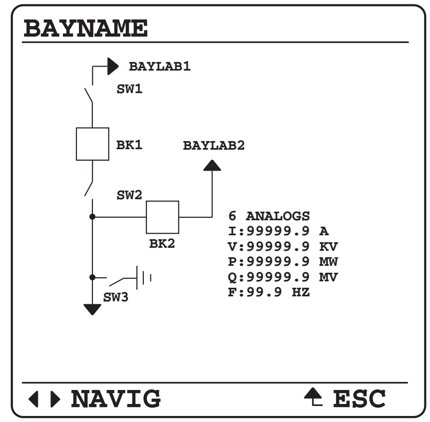


Figure 26 Ring Bus With Ground Switch

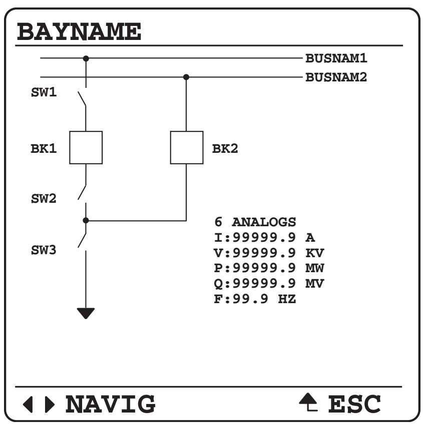


Figure 27 Double Bus/Double Breaker

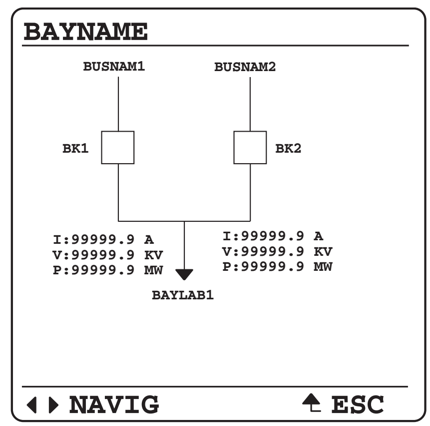


Figure 28 Source Transfer Bus

Figure 29 shows the Breaker Control Screens available when the ENT pushbutton is pressed with the circuit breaker highlighted as shown in *Figure 29(a)*.

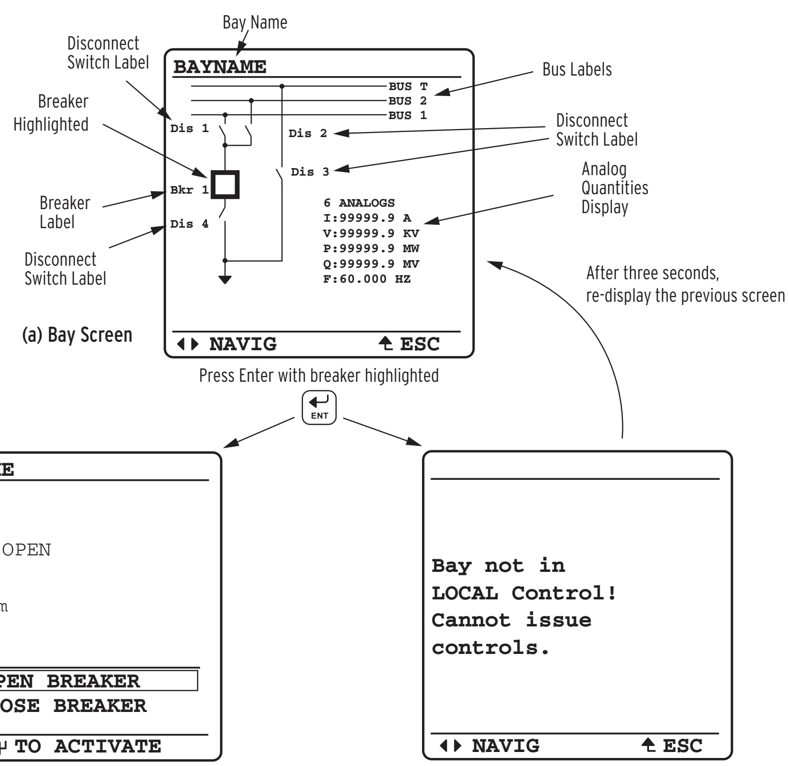


Figure 29 Screens for Circuit Breaker Selection

Status and Trip Target LEDs

The SEL-421 includes programmable status and trip target LEDs, as well as programmable direct-action control pushbuttons on the front panel. These targets are shown in *Figure 22* and *Figure 23*, and explained in *Table 6*.

The SEL-421 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-421. Functions are simple to configure using QuickSet software. Label sets can be printed from a laser printer by using templates supplied with the relay or hand labeled on supplied blank labels.

Table 6 Factory-Default Target LEDs

Target LED	Function
ENABLED	Relay powered properly and self-tests okay
TRIP	Indication that a trip occurred
INST	High-speed trip
TIME	Time-delayed trip
COMM	Communications-assisted trip
SOTF	Switch-onto-fault trip
ZONE 1–4	Trip by Zone 1–4 distance elements
PHASE	
A, B, C	Phases involved in fault
GROUND	Ground involved in fault
50	Instantaneous overcurrent element trip
51	Time-overcurrent element trip
RECLOSER	
79 RESET	Ready for reclose cycle
79 LOCKOUT	Control in lockout state
79 CYCLE[a]	Control in cycle state
25 SYNCH[a]	Voltages within synchronism angle
BKR CLOSE[a]	Breaker close command detected
BKR FAIL[a]	Breaker failure trip
OSB[a]	Out-of-step condition
LOP	Loss-of-potential condition
PMCU OK[a]	Synchrophasor measurement enabled
IRIG LOCKED[a]	IRIG synchronization detected

[a] Only available in 24 LED models.

Alarm Points

You can display messages on the SEL-421 front-panel LCD that indicate alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

Figure 30 shows a sample alarm points screen. The relay is capable of displaying as many as 66 alarm points. The relay automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. The alarm points message is user-configurable and can be triggered using inputs, communications, the SEL-2600, or conditional by using powerful SELOGIC control equations. The asterisk next to the alarm point indicates an active alarm. Inactive alarms can be cleared using the front-panel navigation pushbuttons.

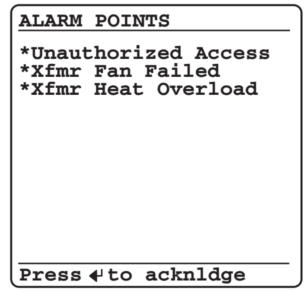


Figure 30 Sample Alarm Points Screen

Advanced Display Points

Create custom screens showing metering values, special text messages, or a mix of analog and status information. *Figure 31* shows an example of how display points can be used to show circuit breaker information and current metering. As many as 96 display points can be created. All display points occupy one, and only one, line on the display at all times. The height of the line is programmable as either single or double as shown in *Figure 31*. These screens become part of the autoscrolling display when the front panel times out.

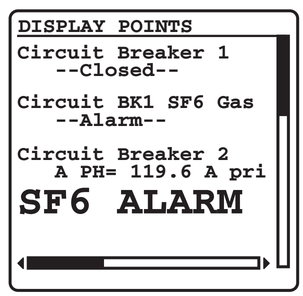


Figure 31 Sample Display Points Screen

Auxiliary Trip/Close Pushbuttons and Indicating LEDs

Optional auxiliary trip and close pushbuttons (see *Figure 32*) 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 powered down. Make the extra connections at Terminals **201** through **208**. See the 5U example shown in *Figure 35* for a rear-panel view. *Figure 33* shows one possible set of connections.

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-421 Relay. The operating voltage ranges of the breaker **CLOSED** and breaker **OPEN** indicating LEDs are also jumper selectable.

Figure 32 Operator Controls (Auxiliary Trip/Close Model)

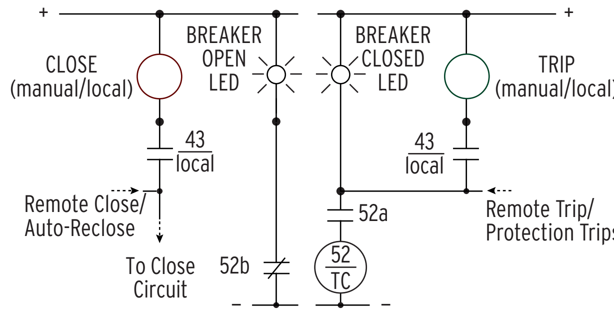
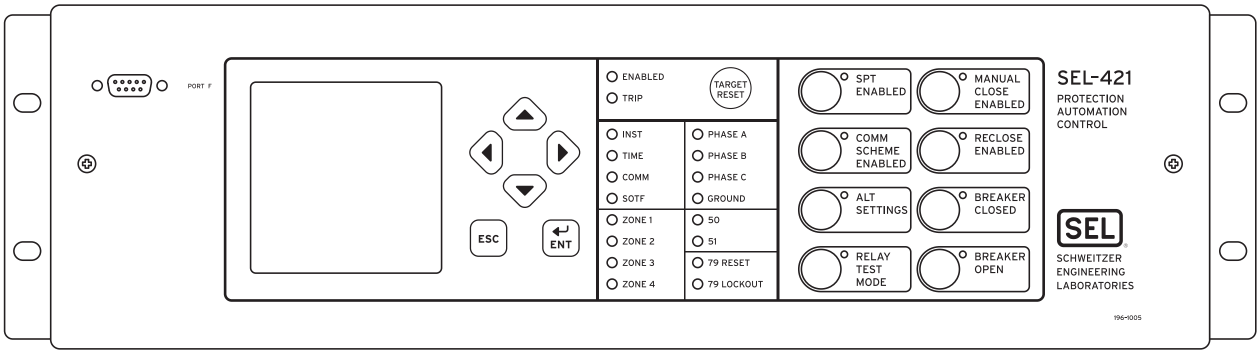
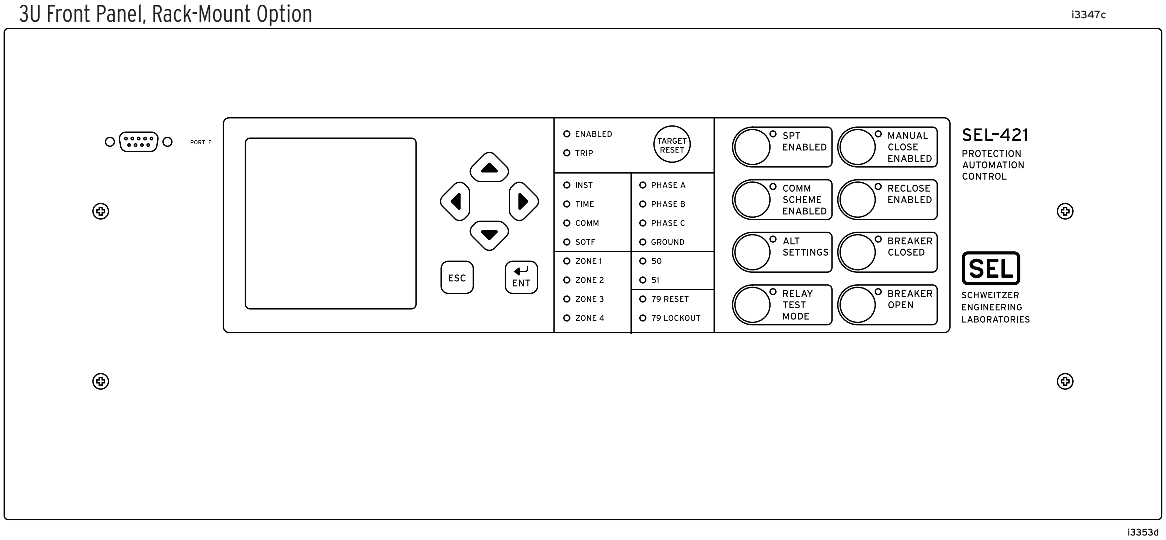


Figure 33 Optional Breaker Trip/Close Control Switches and Indicating Lamps

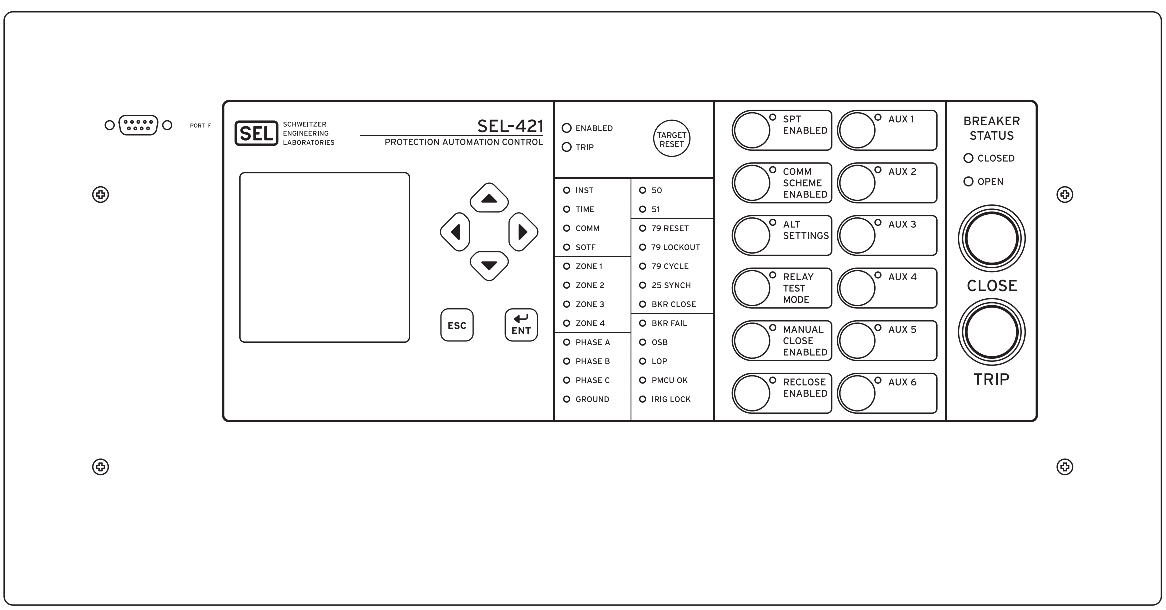
Front- and Rear-Panel Diagrams



3U Front Panel, Rack-Mount Option

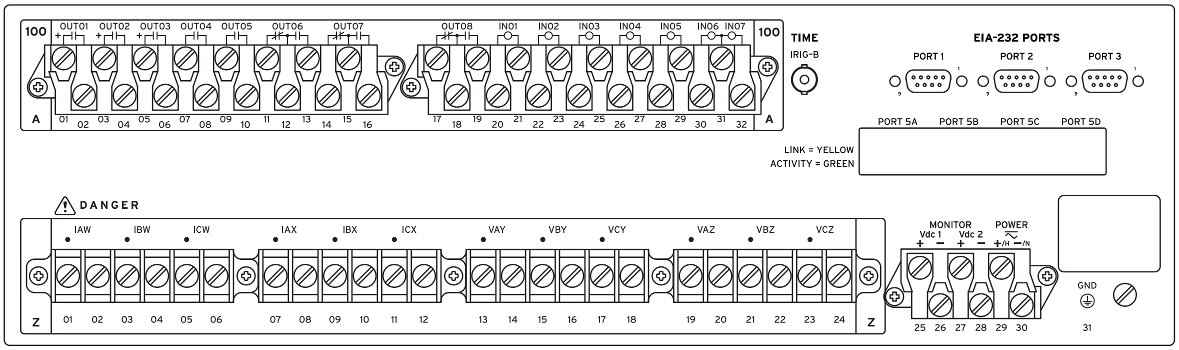


4U Front Panel, Panel-Mount Option



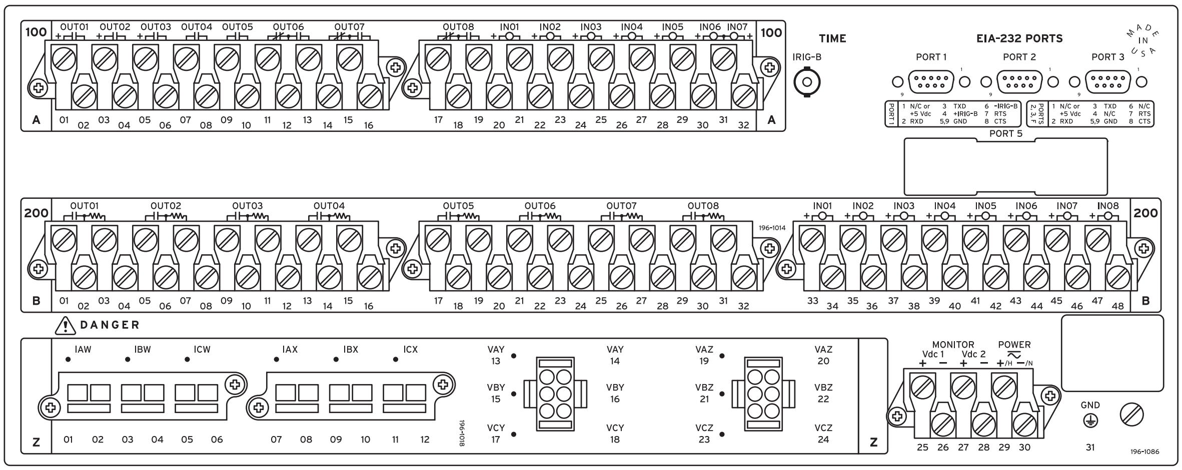
5U Front Panel, Panel-Mount Option

Figure 34 Typical SEL-421 Front-Panel Diagrams



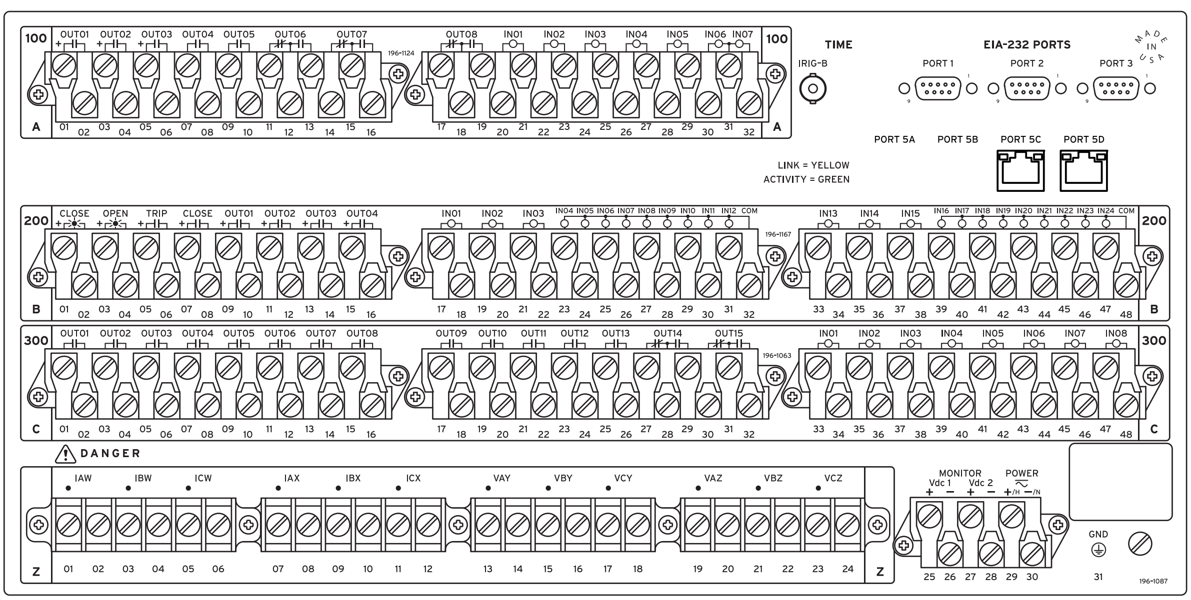
3U Rear Panel, Main Board

i5138b



4U Rear Panel, Main Board, Connectorized® Option, INT5 I/O Board

i3375c



5U Rear Panel, Main Board, INT3 and INT1 I/O Interface Board

i4149a

Figure 35 Typical SEL-421 Rear-Panel Diagrams

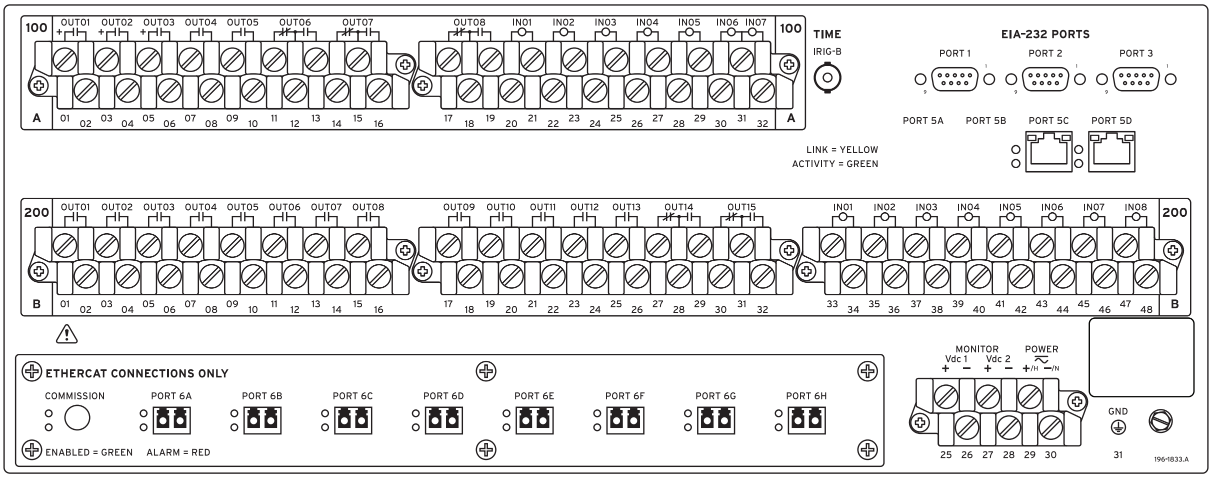
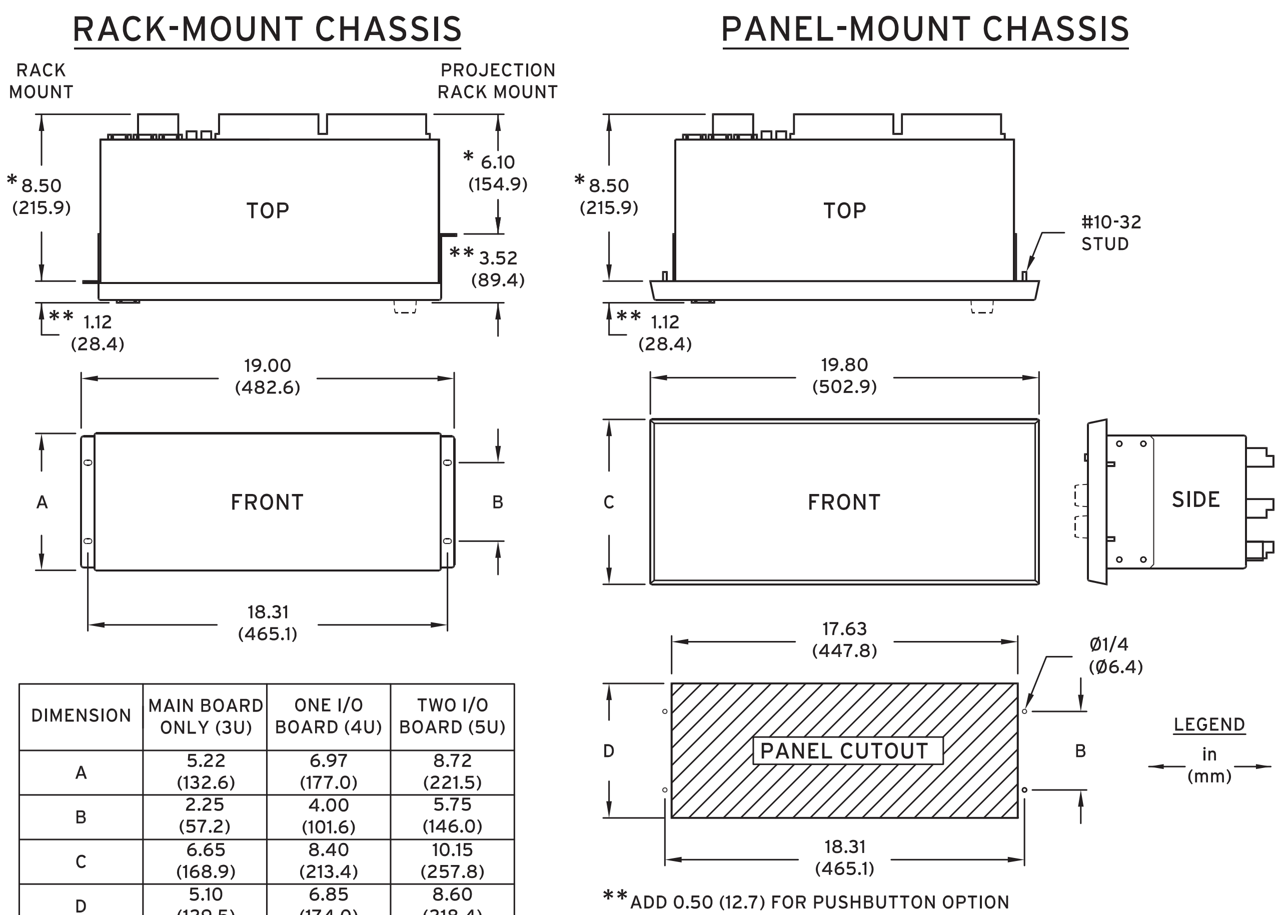


Figure 36 Rear Panel With EtherCAT Board

Relay Dimensions



DIMENSION	MAIN BOARD ONLY (3U)	ONE I/O BOARD (4U)	TWO I/O BOARD (5U)
A	5.22 (132.6)	6.97 (177.0)	8.72 (221.5)
B	2.25 (57.2)	4.00 (101.6)	5.75 (146.0)
C	6.65 (168.9)	8.40 (213.4)	10.15 (257.8)
D	5.10 (129.5)	6.85 (174.0)	8.60 (218.4)

*ADD 0.30 (7.6) FOR CONNECTORIZED RELAYS

**ADD 0.50 (12.7) FOR PUSHBUTTON OPTION
ADD 1.00 (25.4) FOR PUSHBUTTON WITH GUARD

---OPTIONAL PUSHBUTTON

i9027f

(Horizontal Mounting Shown; Dimensions Also Apply to Vertical Mounting)

Figure 37 SEL-421 Dimensions for Rack- and Panel-Mount Models

Specifications

Note: If the relay uses a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay. Element operate times will also have this small added delay.

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

47 CFR 15B Class A

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 Analog Inputs

Sampling Rate: 8 kHz

AC Current Inputs (Secondary Circuits)

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.

5 A Nominal: 247.5 A

1 A Nominal: 49.5 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: 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: 40.0–65.0 Hz
<40 Hz = 40 Hz
>65.0 Hz = 65 Hz

Maximum Slew Rate: 15 Hz/s

Power Supply

24–48 Vdc

Rated Voltage: 24–48 Vdc

Operational Voltage Range: 18–60 Vdc

Vdc Input Ripple: 15% per IEC 60255-26:2013

Interruption: 20 ms at 24 Vdc, 100 ms at 48 Vdc per IEC 60255-26:2013

Burden: <35 W

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

Standard

Make: 30 A

Carry: 6 A continuous carry at 70°C
4 A continuous carry at 85°C

1 s Rating: 50 A

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

Pickup/Dropout Time: ≤6 ms, resistive load

Update Rate: 1/8 cycle

Break Capacity (10,000 Operations):

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

Cyclic Capacity (2.5 Cycle/Second):

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

Hybrid (High-Current Interrupting)

Make: 30 A

Carry: 6 A continuous carry at 70°C
4 A continuous carry at 85°C

1 s Rating: 50 A

MOV Protection (Maximum Voltage): 330 Vdc

Pickup/Dropout Time: ≤ 6 ms, resistive load

Update Rate: 1/8 cycle

Breaking Capacity (10,000 Operations):

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

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

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

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

High-Speed, High-Current Interrupting

Make: 30 A

Carry: 6 A continuous carry at 70°C
4 A continuous carry at 85°C

1 s Rating: 50 A

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

Pickup Time: ≤10 µs, resistive load

Dropout Time: ≤8 ms, resistive load

Update Rate: 1/8 cycle

Breaking Capacity (10,000 Operations):

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

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

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

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.

Auxiliary Trip/Close Pushbuttons (Select Models Only)

Resistive DC or AC Outputs With Arc Suppression Disabled

Make: 30 A

Carry: 6 A continuous carry

1 s Rating: 50 A

MOV Protection: 250 Vac/330 Vdc/130 J

Breaking Capacity (1000 Operations):

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

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 Vdc	10 A	L/R = 40 ms
125 Vdc	10 A	L/R = 40 ms
250 Vdc	10 A	L/R = 20 ms

Breaker Open/Closed LEDs:

250 Vdc:	on for 150–300 Vdc; 192–288 Vac
125 Vdc:	on for 80–150 Vdc; 96–144 Vac
48 Vdc:	on for 30–60 Vdc;
24 Vdc:	on for 15–30 Vdc

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.

Control Inputs

Direct-Coupled (For Use With DC Signals)

INT1, INT5, and INT6 Interface Boards: 8 inputs with no shared terminals

Range: 15–265 Vdc, independently adjustable

Accuracy: ±5% ±3 Vdc

Maximum Voltage: 300 Vdc

Sampling Rate: 2 kHz

Typical Burden: 0.24 W @ 125 Vdc

Optoisolated (Use With AC or DC Signals)

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 Interface Boards: 6 inputs with no shared terminals
18 inputs with shared terminals
(2 groups of 9 inputs with each group sharing one terminal)

Voltage Options: 24 V standard
48, 110, 125, 220, 250 V level-sensitive

DC Thresholds (Dropout Thresholds Indicate Level-Sensitive Option)

24 Vdc:	Pickup 19.2–30.0 Vdc
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

AC Thresholds (Ratings Met Only When Recommended Control Input Settings Are Used—see *Table 2.1 on page 2.6*)

24 Vac:	Pickup 16.4–30.0 Vac rms
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 Vac rms; Dropout <93.2 Vac rms

250 Vac: Pickup 170.6–300 Vac rms; Dropout <106 Vac rms

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

Sampling Rate: 2 kHz

Communications Ports

EIA-232: 1 Front and 3 Rear

Serial Data Speed: 300–57600 bps

Communications Card Slot for Optional Ethernet Card

Ordering Options: 100BASE-FX fiber-optic Ethernet

Fiber Type: Multimode

Wavelength: 1300 nm

Source: LED

Connector Type: LC fiber

Min. TX Power: –19 dBm

Max. TX Power: –14 dBm

RX Sensitivity: –32 dBm

Sys. Gain: 13 dB

Communications Ports for Optional TiDL Interface

EtherCAT Fiber-Optic Ports: 8

Data Rate: Automatic

Connector Type: LC fiber

Protocols: Dedicated EtherCAT

Class 1 LASER/LED

Wavelength: 1300 nm

Fiber Type: Multimode

Link Budget: 11 dB

Min. TX Power: –20 dBm

Min. RX Sensitivity: –31 dBm

Fiber Size: 50–200 µm

Approximate Range: 2 km

Data Rate: 100 Mbps

Typical Fiber Attenuation: –2 dB/km

Time Inputs

IRIG Time 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: 50 Ω or > 1 kΩ

Dielectric Test Voltage: 0.5 kVac

PTP—Ethernet Port 5A, 5B

Input: IEEE 1588 PTPv2

Profiles: Default, C37.238-2011 (Power Profile)

Synchronization Accuracy: ±100 ns @ 1-second synchronization intervals when communicating directly with master clock

Operating Temperature

–40° to +85°C (–40° to +185°F)

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

Humidity

5% to 95% without condensation

Weight (Maximum)

3U Rack Unit: 8.0 kg (17.7 lb)

4U Rack Unit: 9.4 kg (20.7 lb)

5U Rack Unit: 11.3 kg (25.0 lb)

Terminal Connections

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 Sizes 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 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

These tests do not apply to contacts rated for 24 Vdc.

Electromagnetic Compatibility (EMC)

Emissions: IEC 60255-25:2000

Electromagnetic Compatibility Immunity

Conducted RF Immunity: IEC 60255-22-6:2001, 10 Vrms
IEC 61000-4-6:2008, 10 Vrms

Electrostatic Discharge Immunity: IEC 60255-22-2:2008
IEC 61000-4-2:2008
Levels 2, 4, 6, and 8 kV contact;
Levels 2, 4, 8, and 15 kV air
IEEE C37.90.3-2001
Levels 2, 4, and 8 kV contact;
Levels 4, 8, and 15 kV air

Fast Transient/Burst Immunity:	IEC 60255-22-4:2008 4 kV at 5 kHz and 2 kV at 5 kHz (Comm Ports) IEC 61000-4-4:2011 4 kV at 5 kHz
Magnetic Field Immunity:	IEC 61000-4-8:2009 1000 A/m for 3 s 100 A/m for 1 min IEC 61000-4-9:2001 1000 A/m
Damped Oscillatory Magnetic Field:	IEC 61000-4-10:2001 Severity Level: 100 A/m
Power Supply Immunity:	IEC 60255-11:2008 IEC 61000-4-11:2004 IEC 61000-4-29:2000
Radiated Digital Radio Telephone RF Immunity:	ENV 50204:1995 10 V/m at 900 MHz and 1.89 GHz
Radiated Radio Frequency Immunity:	IEC 60255-22-3:2007, 10 V/m IEC 61000-4-3:2010, 10 V/m IEEE C37.90.2-2004, 35 V/m
Surge Immunity:	IEC 60255-22-5:2008 IEC 61000-4-5:2005 1.0 kV line-to-line 2.0 kV line-to-earth
Surge Withstand Capability Immunity:	IEC 60255-22-1:2007 2.5 kV peak common mode 1.0 kV peak differential mode IEEE C37.90.1-2002 2.5 kV oscillatory 4.0 kV fast transient waveform

Environmental

Cold:	IEC 60068-2-1:2007 Severity Level: 16 hours at –40°C
Damp Heat, Cyclic:	IEC 60068-2-30:2005 Severity Level: 25°C to 55°C, 6 cycles, Relative Humidity: 95%
Dry Heat:	IEC 60068-2-2:2007 Severity Level: 16 hours at +85°C
Vibration:	IEC 60255-21-1:1988 Severity Level: Class 2 (endurance); Class 2 (response) IEC 60255-21-2:1988 Severity Level: Class 1 (shock withstand, bump); Class 2 (shock response) IEC 60255-21-3:1993 Severity Level: Class 2 (quake response)

Safety

Dielectric Strength:	IEC 60255-5:2000 IEEE C37.90-2005 2500 Vac on contact inputs, contact outputs, and analog inputs for 1 min 3100 Vdc on power supply for 1 min
Impulse:	IEC 60255-5:2000, 0.5 J, 5 kV IEEE C37.90-2005, 0.5 J, 5 kV
IP Code:	IEC 60529:2001 + CRGD:2003, IP3X

Reporting Functions

High-Resolution Data

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

Note: Per IEEE C37.111-1999 and C37.111-2013, *IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems.*

Event Reports

Length:	0.25–24 seconds (based on LER and SRATE settings)
Volatile Memory:	3 s of back-to-back event reports sampled at 8 kHz
Nonvolatile Memory:	At least 4 event reports of a 3 s duration sampled at 8 kHz
Resolution:	4 and 8 samples/cycle

Event Summary

Storage:	100 summaries

Breaker History

Storage:	128 histories

Sequential Events Recorder

Storage:	1000 entries
Trigger Elements:	250 relay elements
Resolution:	0.5 ms for contact inputs 1/8 cycle for all elements

Processing Specifications

AC Voltage and Current Inputs

8000 samples per second, 3 dB low-pass analog filter cut-off frequency of 3000 Hz.

Digital Filtering

Full-cycle cosine and half-cycle Fourier filters after low-pass analog and digital filtering.

Protection and Control Processing

8 times per power system cycle
Reclosing logic runs once 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

Mho Phase-Distance Elements

Zones 1–5 Impedance Reach

Setting Range

5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model:	0.5 A_{P-P} secondary
1 A Model:	0.1 A_{P-P} secondary (Minimum sensitivity is controlled by the pickup of the supervising phase-to-phase overcurrent elements for each zone.)
Accuracy (Steady State):	± 3% of setting at line angle for SIR (source-to-line impedance ratio) < 30 ± 5% of setting at line angle for 30 ≤ SIR ≤ 60
Zone 1 Transient Overreach:	< 5% of setting plus steady-state accuracy
SEL-421-5 Maximum Operating Time:	0.8 cycle at 100% of reach and SIR = 1
SEL-421-4 Maximum Operating Time:	1.5 cycle at 100% of reach and SIR = 1

Quadrilateral Phase-Distance Elements

Zones 1–5 Impedance Reach

Quadrilateral Reactance Reach

5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

Quadrilateral Resistance Reach

Zones 1, 2, and 3

5 A Model:	OFF, 0.05 to 50 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 250 Ω secondary, 0.01 Ω steps

Zones 4 and 5

5 A Model:	OFF, 0.05 to 150 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 750 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model:	0.5 A secondary
1 A Model:	0.1 A secondary
Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Transient Overreach:	<5% of setting *plus* steady-state accuracy
Relay Version -1 Maximum Operating Time:	1.0 cycle at 70% of reach and SIR = 1
Relay Version -0 Maximum Operating Time:	1.5 cycle at 70% of reach and SIR = 1

Mho Ground-Distance Elements

Zones 1–5 Impedance Reach

Mho Element Reach

5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model:	0.5 A secondary
1 A Model:	0.1 A secondary (Minimum sensitivity is controlled by the pickup of the supervising phase and residual overcurrent elements for each zone.)
Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Zone 1 Transient Overreach:	<5% of setting *plus* steady-state accuracy
SEL-421-5 Maximum Operating Time:	0.8 cycle at 100% of reach and SIR = 1
SEL-421-4 Maximum Operating Time:	1.5 cycle at 100% of reach and SIR = 1

Quadrilateral Ground-Distance Elements

Zones 1–5 Impedance Reach

Quadrilateral Reactance Reach

5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

Quadrilateral Resistance Reach

Zones 1, 2, and 3

5 A Model:	OFF, 0.05 to 50 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 250 Ω secondary, 0.01 Ω steps

Zones 4 and 5

5 A Model:	OFF, 0.05 to 150 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 750 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model:	0.5 A secondary
1 A Model:	0.1 A secondary (Minimum sensitivity is controlled by the pickup of the supervising phase and residual overcurrent elements for each zone.)
Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Transient Overreach:	<5% of setting plus steady-state accuracy
Relay Version -1 Maximum Operating Time:	1.0 cycle at 70% of reach and SIR = 1
Relay Version -0 Maximum Operating Time:	1.5 cycle at 70% of reach and SIR = 1

Instantaneous/Definite-Time Overcurrent Elements

Phase, Residual Ground, and Negative-Sequence

Pickup Range

5 A Model:	OFF, 0.25–100.00 A secondary, 0.01 A steps
1 A Model:	OFF, 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 setting
Transient Overreach:	<5% of pickup
Time-Delay:	0.00–16000.00 cycles, 0.125 cycle steps
Timer Accuracy:	±0.125 cycle plus ±0.1% of setting
Maximum Operating Time:	1.5 cycles

High-Speed Directional Overcurrent Elements

Ground and Phase

Pickup Range

5 A Model:	OFF, 0.25–100 A secondary, 0.01 A steps
1 A Model:	OFF, 0.05–20 A secondary, 0.01 A steps
Transient Overreach:	5% of pickup
Maximum Operating Time:	0.75 cycles

Time-Overcurrent Elements

Pickup Range	
5 A Model:	0.25–16.00 A secondary, 0.01 A steps
1 A Model:	0.05–3.20 A secondary, 0.01 A steps
Accuracy (Steady State)	
5 A Model:	±0.05 A plus ± 3% of setting
1 A Model:	±0.01 A plus ± 3% of setting
Time Dial Range	
US:	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)
Reset:	1 power cycle or Electromechanical Reset Emulation time

Ground Directional Elements

Neg.-Seq. Directional Impedance Threshold (Z2F, Z2R)	
5 A Model:	–64 to 64 Ω
1 A Model:	–320 to 320 Ω
Zero-Seq. Directional Impedance Threshold (Z0F, Z0R)	
5 A Model:	–64 to 64 Ω
1 A Model:	–320 to 320 Ω
Supervisory Overcurrent Pickup 50FP, 50RP	
5 A Model:	0.25 to 5.00 A 3I0 secondary 0.25 to 5.00 A 3I2 secondary
1 A Model:	0.05 to 1.00 A 3I0 secondary 0.05 to 1.00 A 3I2 secondary

Directional Power Elements

Pickup Range	
5 A Model:	–20000.00 to 20000 VA, 0.01 VA steps
1 A Model:	–4000.00 to 4000 VA, 0.01 VA steps
Accuracy (Steady State):	±5 VA plus ±3% of setting at nominal frequency and voltage
Time-Delay:	0.00–16000.00 cycles, 0.25 cycle steps
Timer Accuracy:	±0.25 cycle plus ±0.1% of setting

Undervoltage and Overvoltage Elements

Pickup Ranges	
Phase Elements:	2–300 V secondary, 0.01 V steps
Phase-to-Phase Elements:	4–520.0 V secondary, 0.01 V steps
Accuracy (Steady State):	±0.5 V plus ± 5% of setting
Transient Overreach:	<5% of pickup

Underfrequency and Overfrequency Elements

Pickup Range:	40.01–69.99 Hz, 0.01 Hz steps
Accuracy, Steady State Plus Transient:	±0.005 Hz for frequencies between 40.00 and 70.00 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:	20–200 V_{LN} (Wye)
Pickup Accuracy, Undervoltage Blocking:	±2% ±0.5 V

Optional RTD Elements (Models Compatible With SEL-2600 RTD Module)

12 RTD Inputs Via SEL-2600 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

As long as 500 m Fiber-Optic Cable to SEL-2600 RTD Module

Breaker Failure Instantaneous Overcurrent

Setting Range	
5 A Model:	0.50–50.0 A, 0.01 A steps
1 A Model:	0.10–10.0 A, 0.01 A steps
Accuracy	
5 A Model:	±0.05 A plus ± 3% of setting
1 A Model:	±0.01 A plus ± 3% of setting
Transient Overreach:	<5% of setting
Maximum Pickup Time:	1.5 cycles
Maximum Reset Time:	1 cycle
Timers Setting Range:	0–6000 cycles, 0.125 cycle steps (All but BFIDO*n*, BFISP*n*) 0–1000 cycles, 0.125 cycle steps (BFIDO*n*, BFISP*n*)
Time Delay Accuracy:	0.125 cycle plus ± 0.1% of setting

Synchronism-Check Elements

Slip Frequency Pickup Range:	0.005–0.500 Hz, 0.001 Hz steps
Slip Frequency Pickup Accuracy:	±0.0025 Hz plus ± 2% of setting
Close Angle Range:	3–80°, 1° steps
Close Angle Accuracy:	±3°

Load-Encroachment Detection

Setting Range	
5 A Model:	0.05–64 Ω secondary, 0.01 Ω steps
1 A Model:	0.25–320 Ω secondary, 0.01 Ω steps
Forward Load Angle:	–90° to +90°
Reverse Load Angle:	+90° to +270°
Accuracy	
Impedance Measurement:	±3%
Angle Measurement:	±2°

Out-of-Step Elements

Blinders (R1) Parallel to the Line Angle	
5 A Model:	0.05 to 70 Ω secondary –0.05 to –70 Ω secondary
1 A Model:	0.25 to 350 Ω secondary –0.25 to –350 Ω secondary
Blinders (X1) Perpendicular to the Line Angle	
5 A Model:	0.05 to 96 Ω secondary –0.05 to –96 Ω secondary
1 A Model:	0.25 to 480 Ω secondary –0.25 to –480 Ω secondary

Accuracy (Steady State)

5 A Model:	±5% of setting plus ±0.01 A for SIR (source to line impedance ratio) < 30 ±10% of setting plus ±0.01 A for 30 ≤ SIR ≤ 60
1 A Model:	±5% of setting plus ±0.05 A for SIR (source to line impedance ratio) < 30 ±10% of setting plus ±0.05 A for 30 ≤ SIR ≤ 60
Transient Overreach:	< 5% of setting *plus* steady-state accuracy

Positive-Sequence Overcurrent Supervision

Setting Range

5 A Model:	1.0–100.0 A, 0.01 A steps
1 A Model:	0.2–20.0 A, 0.01 A steps

Accuracy (Steady State)

5 A Model:	±3% of setting plus ± 0.05 A
1 A Model:	±3% of setting plus ± 0.01 A
Transient Overreach:	<5% of setting

Bay Control

Breakers:	2 (control), 3rd indication
Disconnects (Isolators):	10 (maximum)
Timers Setting Range:	1–99999 cycles, 1-cycle steps
Time-Delay Accuracy:	±0.1% of setting, ±0.125 cycle

Timer Specifications

Breaker Failure:	0–6000 cycles, 0.125 cycle steps (All but BFIDO*n*, BFISP*n*) 0–1000 cycles, 0.125 cycle steps (BFIDO*n*, BFISP*n*)
Communications-Assisted Tripping Schemes:	0.000–16000 cycles, 0.125 cycle steps
Out-of-Step Timers	
OSBD, OSTD:	0.500–8000 cycles, 0.125 cycle steps
UBD:	0.500–120 cycles, 0.125 cycle steps
Pole-Open Timer:	0.000–60 cycles, 0.125 cycle steps
Recloser:	1–99999 cycles, 1 cycle steps
Switch-Onto-Fault	
CLOEND, 52AEND:	OFF, 0.000–16000 cycles, 0.125 cycle steps
SOTFD:	0.50–16000 cycles, 0.125 cycle steps
Synchronism-Check Timers	
TCLSBK1, TCLSBK2:	1.00–30.00 cycles, 0.25 cycle steps
Zone Time Delay:	0.000–16000 cycles, 0.125 cycle steps

Station DC Battery System Monitor Specifications

Rated Voltage:	15–300 Vdc
Sampling Rate:	DC1: 2 kHz DC2: 1 kHz
Processing Rate:	1/8 cycle
Operating Time:	Less than 1.5 cycles (all elements except ac ripple) Less than 1.5 seconds (ac ripple element)

Setting Range

15–300 Vdc, 1 Vdc steps (all elements except ac ripple)

1–300 Vac, 1 Vac steps (ac ripple element)

Accuracy

Pickup Accuracy:	±3% ±2 Vdc (all elements except ac ripple) ±10% ±2 Vac (ac ripple element)

Metering Accuracy

All metering accuracy is at 20°C, and nominal frequency unless otherwise noted.

Currents

Phase Current Magnitude

5 A Model:	±0.2% plus ±4 mA (2.5–15 A sec)
1 A Model:	±0.2% plus ±0.8 mA (0.5–3.0 A sec)

Phase Current Angle

All Models:	±0.2° in the current range 0.5 • I_{NOM} to 3.0 • I_{NOM}

Sequence Current Magnitude

5 A Model:	±0.3% plus ± 4 mA (2.5–15 A sec)
1 A Model:	±0.3% plus ± 0.8 mA (0.5–3 A sec)

Sequence Current Angle

All Models:	±0.3° in the current range 0.5 • I_{NOM} to 3.0 • I_{NOM}

Voltages

Phase and Phase-to-Phase Voltage Magnitude:	±0.1% (33.5–300 $V_{L–N}$)
Phase and Phase-to-Phase Angle:	±0.5° (33.5–300 $V_{L–N}$)
Sequence Voltage Magnitude:	±0.1% (33.5–300 V_{L-N})
Sequence Voltage Angle:	±0.5° (33.5–300 V_{L-N})

Frequency (Input 40–65 Hz)

Accuracy:	± 0.01 Hz

Power

MW (P), Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

MVAr (Q), Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (3ϕ)

MVA (S), Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

PF, Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

Energy

MWh (P), Per Phase (Wye), 3ϕ (Wye or Delta)

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

Synchrophasor

Number of Synchrophasor Data Streams:	5

Number of Synchrophasors for Each Stream:
15 Phase Synchrophasors (6 Voltage and 9 Currents)
5 Positive-Sequence Synchrophasors (2 Voltage and 3 Currents)

Number of User Analogs for Each Stream:	16 (any analog quantity)
Number of User Digitals for Each Stream:	64 (any analog quantity)

Synchrophasor Protocol:	IEEE C37.118, 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 (0.1–2.0) • I_{NOM} A, f_{NOM} ±5 Hz
Synchrophasor Data Recording:	Records as much as 120 s IEEE C37.232 File Naming Convention

Notes

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court • Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.332.1890 • Fax: +1.509.332.7990
selinc.com • info@selinc.com

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