**Major Features and Benefits**

The SEL-421-7 Protection, Automation, and Control System With Sampled Values combines high-speed distance and directional protection with complete control for a two-breaker bay. The SEL-421 SV Subscriber Relay subscribes to current and voltage information that is provided by remote merging units instead of standard PT and CT inputs to reduce cable lengths, labor costs, and improve the overall safety of the substation. The SEL-421 with SV publication capability publishes IEC 61850-9-2 Sampled Values (SV) data streams according to the UCA 61850-9-2LE (9-2LE) guideline to be used by compliant substation relays and provides full backup protection in the absence of substation network communication.

➤ **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 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 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 Edition 2 GOOSE messages and Manufacturing Message Specification (MMS) reports, Sequential Events Recorder (SER) reports, breaker monitoring, 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 to speed and improve control actions.
**IEC 61850-9-2 Sampled Values Relay.** Subscribes to current and voltage information that is provided by UCA 61850-9-2LE (9-2LE)-compliant remote merging units instead of standard PT and CT inputs to reduce cable lengths, labor costs, and improve the overall safety of the substation. At the initial product configuration, the SEL-421-7 can alternatively be selected to publish SV streams and provide full backup protection as a merging unit.

**IEC 61850 Operating Modes.** The relay supports IEC 61850 standard operating modes such as Test, Blocked, On, and Off.

**Current Summation.** The relay can combine multiple SV Stream currents to simplify external wiring.

**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.

**Synchronphasors.** Make informed load dispatch decisions based on actual real-time phasor measurements from SEL-421-7 Relays across your power system. Record streaming synchronphasor data from SEL-421-7 Relays for system-wide disturbance recording. Control the power system by using local and remote synchronphasor data.

**Digital Relay-to-Relay Communications.** Use MIRRORED BITS® communications to monitor internal element conditions between relays within a station, or between stations, using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel. Receive synchronphasor data from as many as two other devices transmitting IEEE C37.118-2005 format synchronphasors at rates as high as 60 messages per second. The SEL-421-7 time correlates the data for use in SELOGIC control equations.

**Primary Potential Redundancy.** Provide primary input redundancy through the use of multiple voltage inputs to the SEL-421-7. 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.

**IEEE 1588-2008 Precision Time Protocol (PTP).** Provide high-accuracy timing over an Ethernet network.

**Parallel Redundancy Protocol (PRP).** Provide seamless recovery from any single Ethernet network failure, in accordance with IEC 62439-3:2010. The Ethernet network traffic is fully duplicated with both copies operating in parallel, with the exception of SV.

**Ethernet Access.** Interconnect with automation systems by using IEC 61850 Edition 2 or DNP3 protocols 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 synchronphasors in the IEEE C37.118-2005 format by using 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 the 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-421-7 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-421-7 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.

### Functional Overview

![SEL-421 Functional Overview](image-url)

**Figure 1  SEL-421 With SV Publication Capability Functional Overview**

<table>
<thead>
<tr>
<th>ANSI NUMBERS/ACRONYMS AND FUNCTIONS</th>
<th>ADDITIONAL FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 Phase and Ground Distance</td>
<td>BRM Breaker Wear Monitor</td>
</tr>
<tr>
<td>25 Synchronism Check</td>
<td>LDE Load Encroachment</td>
</tr>
<tr>
<td>27 Undervoltage</td>
<td>LOC Fault Locator</td>
</tr>
<tr>
<td>32 Directional Power</td>
<td>SBM Station Battery Monitor</td>
</tr>
<tr>
<td>50 Overcurrent</td>
<td>SIP Software-Invertible Polarities</td>
</tr>
<tr>
<td>50BF Dual Breaker Failure Overcurrent</td>
<td>THM IEC 60255-Compliant Thermal Model</td>
</tr>
<tr>
<td>51 Time-Overcurrent</td>
<td></td>
</tr>
<tr>
<td>59 Overvoltage</td>
<td></td>
</tr>
<tr>
<td>67 Directional Overcurrent</td>
<td></td>
</tr>
<tr>
<td>68 Out-of-Step Block/Trip</td>
<td></td>
</tr>
<tr>
<td>79 Single-/Three-Pole Reclosing</td>
<td></td>
</tr>
<tr>
<td>81 (O, U) Over-/Underfrequency</td>
<td></td>
</tr>
<tr>
<td>85 RIO MIRRORED BITS Communications</td>
<td></td>
</tr>
<tr>
<td>DFR Event Reports</td>
<td></td>
</tr>
<tr>
<td>ENV SEL-2600*</td>
<td></td>
</tr>
<tr>
<td>HMI Operator Interface</td>
<td></td>
</tr>
<tr>
<td>LGC SELOGIC Control Equations</td>
<td></td>
</tr>
<tr>
<td>MET High-Accuracy Metering</td>
<td></td>
</tr>
<tr>
<td>PMU Synchrophasors</td>
<td></td>
</tr>
<tr>
<td>SER Sequential Events Recorder</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Both copper and fiber-optic Ethernet ports are available.

* Optional Feature
The SEL-421-7 SV Subscriber Relay subscribes to data streams that are published from a merging unit, such as the SEL-421 with SV publication capability or SEL-401 Merging Unit. The SEL-421 with SV publication capability provides full backup protection while the SEL-401 can provide basic phase overcurrent and breaker failure protection in the absence of communication. Using the process bus, the SEL-421 with SV publication capability or SEL-401 can provide voltage and current information to multiple relays that subscribe to SV streams (see Figure 1 and Figure 2). The data are synchronized using IEEE 1588-2008 Precision Time Protocol.

**Product Offerings**

- Line protective relay (SEL-421-7 SV Subscriber Relay)
- Merging Unit with full distance protection (SEL-421 with SV publication capability)
Protection Features

The SEL-421-7 contains all the necessary protective elements and control logic to protect overhead transmission lines and underground cables. The unit simultaneously measures five zones of phase and ground mho distance plus five zones of phase and ground quadrilateral distance. These distance elements, together with 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 by using expanded SELogic control equations.

Mho Distance Elements

The SEL-421-7 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 (see Figure 4). 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, $Z_R$.

Series compensation line logic prevents overreach of the Zone 1 distance element resulting from the series capacitor transient response.
Load-Encroachment Logic

Load-encroachment logic (see Figure 5) prevents operation of the phase-distance elements under high load conditions. This unique SEL feature permits a load to enter a predefined area of the phase-distance characteristic without causing a trip.

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-421-7 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 by using 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

Multiple directional elements are available 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-421-7 includes a number of directional elements for the supervision of overcurrent elements and distance elements. The negative-sequence directional element uses the same patented principle proven in our SEL-321 Phase and Ground Distance 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 logic 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.)

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

In addition to standard directional elements, the SEL-421-7 includes an HSDPS function that uses 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-421-7 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. The following schemes are supported:

➤ 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 SELOGIC 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.

Overcurrent Elements

The SEL-421-7 includes four phase, four negative-sequence, and four ground instantaneous overcurrent elements. The SEL-421-7 also includes three selectable operating quantity inverse-time overcurrent elements. You can select the operating quantities from the following:

| $|I_A|$ | $|I_B|$ | $|I_C|$ | MAX($|I_A|$, $|I_B|$, $|I_C|$) | $|I_{II1}|$, $|I_{II2}|$, $|I_{IIG}|$

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

<table>
<thead>
<tr>
<th>Table 1 Time-Overcurrent Curves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>US</strong></td>
</tr>
<tr>
<td>Moderately Inverse</td>
</tr>
<tr>
<td>Inverse</td>
</tr>
<tr>
<td>Very Inverse</td>
</tr>
<tr>
<td>Extremely Inverse</td>
</tr>
<tr>
<td>Short-Time Inverse</td>
</tr>
</tbody>
</table>
**Breaker Failure Protection**

A full-function breaker failure system is incorporated into the SEL-421-7. 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 the minimum load for sensitivity without sacrificing high-speed dropout. Even in cases with delayed current zeros in the secondary of the CT caused by trapped flux, high-speed detection of circuit breaker opening occurs. If breaker failure is initiated on all circuit breaker trips, this feature is essential. A 5/8-cycle reset reduces coordination times, improving stability.

**LOP Logic Supervises Directional Elements**

The SEL-421-7 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.

**Out-of-Step Detection**

The SEL-421-7 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 7) to closely approximate the swing center voltage (SCV) allows the relay to use the rate-of-change of the SCV to quantify the power swing condition.

System performance 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 blinding that are set outside any of the distance elements. A power swing is declared when an impedance loci 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-421-7 ideal for applications requiring frequent settings changes and for adapting the protection to changing system conditions.

---

**Figure 7**  **VS and the Swing Center Voltage**

Applying VS to approximate the swing center voltage provides an accurate local quantity to detect power swings.
Selecting a settings 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.

Software-Invertible Polarities Save Commissioning Time and Costs

The SEL-421 provides software-invertible CT and PT polarities. You can invert individual phase CT and PT inputs to account for field wiring or invert whole CT terminals to change a relay zone of protection without having to change field wiring.

All signal processing uses the software-inverted polarities for CEV file generation, metering, and protection logic. COMTRADE file generation is isolated from the impacts of the inverted polarities, and records signals as applied to the relay terminals.

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-421-7 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-421-7. Breaker diagnostics are reported on a comparative basis, allowing for advanced proactive troubleshooting.

Control Inputs and Outputs

The basic SEL-421-7 does not include main-board I/O. The following additional I/O boards are currently available.

- Eight optoisolated, independent, level-sensitive inputs; thirteen standard Form A and two standard Form C contact outputs
- Eight optoisolated, independent, level-sensitive inputs, thirteen high-current interrupting Form A outputs and two standard Form C contact outputs
- Twenty-four optoisolated, independent, level-sensitive inputs and eight standard Form A outputs
- Twenty-four optoisolated, independent, level-sensitive inputs and eight high-speed, high-current interrupting, Form A contact outputs
- Twenty-four optoisolated, independent, level-sensitive inputs and eight Form A outputs

Assign the control inputs for control functions, monitoring logic, and general indication. Each control output is programmable using SELOGIC control equations. The SEL-421-7 Relay is only available in a 4U chassis, supporting one I/O board. When ordered as a publishing merging unit, the SEL-421-7 is available in a 4U, 5U, or 6U chassis, supporting one to three I/O boards.

Multifunction Recloser With Flexible Applications

The SEL-421-7 includes both single-pole and three-pole trip and reclose functions for either one or two breakers. 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- and 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.

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 when an error has occurred in the system to allow operator action to find and repair the faulty element.

Two-Breaker Control

The SEL-421-7 contains analog voltage inputs for multiple sources and control inputs to indicate both the 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 con-
trol 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-421-7 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>
<thead>
<tr>
<th>Analog Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VA, VB, VC</td>
<td>L-N Phase Voltage</td>
</tr>
<tr>
<td>VNMAX, VNMIN</td>
<td>Neutral Voltage Min/Max</td>
</tr>
<tr>
<td>VAB, VBC, VCA</td>
<td>L-L Phase Voltage</td>
</tr>
<tr>
<td>VA-VN², VB-VN², VC-VN²</td>
<td>Phase Voltage with Neutral Voltage Subtracted</td>
</tr>
<tr>
<td>VPMAX, PVMIN</td>
<td>Phase Voltage Min/Max</td>
</tr>
<tr>
<td>V¹, V², V⁰</td>
<td>Positive-, Negative-, Zero-Sequence</td>
</tr>
</tbody>
</table>

* Fundamental quantities only.

Frequency Elements

The SEL-421-7 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 underfrequency. 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 frequency element when the selected voltage input falls below a programmable undervoltage supervision threshold.

Network Connection and Integration

Ethernet Card

The Ethernet card mounts directly in the SEL-421-7. The Ethernet card provides PTP for data time synchronization. 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 the IEEE C37.118-2005, Standard for Synchrophasors for Power Systems. Communicate with SCADA and other substation IEDs by using 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

The SEL-421-7 is equipped with an Ethernet communications card that supports Telnet and FTP that enhance communication sessions. Use Telnet to access relay settings, metering and event reports remotely 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-421-7 provides two independent connections by using 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-421-7 with DNP3 Level 2 Outstation functionality over Ethernet. Custom DNP3 data maps can be configured for use with specific DNP3 masters.

HTTP Web Server

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

IEC 61850 Ethernet Communications

The SEL-421-7 supports IEC 61850-9-2 SV protocol. The SEL-421 SV Subscriber Relay can subscribe to as many as seven SV streams and is interoperable with other vendor’s products that meet the IEC 61850-9-2 standard and are compliant with the UCA 61850-9-2LE guideline (9-2LE). Self-monitoring of the Ethernet links validates the data quality and reduces the need for periodic testing of the communication network. The SEL-421 with SV publication capability can publish as many as seven data streams of SV data as well as provide full backup distance protection in the absence of substation network communication.

IEC 61850 Edition 2 Ethernet-based communications provide interoperability between intelligent devices within the substation. Logical nodes 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. Eliminate system remote terminal units (RTUs) by streaming monitoring and control information from the intelligent devices directly to remote SCADA client devices.

Metering and Monitoring

Complete Metering Capabilities

The SEL-421-7 provides extensive metering capabilities, as listed in Table 3.

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous Quantities</td>
<td>0–300 V with phase quantities for each of the six voltage sources available as a separate quantity.</td>
</tr>
</tbody>
</table>

The SEL-421-7 supports embedded IEC 61850 Edition 2 protocols operating on 100 Mbps Ethernet. Use the 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 Edition 2 Data Server: The SEL-421-7 is equipped with embedded IEC 61850 Edition 2 Ethernet protocols and 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 the status of relay elements, inputs, outputs, or SELOGIC equations can be monitored using the 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 network data between logical nodes by using IEC 61850 Edition 2-compliant Configured IED Description (CID) files. CID files are used by Architect to describe the data that will be provided by the logical node within each relay.
Event Reporting and SER

Event reports and SER features simplify post-fault analysis and help improve your understanding of both simple and complex protective scheme operations. These features also aid in testing and troubleshooting relay settings and 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 that are operational in the relay at the time of the event are appended to each event report.

Event Summary

Each time the SEL-421-7 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.

SV Reporting

The SEL-421-7 includes a comprehensive report of the SV communication stream. The ASCII command COM SV displays statistics information from the sample values stream to aid in troubleshooting.
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 or IEEE 1588 from a global positioning satellite clock, the SEL-421-7 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 an 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 IEEE 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-421-7).

Figure 8 contains actual data from back-to-back testing using two different manufacturers’ time clocks. Voltage peak is measured to 1-microsecond accuracy in this example.

SNTP Time Synchronization

Use SNTP to cost-effectively synchronize the SEL-421-7 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.

Substation Battery Monitor for DC Quality Assurance

The SEL-421-7 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 communication, 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-421-7 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 10), 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 the last and the 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.

Automation

Flexible Control Logic and Integration Features

Use the SEL-421-7 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 (for example, trip, close, settings group selection).

Open Communications Protocols

The SEL-421-7 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 (Sheet 1 of 2)

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCII</td>
<td>Plain-language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.</td>
</tr>
<tr>
<td>Compressed ASCII</td>
<td>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.</td>
</tr>
<tr>
<td>Extended Fast Meter, Fast Operate, and Fast SER</td>
<td>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.</td>
</tr>
</tbody>
</table>
**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-421-7. 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, such as in the following ways:

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

**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-421-7 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:

---

**Table 4 Open Communications Protocol (Sheet 2 of 2)**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ymodem</td>
<td>Support for reading event, settings, and oscillography files.</td>
</tr>
<tr>
<td>Optional DNP3 Level 2 Outstation</td>
<td>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.</td>
</tr>
<tr>
<td>IEEE C37.118</td>
<td>Phasor measurement protocol.</td>
</tr>
<tr>
<td>IEC 61850</td>
<td>Ethernet-based international standard for interoperability between intelligent electronic devices in a substation.</td>
</tr>
</tbody>
</table>

**Table 5 SELogic Control Equation Operators**

<table>
<thead>
<tr>
<th>Operator Type</th>
<th>Operators</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>AND, OR, NOT</td>
<td>Allows combination of measuring units.</td>
</tr>
<tr>
<td>Edge Detection</td>
<td>F_TRIG, R_TRIG</td>
<td>Operates at the change of state of an internal function.</td>
</tr>
<tr>
<td>Comparison</td>
<td>&gt;, ≥, =, ≤, &lt;, &lt; &gt;</td>
<td></td>
</tr>
<tr>
<td>Arithmetic</td>
<td>+, −, *, /</td>
<td>Uses traditional math functions for analog quantities in an easily programmable equation.</td>
</tr>
<tr>
<td>Numerical</td>
<td>ABS, SIN, COS, LN, EXP, SQRT</td>
<td></td>
</tr>
<tr>
<td>Precedence Control</td>
<td>(</td>
<td>Allows multiple and nested sets of parentheses.</td>
</tr>
<tr>
<td>Comment</td>
<td>#</td>
<td>Provides for easy documentation of control and protection logic.</td>
</tr>
</tbody>
</table>

Schweitzer Engineering Laboratories, Inc.
Add programmable control functions to your protection and automation systems. New functions and capabilities enable the use of analog values in conditional logic statements. The following are examples of possible applications of SELOGIC control equations with expanded capabilities:

➤ 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.

Advanced Front-Panel Operation

Front-Panel Display

The LCD shows event, metering, setting, and relay self-test status information. The target LEDs display relay target information as described in Figure 11.

The LCD is controlled by the navigation pushbuttons (Figure 12), 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.

Relay-to-Relay Digital Communication (MIRRORED BITS)

The SEL-patented MIRRORED BITS technology provides bidirectional relay-to-relay digital communication. In the SEL-421-7, MIRRORED BITS can operate simultaneously on any two serial ports for three-terminal power system operation.

The SEL-421-7 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 by using either SEL Fast Messaging for Synchrophasors or the IEEE C37.118-2005 Standard for Synchrophasors for Power Systems.

Figure 11 Factory-Default Status and Trip Target LEDs (12-Pushbutton, 24-Target LED Option)

Close-up views of the front panel of the SEL-421-7 are shown in Figure 11 and Figure 12. The front panel includes a 128 x 128 pixel, 3” x 3” LCD screen; LED tar-
get 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.

The SEL-421-7 features a versatile, customizable front panel to fit your needs. Use SELOGIC control equations and slide-in, configurable labels to change the function and identification of target LEDs, operator control pushbuttons, and LEDs. The blank slide-in label set is included with the SEL-421-7. Functions are simple to configure using QuickSet software. Label sets can be hand labeled on supplied blank labels or printed using templates supplied with the relay.

Bay Control

The SEL-421-7 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 ten 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-421-7 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 in real-time along with the breakers and switch position to give instant status and complete control of a bay. *Figure 13 through Figure 16* demonstrate some of the preconfigured bay arrangements available in the SEL-421-7.

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-421-7 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 13 through Figure 16* are examples of some of the selectable one-line diagrams in the SEL-421-7. 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
Alarm Points

You can display messages on the SEL-421-7 front-panel LCD that indicate alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

*Unauthorized Access
*Xfmr Fan Fail
*Xfmr Heat Overload

Press \( \wedge \) to acknldge

Advanced Display Points

Create custom screens showing metering values, special text messages, or a mix of analog and status information with programmable display points. Figure 18 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 18. These screens become part of the autoscrolling display when the front panel times out.
Front- and Rear-Panel Diagrams

Figure 18  Sample Display Points Screen

Figure 19  SEL-421-7 4U Front Panel, Panel-Mount Option

Figure 20  SEL-421-7 SV Subscriber Relay 4U Rear Panel, High-Speed INTC (200 Slot) Interface Board
Figure 21  SEL-421 With SV Publication Capability 4U Rear Panel, High-Speed INTC (200 Slot) Interface Board

Dimensions

**RACK-MOUNT CHASSIS**

Rack Mount

Projection Rack Mount

**PANEL-MOUNT CHASSIS**

A

1.12
(28.4)

19.00
(482.6)

18.31
(465.1)

D

17.63
(447.8)

18.31
(465.1)

E

N/A

N/A

F

3.00
(76.2)

3.46
(87.5)

3.00
(76.2)

*ADD 0.50 (12.7) FOR CONNECTORIZED RELAYS

**Figure 22  SEL-421-7 Dimensions for Rack- and Panel-Mount Models**
Specifications

Note: The SEL-421 SV Subscriber Relay uses an SV-based remote data acquisition system. Operating times will be delayed by the configured channel delay, CH_DLY. Use caution when setting the relay coordination times to account for this added delay. See SV Network Delays in Section 17 in the SEL-400 Series Relays Instruction Manual for more details on this setting.

Note: The metering and protection element accuracies specified for the SEL-421 SV Subscriber Relay are valid only when using SEL SV publisher relays. Third-party SV publisher devices are supported, but hardware accuracies and analog filtering need to be considered to determine the effect on SEL-421 performance.

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
RCM Mark

General

AC Analog Inputs

Sampling Rate: 8 kHz

AC Current Input (Secondary Circuit)

Current Range Rating (With DC Offset at X/R = 10, 1.5 Cycles)
1 A Nominal: 0.1–18.2 A
5 A Nominal: 0.5–91 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 (Peak)
1 A Nominal: 49.5 A
5 A Nominal: 247.5 A

Note: Signal clipping can occur beyond this limit.

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 @ 1 A
5 A Nominal: ≤0.5 VA @ 5 A

AC Voltage Inputs

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

Rated Voltage Range: 67–250 VT-N
Operational Voltage Range: 0–300 VT-N

Ten-Second Thermal Rating: 600 Vac
Burden: ≤0.1 VA @ 125 V

Frequency and Rotation

Nominal Frequency Range: 50 ± 5 Hz
60 ± 5 Hz

Phase Rotation: ABC or ACB

Frequency Tracking Range: <40 Hz = 40 Hz
>65 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

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

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

Burden: <35 W, <90 VA

Control Outputs


Update Rate: 1/8 cycle

Make (Short Duration Contact Current):
30 A dc
1,000 operations at 250 Vdc
2,000 operations at 125 Vdc

Limiting Making Capacity: 1000 W at 250 Vdc (L/R = 40 ms)

Mechanical Endurance: 10,000 operations
### Standard

<table>
<thead>
<tr>
<th>Rated Voltage</th>
<th>Resistive Break</th>
<th>Inductive Break L/R = 40 ms (DC)</th>
<th>PF = 0.4 (AC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Vdc</td>
<td>0.75 Adc</td>
<td>0.75 Adc</td>
<td></td>
</tr>
<tr>
<td>48 Vdc</td>
<td>0.63 Adc</td>
<td>0.63 Adc</td>
<td></td>
</tr>
<tr>
<td>125 Vdc</td>
<td>0.30 Adc</td>
<td>0.30 Adc</td>
<td></td>
</tr>
<tr>
<td>250 Vdc</td>
<td>0.20 Adc</td>
<td>0.20 Adc</td>
<td></td>
</tr>
<tr>
<td>110 Vrms</td>
<td>0.30 Arms</td>
<td>0.30 Arms</td>
<td></td>
</tr>
<tr>
<td>240 Vrms</td>
<td>0.20 Arms</td>
<td>0.20 Arms</td>
<td></td>
</tr>
</tbody>
</table>

### Hybrid (High-Current Interrupting)

<table>
<thead>
<tr>
<th>Rated Voltage</th>
<th>Resistive Break</th>
<th>Inductive Break L/R = 40 ms (DC)</th>
<th>PF = 0.4 (AC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
<td></td>
</tr>
<tr>
<td>48 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
<td></td>
</tr>
<tr>
<td>125 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
<td></td>
</tr>
<tr>
<td>250 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 20 ms)</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Rated Voltage</th>
<th>Resistive Break</th>
<th>Inductive Break L/R = 40 ms (DC)</th>
<th>PF = 0.4 (AC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
<td></td>
</tr>
<tr>
<td>48 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
<td></td>
</tr>
<tr>
<td>125 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
<td></td>
</tr>
<tr>
<td>250 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 20 ms)</td>
<td></td>
</tr>
</tbody>
</table>

### Limiting Breaking Capacity

<table>
<thead>
<tr>
<th>Rated Voltage</th>
<th>Resistive Break</th>
<th>Inductive Break</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>48 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>125 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>250 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 20 ms)</td>
</tr>
</tbody>
</table>

### Electrical Endurance

- 10,000 operations in 1 second, followed by 2 minutes idle

### Control Inputs

- Optoisolated (For Use With AC or DC Signals)
  - Main Board: No I/O
  - INT2, INT7, INT8 Interface Boards: 8 inputs with no shared terminals
  - INTC, INT4, and INTD Interface Boards: 18 inputs with shared terminals

### DC Thresholds

<table>
<thead>
<tr>
<th>Rated Voltage</th>
<th>Resistive Break</th>
<th>Inductive Break</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>48 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>125 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>250 Vdc</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 20 ms)</td>
</tr>
</tbody>
</table>

### AC Thresholds

<table>
<thead>
<tr>
<th>Rated Voltage</th>
<th>Resistive Break</th>
<th>Inductive Break</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Vac</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>48 Vac</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>110 Vac</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>125 Vac</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>220 Vac</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 40 ms)</td>
</tr>
<tr>
<td>250 Vac</td>
<td>10 Adc</td>
<td>10 Adc (L/R = 20 ms)</td>
</tr>
</tbody>
</table>

### Communications Ports

- EIA-232: 1 front and 3 rear
- Serial Data Speed: 300–57600 bps
- Ethernet Card Slot: Multi
  - Mode: Multi
  - Wavelength (mm): 1300
Source: LED
Connector Type: LC
Min. TX Pwr. (dBm): –19
Max. TX Pwr. (dBm): –14
RX Sens. (dBm): –32
Sys. Gain (dB): 13

Time Inputs
IRIG-B Input—Serial Port 1
Input: Demodulated IRIG-B
Rated I/O Voltage: 5 Vdc
Operating Voltage Range: 0–8 Vdc
Logic High Threshold: ≥2.8 Vdc
Logic Low Threshold: ≤0.8 Vdc
Input Impedance: 2.5 kΩ
IRIG-B Input—BNC Connector
Input: Demodulated IRIG-B
Rated I/O Voltage: 5 Vdc
Operating Voltage Range: 0–8 Vdc
Logic High Threshold: ≥2.2 Vdc
Logic Low Threshold: ≤0.8 Vdc
Input Impedance: >1 kΩ
Rated Insulation Voltage: 150 Vdc
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)
SV Publisher Relay
4U Rack Unit: 10.2 kg (22.5 lb)
5U Rack Unit: 11.8 kg (26 lb)
6U Rack Unit: 13.5 kg (30 lb)
SV Subscriber Relay
4U Rack Unit: 6.5 kg (14.5 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:

<table>
<thead>
<tr>
<th>Connection Type</th>
<th>Min. Wire Size</th>
<th>Max. Wire Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grounding (Earthing)</td>
<td>14 AWG (2.5 mm²)</td>
<td>N/A</td>
</tr>
<tr>
<td>Contact I/O</td>
<td>18 AWG (0.8 mm²)</td>
<td>10 AWG (5.3 mm²)</td>
</tr>
<tr>
<td>Other Connection</td>
<td>18 AWG (0.8 mm²)</td>
<td>10 AWG (5.3 mm²)</td>
</tr>
</tbody>
</table>

Type Tests

Installation Requirements
Overvoltage Category: 3
Pollution Degree: 2

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

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

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

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

Protective Bonding:
IEC 60255-27:2013, Section 10.6.4.5
>0.1 Ω @ 12 Vdc, 30 A for 1 min

Object Penetration:
Protection Class: IP30

Max Temperature of Parts and Materials:
IEC 60255-27:2013, Section 7.3
Flammability of Insulating Materials:
IEC 60255-27:2013, Section 7.6
Compliant

Electromagnetic (EMC) Immunity
Product Standards:
IEC 60255-26:2013
IEC 60255-27:2013
IEEE C37.90-2005

Surge Withstand Capability (SWC):
IEC 61000-4-8:2006 + A:2010
IEEE C37.90.1-2012
Slow Damped Oscillatory, Common and Differential Mode:
±1.0 kV
±2.5 kV
Fast Transient, Common and Differential Mode:
±4.0 kV

Electrostatic Discharge (ESD):
IEC 61000-4-2:2008
IEEE C37.90.3-2001
Contact:
±8 kV
Air Discharge:
±15 kV
Radiated RF Immunity: IEEE C37.90.2-2004
- 20 V/m (>35 V/m, 80% AM, 1 kHz)
  Sweep: 80 MHz to 1 GHz
  Spot: 80, 160, 450, 900 MHz
- 10 V/m (>15 V/m, 80% AM, 1 kHz)
  Sweep: 80 MHz to 1 GHz
  Sweep: 1.4 GHz to 2.7 GHz
  Spot: 80, 160, 380, 450, 900, 1850, 2150 MHz

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

Surge Immunity: IEC 61000-4-5:2005
- Zone A: ±2 kV_{LL}, ±4 kV_{LE}
- ±4 kV, Communication Ports
  Note: Cables connected to IRIG-B ports shall be less than 10 m in length for Zone A compliance.
- Zone B: ±2 kV, Communication Ports

Conducted Immunity: IEC 61000-4-6:2013
- 20 V/m (>35 V/m, 80% AM, 1 kHz)
  Sweep: 150 kHz–80 MHz
  Spot: 27, 68 MHz

Power Frequency Immunity (DC Inputs): IEC 61000-4-16:2015
- Zone A: Differential: 150 V_{RMS}
  Common Mode: 300 V_{RMS}

Power Frequency Magnetic Field: IEC 61000-4-8:2009
- Level 5:
  100 A/m: ≥60 Seconds; 50/60 Hz
  1000 A/m: 1 to 3 Seconds; 50/60 Hz
  Note: 50G1P ≥0.03 (ESS = N, 1, 2)
  50G1P ≥0.1 (ESS = 3, 4)

Power Supply Immunity: IEC 61000-4-11:2004
IEC 61000-4-29:2000
AC Dips & Interruptions
Ripple on DC Power Input
DC Dips & Interruptions
Gradual Shutdown/Startup (DC only)
Discharge of Capacitors
Slow Ramp Down/Up
Reverse Polarity (DC only)

Damped Oscillatory Magnetic Field: IEC 61000-4-10:2016
- Level 5: 100 A/m

EMC Compatibility
Product Standards: IEC 60255-26:2013
47 CFR
ICES-003

Emissions: IEC 60255-26:2013, Section 7.1
47 CFR Part 15.109
47 CFR Part 15.107
ICES-003, Issue 6
- Radiated:
  Class A
- Conducted:
  Class A

Environmental
Cold, Operational: IEC 60068-2-1:2007
Test Ad: 16 hours at ~40°C

Event Reports
High-Resolution Data
- Rate: 8000 samples/second
- 4000 samples/second
- 2000 samples/second
- 1000 samples/second

Output Format: Binary COMTRADE


Event Reports
- Storage: 35 quarter-second events or 24 half-second events
- Maximum Duration: Five records of 24 seconds each of 4000 samples/second

Event Summary
- Storage: 100 summaries

Breaker History
- Storage: 128 histories

Sequential Events Recorder (SER)
- 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

<table>
<thead>
<tr>
<th>Zones 1–5 Impedance Reach</th>
<th>Setting Range</th>
<th>Sensitivity</th>
<th>Accuracy (Steady State)</th>
<th>Zone 1 Transient Overreach</th>
<th>Maximum Operating Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps</td>
<td>0.5 A&lt;sub&gt;P&lt;/sub&gt; secondary</td>
<td>±3% of setting at line angle for SIR &lt; 30</td>
<td>&lt;5% of setting plus steady-state accuracy</td>
<td>0.8 cycle at 100% of reach and SIR = 1</td>
<td></td>
</tr>
<tr>
<td>1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps</td>
<td>0.1 A&lt;sub&gt;P&lt;/sub&gt; secondary</td>
<td>±5% of setting at line angle for 30 ≤ SIR ≤ 60</td>
<td>Maximum Operating Time: 1.0 cycle at 70% reach and SIR = 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Quadrilateral Phase Distance Elements

<table>
<thead>
<tr>
<th>Zones 1–5 Impedance Reach</th>
<th>Quadrilateral Reactance Reach</th>
<th>Quadrilateral Resistance Reach</th>
<th>Sensitivity</th>
<th>Accuracy (Steady State)</th>
<th>Zone 1 Transient Overreach</th>
<th>Maximum Operating Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps</td>
<td>OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps</td>
<td>OFF, 0.05 to 50 Ω secondary, 0.01 Ω steps</td>
<td>0.5 A secondary</td>
<td>±3% of setting at line angle for SIR &lt; 30</td>
<td>&lt;5% of setting plus steady-state accuracy</td>
<td>1.0 cycle at 70% reach and SIR = 1</td>
</tr>
<tr>
<td>1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps</td>
<td>OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps</td>
<td>OFF, 0.25 to 250 Ω secondary, 0.01 Ω steps</td>
<td>0.1 A secondary</td>
<td>±5% of setting at line angle for 30 ≤ SIR ≤ 60</td>
<td>Maximum Operating Time: 1.5 cycles</td>
<td></td>
</tr>
</tbody>
</table>

#### Mho Ground Distance Elements

<table>
<thead>
<tr>
<th>Zones 1–5 Impedance Reach</th>
<th>Mho Element Reach</th>
<th>Sensitivity</th>
<th>Accuracy (Steady State)</th>
<th>Zone 1 Transient Overreach</th>
<th>Maximum Operating Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps</td>
<td>OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps</td>
<td>0.5 A secondary</td>
<td>±3% of setting at line angle for SIR &lt; 30</td>
<td>&lt;5% of setting plus steady-state accuracy</td>
<td>1.5 cycles</td>
</tr>
<tr>
<td>1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps</td>
<td>OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps</td>
<td>0.1 A secondary</td>
<td>±5% of setting at line angle for 30 ≤ SIR ≤ 60</td>
<td>Maximum Operating Time: 1.5 cycles</td>
<td></td>
</tr>
</tbody>
</table>

#### Quadrilateral Ground Distance Elements

<table>
<thead>
<tr>
<th>Zones 1–5 Impedance Reach</th>
<th>Quadrilateral Reactance Reach</th>
<th>Quadrilateral Resistance Reach</th>
<th>Sensitivity</th>
<th>Accuracy (Steady State)</th>
<th>Zone 1 Transient Overreach</th>
<th>Maximum Operating Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps</td>
<td>OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps</td>
<td>OFF, 0.05 to 50 Ω secondary, 0.01 Ω steps</td>
<td>0.5 A secondary</td>
<td>±3% of setting at line angle for SIR &lt; 30</td>
<td>&lt;5% of setting plus steady-state accuracy</td>
<td>1.0 cycle at 70% reach and SIR = 1</td>
</tr>
<tr>
<td>1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps</td>
<td>OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps</td>
<td>OFF, 0.25 to 250 Ω secondary, 0.01 Ω steps</td>
<td>0.1 A secondary</td>
<td>±5% of setting at line angle for 30 ≤ SIR ≤ 60</td>
<td>Maximum Operating Time: 1.5 cycles</td>
<td></td>
</tr>
</tbody>
</table>

#### Instantaneous/Definite-Time Overcurrent Elements

<table>
<thead>
<tr>
<th>Phase, Residual Ground, and Negative-Sequence</th>
<th>Pickup Range</th>
<th>Accuracy (Steady State)</th>
<th>Zone 1 Transient Overreach</th>
<th>Maximum Operating Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 A Model: OFF, 0.25–100.00 A secondary, 0.01 A steps</td>
<td>±0.05 A plus ±3% of setting</td>
<td>&lt;5% of pickup</td>
<td>0.00–16000.00 cycles, 0.125 cycle steps</td>
<td></td>
</tr>
<tr>
<td>1 A Model: OFF, 0.05–20.00 A secondary, 0.01 A steps</td>
<td>±0.01 A plus ±3% of setting</td>
<td>Timer Accuracy: ±0.125 cycle plus ±0.1% of setting</td>
<td>Maximum Operating Time: 1.5 cycles</td>
<td></td>
</tr>
</tbody>
</table>
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

Transmit Overreach: 5% of pickup

Maximum Operating Time: 0.75 cycles
(Operate time is relay processing time only and does not include SV delay, 1.5 ms minimal.)

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)
(Operate time is relay processing time only and does not include SV delay, 1.5 ms minimal.)

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 V A, 0.01 V A steps
1 A Model: –4000.00 to 4000 V A, 0.01 V A steps

Accuracy (Steady State): ± 5 V A 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
(Operate time is relay processing time only and does not include SV delay, 1.5 ms minimal.)

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

(Model 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

Transmit 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, BFISP)
0–1000 cycles, 0.125 cycle steps
(BFIDO, BFISP)

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 < 30
±10% of setting plus ±0.01 A for 30 ≤ SIR ≤ 60
1 A Model: ±5% of setting plus ±0.05 A for SIR < 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
5 A Model: ±3% of setting plus ±0.05 A
1 A Model: ±3% of setting plus ±0.01 A

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
Setting Ranges
Breaker Failure: 0–6000 cycles, 0.125 cycle steps
(All but BFIDOn, BFISPn)
Communications-Assisted Tripping Schemes: 0–1000 cycles, 0.125 cycle steps
(BFIDOn, BFISPn)
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: 24–250 Vdc
Operational Voltage Range: 0–300 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 A sec)
Phase Current Angle
All Models: ±0.2° in the current range 0.5 • INOM to 3.0 • INOM
Sequence Currents 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 • INOM to 3.0 • INOM

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) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
±0.7% (0.1–1.2) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3φ)
MVA (S), Per Phase (Wye), 3φ (Wye or Delta) Per Terminal
±1% (0.1–1.2) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
±0.7% (0.1–1.2) • INOM, 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) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
±0.7% (0.1–1.2) • INOM, 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) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
±0.7% (0.1–1.2) • INOM, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3φ)

Synchrophasors
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 Relay Word bit)
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 (0.1–20) * f_{NOM} A, f_{NOM} ±5 Hz
Synchrophasor Data Recording: Records as much as 120 s
IEEE C37.232 File Naming Convention

Technical Support

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

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