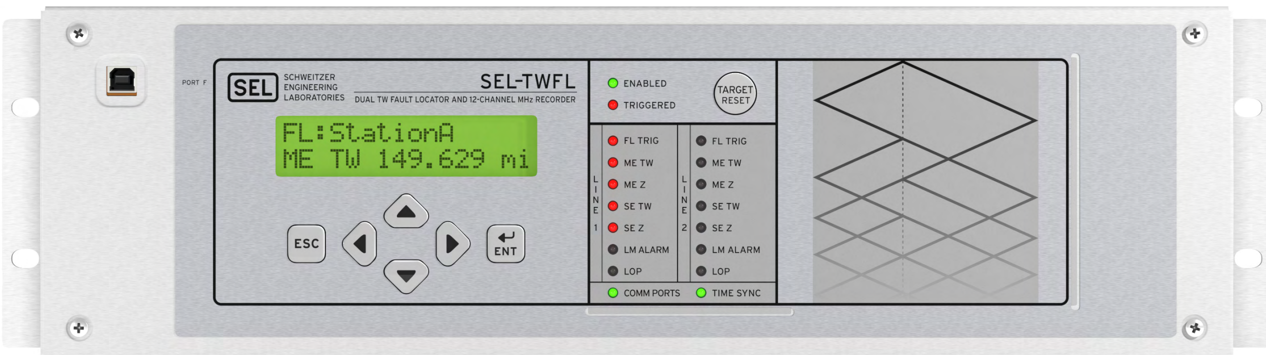
SEL-TWFL

Dual Traveling-Wave Fault Locator and 12-Channel MHz Recorder



Key Features and Benefits

The SEL-TWFL is a standalone and economical traveling-wave-based fault locator that uses traveling-wave-based fault-locating technology with a field-proven accuracy of about one tower span. The SEL-TWFL provides you with the following capabilities and benefits.

- **Accurate Fault Locating.** Locate faults to the nearest tower with the field-proven SEL traveling-wave-based fault-locating technology. Obtain a reliable fault location with the multi-ended traveling-wave-based fault-locating method by using a 64 kbps digital channel with IEEE C37.94 encoding. In applications without a digital device-to-device communications channel, use the single-ended traveling-wave-based fault-locating method and obtain a short prioritized list of possible fault locations. Ensure dependable fault-locating results under a wide range of operating conditions by relying on the multi-ended and single-ended impedance-based fault-locating methods to back up the traveling-wave-based fault-locating methods.
- **Line Monitoring.** Monitor power lines for incipient and recurring faults. Obtain a location-tabulated event count to detect low-energy activity and faults along the line. Prevent faults by selectively cleaning or replacing insulators, trimming vegetation, improving antigalloping solutions, applying line spacers, or improving lightning protection. Line monitoring works over a 64 kbps IEEE C37.94-compliant multiplexed channel.
- **Ultra-High-Resolution Recording.** Record as many as six currents and six voltages at a 1 MHz sampling rate with 18 bits of resolution. Store as much as 60 s of total recording time, with individual records as long as 1.2 s and back-to-back event triggering for as much as 3.6 s of recording time. Use contact inputs and overcurrent and voltage elements to trigger the recorder. Study switching events, breaker reignition, transient recovery voltage, and other high-frequency phenomena in a single substation or throughout the system by deploying multiple SEL-TWFL devices as part of a recording system with 100 ns accuracy time synchronization.
- **Comprehensive Applications.** Accurately locate faults on overhead and cable lines, as well as hybrid lines with both overhead and cable sections. The SEL-TWFL interfaces with standard protection instrument transformers and can be used to monitor two line terminals at a substation. It can be applied on radial, two-terminal, and three-terminal lines for fault locating and line monitoring. The SEL-TWFL is an accurate and dependable fault locator that uses traveling-wave-based and impedance-based fault-locating methods.

Functional Overview

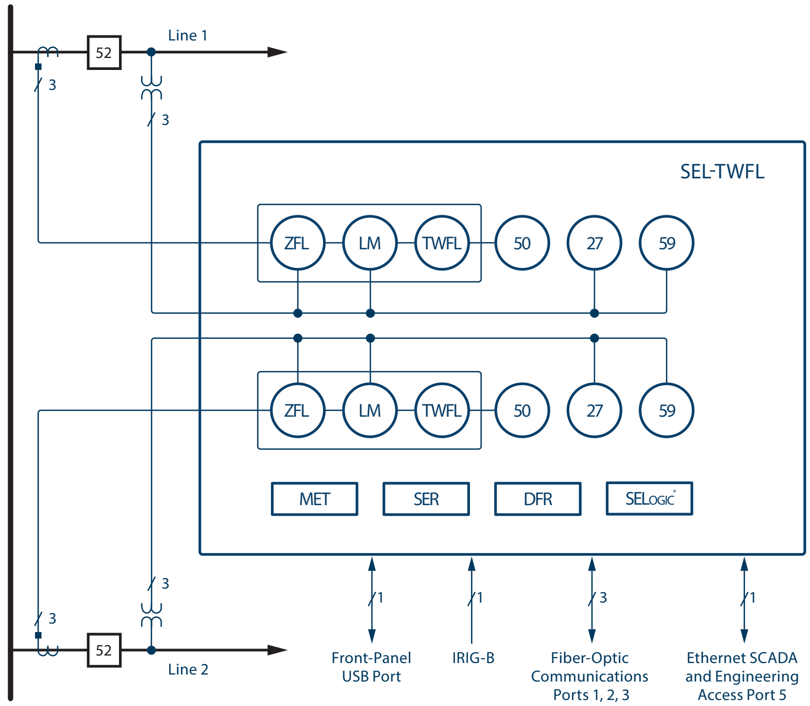


Figure 1 Functional Overview Diagram

ANSI Number or Acronym	Description
ZFL	Impedance-Based Fault Locator
TWFL	Traveling-Wave-Based Fault Locator
LM	Line Monitor
27	Undervoltage (phase and positive-sequence)
50	Instantaneous Overcurrent (phase, zero-sequence, and negative-sequence)
59	Overvoltage (phase, positive-sequence, zero-sequence, and negative-sequence)
OP	Open-Pole Detection Logic
LOP	Loss-of-Potential Logic
85 RIO	SEL MIRRORED BITS I/O With Selectable SEL MB8 or IEEE C37.94 Encoding
MET	Metering
SELOGIC	Programmable Logic
SER	Sequential Events Recorder
DFR	Digital Fault Recorder
TWTEST	Traveling-Wave Test Mode
HMI	Local Operator Interface
DNP3	Distributed Network Protocol 3.0 (Ethernet)
FTP	File Transfer Protocol

Front- and Rear-Panel Overview

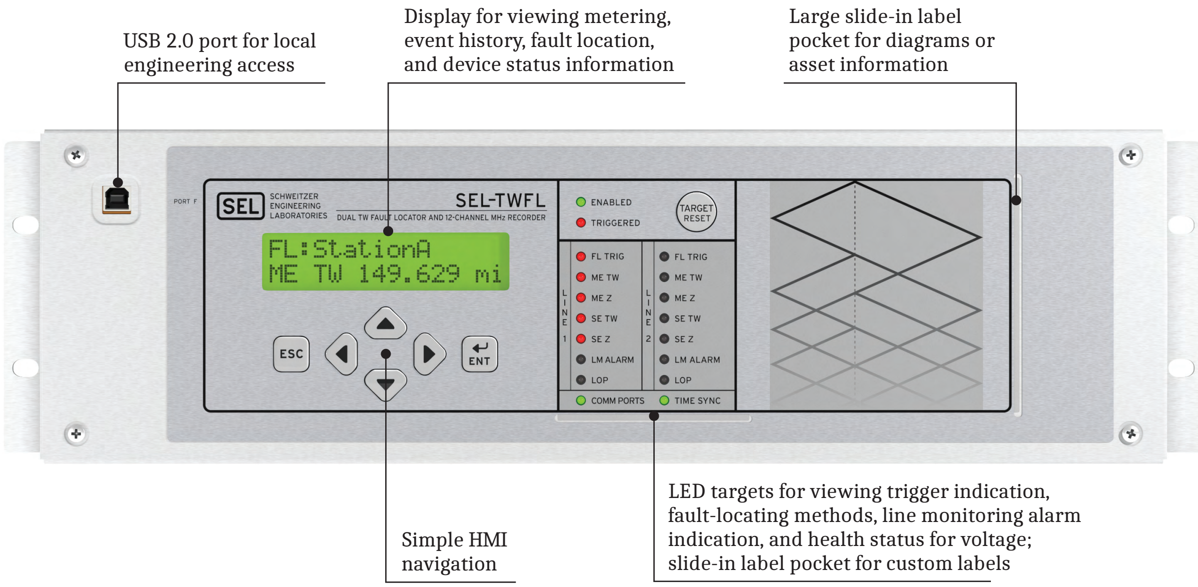


Figure 2 Front Panel

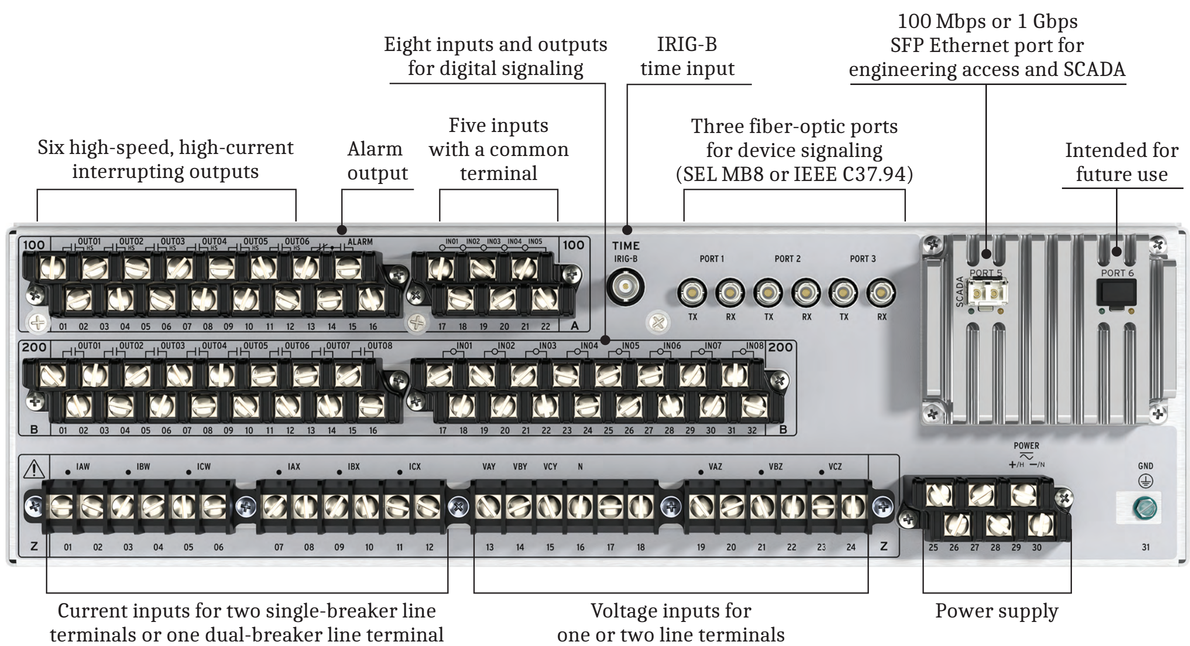


Figure 3 Rear Panel

Fault Locating

The SEL-TWFL accurately determines the fault location by using single- and multi-ended traveling-wave-based and impedance-based methods. Reduce the time and effort to find faults when dispatching line crews based on the fault-location information. The traveling-wave-based technology used in the SEL-TWFL has a field-proven accuracy of about one tower span (±300 m or ±1,000 ft), regardless of the line length. When a fault occurs, waves propagate from the fault to the line ends. The single-ended traveling-wave-based method uses the first traveling wave (TW) as well as several successive TW reflections. The multi-ended TW-based method uses only the first TW at each line terminal but requires communications between the devices and time synchronization for each device.

Trigger the fault locator from the connected line protection system by using a contact input or a MIRRORED BITS input. Internal fault locator logic determines the most reliable fault location based on all fault-locating methods available at the time of the fault. Obtain the fault-locating result via DNP3, by using SEL ASCII commands, from the device front-panel display, or as a part of the IEEE COMTRADE record. The results from all the methods are also available in the IEEE COMTRADE record.

Deploy the multi-ended TW-based method by using a 64 kbps IEEE C37.94-compliant multiplexed channel and an IRIG-B-connected high-accuracy clock at all line terminals, and benefit from the reliability and accuracy of this method.

Resort to the single-ended TW-based method if your channel is temporarily down or not available at all. This method is accurate, with a good track record in the field, but it cannot narrow down the fault location to a single place on the line with 100 percent certainty. Instead, it provides you with a short, prioritized list of as many as four possible fault locations to be inspected. Avoid patrolling a long stretch of line to find the fault, and instead inspect just one to four locations along the line, each just a few tower spans long.

If the TW signals are small, heavily distorted, or otherwise unusable, the SEL-TWFL provides you with the best-available results from the impedance-based multi-ended and single-ended fault-locating method. For each fault-locating trigger, the device provides results from all four fault-locating methods, as well as TW arrival time stamps and pre-fault and fault current and voltage phasors. You can obtain these data via DNP3 or by parsing the IEEE COMTRADE header file. You can use these data in any custom fault-locating application that you have implemented in the SCADA/HMI software.

To calculate the distance to the fault, the TW-based methods use time stamps of current TWs obtained from standard protection CTs. The fault locator allows you to compensate for the length of the CT secondary wires. The TW-based methods work with samples acquired at 1 Msps (megasample per second) and use interpolation to obtain high-accuracy time stamps with a resolution and accuracy of a small fraction of a microsecond.

The SEL-TWFL fault-locating accuracy, including tolerances in the current and time input circuitries, is on the order of ±10 m (±33 ft). Application errors, such as line data inaccuracy, line sag, or an error in the external clock, may increase the total fault-locating error in any given application. SEL field experience with the TW-based technology proves typical accuracy of about ±300 m (±1,000 ft).

Multi-Ended TW-Based Method

The multi-ended TW-based method uses the first TW arrival time from all configured terminals and the line information to estimate the fault location. The multi-ended TW-based method in the SEL-TWFL allows users to locate faults on two-terminal and three-terminal lines. The multi-ended TW-based method works with an IEEE C37.94-compliant multiplexed channel on Port 1, 2, or 3. When using Port 1, 2, or 3 for multi-ended TW-based fault locating, you must connect all devices to accurate time sources, such as IEEE C37.118-compliant satellite clocks with submicrosecond accuracy.

When device-to-device communications are not available, you can program your SCADA/HMI software to perform multi-ended TW-based fault locating by using TW time stamps from the SEL-TWFL devices.

Two-Terminal Line

The multi-ended TW-based method uses the time difference between the first current TWs recorded at the line terminals to calculate the fault location (see *Figure 4*):

$$M = \frac{L}{2}\left(1 + \frac{t_S - t_R}{T}\right)$$

where:

- M is the distance to the fault from Terminal S in line length units
- t_S and t_R are time stamps of the first TWs at Terminals S and R, respectively
- L and T are the user settings specifying the line length and the TW line propagation time, respectively

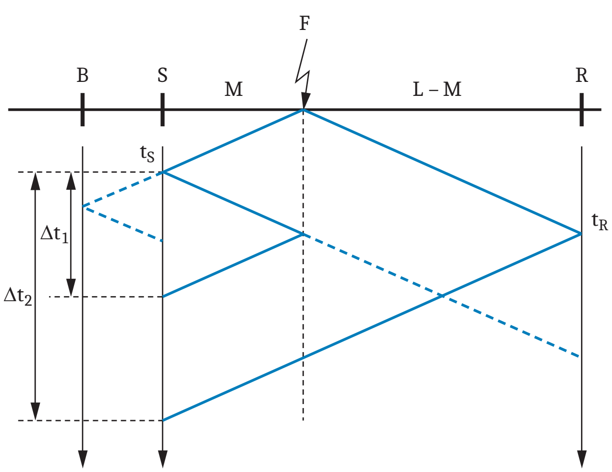


Figure 4 Bewley Diagram Illustrating TW-Based Fault-Locating Principles

Three-Terminal Line

For three-terminal line applications, the multi-ended TW-based method identifies the faulted line section (terminal to the tap location). Once the faulted line section is identified, the three-terminal line application is reduced to an effective two-terminal line application to estimate the fault location.

Single-Ended TW-Based Method

The single-ended TW-based method uses the time difference between the first TW and the first reflection from the fault (Δt_1) to calculate the fault location as follows (see *Figure 4*):

$$M = \frac{L}{2}\left(\frac{\Delta t_1}{T}\right)$$

The single-ended TW-based method does not need data from the remote terminal, and therefore it works without communications and is not affected by the timing errors between the local and remote line terminals. However, this method depends on reliable identification of the first reflection from the fault among many other TWs that may arrive at the local terminal, especially from discontinuities behind the device (Bus B in *Figure 4*). The SEL-TWFL design uses several approaches to identify possible reflections from the fault. For example, the device uses the output from the impedance-based method to narrow the search for the true fault location and the first TW reflection associated with the fault. The device also finds fault reflections by simultaneously identifying the first reflection from the fault (Δt_1 in *Figure 4*) and the first reflection from the remote bus (Δt_2) and observing that $\Delta t_1 + \Delta t_2 = 2T$.

Multi-Ended Impedance-Based Method

The multi-ended impedance-based method allows users to locate faults on two- and three-terminal lines. The multi-ended impedance-based method works with IEEE C37.94-compliant multiplexed channels on Port 1, 2, or 3. When using multi-ended impedance-based fault locating, you must connect all devices to accurate time sources, such as IEEE C37.118-compliant satellite clocks.

Two-Terminal Line

For unbalanced faults, the SEL-TWFL multi-ended impedance-based method uses the principle of the negative-sequence voltage profile along the faulted line (see *Figure 5*).

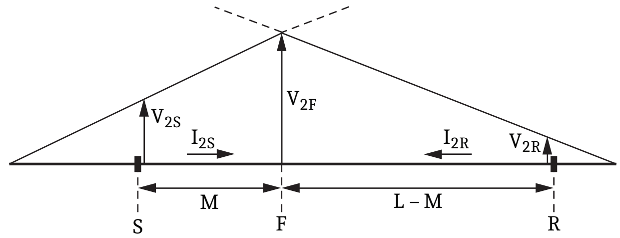


Figure 5 Negative-Sequence Voltage Profile for the Multi-Ended Impedance-Based Fault-Locating Method

For three-phase balanced faults, the method uses the positive-sequence voltage profile. The SEL-TWFL multi-ended impedance-based method uses time-synchronized local and remote current and voltage phasors to calculate the fault location. For unbalanced faults, the multi-ended impedance-based method estimates the fault location as follows:

$$M = L \bullet \operatorname{Re}\left(\frac{(V_{2S} - V_{2R}) + Z_1 I_{2R}}{Z_1(I_{2S} + I_{2R})}\right)$$

where:

V_{2S} and I_{2S} are the measured negative-sequence voltage and current at Terminal S

V_{2R} and I_{2R} are the measured negative-sequence voltage and current at Terminal R

Z_1 is the positive-sequence line impedance

Three-Terminal Line

The multi-ended impedance-based method uses time-synchronized current and voltage measurements to identify the faulted section (terminal to the tap location) on a three-terminal line. Once the faulted section is identified, the three-terminal line application is reduced to an effective two-terminal line application to estimate the fault location.

Single-Ended Impedance-Based Method

The SEL-TWFL uses a single-ended impedance-based method with negative-sequence current polarization for unbalanced faults and positive-sequence polarization for three-phase symmetrical faults. Based on fault-type identification, the single-ended impedance-based method selects, for further calculations, one of six measurement loops that uses local voltages and currents. The single-ended impedance-based method calculates the fault location as follows:

$$M = L \bullet \left(\frac{\operatorname{Im}(V_{LP} \bullet I^*_{POL})}{\operatorname{Im}(Z_1 \bullet I_{LP} \bullet I^*_{POL})}\right)$$

where:

Im	stands for the imaginary part of a complex number
V_{LP} and I_{LP}	are the measured loop voltage and current based on the fault-type identification
I_{POL}	is the polarizing current based on the fault-type identification
*	denotes a complex conjugate
Z_1	is the positive-sequence line impedance

Fault Locating on Hybrid Lines

Use the multi-ended methods to locate faults on hybrid lines comprising both overhead and cable sections. For two-terminal line applications, the SEL-TWFL allows configuring a line with as many as five different line sections. For three-terminal line applications, the SEL-TWFL requires each section (terminal to the tap location) to be homogeneous.

TW-Based Fault Locating

The SEL-TWFL multi-ended TW-based method corrects for the nonhomogeneity of the propagation velocity in the overhead sections and cable sections (see *Figure 6*). To use the fault locator on hybrid lines, enter the total line length (L) and the total TW line propagation time (T) as settings and provide the breakdown of these values for each of as many as five line sections. Use the ultra-high-resolution recording capability of the SEL-TWFL to measure these propagation times during the line energization tests. Expect TW-based fault-locating accuracy on the order of ±300 m (±1,000 ft) for faults on overhead sections and ±150 m (±500 ft) for faults on cable sections.

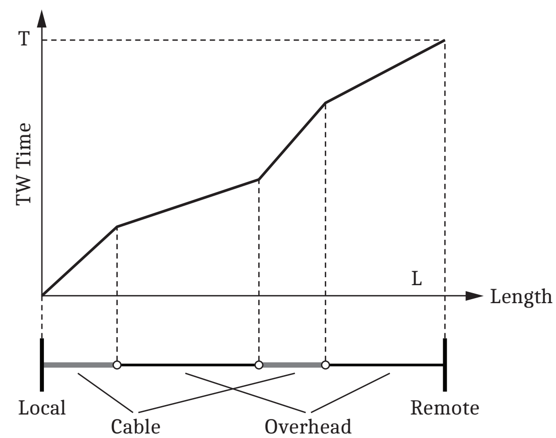


Figure 6 Multi-Ended TW-Based Fault Locator Corrects for Differences in TW Propagation Velocities Between Overhead and Cable Sections

Impedance-Based Fault Locating

The SEL-TWFL multi-ended impedance-based method accounts for the nonhomogeneity of the line impedances in the overhead sections and cable sections. For unbalanced faults, the SEL-TWFL uses the negative-sequence voltage profile along the nonhomogeneous line to identify the faulted section. The device then uses the equivalent negative-sequence network associated with the identified faulted section to estimate the fault location. For balanced faults, the SEL-TWFL uses the positive-sequence voltage profile.

Line Monitoring

Identify trouble spots along the line and prevent faults through a condition-based line maintenance program based on the SEL-TWFL line monitoring function. The line monitoring logic triggers on current TWs launched by fault precursors, locates these events with high accuracy by using the multi-ended TW-based method (this application requires an IEEE C37.94-compliant multiplexed channel), tabulates these events for locations along the line(s), and alarms if the event count exceeds a user-settable threshold. Monitor the line(s) for dirty or cracked insulators, encroaching vegetation, marginal clearances, marginal lightning protection, incipient cable faults, conductor galloping resulting from insufficient damping or faulty spacers, ice unloading, and similar conditions. Reset the event counters for the problem locations after performing adequate maintenance and addressing the underlying problem.

Configure as many as two blocking regions per line to prevent false alarms for routine switching operations of tapped loads or in-line series capacitors. Monitor the daily event counts at the tap or series capacitor locations, and alarm on unexpected switching patterns. In three-terminal line applications, the blocking regions can be configured between the local terminal and the tap location.

Triggering Functions

Configure the fault locator trigger by programming a dedicated SELogic setting for each monitored line. Use a contact input or a Mirrored Bits input to trigger on trip signals from relays or on other external conditions. When you use the line monitor, the assertion of the fault locator trigger informs the line monitoring logic that the event is a fault and not a low-energy event. The SEL-TWFL includes two levels of phase, negative-sequence, and zero-sequence nondirectional overcurrent elements and two levels of phase and positive-sequence undervoltage and overvoltage elements to trigger the transient recorder.

Programmable Logic

The SEL-TWFL allows you to customize applications through SELogic equations. SELogic equations, such as the fault locator trigger, the transient recorder trigger, torque-control inputs, or bits driving binary outputs, are available as dedicated SELogic equations. In addition, the device includes 64 generic SELogic equations, 16 programmable timers, and 16 nonvolatile reset-dominant latches. SELogic equations allow NOT, OR, AND, R_TRIG, and F_TRIG operators.

Applications

The SEL-TWFL is suitable for a range of applications including radial lines, two- or three-terminal lines, lines with unmeasured taps, and hybrid lines comprising overhead and cable sections. A single device can be applied to monitor two line terminals. The following four examples are applications for two- and three-terminal lines with IEEE C37.94-compliant multiplexed channels. Connect the line currents and voltages to the SEL-TWFL; to reliably detect an open-pole condition, provide the breaker position status to the SEL-TWFL. For multi-ended fault locating, connect a high-accuracy IEEE C37.118-compliant GPS clock to each SEL-TWFL and use IEEE C37.94-compliant multiplexed channels to exchange fault-locating data between the SEL-TWFL devices.

Two-Terminal Overhead Line

Figure 7 shows two SEL-TWFL devices monitoring an overhead transmission line with a three-pole mechanism breaker at each line terminal. Each SEL-TWFL obtains currents from line CTs and voltages from line-side VTs. Each SEL protective relay sends fault locator (FL) trigger signals to Port 1 of the corresponding SEL-TWFL by using Mirrored Bits communications via an SEL-2814 Fiber-Optic Transceiver With Hardware Flow Control. To calculate fault locations by using TW- and impedance-based methods, the two SEL-TWFL devices exchange data via Port 2 over IEEE C37.94-compliant multiplexed channels. In installations with dual breakers, connect and monitor both breaker currents individually.

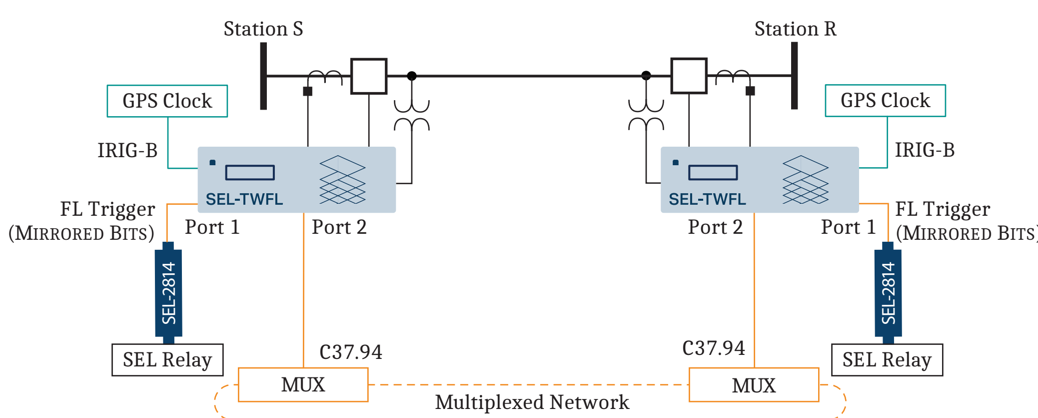


Figure 7 Single-Breaker, Two-Terminal Overhead Line Application That Uses SEL-2814 Transceivers, IEEE C37.94-Compliant Multiplexed Channels, and Mirrored Bits Communications

Dual Two-Terminal Overhead Lines

Figure 8 shows three SEL-TWFL devices monitoring two overhead transmission lines. Each device obtains currents from line CTs and voltages from line-side VTs. The device at Station S obtains currents and voltages from both lines. Protective relays send FL trigger signals to the SEL-TWFL devices by using the corresponding SEL-TWFL contact inputs. To calculate the location of faults on both lines, the Station S and Station R SEL-TWFL devices exchange data via Port 1 and the Station S and Station T devices exchange data via Port 2 over IEEE C37.94-compliant multiplexed channels.

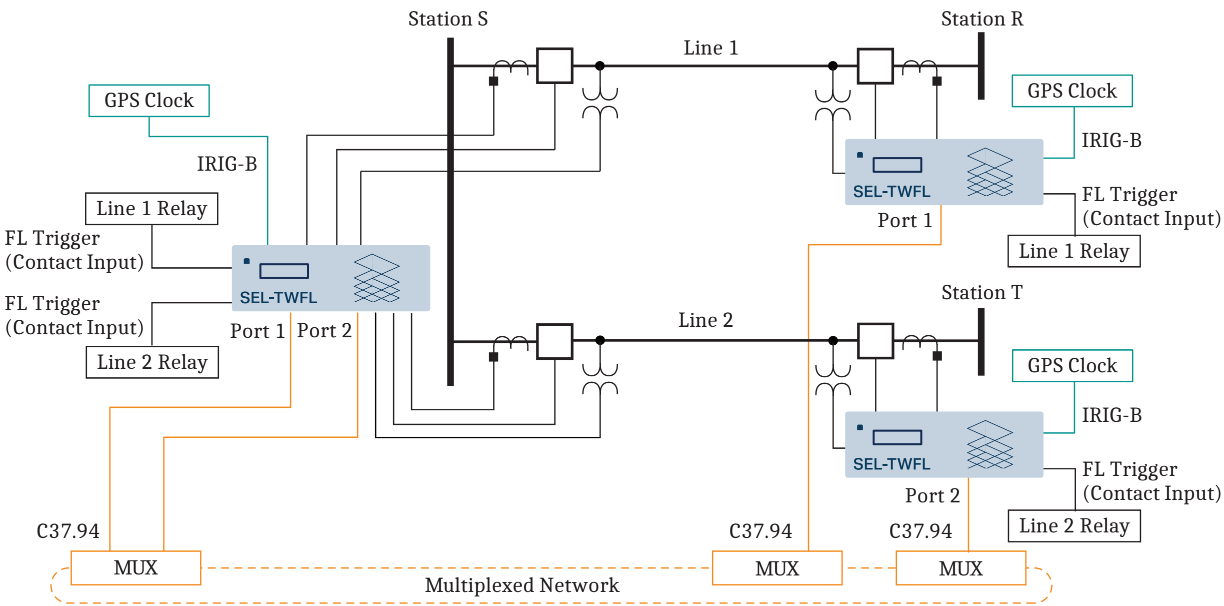


Figure 8 Application for Dual Two-Terminal Overhead Lines That Uses IEEE C37.94-Compliant Multiplexed Channels and Protective Relays With Contact Inputs

Three-Terminal Overhead Line

Figure 9 shows three SEL-TWFL devices monitoring a three-terminal overhead transmission line. Each device obtains currents from line CTs and voltages from line-side VTs. At each line terminal, the breaker auxiliary contact is wired to one of the corresponding SEL-TWFL contact inputs and provides breaker position status to reliably detect open-pole conditions. Protective relays send FL trigger signals to the SEL-TWFL devices by using the corresponding SEL-TWFL contact inputs. To calculate fault locations by using the TW- and impedance-based methods, the devices exchange data for the three-terminal line over IEEE C37.94-compliant multiplexed channels. The Station S device exchanges data with the Station R and Station T devices via Port 1 and Port 2, respectively. The Station R device exchanges data with the Station S and Station T devices via Port 1 and Port 3, respectively. The Station T device exchanges data with the Station S and Station R devices via Port 2 and Port 3, respectively.

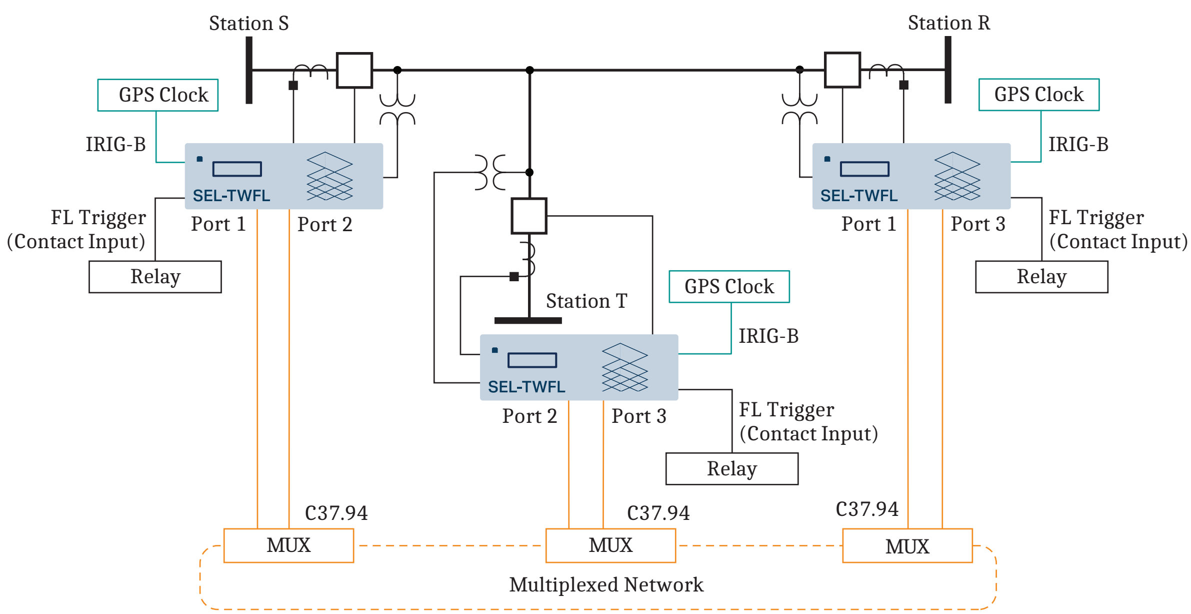


Figure 9 Three-Terminal Line Application That Uses IEEE C37.94-Compliant Multiplexed Channels and Protective Relays With Contact Inputs

Two-Terminal Overhead Line Without Device-to-Device Communications

When device-to-device communications is not available, you can use DNP3 protocol over Ethernet to send TW arrival times to a central location where the DNP3 client calculates the TW-based fault location. *Figure 10* shows two SEL-TWFL devices monitoring one transmission line. Each device obtains currents from line CTs and voltages from line-side VTs. Each SEL protective relay sends FL trigger signals to Port 1 of the corresponding SEL-TWFL by using MIRRORED BITS communications via an SEL-2814. Each SEL-TWFL sends data via Port 5 to the corresponding Real-Time Automation Controller (RTAC) by using DNP3 protocol over Ethernet, and each RTAC sends data over a SCADA network to the RTAC DNP3 client computer at the control center. The control center RTAC calculates the fault location by using the multi-ended TW-based method.

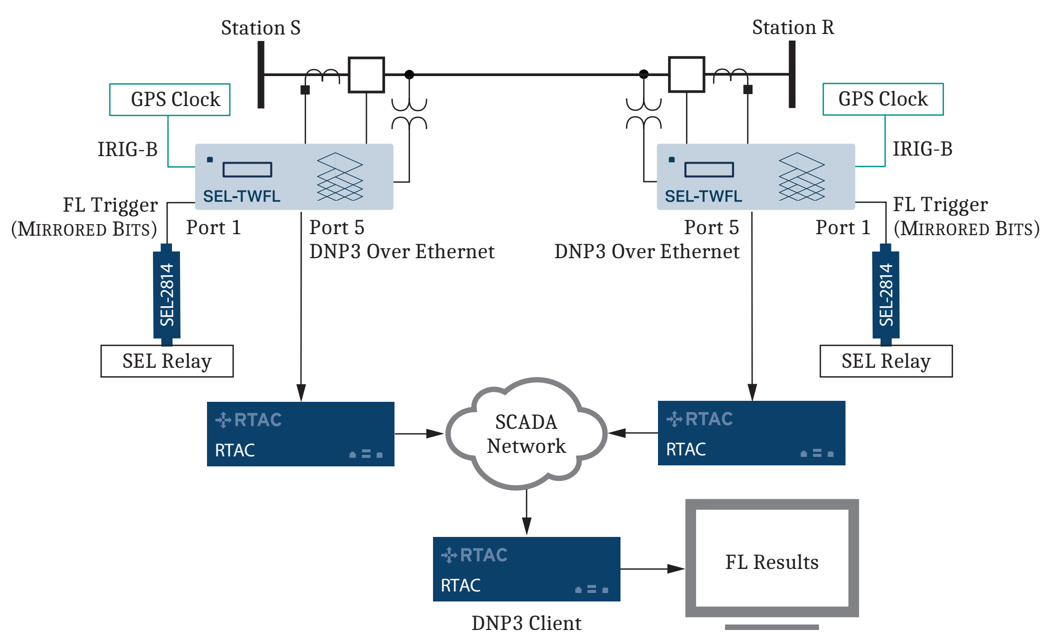


Figure 10 Two-Terminal Overhead Line Application That Uses SEL-2814 Transceivers, DNP3 Protocol, and MIRRORED BITS Communications

Metering, Transient Recording, and Timekeeping

The SEL-TWFL provides high-resolution transient recording and high-accuracy metering. These functions help you commission the device and gain better insights into the power system, especially when high-frequency transients occur.

Metering

The SEL-TWFL measures fundamental-frequency phasors (magnitude and angle) for all input currents and voltages. Phase quantities, as well as symmetrical components and frequency, are available for each line separately.

During commissioning and troubleshooting, access the metering data on the front-panel HMI and the commissioning laptop connected to the device (use an SEL ASCII command or the SEL Fast Meter protocol). Use DNP3 over Ethernet to integrate the metering data into your SCADA/HMI system.

Transient Recording

The SEL-TWFL provides transient recording at a 1 MHz sampling rate, storage for no less than 60 s of total recording time (as many as 50 transient records with a duration of 1.2 s), IEEE C37.111-2013 COMTRADE file format, and a user-configurable trigger. Back-to-back triggering allows you to capture as much as 3.6 s of recording time, such as in three 1.2 s long records or eighteen 0.2 s long records. Analyze high-frequency power system events, including lightning strikes, breaker restrikes, and breaker transient recovery voltages with the exceptional 1 MHz, 18-bit recording capability of the SEL-TWFL.

The 1 MHz IEEE COMTRADE record (MHR record) contains currents and voltages sampled at 1 MHz with 18 bits of resolution, device settings, fault location, and event summary data. The 10 kHz IEEE COMTRADE record (TDR record) contains currents and voltages sampled at 10 kHz with an effective resolution of 20 bits, selected analog quantities, Relay Word bits, device settings, fault location, and event summary data. The samples in the transient records are time-stamped with a resolution of 1 µs and an accuracy of 100 ns when the device is connected to a high-accuracy clock.

Connect the current inputs of the SEL-TWFL to breaker CTs to study breaker reignition and restrike, especially for reactor and capacitor banks, generators, or otherwise stressed or marginally rated breakers. *Figure 11* shows the current through one phase of a breaker while clearing a fault on a transmission line. Observe the reignition occurring at 369 µs, indicating the inability of the breaker to interrupt this current at the first zero-crossing.

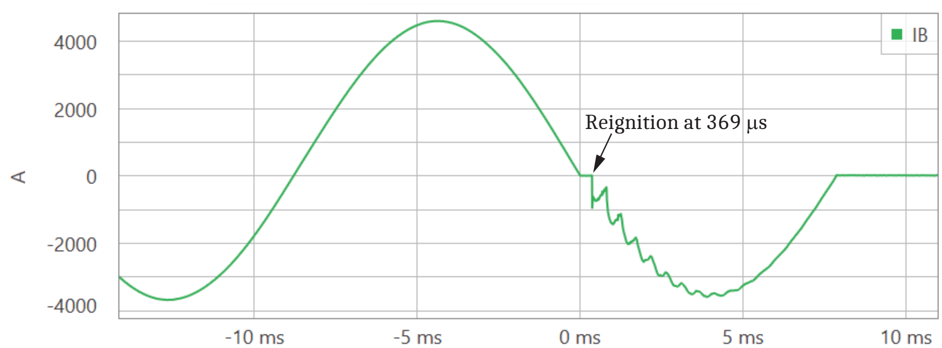


Figure 11 Breaker Reignition Increased Fault Clearing Time

Connect voltage inputs of the SEL-TWFL to voltage instrument transformers on both sides of the breaker (see *Figure 12*) to study the transient recovery voltage (TRV) and rate-of-rise of recovery voltage (RRRV) associated with breaker operations.

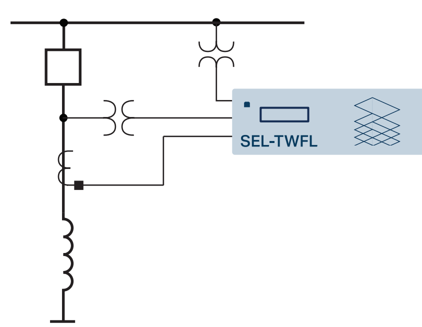


Figure 12 Configure the SEL-TWFL to Trigger the Event Record on Breaker Switching

Figure 13 shows (a) the current through one phase of a reactor breaker, (b) voltages at both sides of the breaker, and (c) the voltage difference across the breaker while de-energizing a shunt reactor.

In *Figure 13(a)*, observe the arc extinction around 0 ms. The voltage measured on the reactor side (VB_REACTOR) in *Figure 13(b)* includes the LC resonant frequency of 1.3 kHz. Use the voltage across the circuit breaker (VBKR_B) in *Figure 13(c)* to calculate the TRV and RRRV, where VBKR_B = VB_BUS – VB_REACTOR. For this operation, *Figure 14* shows the TRV and RRRV are 857 kV and 1.9 kV/µs, respectively.

Use SEL-5601-2 SYNCHROWAVE® Event Software or any IEEE COMTRADE-compatible program for post-event analysis. Use File Transfer Protocol (FTP) over the Ethernet port to quickly download these transient records.

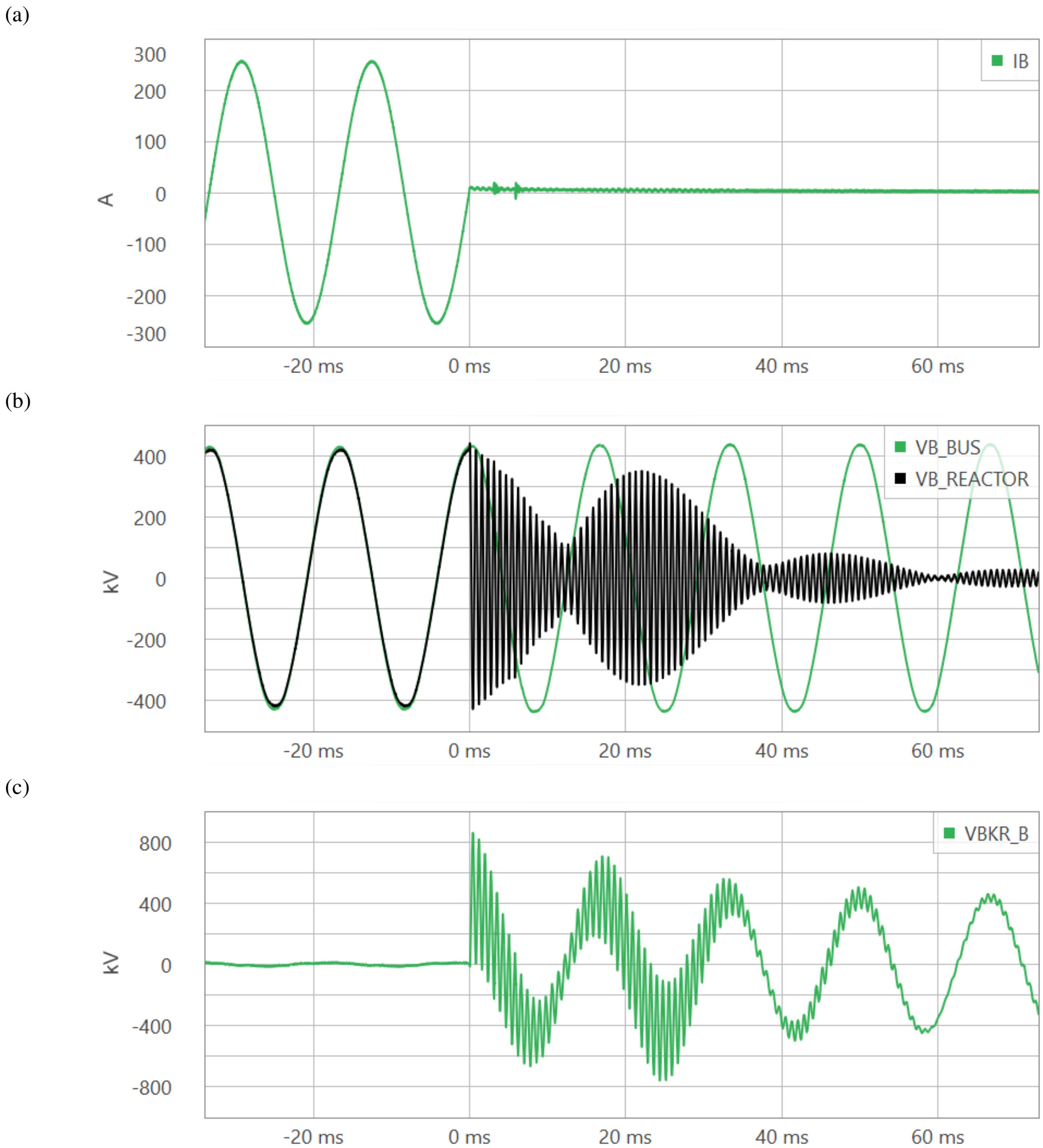


Figure 13 Use MHz Records to Calculate TRV and RRRV

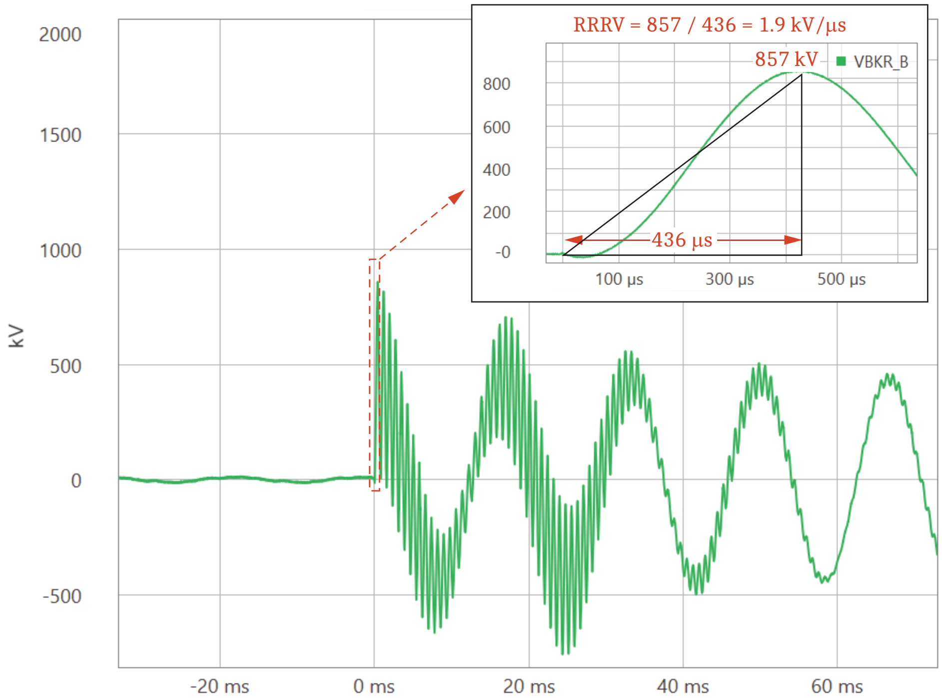


Figure 14 Estimated RRRV Is 1.9 kV/µs

Sequential Events Recording

Monitor device operation and device input changes with the Sequential Events Recorder (SER). Configure the SER by selecting Relay Word bits to be recorded and time-stamped. The SER inherently records selected device events such as power-up and settings changes. When configuring the SER, you can select rules to address chattering bits. The SER record stores the latest 10,000 entries in nonvolatile memory. The SER time-stamps the events with a resolution of 100 µs and an accuracy of 100 ns when the device is connected to a high-accuracy clock. The device makes the SER record available as an ASCII file. Use DNP3 over Ethernet to provide a continuous real-time reporting of binary state changes to your SCADA/HMI system.

Event Summary

Each time the SEL-TWFL creates a transient record, it also generates a corresponding event summary for the configured lines. The event summary contains device identification, time and date of trigger, and event type. For faults, the event summary provides the fault location and pre-fault and fault current and voltage phasors. The header file of the IEEE COMTRADE record includes the event summary. Use an SEL command to print the event summary for a selected transient record.

High-Accuracy Timekeeping

To keep track of absolute time, the SEL-TWFL accepts a high-accuracy, demodulated, IEEE C37.118-compliant IRIG-B external timing signal from a high-accuracy clock, such as an SEL-2488 Satellite-Synchronized Network Clock, or a terrestrial time distribution system, such as an SEL ICON® Integrated Communications Optical Network. The device keeps internal time locked to the time input with an accuracy of 100 ns. The device works in UTC time.

The external clock is primarily used for precise time-stamping of records and for multi-ended fault-locating methods.

User Interfaces, Network Connections, and SCADA

Front-Panel Display and Targets

The LCD and associated navigation pushbuttons form the HMI, which allows direct access to metering, event summary and line monitoring data for the configured lines, and device identification and status information. Multicolor LEDs provide a visual indication of device status and fault-locating methods for as many as two lines (see *Figure 15*). The targets are predefined and cannot be configured. You can print and insert your own target labels to account for the local operator language and to align with your company standards.

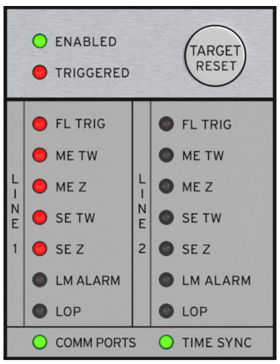


Figure 15 SEL-TWFL Targets Indicate Fault Locator Triggering, Calculation Methods, and Line Monitoring Alarm for Two Lines

Software Configuration and Engineering Tool

ACSELERATOR QuickSet® SEL-5030 Software is the SEL-TWFL engineering tool, but you can perform many tasks by using a generic terminal emulator, an FTP client, or an ASCII text editor. Use QuickSet to perform the following:

- Develop SEL-TWFL settings offline, and then connect to your devices to transfer settings and monitor device performance during commissioning.
- Compare, convert, merge, and amend multiple SEL-TWFL settings files to help reduce the overall life-cycle costs of the device.
- Access SEL-TWFL data locally (front-panel Port F) or remotely (Ethernet Port 5) from the convenience of your PC.
- Design and organize the SEL-TWFL settings with the Device Manager, helping your protection and control department to organize all their relevant device information in a central database with a history of the changes.

Use SEL Compass® to keep your software, drivers, and SEL documentation up to date.

Local Engineering Access

Use the front-panel USB 2.0 Port F for occasional engineering access, including device configuration and upgrading firmware. Use QuickSet or terminal emulator tools to communicate with the SEL-TWFL by using SEL ASCII commands and the Fast Meter protocol on Port F. You can use Port F for data collection, but to minimize the transfer time, consider using Ethernet Port 5 instead for retrieving large IEEE COMTRADE files.

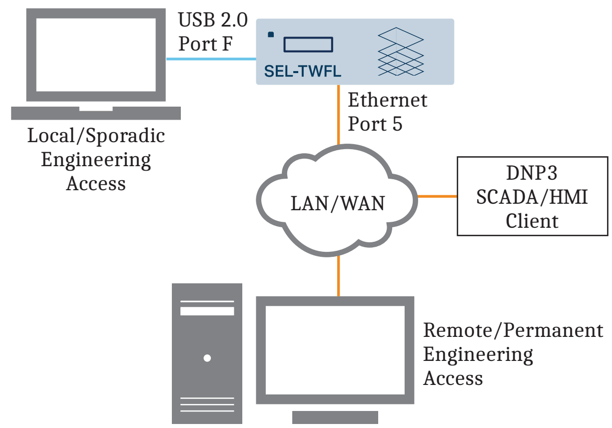


Figure 16 SEL-TWFL Engineering and SCADA/HMI Connections

SCADA/HMI Integration and Permanent Engineering Access

Use the rear-panel fiber-optic Ethernet Port 5 for SCADA/HMI applications, including retrieving metering and data reporting with DNP3, SEL Fast Meter, and SEL Fast SER protocols, as well as event-driven, polling, and ad-hoc file retrieval with FTP. Also, use Port 5 for permanent and remote engineering access. The SEL-TWFL allows you to use SEL ASCII commands over Telnet on Port 5 to permit QuickSet and terminal emulator tools. FTP allows you to browse the device file directories with Windows Explorer or any FTP client. You can conveniently view and copy files between the device and the computer. For excellent data integrity, Port 5 works with fiber-based transceivers only.

The SEL-TWFL includes DNP3 Level 2 outstation protocol over Ethernet. Use a DNP3-compliant SCADA system to access fault-locating information, metering data, Relay Word bit status, diagnostics, and fault summary information. The device allows six DNP3 sessions, each with custom data mapping, analog deadbands, and other typical characteristics. Use the built-in test feature to force selected data points during commissioning. *Table 1* summarizes the SEL-TWFL DNP3 capabilities.

Table 1 Summary of the SEL-TWFL DNP3 Capabilities

Feature	Application
Event data	Report data: either unsolicited or when requested
Deadbands	Apply analog deadbands independently for each DNP session on a per-point basis
Sequence-of-events data	Log binary input state changes with time stamps of occurrence
Custom mapping	Select data for each session
Acknowledgment and reset	Reset front-panel targets; reset DNP event summary data and load event summary information
Time synchronization	Set the device time from the master or request time synchronization from the master
Object 0 device attributes	Provide device attributes (Device ID, number of binary and analog points, manufacturer information, etc.) for the active session
TEST DB2 command	Test the DNP3 protocol interface by forcing analog and binary points

For security, the SEL-TWFL does not allow the DNP3 master to directly control any device outputs. The DNP3 binary output control points are internal to the device for event acknowledgment and data housekeeping, including resetting device targets, resetting DNP3 event data, and loading the next new event via DNP3.

Cybersecurity

The SEL-TWFL provides four levels of access for various functions, including viewing status, diagnostics, and changing settings. The device accepts strong passwords with as many as 12 printable characters. You can limit the access level for remote access over Ethernet, and by doing so, intentionally limit the type of engineering tasks that can be performed remotely. The SEL-TWFL is compatible with SEL cybersecurity products such as the SEL-3620 Ethernet Security Gateway.

Built-In Testing and Commissioning Tools

Simplify SEL-TWFL commissioning, troubleshooting, and approval testing with built-in testing and commissioning functions. Test and troubleshoot IEEE C37.94-compliant multiplexed channels with the SEL-standard loopback mode. Apply the TW test mode to test and commission the line monitoring logic without the need to simultaneously inject the fundamental-frequency currents and voltages. Use traditional test equipment to test the impedance-based fault-locating methods. Force DNP3 data points to test and commission the SCADA/HMI connection to the device.

Loopback Test Mode for Digital Channels

Use the port loopback test mode to simplify testing and speed up troubleshooting of the IEEE C37.94-compliant multiplexed channels. The loopback test mode allows the device to receive its own packets while either permitting the payload bits to be received as sent or forcing the received bits to the fail-safe value of logical 0. Put the SEL-TWFL port connecting the channel you want to test into a loopback test mode. Loop the transmit path back to the receive path at various points in the communications chain to pinpoint problems related to data clocking, data corruption, noise, or misconnections between devices. Use the port communications report to obtain the present channel status and the historical data collected during normal operation and while in loopback test mode. The loopback feature is available for Ports 1 through 3.

Traveling-Wave Test Mode

Use the TW test mode to simplify testing and commissioning of the line monitoring logic. While the SEL-TWFL is in the TW test mode, use a high-fidelity test source, such as the SEL-T4287 Traveling-Wave Test System, to inject TW test signals, without the need to simultaneously inject fundamental-frequency currents and voltages into the device. Prevent an unintentional or malicious initiation of the TW test mode to in-service devices by monitoring the Alarm output on the tested device and requiring that your testing and commissioning personnel use the device front panel to acknowledge the TW test mode initiation sent over the engineering access port. The TW test mode expires after 30 minutes if the device is left in the TW test mode unintentionally.

As an alternative to the TW test mode, use the SEL-T4287 in parallel with a conventional test set capable of injecting low-frequency signals and have the two test sets cross-trigger each other.

DNP3 Data Forcing

Simplify and speed up testing and commissioning of the substation automation system, including network configuration and data mapping, with the **TEST DB2** command. This feature provides you with a method to override digital and analog DNP3 inputs for testing DNP3 functionality. The command overrides values in the DNP3 communications interface only. For security, when the **TEST DB2** command forces the DNP3 inputs to test values, it also asserts a Relay Word bit to indicate that the DNP3 test mode is active.

Front- and Rear-Panel Diagrams

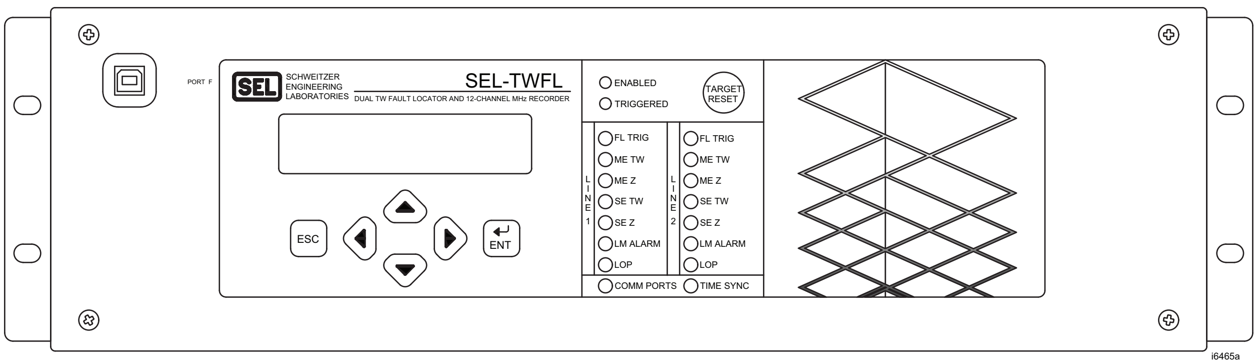


Figure 17 Front-Panel View

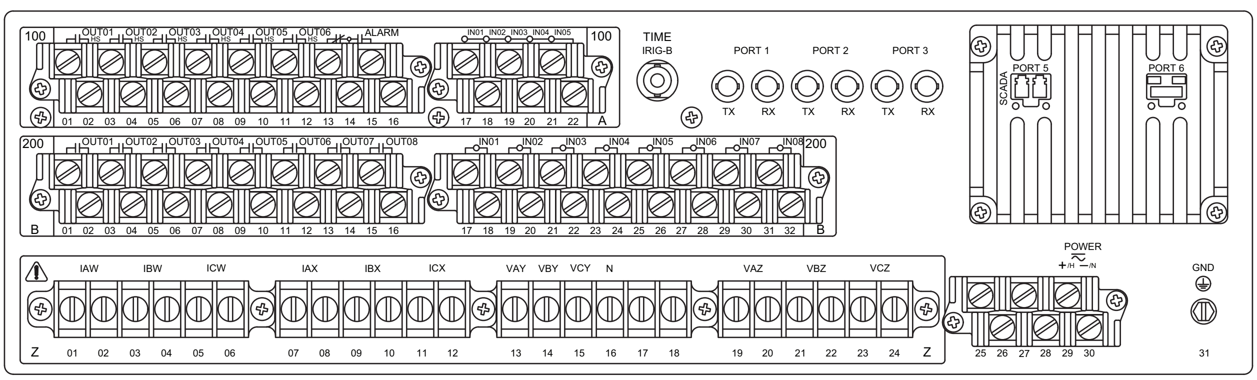


Figure 18 Rear-Panel View

Dimensions

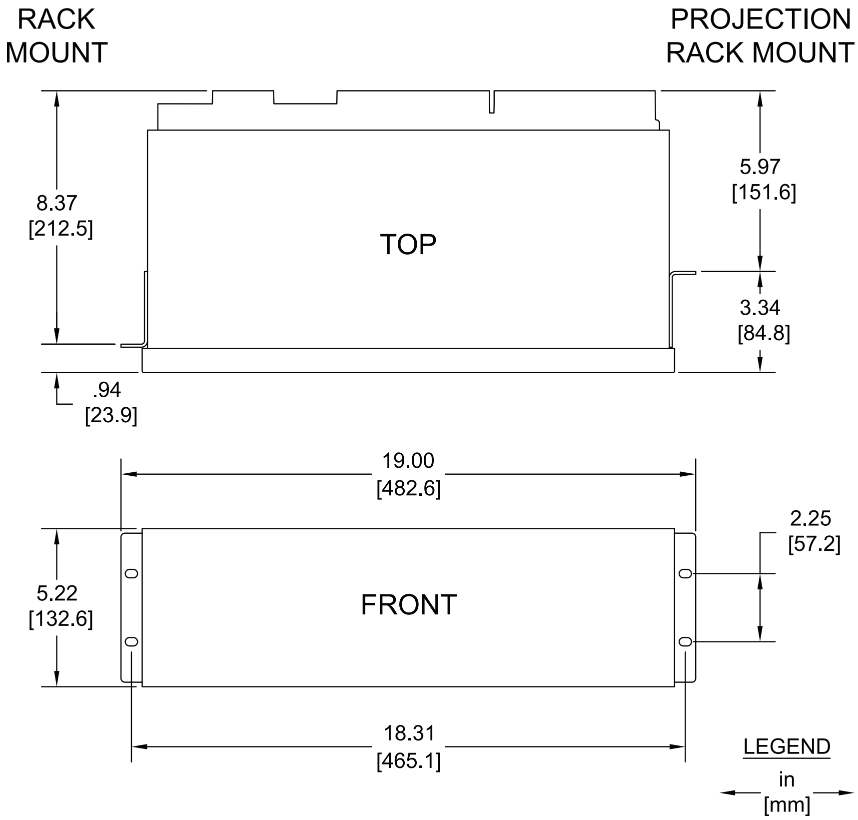


Figure 19 Rack-Mount Chassis Dimensions

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

FCC Compliance Statement

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

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

CE Mark

UKCA Mark

RCM Mark

General

AC Analog Inputs

Sampling Rate:	1 MHz
A/D Resolution:	18 bits

AC Current Inputs

Rated Input Current:	1 A Model: 1 A 5 A Model: 5 A
Continuous Thermal Rating:	1 A Model: 3 A 5 A Model: 15 A
A/D Measurement Limit:	1 A Model: 50 A peak (17.67 Arms fully offset ac current) 5 A Model: 250 A peak (88.4 Arms fully offset ac current)
One-Second Thermal Withstand:	1 A Model: 100 Arms 5 A Model: 500 Arms
Burden:	1 A Model: <0.1 VA at 1 A, 60 Hz 5 A Model: <0.5 VA at 5 A, 60 Hz

AC Voltage Inputs

Connection:	Three-phase four-wire wye with a common neutral, dc coupled (Voltage Input VY) Three-phase six-wire individually isolated, dc coupled (Voltage Input VZ)
Rated Voltage Range:	57.7–144.3 V LN (100–250 V LL)
Continuous Thermal Rating:	175 Vrms LN
A/D Measurement Limit:	280 V peak LN
Ten-Second Thermal Withstand:	350 Vrms LN
Burden:	<0.1 VA at 120 V LN

Power Supply

High-Voltage Range (125–250 Vdc)

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
Control Power Interruption Ride-Through:	46 ms @ 125 Vdc, 250 ms @ 250 Vdc per IEC 60255-26:2013
Burden:	<35 W, <90 VA

Medium-Voltage Range (48–125 Vdc)

Rated Voltage:	48–125 Vdc 110–120 Vac
Operational Voltage Range:	38–200 Vdc 85–140 Vac
Rated Frequency:	50/60 Hz
Operational Frequency Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-26:2013
Control Power Interruption Ride-Through:	14 ms @ 48 Vdc, 160 ms @ 125 Vdc per IEC 60255-26:2013
Burden:	<35 W, <90 VA

Contact Outputs

Update Rate:	10 kHz
Mechanical Endurance:	10,000 operations

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

Rated Voltage:	48–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time:	Pickup time ≤10 µs (resistive load) Dropout ≤8 ms (resistive load)
Make[1, 2] (Short Duration Contact Current):	30 Adc 2,000 operations
Limiting Making Capacity[2]:	1,000 W at 250 Vdc (L/R = 40 ms)
Short-Time Thermal Withstand:	50 Adc for 1 s
Continuous Contact Current:	6 Adc at 70°C (158°F) 4 Adc at 85°C (185°F)
Contact Protection:	MOV protection across open contacts 300 Vdc continuous voltage
Maximum Leakage Current:	<100 µA at 300 Vdc
Limiting Breaking Capacity/Electrical Endurance[1, 2]:	10,000 operations 4 operations in 1 s, followed by 2 min idle

[1] According to IEEE C37.90-2005.
[2] According to IEC 60255-27:2013.

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

Standard Form A

Rated Voltage:	48–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time:	Pickup time ≤6 ms (resistive load) Dropout ≤6 ms (resistive load)
Make[1, 2] (Short Duration Contact Current):	30 Adc 1,000 operations at 250 Vdc 2,000 operations at 125 Vdc
Limiting Making Capacity[2]:	1,000 W at 250 Vdc (L/R = 40 ms)

Short-Time Thermal Withstand: 50 Adc for 1 s

Continuous Contact Current: 6 Adc at 70°C (158°F)
4 Adc at 85°C (185°F)

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

Limiting Breaking Capacity/Electrical Endurance[1, 2]: 10,000 operations
10 operations in 4 s, followed by 2 min idle

[1] According to IEEE C37.90-2005.
[2] According to IEC 60255-27:2013.

Rated Voltage	Resistive Break	Inductive Break
48 Vdc	0.63 Adc	0.63 Adc (L/R = 40 ms)
125 Vdc	0.30 Adc	0.30 Adc (L/R = 40 ms)
250 Vdc	0.20 Adc	0.20 Adc (L/R = 40 ms)

Alarm Output (Form C)

Rated Voltage: 48–250 Vdc

Operational Voltage Range: 0–300 Vdc

Operating Time: Pickup time ≤6 ms (resistive load)
Dropout ≤6 ms (resistive load)

Short-Time Thermal Withstand: 50 Adc for 1 s

Continuous Contact Current: 6 Adc at 70°C (158°F)
4 Adc at 85°C (185°F)

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

Limiting Breaking Capacity/Electrical Endurance[1, 2]: 10,000 operations
10 operations in 4 s, followed by 2 min idle

[1] According to IEEE C37.90-2005.
[2] According to IEC 60255-27:2013.

Rated Voltage	Resistive Break	Inductive Break
48 Vdc	0.63 Adc	0.63 Adc (L/R = 40 ms)
125 Vdc	0.30 Adc	0.30 Adc (L/R = 40 ms)
250 Vdc	0.20 Adc	0.20 Adc (L/R = 40 ms)

Contact Inputs

Optoisolated (Bipolar Operation)

Connection: Terminal Block 100: 5 inputs with a shared common terminal
Terminal Block 200: 8 fully isolated inputs

Sampling Rate: 10 kHz

Input Voltage Options:

Rated Voltage	Maximum Voltage	Pickup Voltage	Dropout Voltage
48 Vdc	60 Vdc	38 Vdc	28 Vdc
110 Vdc	132 Vdc	88 Vdc	66 Vdc
125 Vdc	150 Vdc	100 Vdc	75 Vdc
220 Vdc	264 Vdc	176 Vdc	132 Vdc
250 Vdc	300 Vdc	200 Vdc	150 Vdc

Current Draw: ≤5 mA at rated voltage
≥1 mA required for assertion (220, 250 Vdc option)
≥2 mA required for assertion (48, 110, 125 Vdc option)

Communications Ports

Fiber-Optic Communications Ports 1, 2, and 3

Applications: Multi-ended traveling-wave-based fault locating[1], multi-ended impedance-based fault locating[1], line monitoring[1], and fault locator and event recorder triggering

[1] IEEE C37.94 encoding, 30 ms maximum channel latency

Data Rate: 19,200 to 115,200 bps (SEL MIRRORED BITS encoding)
64 kbps (IEEE C37.94 encoding)

Connector Type: ST

Fiber Type: Multimode

Wavelength: 820 nm

Fiber Size: 62.5/125 µm

Minimum Receiver Sensitivity: –24 dBm

Transmitter Power: –18.5 dBm (minimum)
–10.5 dBm (maximum)

Maximum Distance: 2 km (for typical continuous fiber-optic cable)

USB Front-Panel Port F

Connector Type: Type B

USB Type: 2.0

Fiber-Optic Ethernet Port 5

Applications: Remote engineering access and permanent connection to SCADA or HMI client

Installed SFP Transceiver: 2 km, 1,310 nm, multimode

Connector Type: LC

Port 5-Compliant SFP Transceivers

2 km, 1,310 nm, multimode
0.3/0.55 km, 850 nm, multimode
10 km, 1,310 nm, single-mode
20 km, 1,310 nm, single-mode
30 km, 1,310 nm, single-mode
40 km, 1,310 nm, single-mode
50 km, 1,550 nm, single-mode
80 km, 1,550 nm, single-mode
160 km, 1,550 nm, single-mode
200 km, 1,550 nm, single-mode

Time Input

IRIG-B Input

Applications: Precise time synchronization for digital fault recording, sequential events recording, multi-ended traveling-wave-based fault locating, multi-ended impedance-based fault locating, and line monitoring

Format: Demodulated IRIG-B

Rated I/O Voltage: 5 Vdc

Operating Voltage Range: 0–8 Vdc

Input Impedance: ≥1 kΩ

Time Accuracy: 100 ns when connected to a high-accuracy clock

Holdover Accuracy: <1 µs for 15 s

Clock Drift When Free Running: <5 min per year typical

Installation

According to IEC 60255-27:2013

Operating Temperature

Device: –40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20°C (–4°F) and above +70°C (+158°F).

SFP Transceivers: –40° to +70°C (–40° to +158°F)

Humidity: 5% to 95% without condensation

Altitude: <2000 m

Overvoltage Category: Category III

Insulation Class: I

Pollution Degree: 2

Size and Weight

Size: 3U 19-in horizontal rack-mount

Weight: 7.54 kg (16.63 lb) (maximum)

Terminal Connections and Wire Sizes

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 (221°F). Ring terminals are recommended.

Wire Sizes

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 in the same cable connected to the device, unless otherwise required by local or national wiring regulations.

Connection Type	Minimum Wire Size	Maximum 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)
Power, Contact I/O	18 AWG (0.8 mm^2)	10 AWG (5.3 mm^2)

Type Tests

Electromagnetic Compatibility (EMC)

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

Electromagnetic Compatibility Immunity

Conducted RFI Immunity: IEC 60255-26:2013, Section 7.2.8
10 Vrms

Radiated RFI Immunity: IEC 60255-26:2013, Section 7.2.4
10 V/m (modulated)
IEEE C37.90.2-2004
20 V/m (modulated, >35 V/m peak)

Electrostatic Discharge Immunity: IEC 60255-26:2013, Section 7.2.3
IEEE C37.90.3-2001
2, 4, 6, and 8 kV contact discharge
2, 4, 8, and 15 kV air discharge

Electrical Fast Transient Burst Immunity: IEC 60255-26:2013, Section 7.2.5
Zone A
4 kV, 5 kHz repetition rate on power supply I/O, signal data, and control lines
2 kV, 5 kHz repetition rate on communications ports (IRIG-B)

Power Frequency Immunity: IEC 60255-26:2013, Section 7.2.9
Zone A

Power Frequency Magnetic Field Immunity: IEC 60255-26:2013, Section 7.2.10
Level 5
1,000 A/m for 3 s
100 A/m for 60 s

Pulse Magnetic Field Immunity: IEC 61000-4-9:2001
Level 5
1,000 A/m

Damped Oscillatory Magnetic Field: IEC 61000-4-10:2001
Level 5
100 A/m at 100 kHz and 1 MHz

Power Supply Immunity: IEC 60255-26:2013, Section 7.2.11, 7.2.12, and 7.2.13
IEC 60255-27:2013, Section 5.1.3, 10.6.6

Surge Immunity: IEC 60255-26:2013, Section 7.2.7
Zone A
Line-to-line: 0.5, 1.0, 2.0 kV
Line-to-earth: 0.5, 1.0, 2.0, 4.0 kV

Surge Withstand Capability Immunity and Damped Oscillatory Wave Immunity: IEC 60255-26:2013, Section 7.2.6
2.5 kV peak common mode
1.0 kV peak differential mode
1 MHz damped oscillatory
IEEE C37.90.1-2012
2.5 kV oscillatory
4.0 kV fast transient
2.5 kV, 1 MHz damped oscillatory

Environmental

Cold, Operational: IEC 60255-27:2013, Section 10.6.1.2
Test Ad: 16 hours at –40°C

Dry Heat, Operational: IEC 60255-27:2013, Section 10.6.1.1
Test Bd: 16 hours at +85°C

Damp Heat, Cyclic: IEC 60255-27:2013, Section 10.6.1.6
Test Db: +25° to +55°C, 6 cycles (12 + 12-hour cycle), 95% RH

Damp Heat, Steady State: IEC 60255-27:2013, Section 10.6.1.5
Test Cab: 93% RH, +40°C, 10 days

Object Penetration: IEC 60255-27:2013, Section 10.6.2.6
Protection Class: IP30

Vibration Resistance: IEC 60255-27:2013, Section 10.6.2.1
Class 2 Endurance, Class 2 Response

Shock Resistance: IEC 60255-27:2013, Section 10.6.2.2, 10.6.2.3
Class 1 Shock Withstand, Class 1 Bump Withstand, Class 2 Shock Response

Seismic: IEC 60255-27:2013, Section 10.6.2.4
Class 2 Quake Response

Safety

Dielectric Strength: IEC 60255-27:2013, Section 10.6.4.3
IEEE C37.90-2005, Section 8
2.5 kVrms: analog inputs, contact inputs, contact outputs, and IRIG-B input
3.6 kVdc: power supply

Impulse: IEC 60255-27:2013, Section 10.6.4.2
IEEE C37.90-2005, Impulse section
5.0 kV: analog inputs, digital inputs, digital outputs, power supply, and IRIG-B input

Product Safety Requirements: IEC 60255-27:2013

Laser Safety: 21 CFR 1040.10
IEC 60825-1:2014
Class 1

Fault Locator and Line Monitor

Fault Locator

Methods:	Multi-ended and single-ended traveling-wave-based; multi-ended and single-ended impedance-based
Communications Port for Multi-Ended Methods:	User-selectable, Port 1, 2, and/or 3
Time Synchronization Requirements:	None for single-ended methods High-accuracy IRIG-B when using Port 1, 2, or 3 for multi-ended methods
Data Presentation:	Summary report, transient record (IEEE COMTRADE[1] header file), front-panel HMI, SCADA protocols

[1] IEEE Std C37.111-2013 (IEC 60255-24:2013), *Measuring Relays and Protection Equipment – Part 24: Common Format for Transient Data Exchange (COMTRADE) for Power Systems*

Multi-Ended Traveling-Wave-Based Method

Channel Requirements:	IEEE C37.94 channel on user-selectable Port 1, 2, or 3 with a high-accuracy clock at all line terminals and channel latency less than 30 ms
Device Accuracy[1]:	20 m (90th percentile error) 10 m (median error)

[1] Device accuracy tested with a current step

Application Accuracy:	300 m typical
Number of Line Terminals:	As many as 3
Number of Nonhomogeneous Line Sections:	As many as 5 (only for two-terminal line applications)
CT Cable Length Compensation:	0.000 to 10.000 µs

Single-Ended Traveling-Wave-Based Method

Device Accuracy[1]:	20 m (90th percentile error) 10 m (median error)

[1] Device accuracy tested with a current step

Application Accuracy:	300 m typical
Number of Ranked Fault Location Alternatives Reported:	As many as 4
CT Cable Length Compensation:	Not required

Multi-Ended Impedance-Based Method

Channel Requirements:	IEEE C37.94 channel on user-selectable Port 1, 2, or 3 with a high-accuracy clock at all line terminals and channel latency less than 30 ms
Method:	Negative-sequence line voltage profile (unbalanced faults) or positive-sequence line voltage profile (three-phase faults)
Number of Line Terminals:	As many as 3
Number of Nonhomogeneous Line Sections:	As many as 5 (only for two-terminal line applications)

Single-Ended Impedance-Based Method

Method:	Apparent impedance polarized with negative-sequence current (unbalanced faults) or positive-sequence current (three-phase faults)
Number of Nonhomogeneous Line Sections:	As many as 5

Line Monitor

Operation:	Detects, locates, tabulates, and alarms on fault precursors. Provides blocking regions for line taps with load or generation, or in-line series capacitors. Tabulates and alarms for total line events outside the blocking regions and for daily event counts within the blocking regions
Channel Requirements:	IEEE C37.94 channel on user-selectable Port 1, 2, or 3 with a high-accuracy clock at each line terminal and channel latency less than 30 ms
Triggering Mechanism:	Low-energy events only, faults only, low-energy events and faults (user-selectable)
Sensitivity:	Current traveling waves at each line terminal greater than 2.5% of peak nominal current
Location Resolution:	0.25 mi or km
Counter Range per Location:	0–255 (counting stops at 255)
Number of Line Terminals:	As many as 3
Number of Line Monitoring Blocking Regions per Line:	2
Alarm Threshold:	1–200
Data Presentation:	A text file with tabulated event location and count, alarm bits, and alarm locations available over SCADA protocols

Transient Recording

Recording Rates:	1 MHz concurrently with 10 kHz
Maximum Duration:	3.6 s total in back-to-back recording
Output Format:	Binary 32-bit IEEE COMTRADE

Record Storage (Summary, History, Transient Records)

Total Storage:	No less than 60 s of total recording time 50 records at LER = 1.2 s 200 records at LER = 0.3 s

Sequential Events Recorder

Storage	10,000 entries
Number of Configurable Points:	100
Burst Mode:	1,000 entries
Resolution	100 µs

Supervisory and Triggering Elements and SELogic Equations

Processing Intervals

Calculations and Logic Processing for Supervisory and Triggering Elements:	500 µs
SELogic Processing:	100 µs

Steady-State Accuracy

Pickup Accuracy for Phase Current Elements:	±(1% of setting or 1% of nominal, whichever is greater)
Pickup Accuracy for Sequence Current Elements:	±(2% of the highest phase current or 1% of nominal, whichever is greater)
Pickup Accuracy for Phase Voltage Elements:	±(0.25% of setting or 0.1 V secondary, whichever is greater)

Pickup Accuracy for Sequence Voltage Elements:	±(0.5% of highest phase voltage or 0.2 V secondary, whichever is greater)
Accuracy of Timers for Definite-Time Elements:	±(1 ms or 0.1% of the setting, whichever is greater)

System Configuration

Nominal System Frequency:	50 Hz or 60 Hz
Frequency Tracking Range:	±10 Hz from nominal
Maximum Frequency Slew Rate:	±10 Hz/s
System Phase Rotation:	ABC or ACB
Current Transformer Ratio:	1 to 50,000 in steps of 1
Line Current Source:	IW, IX, or COMB (combined)
Line Voltage Source:	VY, VZ
Secondary CT Cable-Delay Compensation:	0.000 to 10.000 µs in steps of 0.001 µs
Potential Transformer Ratio:	1.00 to 10,000.00 in steps of 0.01
Nominal Voltage (LL):	100 to 250 V secondary in steps of 1 V

Line Configuration

Number of Lines:	As many as 2
Positive-Sequence Line Impedance Magnitude:	1 A Model: 0.25 to 1,275.00 Ω secondary in steps of 0.01 Ω 5 A Model: 0.05 to 255.00 Ω secondary in steps of 0.01 Ω
Positive-Sequence Line Impedance Angle:	50.00° to 90.00° in steps of 0.01°
Zero-Sequence Line Impedance Magnitude:	1 A Model: 0.25 to 1,275.00 Ω secondary in steps of 0.01 Ω 5 A Model: 0.05 to 255.00 Ω secondary in steps of 0.01 Ω
Zero-Sequence Line Impedance Angle:	50.00° to 90.00° in steps of 0.01°
Line Length:	0.01 to 500.00 in steps of 0.01
Line Length Unit:	km or mi
TW Line Propagation Time:	10.00 to 1,700.00 µs in steps of 0.01 µs

Instantaneous and Definite-Time Zero-Sequence Overcurrent Element (50G/67GT)

Number of Elements (Levels):	2
Operating Current:	3I0
Pickup:	1 A Model: 0.05 to 20.00 A secondary in steps of 0.01 A 5 A Model: 0.25 to 100.00 A secondary in steps of 0.01 A
Delay:	0.000 to 10.000 s in steps of 0.001 s
Timer Operation:	Integrating with reset time delay of 25 ms
Torque Control:	Configurable through a SELOGIC equation
Pickup Time:	<1.5 cycles
Transient Overreach:	<10%

Instantaneous and Definite-Time Negative-Sequence Overcurrent Element (50Q/67QT)

Number of Elements (Levels):	2
Operating Current:	3I2
Pickup:	1 A Model: 0.05 to 20.00 A secondary in steps of 0.01 A 5 A Model: 0.25 to 100.00 A secondary in steps of 0.01 A
Delay:	0.000 to 10.000 s in steps of 0.001 s
Timer Operation:	Integrating with reset time delay of 25 ms
Torque Control:	Configurable through a SELOGIC equation
Pickup Time:	<1.5 cycles
Transient Overreach:	<10%

Instantaneous and Definite-Time Phase Overcurrent Element (50P/67PT)

Number of Elements (Levels):	2
Operation:	Phase-segregated pickup with common torque control and timer
Pickup:	1 A Model: 0.05 to 20.00 A secondary in steps of 0.01 A 5 A Model: 0.25 to 100.00 A secondary in steps of 0.01 A
Delay:	0.000 to 10.000 s in steps of 0.001 s
Timer Operation:	Integrating with reset time delay of 25 ms
Torque Control:	Configurable through a SELOGIC equation
Pickup Time:	<1.5 cycles
Transient Overreach:	<10%

Instantaneous and Definite-Time Phase Undervoltage Element (27P/27PT)

Number of Elements (Levels):	2
Operation:	Phase-segregated pickup with common torque control and timer
Operating Voltage:	Phase-to-neutral
Pickup:	OFF, 2.00 to 175.00 V secondary in steps of 0.01 V
Delay:	0.000 to 10.000 s in steps of 0.001 s
Timer Operation:	Integrating with reset time delay of 25 ms
Torque Control:	Configurable through a SELOGIC equation
Pickup Time:	<1.5 cycles

Instantaneous and Definite-Time Positive-Sequence Undervoltage Element (27PS/27PST)

Number of Elements (Levels):	2
Operating Voltage:	Positive-sequence
Pickup:	OFF, 2.00 to 175.00 V secondary in steps of 0.01 V
Delay:	0.000 to 10.000 s in steps of 0.001 s
Timer Operation:	Integrating with reset time delay of 25 ms
Torque Control:	Configurable through a SELOGIC equation
Pickup Time:	<1.5 cycles

Instantaneous and Definite-Time Phase Overvoltage Element (59P/59PT)

Number of Elements (Levels):	2
Operation:	Phase-segregated pickup with common torque control and timer
Operating Voltage:	Phase-to-neutral
Pickup:	OFF, 2.00 to 175.00 V secondary in steps of 0.01 V
Delay:	0.000 to 10.000 s in steps of 0.001 s
Timer Operation:	Integrating with reset time delay of 25 ms
Torque Control:	Configurable through a SELOGIC equation
Pickup Time:	<1.5 cycles

Instantaneous and Definite-Time Positive-Sequence Overvoltage Element (59PS/59PST)

Number of Elements (Levels):	2
Operating Voltage:	Positive-sequence
Pickup:	OFF, 2.00 to 175.00 V secondary in steps of 0.01 V
Delay:	0.000 to 10.000 s in steps of 0.001 s
Timer Operation:	Integrating with reset time delay of 25 ms
Torque Control:	Configurable through a SELOGIC equation
Pickup Time:	<1.5 cycles

Instantaneous and Definite-Time Zero-Sequence Overvoltage Element (59G/59GT)

Number of Elements (Levels):	2
Operating Voltage:	3V0
Pickup:	OFF, 2.00 to 300.00 V secondary in steps of 0.01 V
Delay:	0.000 to 10.000 s in steps of 0.001 s
Timer Operation:	Integrating with reset time delay of 25 ms
Torque Control:	Configurable through a SELOGIC equation
Pickup Time:	<1.5 cycles

Instantaneous and Definite-Time Negative-Sequence Overvoltage Element (59Q/59QT)

Number of Elements (Levels):	2
Operating Voltage:	3V2
Pickup:	OFF, 2.00 to 300.00 V secondary in steps of 0.01 V
Delay:	0.000 to 10.000 s in steps of 0.001 s
Timer Operation:	Integrating with reset time delay of 25 ms
Torque Control:	Configurable through a SELOGIC equation
Pickup Time:	<1.5 cycles

Open-Pole Logic

Number of Breakers per Line:	1 or 2
Breaker Operation:	Single-pole or three-pole (per breaker)
Principle of Operation:	Current with 52a position (per breaker) or current with voltage supervision
52a Inputs:	Dedicated SELOGIC equations, including contact inputs and MIRRORED BITS inputs
Current Selection:	IW, IX, or COMB (combined)
Undervoltage Pickup:	1 to 200 V secondary in steps of 1 V
Security Dropout Timer:	0.000 to 1.000 s in steps of 0.001 s

SELOGIC Equations, Latches, and Timers

Equations

Number of Equations:	64

Note: Torque-control inputs, output actuation, timers, latches, and other relevant settings have their own separate equations.

Logical Operations:	AND, OR, NOT, rising edge, falling edge
Number of Inputs:	As many as 15
Parentheses:	As many as 14
Length Limit:	511 characters

Latches

Number of Latches:	16
Operation:	Reset-dominant, nonvolatile
Set and Reset Inputs:	Dedicated equations

Timers

Number of Timers:	16
Pickup Time:	0.0 to 60,000.0 ms in steps of 0.1 ms
Dropout Time:	0.0 to 60,000.0 ms in steps of 0.1 ms
Timing Accuracy:	±(0.2 ms or 1% of the setting, whichever is greater)
Inputs:	Dedicated equations

Metering Accuracy

All metering specifications apply at 20°C and nominal frequency unless otherwise noted.

Current (Local)

Phase Current Magnitude:	±0.2% plus ±0.001 • Inom (0.05 • Inom – 3 • Inom)
Phase Current Angle:	±1° (0.05 • Inom – 0.2 • Inom) ±0.2° (0.2 • Inom – 3 • Inom)
Sequence Current Magnitude:	±0.3% plus ±0.001• Inom (0.05 • Inom – 3 • Inom)
Sequence Current Angle:	±1.5° (0.05 • Inom – 0.2 • Inom) ±0.3° (0.2 • Inom – 3 • Inom)

Voltage

Phase Voltage Magnitude:	±0.2% (5–175 V_{LN})
Phase Voltage Angle:	±0.2° (5–175 V_{LN})
Sequence Voltage Magnitude:	±0.3% (5–175 V_{LN})
Sequence Voltage Angle:	±0.3° (5–175 V_{LN})

Frequency (Input 5–175 V_{LN}, 40–70 Hz)

Accuracy:	±0.001 Hz

Built-In Testing Functions

Loopback Mode for Communications Ports 1, 2, and 3

Purpose:	Troubleshoot a communications channel connected to Port 1, 2, or 3 by allowing the device to receive its own packets while passing the received bits to the downstream logic or substituting them with fail-safe values
Initiation:	SEL ASCII command
Annunciation:	Relay Word bit
Security:	Access Level 2 and time-out

Traveling-Wave Test Mode

Purpose:	Test the line monitoring logic by using only high-frequency signals, without the presence of fundamental-frequency components in currents or voltages
Initiation:	SEL ASCII command
Annunciation:	Relay Word bit
Security:	Access Level 2 and confirmation of the initiating command on the front panel; time-out

Technical Support

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

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

This product is covered by the standard SEL 10-year warranty. For warranty details, visit selinc.com or contact your customer service representative.

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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