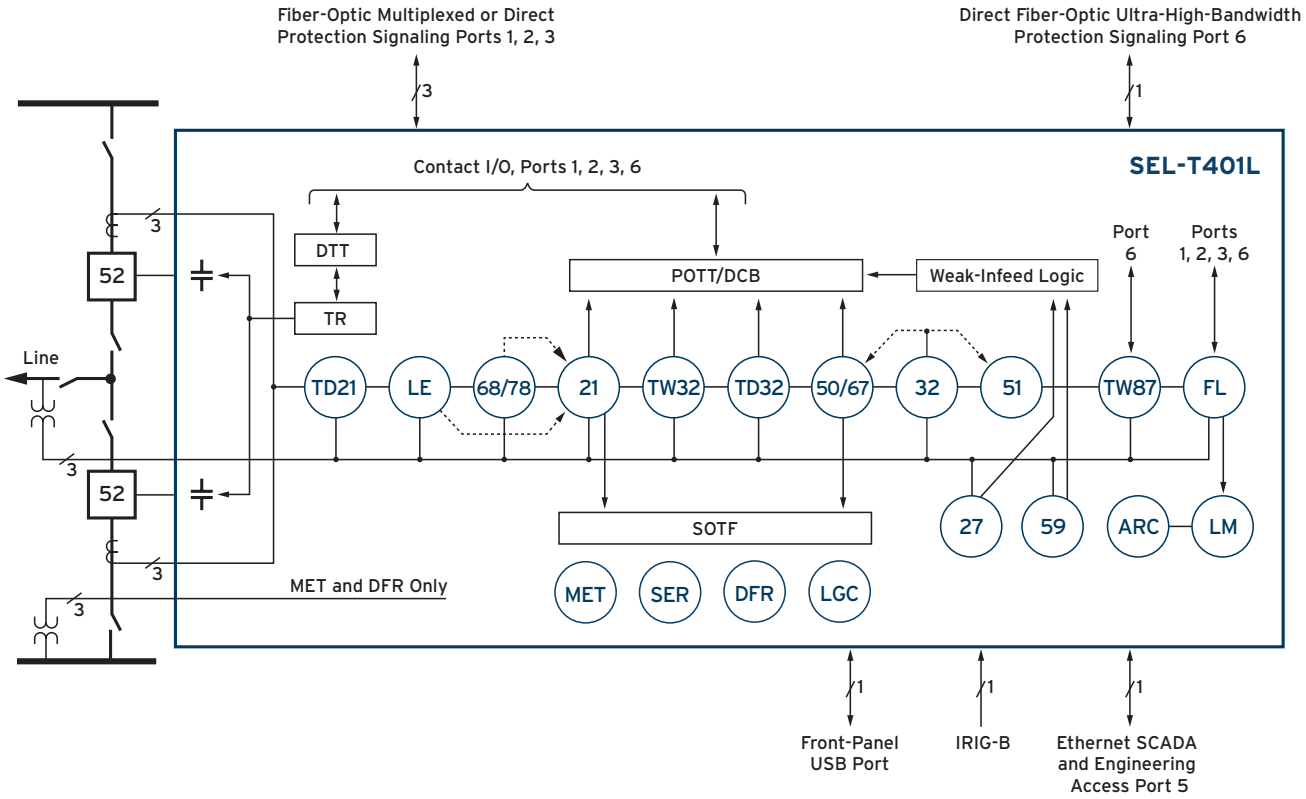
SEL-T401L

Ultra-High-Speed Line Relay

Fast, dependable, and simple

- Apply ultra-high-speed protection based on field-proven SEL time-domain technology with demonstrated trip times on the order of 1—5 ms.
- Complement and back up the traveling-wave and incremental-quantity protection elements and schemes with distance elements, directional elements, and the other protection functions that you expect in a line protection system.
- Improve fault-locating results to within a single tower span by using traveling-wave-based fault-locating methods, and ensure dependability with impedance-based methods.
- Achieve a balance between flexibility and ease of use in a 3U package with programmable logic, flexible I/O, and SCADA functionality.

Functional Overview



ANSI Numbers/Acronyms and Functions

21	Phase and Ground Distance
TD21	Incremental-Quantity Phase and Ground Distance
27	Undervoltage (Phase, Phase to Phase, and Positive Sequence)
32	Directional (Phase, Zero Seq., and Negative Seq.)
TD32	Incremental-Quantity Directional
TW32	Traveling-Wave Directional
50	Instantaneous Overcurrent (Phase, Zero Sequence, and Negative Sequence)
51	Inverse-Time Overcurrent (Phase, Zero Sequence, and Negative Sequence)
59	Overvoltage (Phase, Phase to Phase, Positive Sequence, Zero Sequence, and Negative Sequence)
67	Instantaneous and Definite-Time Directional Overcurrent (Phase, Zero Seq., and Negative Seq.)
68	Power-Swing Blocking
78	Out-of-Step Tripping
85 RIO	SEL Mirrored Bits® I/O With Selectable SEL MB8 or IEEE C37.94 Encoding
TW87	Traveling-Wave Differential
94	High-Speed Trip-Rated Outputs
POTT	Permissive Overreaching Transfer Trip Logic
CBECHO	Open-Breaker Echo Logic
WI	Weak-Infeed Logic
DCB	Directional Comparison Blocking Logic
SOTF	Switch-Onto-Fault Logic
DTT	Direct Transfer Trip Logic (Intertripping)
LOP	Loss-of-Potential Logic
OP	Open-Pole Detection Logic
LE	Load Encroachment Logic
DFR	Digital Fault Recorder
SER	Sequential Events Recorder
FL	Fault Locator
LM	Line Monitor
LGC	SELogic® Equations
MET	Metering
ARC	Adaptive Autoreclose Cancel Logic
HMI	Local Operator Interface
DNP3	Distributed Network Protocol 3.0 (Ethernet)
LB	Local Control Bits (Operated Through Front-Panel HMI)
RB	Remote Control Bits (Operated Through DNP3 and SEL Fast Operate Protocols)
FTP	File Transfer Protocol
FTDV	Fast Time-Domain Values
EMI	Electromagnetic Interference Monitoring for Traveling-Wave Functions
TEST	Event Playback and Traveling-Wave Test Mode

Key Features

Ultra-High-Speed Protection

Using field-proven traveling-wave and incremental-quantity technologies pioneered in the SEL-T400L Time-Domain Line Protection, the SEL-T401L delivers industry-leading operating speed. Sampling line and voltage currents at 1 MHz, processing data every microsecond, using high-speed protection signaling, and tripping with solid-state trip-rated outputs, the SEL-T401L securely trips in as fast as 1 ms. Faster fault clearing improves public and utility personnel safety, widens transient stability margins, limits equipment wear, improves power quality, and confines property damage.

The SEL-T401L offers the complete suite of Main 1 and Main 2 protection functions that you expect in a line protection system. Its high-performance distance protection with five zones of phase and ground distance elements, individually selectable as either mho or quadrilateral, provide subcycle operating times. The SEL-T401L also has dependable protection and supervisory functions, including sensitive directional, switch-onto-fault, overcurrent, over- and undervoltage, load encroachment, out-of-step tripping, and power-swing blocking. You can apply the SEL-T401L on its own or as part of a redundant protection system with other SEL relays without concerns for common-mode failures.

Reset the complexity of your line protection applications with the simple and robust protection philosophies and considerably lower setting count of the SEL-T401L. It is available in a 3U chassis, making it a great option when replacing relays. Gain efficiency by using common SEL configuration and integration tools, and benefit from strong diversity in hardware, software, and protection operating principles.

Unparalleled Fault-Locating Technology

The SEL-T401L provides state-of-the-art fault locating based on robust traveling-wave technology. The relay includes single- and double-ended traveling-wave-based fault-locating methods that are accurate to within a single tower span. It also includes single- and double-ended impedance-based methods. The combination of single-ended and double-ended methods, as well as traveling-wave-based and impedance-based methods, provides the best accuracy and dependability for any combination of operating conditions and fault types. Using the detailed fault location results, you can confidently dispatch crews directly to the tower nearest to the fault, reducing the outage time and maintenance expenses.

Combining the SEL-T401L high-speed double-ended fault-locating technology and built-in adaptive location-dependent autoreclose cancel logic allows selective reclosing on the overhead portion of hybrid lines and inhibits reclosing on cable portions, protecting the cable from additional insulation damage.

You can use the line-monitoring function in the SEL-T401L for condition-based line maintenance. This feature helps to prevent faults and to discover weak spots along the line.

High-Fidelity Transient Recording

The SEL-T401L measures and records line currents and voltages with high-fidelity (1 MHz, 18-bit) sampling, offering an enhanced understanding of the events on your power system. This allows you to analyze high-frequency transients, such as traveling waves from faults, switching events, breaker restrikes, and self-extinguishing faults.

USB 2.0 port for local engineering access

Display for viewing metering, event, fault location, and relay status information

Large slide-in label pocket for diagrams or asset information

Simple HMI navigation

Slide-in label pocket and LED targets for viewing trip cause, fault type, and basic relay status

Eight outputs for POTT, DCB, DTT, breaker failure initiation (BFI), and other signaling

IRIG-B time input

Three fiber-optic ports for multiplexed or direct protection signaling (SEL MB8 or IEEE C37.94)

Alarm output

100 Mbps or 1 Gbps small form-factor pluggable (SFP) Ethernet port for engineering access and SCADA

SFP fiber-optic port for ultra-high-bandwidth protection signaling over direct fiber

Six trip-rated high-speed outputs for single-pole tripping of two breakers

Five inputs with a common terminal

Breaker 1 and 2 current inputs

Line voltage

Eight inputs for POTT, DCB, DTT, triggering, and other signaling

Auxiliary voltage (metering and digital fault recorder)

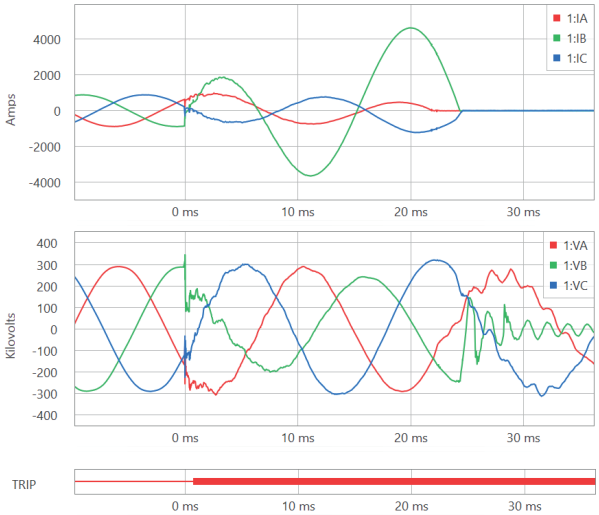
Power supply

Applications

Protection Applications

Ultra-High-Speed Protection

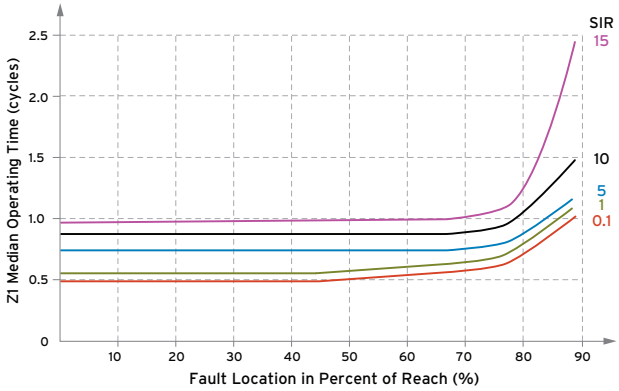
The SEL-T401L uses field-proven traveling-wave and incremental-quantity technologies pioneered in the SEL-T400L. The underreaching distance (TD21) protection element trips using incremental voltages and currents at the relay location. Not dependent on a protection channel, the TD21 element operates as fast as 2 ms for close-in high-current faults. Dependably protect the entire line by using a permissive or blocking pilot protection scheme over a standard digital or analog protection channel with traveling-wave (TW32) and incremental-quantity (TD32) directional elements operating as fast as 0.1 ms and 1.5 ms, respectively. The traveling-wave differential (TW87) protection scheme uses current traveling waves to detect in-zone faults with operating times in the range of 1 to 5 ms, depending on the line length.



The TW87 scheme operates in 1.5 ms, and the breaker clears the fault in less than 25 ms.

Mho and Quadrilateral Distance Elements

The SEL-T401L provides a total of five phase and ground distance zones for direct tripping, pilot protection, step distance, and switch-onto-fault applications. Zones 1 through 4 are directional; each has an individual direction setting (forward or reverse). Zone 5 is nondirectional (offset) with separate forward and reverse reach settings. You can configure the phase and ground distance elements of each zone as either a mho characteristic or a quadrilateral characteristic. Each ground distance zone uses its own zero-sequence compensation factor. All zones use an overcurrent supervision condition with thresholds that can be set individually for the phase and ground distance elements of each zone. Use integrating timers and benefit from the enhanced voltage memory polarizing logic to achieve dependable step distance protection. The SEL-T401L uses simple and robust polarizing methods and just a few settings, making the SEL-T401L distance elements easy to apply and test.

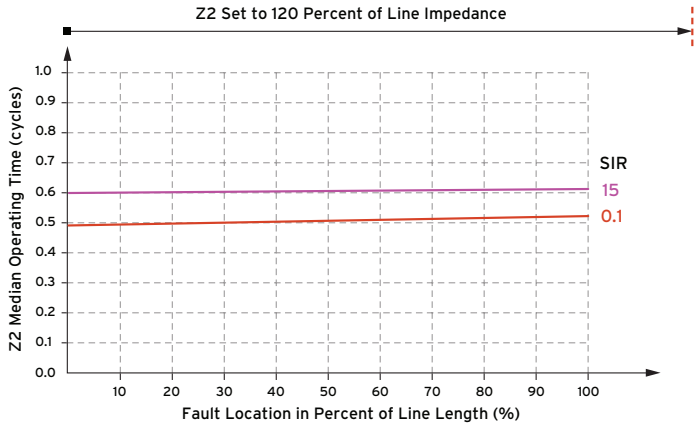


Distance Zone 1 median operating time for varying fault locations and different source-to-impedance ratios (SIRs).

Pilot Protection Schemes (POTT and DCB)

The SEL-T401L provides preconfigured POTT and DCB schemes that are fast, secure, dependable, flexible, and easy to use. You can select traveling-wave (TW32), incremental-quantity (TD32), negative-sequence (67Q), zero-sequence (67G), or phase (67P) directional elements as well as overreaching distance elements (Zone 2) to detect line faults. Using a combination of these elements, the relay can trip with extraordinary speed, exceptional dependability, and very high sensitivity.

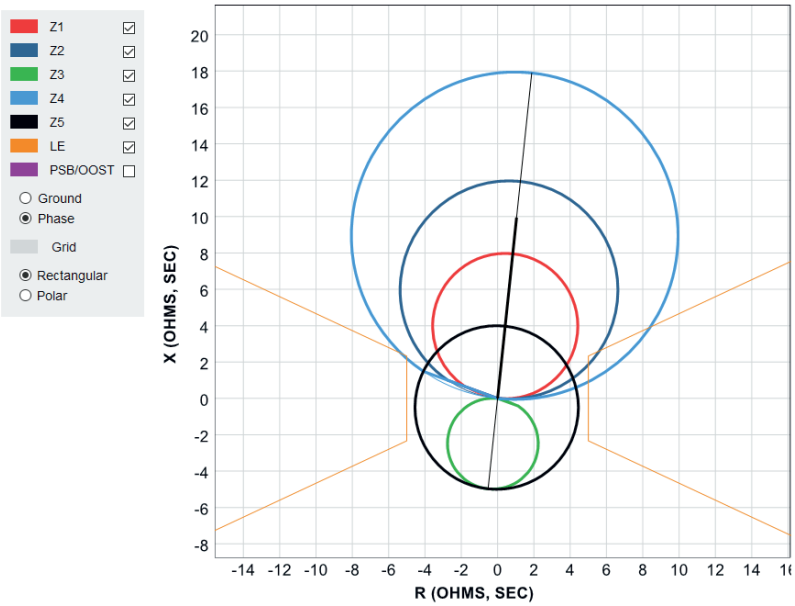
Apply open-breaker echo and weak-infeed logic for dependability of the POTT scheme. Apply the POTT and DCB schemes to multiterminal lines with any number of terminals.



Distance Zone 2 median operating time for varying fault locations and different SIRs.

Supplementary and Backup Protection

The SEL-T401L offers all core protection elements that you typically want duplicated between the Main 1 and Main 2 relays. Apply switch-onto-fault logic with the nondirectional Zone 5 element or phase overcurrent elements. Use phase, zero-sequence, and negative-sequence instantaneous overcurrent elements to clear close-in high-current faults without relying on voltage or protection channels. Inverse-time and definite-time overcurrent elements allow coordination with adjacent relays for backup protection. To detect out-of-bound voltage system conditions, you can apply over- and undervoltage elements. Inverse-time and definite-time ground directional overcurrent elements let you detect high-resistance faults.

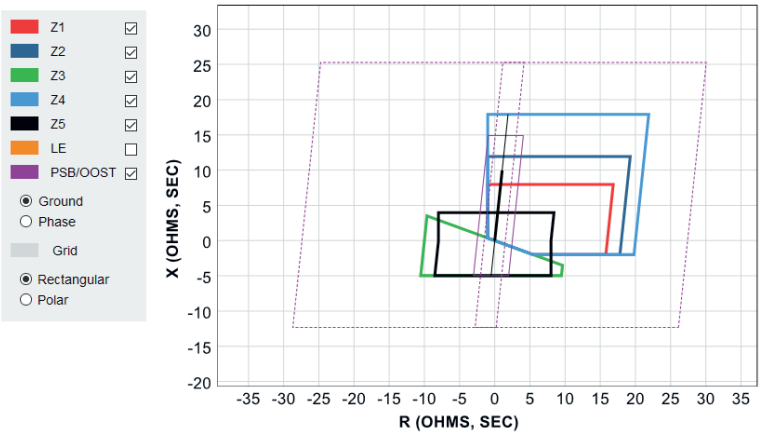


SEL-T401L distance mho operating characteristics with load encroachment.

Supervisory Protection Elements

Apply load encroachment logic to secure the distance and phase overcurrent elements for heavy load conditions. To optimize your single-pole tripping applications, you can apply separate load encroachment settings for the phase and ground measurement loops.

Apply the power-swing blocking logic to secure the SEL-T401L distance elements during power swings. The element operates based on the impedance-rate-of-change principle and does not require any user settings. Apply out-of-step tripping logic to trip for unstable power swings traversing through the unprotected line. This logic is settings-free and applies a simple trip-on-the-way-out operating principle based on the impedance-rate-of-change measurement.

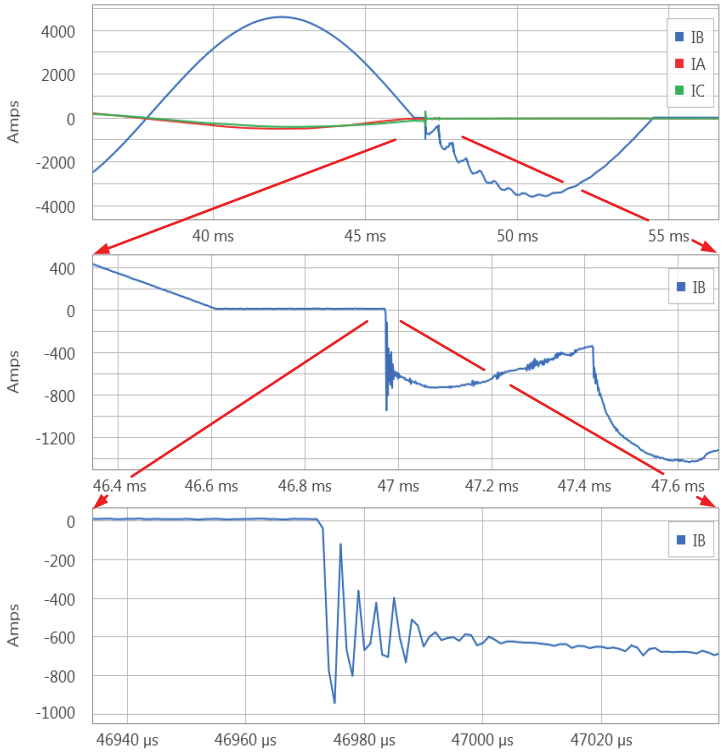


SEL-T401L distance quadrilateral operating characteristics with power-swing blocking and out-of-step tripping.

Ultra-High-Resolution Transient Recording

1 MHz sampling of line currents and voltages provides enhanced detail to understand your power system and analyze traveling-wave functions. The SEL-T401L measures and records two three-phase sets of currents and two three-phase sets of voltages, and if the direct fiber-optic channel is used, it records the remote three-phase line currents and voltages. The relay uses 18 true bits of resolution for excellent data fidelity. You can trigger data capture from any of the internal bits, a contact input, an SEL Mirrored Bits input, or any combination thereof.

The SEL-T401L also offers a 10 kHz record that contains currents and voltages sampled at 10 kHz, selected protection operating quantities, Relay Word bits, settings, and fault location and event summary data. Using this information, you can quickly and easily analyze the relay's operation.



Record fine features of power system voltage and currents, such as a circuit breaker re-ignition.

Fault-Locating and Monitoring Applications

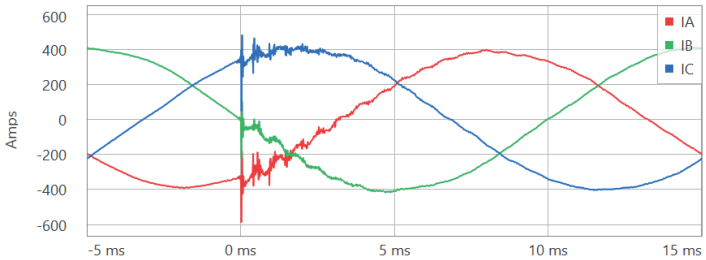
Traveling-Wave-Based Fault Locating

The SEL-T401L relay's simple and robust double-ended traveling-wave-based fault-locating method provides an accurate fault location. The method works over a multiplexed IEEE C37.94 channel with high-accuracy external IRIG-B-connected clocks at both line terminals and over a direct fiber-optic channel (external time is not required). The method works well on overhead lines, cable lines, and hybrid lines comprised of both overhead and cable sections. The single-ended traveling-wave-based fault-locating method is useful in applications without relay-to-relay communications or when your channel is down. By using the double- and single-ended impedance-based fault-locating methods, you can still obtain fault-locating results when the point on wave or termination effects prevent the traveling-wave-based methods from locating the fault.

SEL traveling-wave fault-locating technology has a decade-long track record of accuracy on the order of one tower span.

Line Monitoring

The line-monitoring function allows you to perform condition-based line maintenance and discover weak spots along the line. The line monitor triggers on current traveling waves launched by fault precursors, such as partial discharge due to a dirty insulator, encroaching vegetation, or an incipient cable fault. The line monitor locates fault precursors with high accuracy, tabulates the precursor events for locations along the line, and alarms if the event count exceeds a user-settable alarm threshold at any location. With this information, you can selectively wash or replace insulators and trim vegetation to reduce line faults.



The SEL-T401L detects, locates, tabulates, and alarms on in-zone events to prevent faults and identify line weak spots.

Autoreclose Cancel Logic

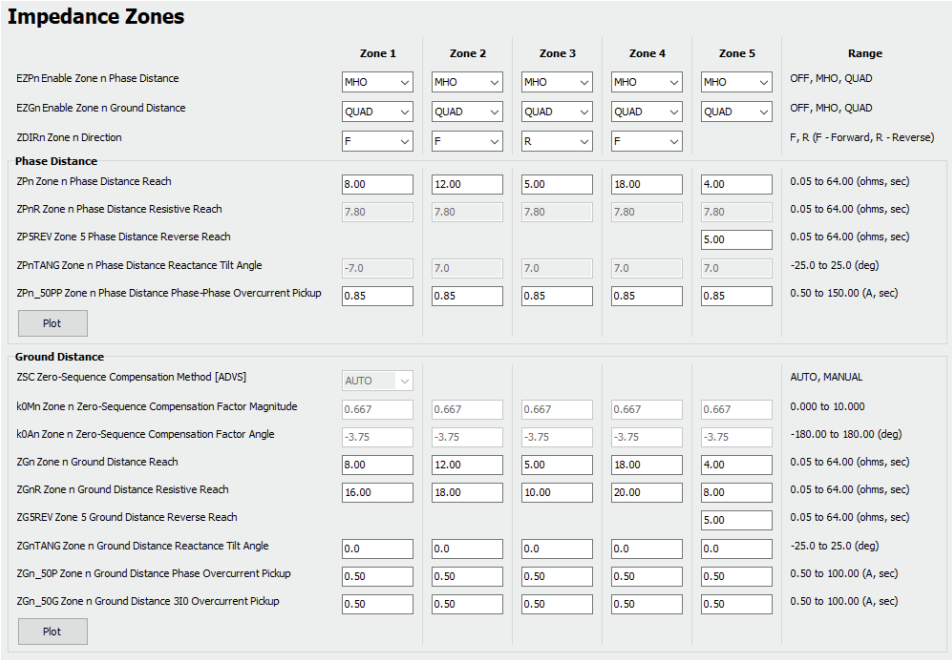
Apply the adaptive location-dependent autoreclose cancel logic to distinguish faults on overhead line sections from faults on cable sections of hybrid lines and to control your autorecloser accordingly. You can apply single-pole tripping and reclosing for faults on overhead sections to improve reliability while avoiding reclosing into faults on a cable section and causing additional damage.

The SEL-T401L locates faults on hybrid overhead-cable lines and allows selective real-time control of autoreclosing.

Simplicity-Focused Relay

Design

The SEL-T401L design achieves the right balance between flexibility and simplicity. Settings are streamlined, named, grouped, and presented for intuitive application and ease of use. You can apply the relay with preconfigured logic or adjust the factory defaults with SELOGIC equations with gates, timers, and latches.



Impedance Zones

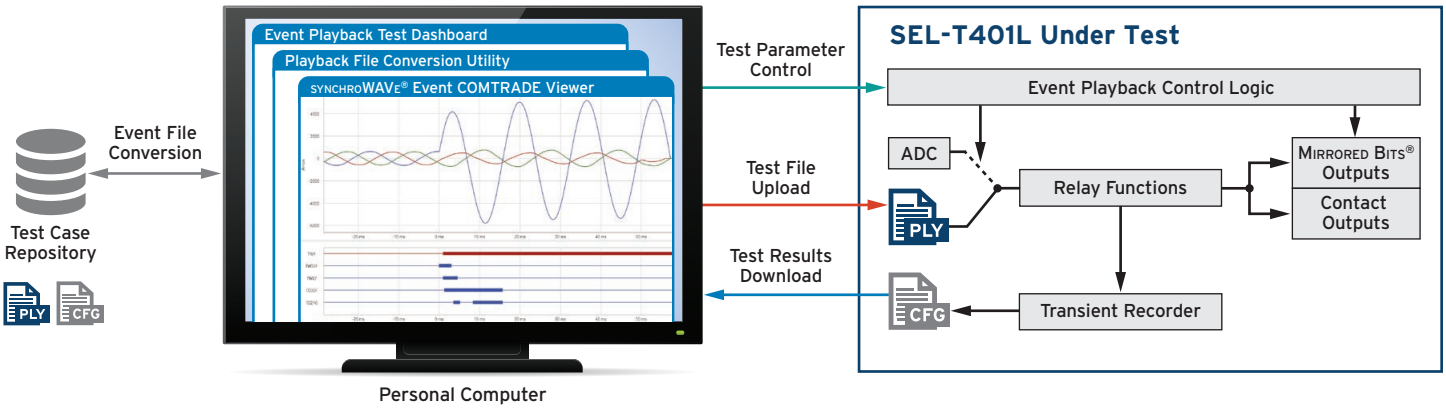
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Range
EZPn Enable Zone n Phase Distance	MHO	MHO	MHO	MHO	MHO	OFF, MHO, QUAD
EZGn Enable Zone n Ground Distance	QUAD	QUAD	QUAD	QUAD	QUAD	OFF, MHO, QUAD
ZDIRn Zone n Direction	F	F	R	F		F, R (F - Forward, R - Reverse)
Phase Distance						
ZPn Zone n Phase Distance Reach	8.00	12.00	5.00	18.00	4.00	0.05 to 64.00 (ohms, sec)
ZPnR Zone n Phase Distance Resistive Reach	7.80	7.80	7.80	7.80	7.80	0.05 to 64.00 (ohms, sec)
ZP5REV Zone 5 Phase Distance Reverse Reach					5.00	0.05 to 64.00 (ohms, sec)
ZPnTANG Zone n Phase Distance Reactance Tilt Angle	-7.0	7.0	7.0	7.0	7.0	-25.0 to 25.0 (deg)
ZPn_50PP Zone n Phase Distance Phase-Phase Overcurrent Pickup	0.85	0.85	0.85	0.85	0.85	0.50 to 150.00 (A, sec)
Plot						
Ground Distance						
ZSC Zero-Sequence Compensation Method [ADVS]	AUTO					AUTO, MANUAL
k0Mn Zone n Zero-Sequence Compensation Factor Magnitude	0.667	0.667	0.667	0.667	0.667	0.000 to 10.000
k0An Zone n Zero-Sequence Compensation Factor Angle	-3.75	-3.75	-3.75	-3.75	-3.75	-180.00 to 180.00 (deg)
ZGn Zone n Ground Distance Reach	8.00	12.00	5.00	18.00	4.00	0.05 to 64.00 (ohms, sec)
ZGnR Zone n Ground Distance Resistive Reach	16.00	18.00	10.00	20.00	8.00	0.05 to 64.00 (ohms, sec)
ZG5REV Zone 5 Ground Distance Reverse Reach					5.00	0.05 to 64.00 (ohms, sec)
ZGnTANG Zone n Ground Distance Reactance Tilt Angle	0.0	0.0	0.0	0.0	0.0	-25.0 to 25.0 (deg)
ZGn_50P Zone n Ground Distance Phase Overcurrent Pickup	0.50	0.50	0.50	0.50	0.50	0.50 to 100.00 (A, sec)
ZGn_50G Zone n Ground Distance 3I0 Overcurrent Pickup	0.50	0.50	0.50	0.50	0.50	0.50 to 100.00 (A, sec)
Plot						

Settings screen for distance elements in ACSELERATOR QuickSet® SEL-5030 Software.

Testing Made Easy

The built-in current and voltage playback feature of the SEL-T401L provides you with new opportunities for relay testing. To test the SEL-T401L, you can upload and play back current and voltage signals recorded by an SEL-T400L, SEL-T401L, SEL-400 series relay, or digital fault recorder in the field. You can also use files generated by transient simulation software.

Secondary injection testing of SEL-T401L I/O, metering, and protection elements is straightforward. Today's relay test sets provide adequate signals to test incremental-quantity and phasor-based protection elements. You can use the SEL-T4287 Traveling-Wave Test System to perform secondary injection testing of the TW32 element, TW87 differential scheme, and traveling-wave-based fault-locating methods.



Upload and play back test files using the built-in event playback capability.

SEL-T401L Specifications

General	
Six AC Current Inputs	Rated input current (5 A model): 5 A Rated input current (1 A model): 1 A
Six AC Voltage Inputs	Rated voltage range: 57.7—144.3 V LN (V_{NOM} = 100—250 V LL) Connection (voltage input VY): Four-wire connection with a shared neutral (protection, recording, and metering) Connection (voltage input VS): Six-wire connection, individually isolated (recording and metering)
Contact Outputs	Rated voltage: 48—250 Vdc Operational voltage range: 0—300 Vdc **Six Fast Hybrid (High-Speed, High-Current Interrupting) Form A Outputs** Operating time (pickup): ≤10 µs (resistive load) **Eight Standard Form A Outputs** Operating time (pickup): ≤6 ms (resistive load) **Alarm Output (Form C)**
Contact Inputs	Optoisolated (bipolar operation): 5 inputs with a shared common terminal; 8 inputs individually isolated Sampling rate: 10 kHz Rated voltage: 48, 110, 125, 220, or 250 Vdc
Three Fiber-Optic Protection Signaling Ports	Data rates: 19,200 to 115,200 bps (SEL Mirrored Bits encoding) or 64 kbps (IEEE C37.94 encoding) Connector type: ST Fiber type: Multimode Wavelength: 820 nm
Front-Panel Port	USB type: 2.0 Connector type: Type B
Fiber-Optic Ethernet Port	Data rate: 100 Mbps or 1 Gbps Fiber type and range: Multimode, 2 km for typical continuous fiber-optic cable Connector type: LC
Ultra-High-Bandwidth Protection Port	Data rate: 1 Gbps Fiber type and range: Multimode, 0.3/0.55 km; single-mode, 10 km to 200 km Connector type: LC (order SFP transceiver separately)
Time Input	IRIG-B input format: Demodulated IRIG-B
Power Supply	Rated high-voltage range: 125—250 Vdc, 110—240 Vac Rated medium-voltage range: 48—125 Vdc, 110—120 Vac
Operating Temperature Range	−40° to +85°C (−40° to +185°F)
Weight and Dimensions	3U rack unit; 7.54 kg (16.63 lb) 482.6 mm W x 132.6 mm H x 236.4 mm D (19.00 in W x 5.22 in H x 9.31 in D)

SEL SCHWEITZER ENGINEERING LABORATORIES

Making Electric Power Safer, More Reliable, and More Economical

+1.509.332.1890 | info@selinc.com | selinc.com

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