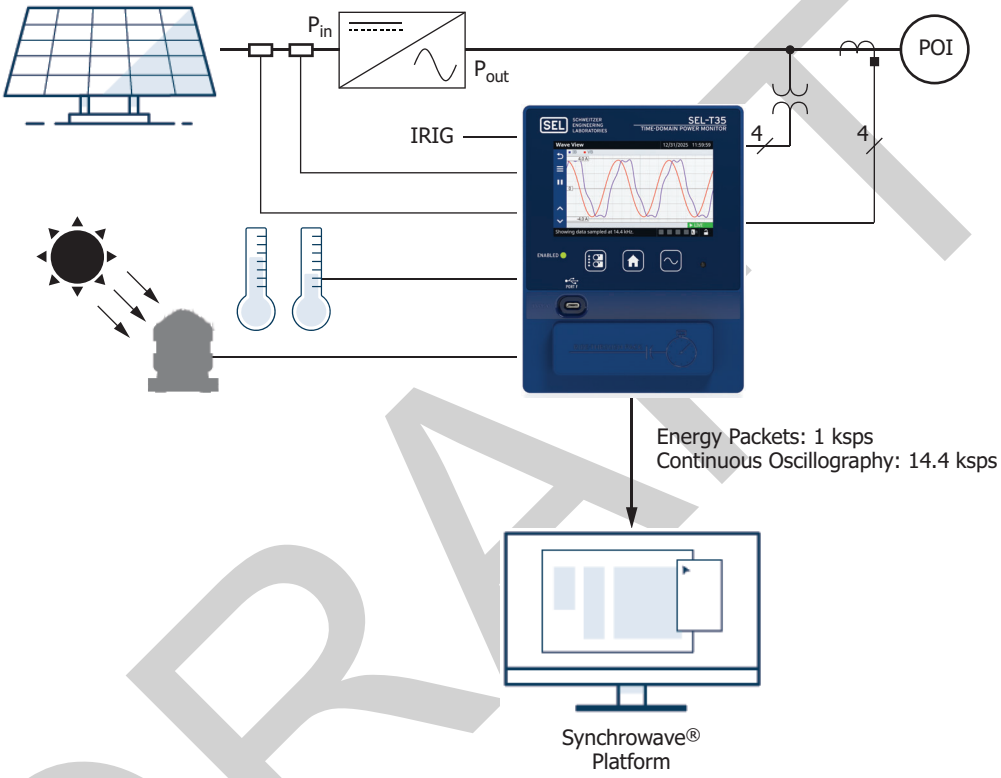
SEL-T35 Time-Domain Power Monitor

Real-Time Waveform Streaming and Centralized Metering



Key Features and Benefits

The SEL-T35 Time-Domain Power Monitor precisely samples ac and dc signals and streams the raw data at 14.4 kilosamples per second (ksps) and energy calculations at 1 ksps to SEL Synchrowave software that precisely measures, analyzes, and records power system operations. Synchrowave software displays real-time oscillography, monitors energy transfer, calculates energy conversion efficiency, and continuously records waveform data. This system provides local and wide-area power monitoring for substations, power plants, solar and wind farms, battery energy storage systems, and 480 V commercial and industrial buildings.

- **Wide-Area Streaming.** Stream continuous oscillography at 14.4 ksps using a modified IEEE C37.118 format transmitted over high-bandwidth networks to SEL-5702 Synchrowave Operations Software or SEL-5703 Synchrowave Monitoring Software.
- **Real-Time Oscillography.** Just like using an oscilloscope, you can view ac and dc voltage and current measurements plus time-domain energy transfer in real time on the color touchscreen HMI. Quickly assess ac system signals and identify non-linear loads or voltage notching and transients lasting longer than 100 µs. Synchrowave software displays both real-time and historic data streams as well as calculated analog quantities.

- **Continuous Waveform Recording.** Never miss a disturbance again by recording the continuous waveform stream within Synchrowave software. Applications include archiving, virtual metering, subsynchronous oscillation analysis, and equipment failure analysis.
- **Synchrowave Virtual Meter.** Synchrowave Monitoring software calculates half-cycle frequency, power, symmetrical components, phasors, voltage, and current with intuitive visualization and trending. An integrated historian can save these trends for months or years. A calculations engine allows custom calculations of additional quantities, such as dc to ac energy conversion efficiency.
- **Energy Packet Streaming.** The data stream includes time-domain energy packets calculated every millisecond. This industry-exclusive energy packet technology captures energy measurements independent of frequency and phase angles, eliminating frequency-tracked delay or calculation issues with nonlinear signals.
- **Subsynchronous Resonance Detection.** Synchrowave Monitoring software analyzes the 14.4 ksps data stream to identify low-frequency resonances on the voltage and current signals. The system can provide an on-screen or email alarm if the resonance persists over a programmable time window and resonance magnitude.
- **Incipient Failure Prediction.** Voltage disturbances of 1 ms or shorter can indicate an impeding failure because of an underground conductor insulation breakdown, a tree branch contacting an overhead line, a failing potential transformer, or increased resistance at a termination point. Synchrowave Monitoring software detects these disturbances and warns if the duration of these disturbances exceeds preprogrammed thresholds.
- **Precise DC Transducer Measurements.** Four low-level milliampere (mA) dc analog inputs measure the output from third-party transducers, including temperature, solar irradiance, and high-energy dc voltage or current.
- **Auxiliary Voltage Input.** A fully isolated 300 Vac/Vdc voltage input measures battery voltage, generator voltage, or bus voltage completely independent of the three-phase voltage inputs.
- **Event Ride-Through.** An integrated power supply ride-through pack continues to power the SEL-T35 for at least seven seconds if the power supply input drops out. This ensures the SEL-T35 never misses an event during short-duration outages.

Product Overview

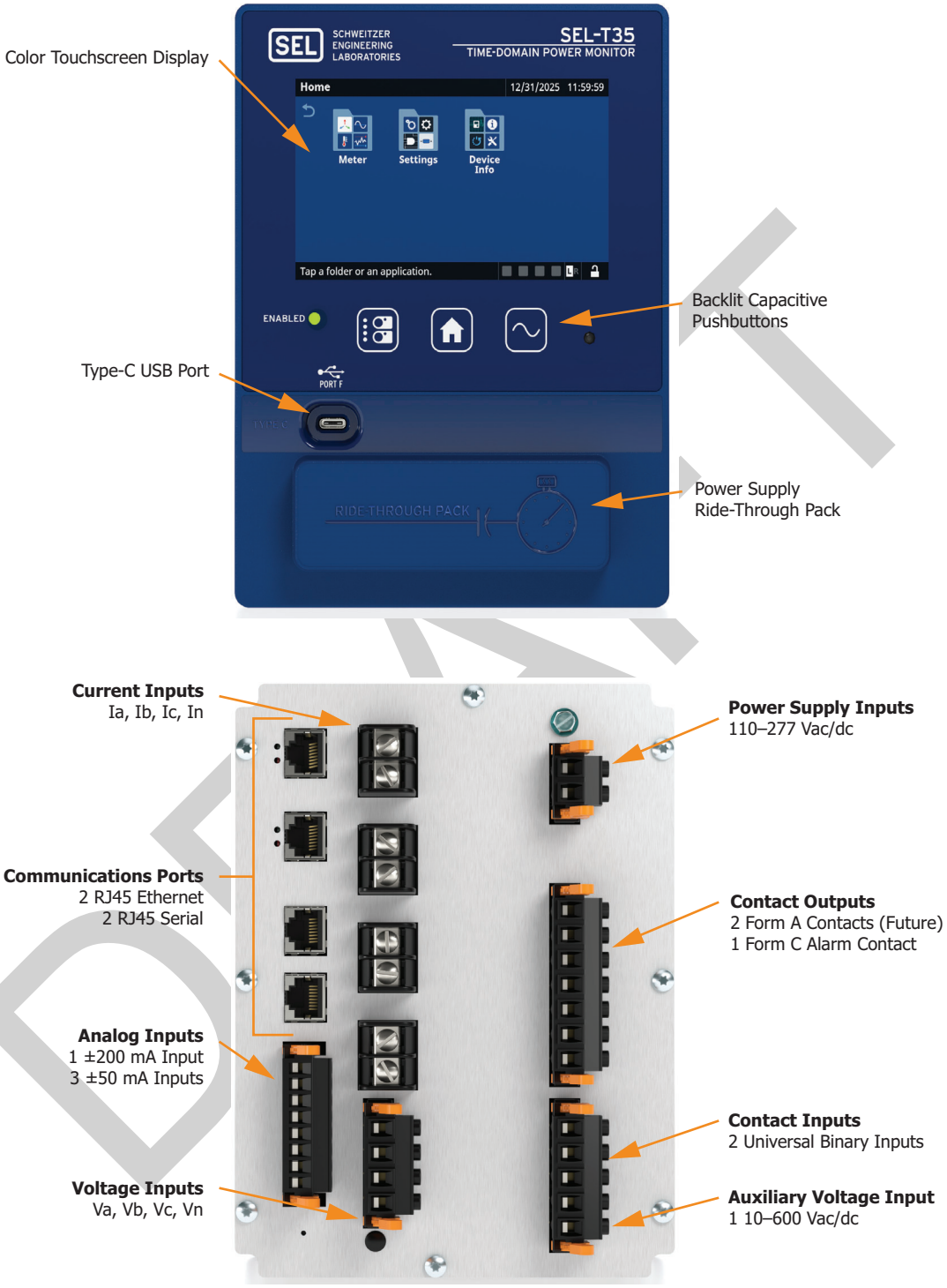


Figure 1 Product Features

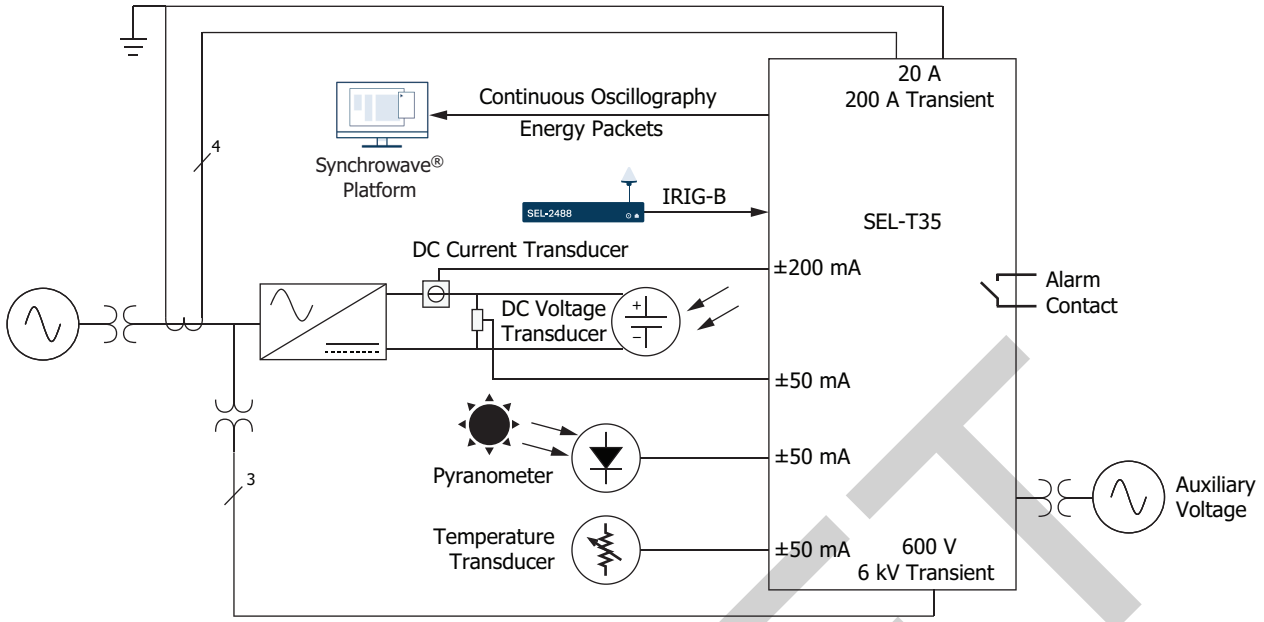


Figure 2 Functional Diagram

Table 1 Inputs and Outputs (Sheet 1 of 2)

Terminals	Power Supply and I/O Board
A01–A02	Vac/Vdc power supply
A03–A06	N/C (Future)
A07–A09	Form C alarm contact
A10–A12	Two universal digital inputs
A13–A14	Auxiliary voltage input
Terminals	**Data Acquisition Board**
Z01–Z08	Four current inputs

Table 1 Inputs and Outputs (Sheet 2 of 2)

Z09–Z12	Three voltage inputs plus neutral
Terminals	**Communication and Analog Input Board**
Port 1	Ethernet Port 1
Port 2	Ethernet Port 2
Port 3	EIA-232/EIA-485 Serial Port 1
Port 4	EIA-232/EIA-485 Serial Port 2
D01–D02	One ±200 mA analog inputs
D03–D08	Three ±50 mA analog input

Features

Energy Packet Streaming

The SEL-T35 calculates single-phase and three-phase energy flow integrated every 1 ms. Industry-exclusive energy packet technology from SEL precisely reports energy flow under all system conditions regardless of frequency, angle, or distortion. This time-domain view provides insight into bidirectional energy transfer, reverse power flow, and sub-cycle oscillations.

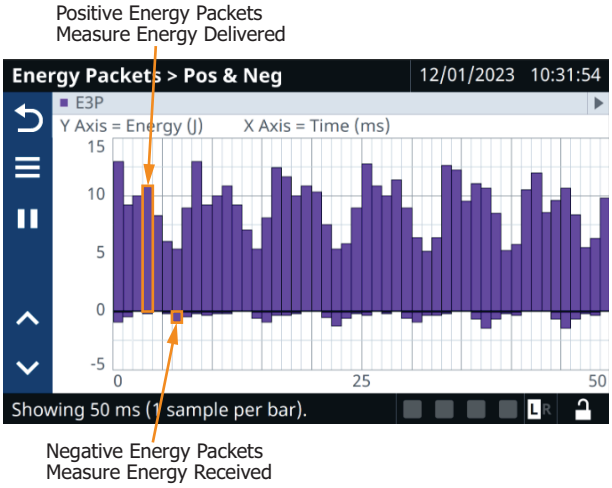


Figure 3 Front-Panel Energy Packets View

Time-domain calculations enable precise estimation of energy transfer for non-linear systems, independent of frequency, angle, or signal distortion. Positive energy packets represent energy delivered to the load. Negative energy packets represent the energy received from the load. Negative energy packets can indicate reduced system capacity and increased losses because of energy returning from the load to the source, historically referred to as volt-ampere reactive power (VARs).

The SEL-T35 streams 1 ms energy packets with precise time to Synchrowave Monitoring and Synchrowave Operations. Use this information to gain insight into bidirectional energy transfer, reverse power flow, subcycle oscillations, and contributors to lost capacity. Operators can clearly identify load changes such as motor starts, inverters cycling, and inrush events.

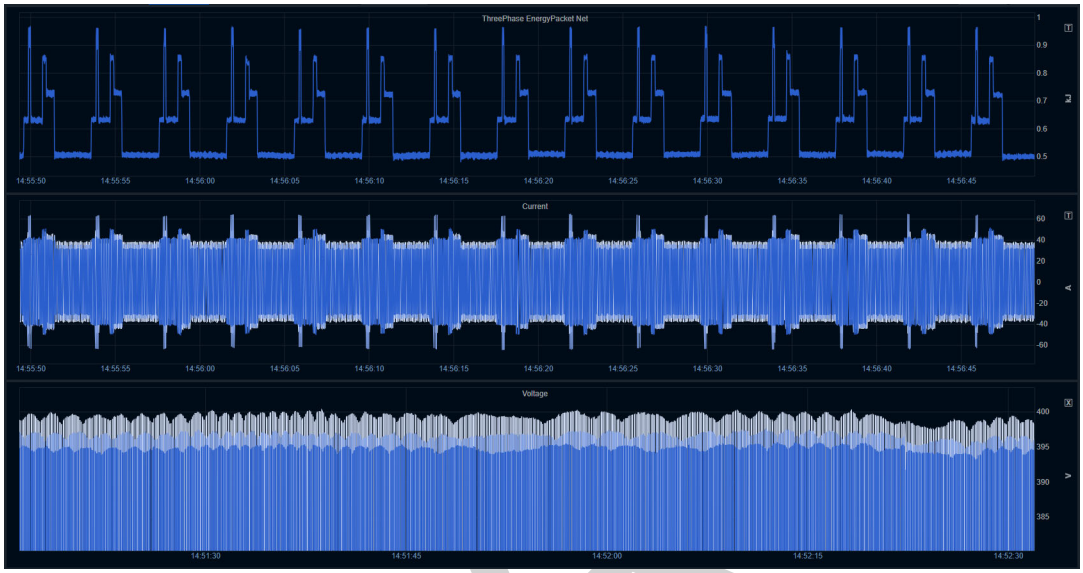


Figure 4 Energy Packet Data

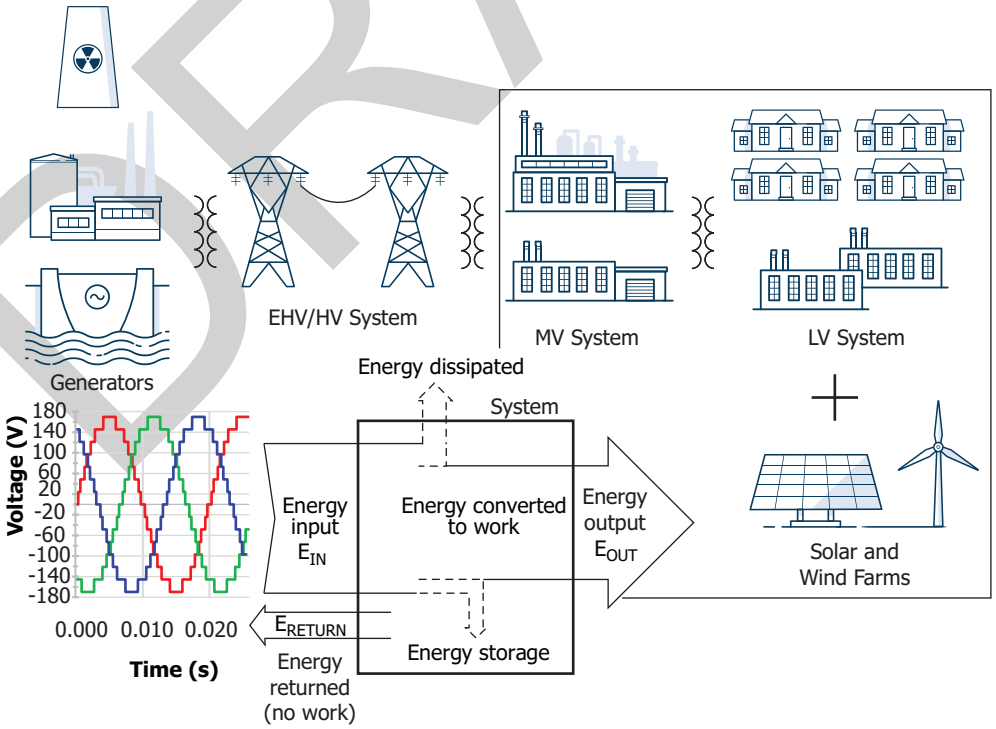


Figure 5 Electric Energy Flow Model

Time-domain energy packet information provides high-resolution insights with 1 ms determinism. SCADA systems only exchange indeterministic time-averaged measurements every few seconds. These fast energy packet calculations help identify power oscillations that are not visible at traditional SCADA speeds.

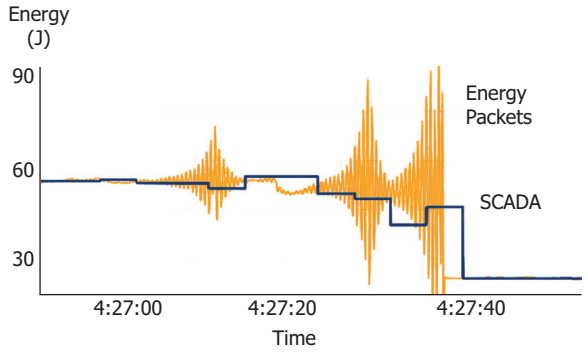


Figure 6 1 ms Energy Measurements Capture System Oscillations

Front-Panel Wave View and Energy Packets

Just like an oscilloscope, the SEL-T35 plots sampled voltage, current, and energy packet measurements on the front-panel touchscreen. Immediately see changes to a power system during switching operations, load transfer, and commissioning tests. Energy packet technology provides a unique view into sub-cycle energy transfer. The SEL-T35 measures every joule of energy exchanged in real time.

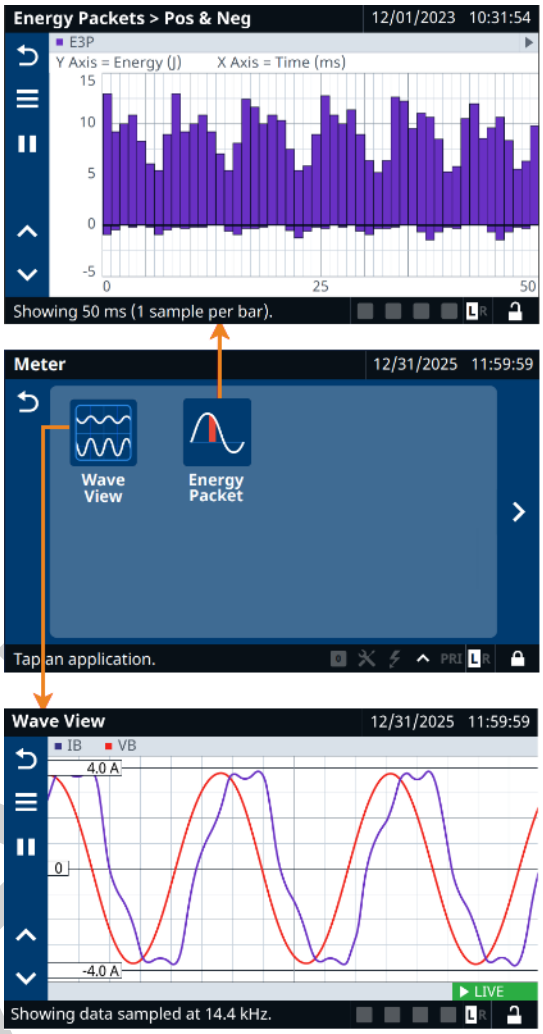


Figure 7 Color Touchscreen Wave View and Energy Packets

DC Transducer Support

Four mA-level analog current inputs coupled with third-party transducers measure outputs from dc transducers including dc voltage, dc current, temperature, and solar irradiance.

Figure 8 Pyranometer Luminance Sensor Output Displayed in Synchrowave Monitoring

Auxiliary Voltage Input

The 300 V ac/dc universal voltage input accepts ac or dc measurements for measuring power supply voltage, bus voltage, UPS battery voltage, or other power sources. The 14.4 ksps data stream includes this voltage channel for visibility within Synchrowave software.

Synchrowave Software Integration

Wide-Area Streaming

The SEL-T35 streams voltage and current waveforms sampled at 14.4 ksps and energy packet data every 1 ms to clearly display power system behavior at one measurement point or across an entire network of measurement locations. View live ac voltage, ac current, and dc sensor waveforms in Synchrowave Operations or Synchrowave Monitoring.

Never Miss an Event

Conventional power monitors depend on phasor-based calculations to detect faults and disturbances, but energy flow changes faster than once per cycle-the typical measurement rate of these devices. Kilosample per second (ksps) time-domain measurements expose power system disturbances that traditional power monitors do not typically capture, allowing you to take immediate action.

Monitoring devices, including protective relays and power quality meters, capture several cycles of waveform disturbance data based on predefined event conditions. Synchrowave Monitoring and Synchrowave Operations software running on a local PC or centralized server can continuously record waveform streams from the SEL-T35.

Power system disturbances become less predictable as more distributed energy resources and nonlinear loads connect to the power system and these monitoring devices may fail to identify an event such as voltage oscillations. Additionally, disturbances like voltage sags on distribution circuits can last longer than the waveform recording window, and traditional recording devices may fail to capture the event. The SEL continuous oscillography streaming and recording system provides years of gapless 14.4 ksps recording of voltage, current, and energy transfer, so you never miss an event.

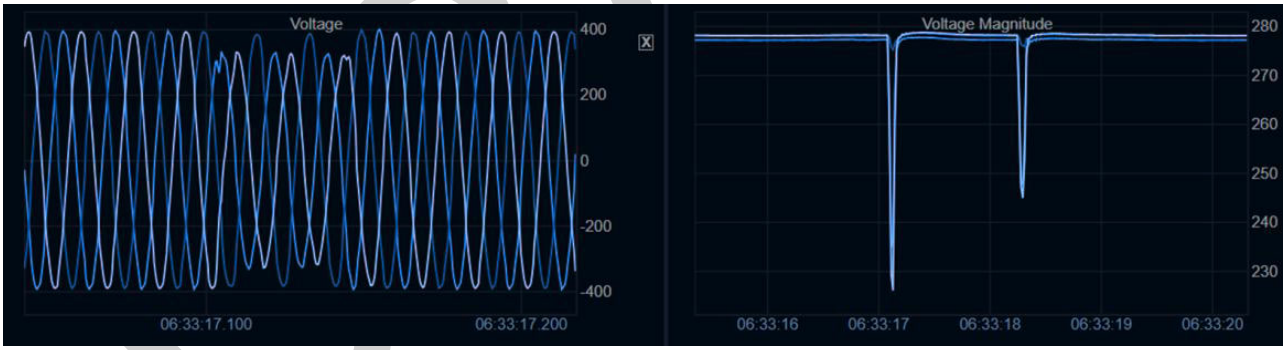


Figure 9 Capture All Voltage Disturbances Regardless of Magnitude

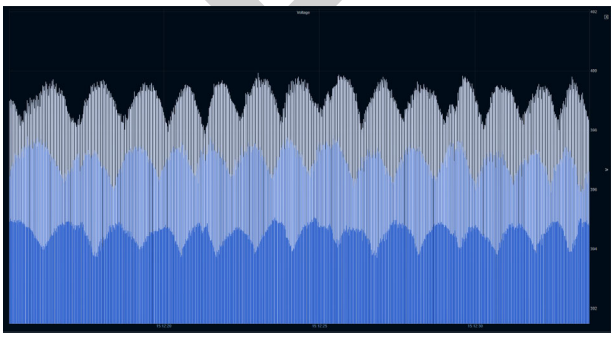


Figure 10 Voltage Ripple Caused by Varying Load

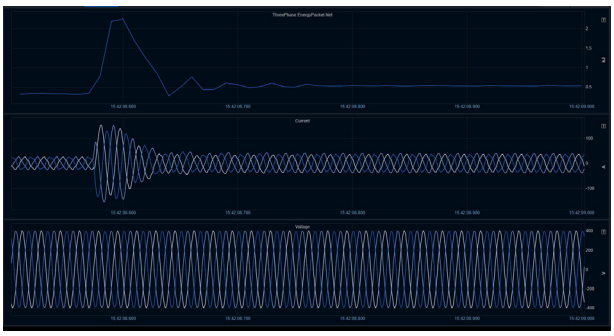


Figure 11 Visualize the Energy Required to Start a Motor

Table 2 describes the network bandwidth and server storage required to support real-time streaming installations with an SEL-T35 at 14.4 ksps.

Table 2 Network Bandwidth and Storage Requirements

# of Channels	Streaming Rate (ksps)	Network Bandwidth (Mbps)	GB/Day of Storage
1	14.4	0.9	5
7	14.4	6.2	35
400	14.4	353	875

Diagrams and Dimensions

The SEL-T35 mounts into existing SEL-2400/SEL-700 series cutouts but with a chassis depth extended by 39.2 mm (1.54 in). A maximum of two SEL-T35 power monitors can mount side-by-side in a 19" rack with the 915900051 5U mounting plate.

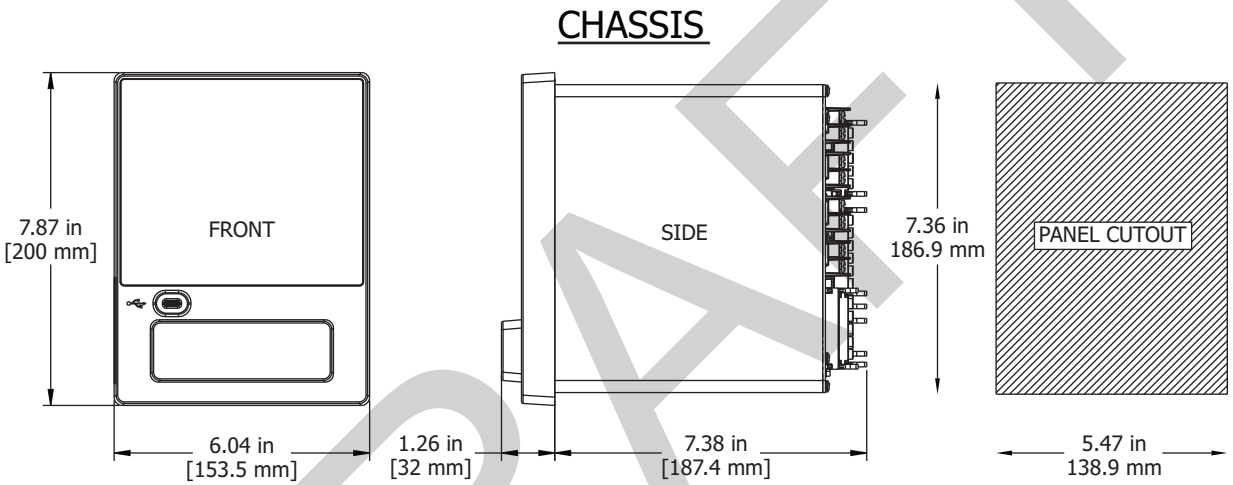


Figure 12 SEL-T35 Dimensions

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system
IEC 61010-1:2017 + CORR1:2019
IEC 61010-2-030:2023
IEC 61010-2-201:2017
UL 61010-1:2019
UL 61010-2-030:2018
UL 61010-2-201:2022
CSA C22.2 No. 61010-1-12:2018
CSA C22.2 No. 61010-2-030:2018
CSA C22.2 No. 61010-2-201:2018
PMD Standards:
IEC 61557-12:2021 + AM1:2022 + CORR1:2022
PMD-I, Class 0.1

General

Voltage Inputs

Measurement Category:	III
Maximum Rating:	600 V_{L-N}, 1039 V_{L-L} continuous 6000 V for 0.5 ms

Alternating Current Inputs

Range:	0.010–22 A
Maximum Rating:	22 A continuous
Thermal Limits:	500 A for 1 s 100 A for 25 s
Burden:	0.5 VA

Milliampere Direct Current Inputs

Channel	Measurement Range	Continuous Thermal Limit	Nominal Burden	Cutoff Frequency
1	±200 mA	±500 mA	2 ohms	5 kHz–3 dB
2, 3, 4	±50 mA	±75 mA	13 ohms	5 kHz–3 dB

Universal Voltage Input

Channel	Measurement Range
V_{AUX}	10–300 Vac/dc

Power Supply

Power Consumption:	35 W, 85 VA
Rated Input US:	110–277 Vac
Input Voltage Range:	85–300 Vac (80–108% of rating)
Mains Frequency:	50/60 ± 5 Hz
AC Ripple on DC Mains:	15% of rated dc value 100/120 Hz per IEC 61000-4-17
Interruption:	>7 second ride-through

Communications I/O

Two independent 100/1000BASE-T RJ45 Ethernet ports
Two independent EIA-232/EIA-485 serial ports with RJ45 connectors
USB-C front port
Demodulated IRIG-B time-code input

Communications Protocols

1 ksps energy packets (modified IEEE C37.118 protocol)
14.4 ksps wave streaming (modified IEEE C37.118 protocol)

Optoisolated Control Inputs

Externally Wetted Optoisolated Binary Inputs

Rated Range:	24, 48, 110, 125, 220, and 250 Vdc/Vac, setting selectable
Minimum Current Draw:	1.5 mA
Pickup Time:	2 ms plus ±1 ms (24–250 Vac) 2 ms plus ±1 ms (48–250 Vdc) 4 ms plus ±1 ms (24 Vdc)
Dropout Time:	10 ms plus ±1 ms (24–250 Vac) 2 ms plus ±1 ms (48–250 Vdc) 4 ms plus ±1 ms (24 Vdc)

Nominal Voltage AC/DC	Deassertion Range (±5%)		Assertion Range (±5%)	
	V_{DC} (V)	V_{AC} (V)	V_{DC} (V)	V_{AC} (V)
24 V	0.0–14.4	0.0–10.1	19.2–30.0	16.8–26.4
48 V	0.0–28.8	0.0–20.2	38.4–60.0	33.6–52.6
110 V	0.0–66.0	0.0–46.2	88.0–132.0	77.0–116.2
125 V	0.0–75.0	0.0–52.5	100.0–156.2	87.5–137.5
220 V	0.0–132.0	0.0–92.4	176.0–264.0	154.0–232.3
250 V	0.0–150.0	0.0–105	200.0–300.0	175.0–264.0

Form C Electrical Alarm Outputs

Ratings determined by IEC 60255-23:1994

Standard (Electromechanical)
250 Vac, 30 Vdc, 3 A resistive

Make:	30 A per IEEE C37.90-1989 3.6 kVA, Cos ϕ = 0.3
Break Rating:	360 VA, Cos ϕ = 0.3

Breaking Capacity (10000 operations):

24 V	0.75 A	L/R = 40 ms
48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

Carry:	3 A at 120 Vac, 50/60 Hz 1.5 A at 240 Vac, 50/60 Hz 50 A for 1 second
Durability:	>10,000 cycles at rated conditions
Pickup/Dropout Time:	<16 ms
Maximum Operating Voltage (Ue):	250 V
Current (Ie):	3 A
Rated Insulation Voltage (Ui) (Excluding EN 61010):	300 V

Operating Temperature

System Operating Temperature:	–40° to +85°C (–40° to +185°F)
Display Visibility Temperature:	–30° to +85°C (–22° to +185°F)

Operating Environment

Ingress Protection Rating:	Front: IP41. IP54 with optional gasket and USB-C port cover. Rear: IP20. IP50 with optional dust protection assembly and 10°C temperature derating. Part number 915900170.
Maximum Humidity:	95% RH non-condensing, 35°C dewpoint

Dimensions

Refer to *Figure 12* for power monitor dimensions.

Weight

3.63 kg (8 lb) maximum

Processing Specifications

AC Voltage and Current Inputs:	14.4 ksps
DC Analog Inputs:	14.4 ksps

Monitoring

Accuracy

AC Voltage Accuracy at 120 Vac and 40–70 Hz

Single-Point 14.4 ksps Continuous Waveform Stream:	0.2%
10/12-Cycle (200 ms) rms Voltage Calculated in Synchrowave:	0.06%

AC Current Accuracy at 2.5 A ac and 40–70 Hz

Single-Point 14.4 ksps Continuous Waveform Stream:	0.2%
10/12-Cycle (200 ms) rms Voltage Calculated in Synchrowave:	0.06%

Universal AC/DC Voltage Input Accuracy at 120 Vac

Single-Point 14.4 ksps Continuous Waveform Stream:	0.5%
10/12-Cycle (200 ms) rms Voltage Calculated in Synchrowave:	0.2%

DC Current Input Accuracy

± 50 mA Input

Single-Point 14.4 ksps Continuous Waveform Stream:	1% ± 50 µA
200 ms Average Current Calculated in Synchrowave:	0.2% ± 50 µA

± 200 mA Input

Single-Point 14.4 ksps Continuous Waveform Stream:	1% ± 200 µA
200 ms Average Current Calculated in Synchrowave:	0.2% ± 200 µA

Energy Packet Accuracy at 120 Vac and 2.5 A ac

1 ms Single-Point Stream:	0.1%
200 ms Average Current Calculated in Synchrowave:	0.06%

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Technical Support

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

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Notes

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