SEL-3780

Test Point Voltage Sensor

Instruction Manual

20240229

SEL SCHWEITZER ENGINEERING LABORATORIES

PM3780-01

Part Number: PM3780-01

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Preface

Overview

This manual provides information and instructions for installing, setting, configuring, and operating the SEL-3780 Test Point Voltage Sensor. Included are detailed technical descriptions of the device and application examples.

Preface. Provides the manual overview, as well as safety and general information about the product.

Section 1: Introduction and Specifications. Introduces SEL-3780 features; summarizes functions and applications; lists device specifications, type tests, and ratings.

Section 2: Application. Provides an SEL-3780 application for a source transfer scheme.

Section 3: Installation and Connections. Provides product dimensions, installation instructions, and information about auxiliary contact connections. Explains the basic steps to install and connect the SEL-3780.

Section 4: Calibration, Setup, and Test. Provides steps to calibrate the SEL-3780 to test points and get the device operational.

Appendix A: Firmware and Manual Versions. Lists the current manual version and details differences between the current and previous versions.

Appendix B: Calibration Details, Voltage Tracking, and Event Detection. Describes details on calibration, voltage tracking, and event detection for the SEL-3780.

Safety Information

Dangers, Warnings, and Cautions

This manual uses three kinds of hazard statements, defined as follows:

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

⚠WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, **may** result in minor or moderate injury or equipment damage.

Safety Symbols

The following symbols are often marked on SEL products.

	**⚠CAUTION** Refer to accompanying documents.	**⚠ATTENTION** Se reporter à la documentation.
	Earth (ground)	Terre
	Protective earth (ground)	Terre de protection
	Direct current	Courant continu
	Alternating current	Courant alternatif
	Both direct and alternating current	Courant continu et alternatif
	Instruction manual	Manuel d'instructions

Safety Marks

The following statements apply to this device.

General Safety Marks

⚠CAUTION To ensure proper safety and operation, the equipment ratings, installation instructions, and operating instructions must be checked before commissioning or maintenance of the equipment. The integrity of any protective conductor connection must be checked before carrying out any other actions. It is the responsibility of the user to ensure that the equipment is installed, operated, and used for its intended function in the manner specified in this manual. If misused, any safety protection provided by the equipment may be impaired.	**⚠ATTENTION** Pour assurer la sécurité et le bon fonctionnement, il faut vérifier les classements d'équipement ainsi que les instructions d'installation et d'opération avant la mise en service ou l'entretien de l'équipement. Il faut vérifier l'intégrité de toute connexion de conducteur de protection avant de réaliser d'autres actions. L'utilisateur est responsable d'assurer l'installation, l'opération et l'utilisation de l'équipement pour la fonction prévue et de la manière indiquée dans ce manuel. Une mauvaise utilisation pourrait diminuer toute protection de sécurité fournie par l'équipement.
Conditions of Acceptability An I/O cable terminal block compliant with IEC 60255-27:2013 is provided by the end user. SEL-3780 is evaluated to IEC 60255-27:2013 for spread of fire only. SEL-3780 is not intended to be accessed in normal use.	Conditions d'acceptabilité Un bornier de câble d'E/S conforme à la norme CEI 60255-27:2013 est fourni par l'utilisateur final. SEL-3780 est évalué selon la norme CEI 60255-27:2013 pour la propagation du feu uniquement. SEL-3780 n'est pas destiné à être accessible dans le cadre d'une utilisation normale.
For use in External Pollution Degree 4 environment.	Pour utilisation dans un environnement de Degré de Pollution Externe 4.
The SEL-3780 does not have any field-serviceable parts. Return a faulty or failed unit to the factory for repair or replacement.	Le SEL-3780 ne comporte aucune pièce remplaçable sur le terrain. Renvoyer une unité défaillante à l'usine afin de la réparer ou la remplacer.
Overvoltage Category: III	Catégorie de surtension : III
For use on a flat surface of a Type 3R enclosure.	Pour utilisation sur une surface plane d'un boîtier de Type 3R.
IP Rating Control Box: IPX8 Phase Sensors: IP67 See product specifications for additional ratings.	Indice IP Boîte de contrôle : IPX8 Capteurs de phase : IP67 Voir les spécifications du dispositif pour des indices supplémentaires.
Contact Rating Maximum Rated Voltage: 300 Vac/300 Vdc Maximum Continuous Contact Current: 3 A	Valeur nominale de contact : Tension nominale maximale : 300 Vca/300 Vcc Courant continu maximal de contact : 3 A

Other Safety Marks

⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	**⚠DANGER** Mettre hors tension ou débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	**⚠DANGER** Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	**⚠AVERTISSEMENT** L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	**⚠AVERTISSEMENT** Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser, blesser d'autres personnes ou endommager l'équipement.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	**⚠AVERTISSEMENT** Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING Incorporated components, such as LEDs and transceivers are not user serviceable. Return units to SEL for repair or replacement.	**⚠AVERTISSEMENT** Les composants internes tels que les leds (diodes électroluminescentes) et émetteurs-récepteurs ne peuvent pas être entretenus par l'usager. Retourner les unités à SEL pour réparation ou remplacement.
⚠CAUTION Do not connect power to the SEL-3780 until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	**⚠ATTENTION** Ne pas mettre le SEL-3780 sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.
⚠CAUTION For use in an access-controlled environment.	**⚠ATTENTION** Pour l'utilisation dans un environnement à accès contrôlé.

General Information

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

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SECTION 1

Introduction and Specifications

Overview

The SEL-3780 Test Point Voltage Sensor detects voltage loss from three test points and indicates the voltage loss status of the distribution circuit with a single output contact. The sensor provides status via an auxiliary contact to the relay in a pad-mount or underground distribution switchgear.

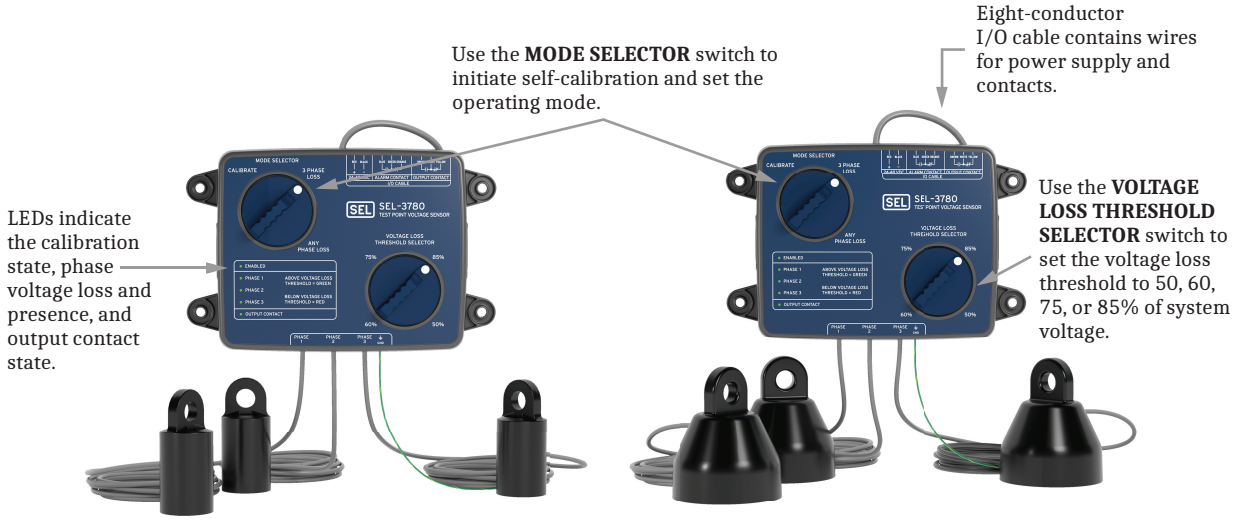

Figure 1.1 SEL-3780 Overview

Features

- Three sensors for test points. Ordering option specifies a set of three sensors for basic insulating plugs (BIPs) or a set of three sensors for capacitive test points.
- Control box with user interface.
- Two selector switches to set the mode and voltage loss threshold.
  - One **MODE SELECTOR** switch:
    - **CALIBRATE**
    - **3 PHASE LOSS**
    - **ANY PHASE LOSS**
  - One **VOLTAGE LOSS THRESHOLD SELECTOR** switch. Choose 50, 60, 75, or 85 percent of nominal phase-to-ground voltage

- LED display with five bi-color LEDs
  - One **ENABLED** LED
  - Three **PHASE** LEDs
  - One **OUTPUT CONTACT** LED
- One Form C output contact to indicate voltage loss (*Table 3.1*)
- One Form C alarm contact to indicate alarm conditions (*Table 3.2*)
- Power supply with 24 to 48 Vdc input range
- One eight-conductor I/O cable
- Four mounting tabs
- One ten-foot 14 AWG stranded ground wire

Models

The complete ordering information is not provided in this instruction manual. See the latest SEL-3780 model options at selinc.com.

Options

- Three BIP sensors with 3.7 m (12 ft) cables
- Three BIP sensors with 6.1 m (20 ft) cables
- Three capacitive test point sensors with 3.7 m (12 ft) cables
- Three capacitive test point sensors with 6.1 m (20 ft) cables
- One 7.6 m (25 ft) eight-conductor I/O cable
- One 15.2 m (50 ft) eight-conductor I/O cable

Accessories

Contact your Technical Service Center or the SEL factory for additional detail and ordering information for the accessories listed in *Table 1.1*.

Table 1.1 SEL-3780 Orderable Accessories

Description	Part Number
Adapter Ring Kit for Capacitive Test Point	915900587
Magnet Mount Kit for SEL-3780 and RadioRANGER®	915900588
Sealing Kit for BIP	915900589
Magnetic Cable Guide (White)	MCG
Magnetic Cable Guide (Blue)	MCGB

Adapter Ring Kit for Capacitive Test Point: A set of three spare rubber adapter ring inserts to mechanically fit sensors on Elastimold capacitive test points.

Magnet Mount Kit for SEL-3780: A set of four high-strength rare earth magnets with screws, washers, nuts, and bushings to provide a mounting solution for magnetic steel pad-mount enclosures.

Sealing Kit for BIP: A set of three worm-gear clamps to seal sensors to each BIP.

Magnetic Cable Guides: SEL Magnetic Cable Guides keep sensor and I/O cables neat and secure. The cable guides are available in white or blue.

User Interface

The user interface of the SEL-3780 provides a simple way to quickly commission the sensor. Highly visible LEDs indicate calibration state, phase loss and presence, and output contact state. Magnetic selector switches communicate the mode and the voltage loss threshold to the hall effect sensors embedded within the SEL-3780.

Use the **MODE SELECTOR** switch to initiate self-calibration and select operating modes. Choose one of four voltage loss thresholds via the **VOLTAGE LOSS THRESHOLD SELECTOR** switch. The sensor automatically sets the voltage presence threshold (see *Figure B.1*).

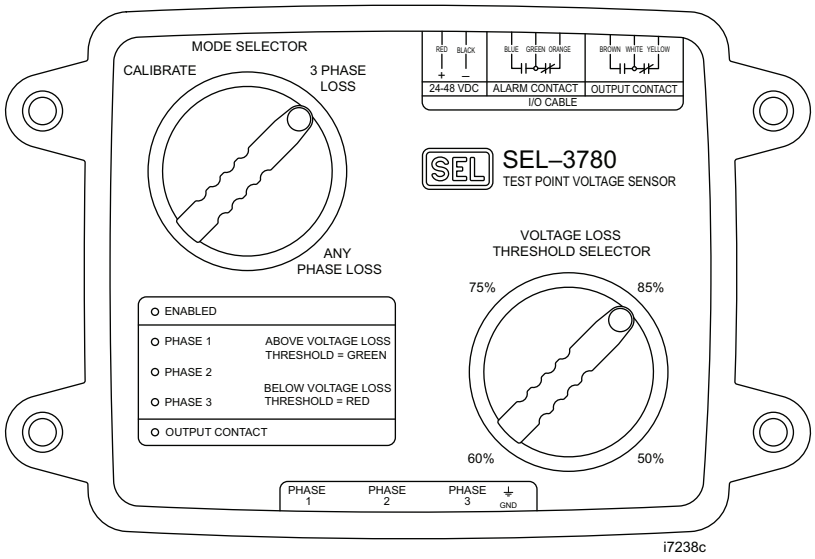

Figure 1.2 SEL-3780 User Interface

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

47 CFR 15B, Class A

Note: 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 to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

General

Compatibility

Separable Connector Voltage Ratings:	15 kV, 25 kV, 28 kV, and 35 kV_{L-L} per IEEE 386
Distribution System Voltage Range:	2.5 kV to 35 kV_{L-L} per IEEE 386
Separable Connector Types:	Elbow or T-Body per IEEE 386
Test Point Styles:	Capacitive Test Point BIP per IEEE 386
Overload Withstand:	Meets Maximum Voltage Ratings per IEEE 386

Power Supply

Start-Up Time:	≤10 s
Rated Supply Voltage:	24–48 Vdc
Power Consumption:	2.5 W maximum
Interruptions:	50 ms
Supply Fluctuations:	±10%

Operating Characteristics

Maximum Time for Self-Calibration:	≤30 s
Voltage Loss Threshold Settings:	50%, 60%, 75%, and 85%
Voltage Presence Threshold:	5% (±1%) above the selected voltage loss threshold setting
Operating Modes:	Voltage loss of any phase Voltage loss of three phases
Nominal System Frequency:	40–66 Hz
Voltage Loss Detection Time:	10 cycles (±2 cycles)
Voltage Presence Detection Time:	10 cycles (±2 cycles)

Output Contacts (Electromechanical)

The SEL-3780 supports two Form C output contacts for voltage loss indication (*Table 3.1*) and alarm (*Table 3.2*).

Mechanical Endurance:	10,000 operations
Maximum Rated Voltage:	300 Vac/300 Vdc
Maximum Continuous Contact Current:	3 A
Operating Time:	Pickup time: ≤10 ms Dropout time: ≤5 ms
Voltage Rating Across Open Contacts:	300 Vac/300 Vdc

Operating Temperature

SEL-3780 Test Point Sensor:	–40°C to +85°C (–40°F to +185°F)

Operating Environment

External Pollution Degree:	4
Relative Humidity:	5%–95%, noncondensing
Overvoltage Category:	3
Insulation Class:	Not Classified
Altitude:	5000 m

Weight

SEL-3780 Control Box:	<2.7 kg (<5.0 lb)

Dimensions

SEL-3780 Control Box:	168.7 mm x 254.5 mm x 62.2 mm (6.64 in x 10.02 in x 2.45 in)
SEL-3780 Sensor for BIP:	104.1 mm x 88.7 mm (4.10 in x 3.49 in)
SEL-3780 Sensor for Capacitive Test Point:	96.5 mm x 41.9 mm (3.8 in x 1.65 in)
I/O Cable Outer Diameter:	6.5 mm (0.256 in)
Ground Wire Diameter:	14 AWG
Ground Wire Length:	3.1 m (10 ft)

Type Tests

Electromagnetic Compatibility

Product Standards:	IEC 60255-26:2013 EN 60255-26:2013 KN 60255-26:2015 IEC 61000-6-2:2005 EN 61000-6-2:2005 IEC 61000-6-4:2006 + A1:2010 EN 61000-6-4:2007 + A1:2011
Emissions:	47 CFR Part 15.107, 109 ICES-001, Issue 5 KS C 9832:2015
Electrostatic Discharge:	IEC/EN 61000-4-2 IEEE C37.90.3 Contact Discharge: ±8 kV Air Discharge: ±15 kV
Surge Immunity:	IEC/EN 61000-4-5 ±2 kV L-L ±4 kV L-E
Surge Withstand Capability:	IEEE C37.90.1 2.5 kV Common and Transverse Oscillatory Test 4.0 kV Common and Transverse Fast Transient Test
Radiated RF Immunity:	EN 61000-4-3 10 V/m IEEE C37.90.2 20 V/m
Electrical Fast Transient Burst Immunity:	IEC 61000-4-4 4 kV at 5.0 kHz for all ports
Conducted RF Immunity:	IEC 61000-4-6 10 Vrms
Slow Damped Oscillatory Wave Immunity:	IEC/EN 61000-4-18 ±1 kV differential mode ±2.5 kV common mode
Power Frequency Magnetic Field Immunity:	IEC/EN 61000-4-8 IEEE 1613.1-2013 100 A/m for 60 seconds 1000 A/m for 3 seconds

Pulse Magnetic Field Immunity:	IEC/EN 61000-4-9 IEEE 1613.1-2013 1000 A/m
AC/DC Voltage Interruptions:	IEC/EN 61000-4-11 IEC/EN 61000-4-29
AC Component in DC (ripple):	IEC/EN 61000-4-17
Harmonics:	IEC/EN 61000-3-2
Flicker:	IEC/EN 61000-3-3

Environmental

Protection Ratings:	IPX8 for SEL-3780 control box IPX8 for sensors for BIP when used with worm gear clamp IP67 for sensors for BIP without clamp sensors IP67 for sensors for capacitive test points
Vibration (Sinusoidal):	IEC/EN 60255-21-1
Shock/Bump:	IEC/EN 60255-21-2
Seismic:	IEC/EN 60255-21-3
Cold:	IEC/EN 60068-2-1
Dry Heat:	IEC/EN 60068-2-2
Damp Heat Cyclic:	IEC/EN 60068-2-30
Damp Heat Steady State:	IEC/EN 60068-2-78

Safety

Product Standards:

Measuring Relays and Protection Equipment:	IEC 60255-27:2013 SEL-3780 is evaluated for spread of fire only EN 60255-27:2014
Dielectric Withstand:	IEC/EN 60255-27 IEC/EN 62850-3
Impulse Severity:	IEC/EN 60255-27 IEC/EN 61850-3
Insulation:	IEC 60255-27 IEEE C37.90-2005

Processing Specifications

Voltage Measurement Error:	≤2.5% of calibrated voltage
Filtering:	15-minute infinite impulse response filter
Dynamic Range:	≥50% to ≤150% of calibrated voltage
Tracking Warning Indication:	≥50% to <60% of calibrated voltage >140% to ≤150% of calibrated voltage

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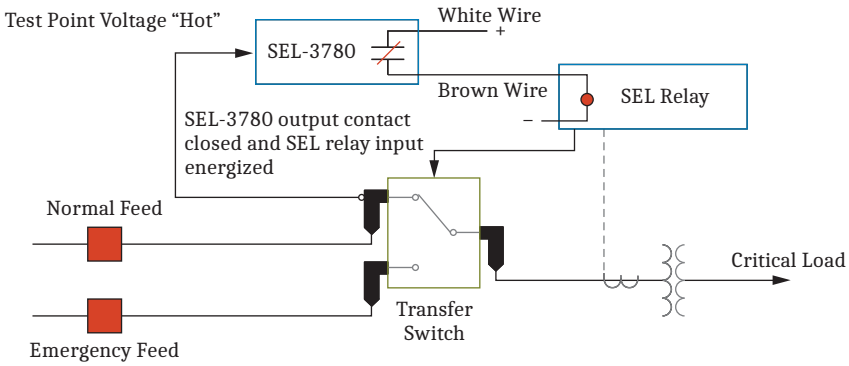
SECTION 2

Application

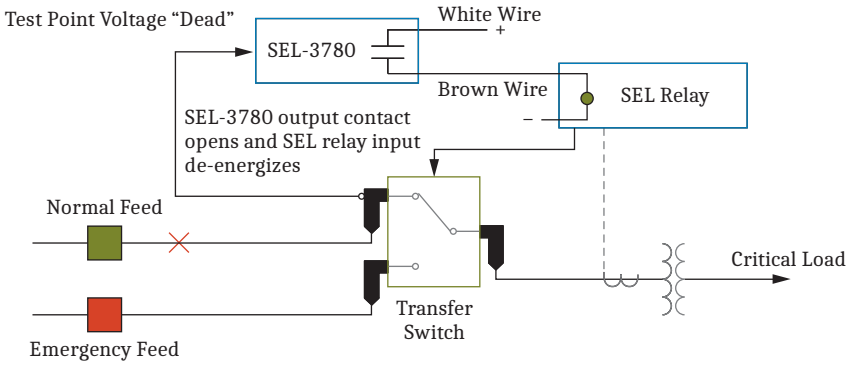
Source Transfer Scheme for Critical Loads

Use the SEL relay as the switch control in your source transfer scheme. Connect the output contact of the SEL-3780 to an input on the relay. When the relay detects an operation of the SEL-3780 output contact, indicating an outage of a primary distribution source, the relay initiates a source transfer to the emergency (secondary) source. Apply additional SEL-3780 sensors to each incoming source of the switch to provide redundant automation for outages of one or more sources. Apply a fault-sensing CT or sensor to the outgoing feed(s) of the switch to block source transfer into the faulted outgoing feed.

During normal conditions, the critical load is served by the normal feed.



When a fault occurs on the normal feed and breaker opens, the SEL-3780 output contact signals the SEL Relay that a loss of normal feed occurred.



When notified of a loss of normal feed, the SEL Relay switches the critical load to the emergency feed.

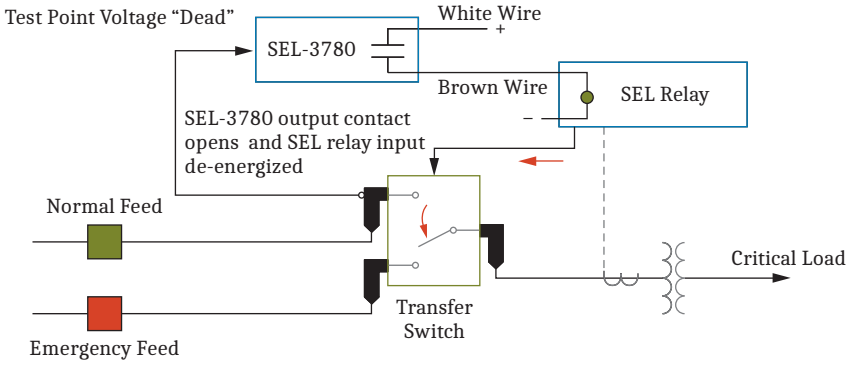


Figure 2.1 SEL-3780 Signals a Loss of Normal Feed and the Critical Load Switches

SECTION 3

Installation and Connections

Install the Control Box

IMPORTANT: You must ground the control box to minimize influence of nearby electromagnetic interference. Failure to do so may result in inadvertent operation.

IMPORTANT: To reduce SEL-3780 exposure to distribution switch electromagnetic interference, do not mount the control box on a distribution switch mechanism (see *Figure 3.1* and *Figure 3.2*). The SEL-3780 is hardwired with separate sensor cables, a ground wire, and an I/O cable that contains eight wires (see *Figure 3.1*, *Table 3.1*, and *Table 3.2*). Before mounting the control box, allow for sufficient cable length to safely train the sensor cables, ground wire, and I/O cable. Optional SEL Magnetic Cable Guides attach to the inside wall of a pad-mount enclosure to keep sensor and I/O cables neat and secure.

Use the optional magnet mount kit to magnetically attach the SEL-3780 to the inside of a pad-mount enclosure or fasten to a vault wall by using suitable screws. Identify a suitable location to mount the SEL-3780 control box. Suitable locations include the inside wall of the pad-mount enclosure and the wall next to a freestanding switch within a vault. Do not mount the control box on distribution switch mechanism (see *Figure 3.1* and *Figure 3.2*).

For dimension drawings, visit selinc.com.

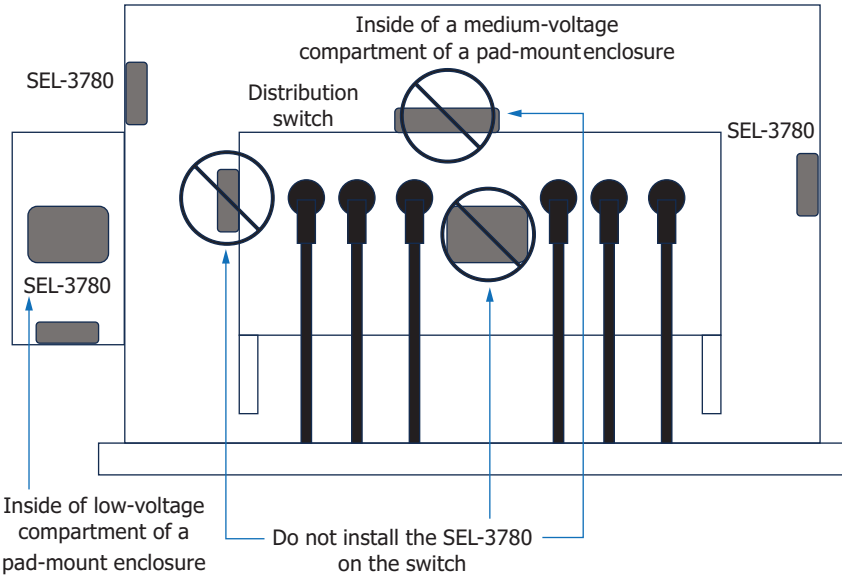


Figure 3.1 Installation of an SEL-3780 Within a Pad-Mount Enclosure

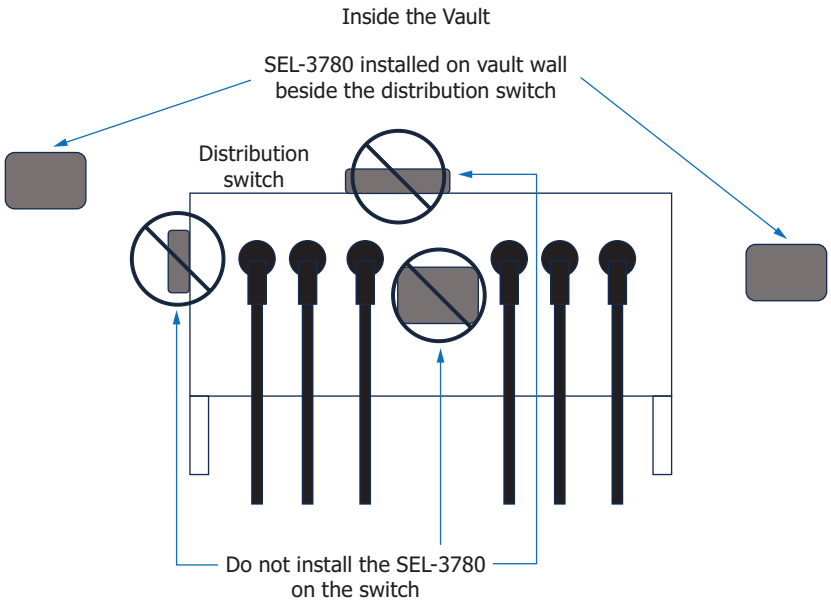


Figure 3.2 Installation of an SEL-3780 Within a Vault

Ground the Control Box

IMPORTANT: Do not coil the ground wire. Determine adequate length and trim excess ground wire to minimize SEL-3780 exposure to distribution switch electromagnetic interference.

Identify the nearby ground connection point, such as a ground rod or a ground cable that bonds the concentric neutral shield wires to ground. Trim the wire to the needed length while also ensuring it will not interfere with normal distribution equipment maintenance and operation. The SEL-3780 ground wire is a 14 AWG stranded wire. Securely connect the SEL-3780 ground wire with a connector or fastener to the grounding point.

Prevent Inadvertent Operation

The primary function of the output contact (see *Table 3.1*, *Figure 3.4*, and *Figure 3.5*) is to signal to a follow-on device (e.g., a relay) that there is a power system outage (or that voltage conditions are otherwise not healthy). The output contact could erroneously operate before all three phase sensors have been connected, before the operating mode has been selected, and before the SEL-3780 has been run through its field calibration routine. To prevent such an erroneous output contact operation from causing the final apparatus to inadvertently operate (e.g., transfer switch switches to emergency power feed), ensure that the follow-on device (or apparatus that the follow-on device operates) is prevented from operating via some kind of lockout/isolation means. Only when the following listed connection steps have been completed (including the field calibration routine; see *Section 4: Calibration, Setup, and Test*) can such lockout/isolation means be suspended and the SEL-3780 outage detection scheme be allowed to run normally.

Connect the Power Supply

NOTE: Observe proper polarity, as indicated by the color of the I/O cable wire: red positive dc input, black negative dc input.

NOTE: The contacts may operate when connecting the power supply. Follow the guidance to lockout/isolate the distribution equipment. See *Install the Control Box*.

Power the SEL-3780 with 24 to 48 Vdc. The I/O cable contains two power supply wires. The red wire is the positive dc input. The black wire is the negative dc input. It is important to connect the SEL-3780 power supply to an uninterruptable dc source, such as a battery or uninterruptible power supply (UPS), to ensure the SEL-3780 remains operational when a distribution outage occurs.

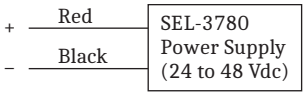


Figure 3.3 Power Supply Wires in I/O Cable

After start up, verify the **ENABLED** LED is one of the following:

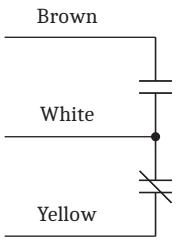
- Flashing red, indicating that the unit is uncalibrated (see *Section 4: Calibration, Setup, and Test* for instructions on how to do so)
- Solid green, indicating that the unit was previously calibrated. If this is a new installation (or something has changed in the existing installation, such as a new primary system elbow), perform the same calibration routine in *Section 4: Calibration, Setup, and Test*.

Connect the Contacts

The SEL-3780 has two Form C contacts: the output contact and the alarm contact.

Connect the output contact (see *Figure 3.4* and *Figure 3.5*) to a relay to communicate system voltage loss. The relay then decides what action to take (e.g., initiate a load transfer to an alternate source). Choose the applicable output contact (Normally Open or Normally Closed) depending on the logic requirements of the connected relay.

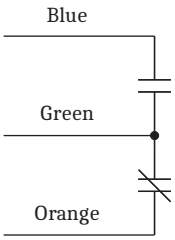
Table 3.1 Output Contact Connection, Type, and State

Wires in I/O Cable	Contact Type	Contact State	
		Asserted	Deasserted
	Normally Open (N.O.)	Closed	Open
	Normally Closed (N.C.)	Open	Closed

In general, the output contact (*Table 3.1*) will do one of the following:

- Asserts for healthy system voltage conditions.
- Deasserts for loss of voltage (based on the operating mode and voltage loss threshold).

Table 3.2 Alarm Contact Connection, Type, and State

Wires in I/O Cable	Contact Type	Contact State	
		Asserted	Deasserted
	Normally Open (N.O.)	Closed	Open
	Normally Closed (N.C.)	Open	Closed

When the SEL-3780 is energized and operating normally, the alarm contact (*Table 3.2*) is asserted.

The alarm contact deasserts if one of the following is true:

- A self-test failure is detected.
- The calibration routine is unsuccessful and the **MODE SELECTOR** switch is still in the **CALIBRATE** position (refer to the Unsuccessful Calibration table shown in *Figure 4.2*).
- A loss of dc power occurs (the SEL-3780 de-energizes).
- A voltage tracking warning occurs (see *Voltage Tracking Warning* on page 4.5).
- A voltage tracking error occurs (see *Voltage Tracking Error* on page 4.5).

Contact States

The following explains the contact states in *Table 3.1* and *Table 3.2*. See *Figure 4.2*, *Table 4.1*, and *Table 4.2* for contact states (asserted or deasserted) for the different operating modes of the SEL-3780.

- Asserted—The driving electronics/coil of the contact is energized, resulting in:
  - Normally Open contact is closed.
  - Normally Closed contact is open.
- Deasserted—The driving electronics/coil of the contact is de-energized, resulting in:
  - Normally Open contact is open.
  - Normally Closed contact is closed.

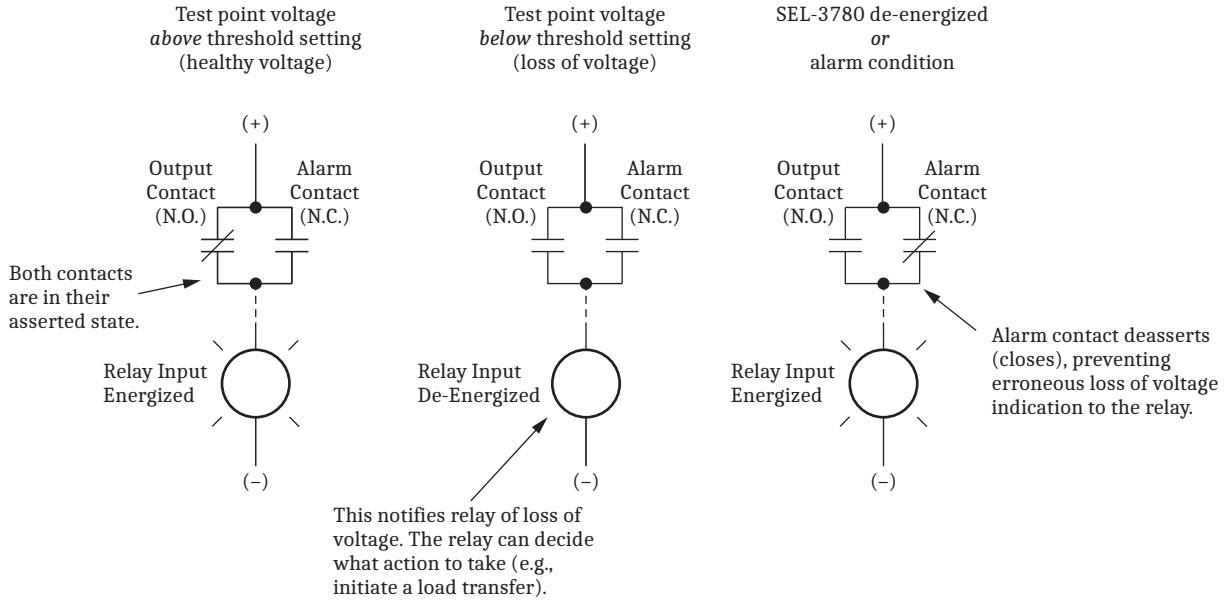
  This definition also applies when the SEL-3780 is de-energized.

Secure Loss of Voltage Indication

As discussed in the accompanying text for *Table 3.1*, the output contact deasserts to indicate a loss of power system voltage. This output contact deassertion can inform another device (e.g., SEL relay) of the loss of voltage condition, and this device can then take action, such as initiating a load transfer to a different feeder (see *Figure 2.1*).

If the SEL-3780 is de-energized or there is an alarm condition (see text accompanying *Table 3.2*), the output contact also deasserts and this causes an erroneous indication of a loss of voltage condition. To prevent this occurrence, wire an alarm contact into this loss of voltage indication circuit.

Figure 3.4 and *Figure 3.5* show the two options for connecting a secure loss of voltage indication circuit. *Figure 3.5* is a more "fail-safe" design, in that if there is loss of dc control voltage for the circuit (e.g., due to an open circuit somewhere in the wiring), the relay input remains de-energized and the relay perceives no loss of voltage indication (and thus takes no action).



Note: The parallel contact arrangement is used in the source transfer examples in ①.

① See *Figure 2.1*.

Figure 3.4 Parallel Output Contact (N.O.) and Alarm Contact (N.C.) for Secure Loss of Voltage Indication

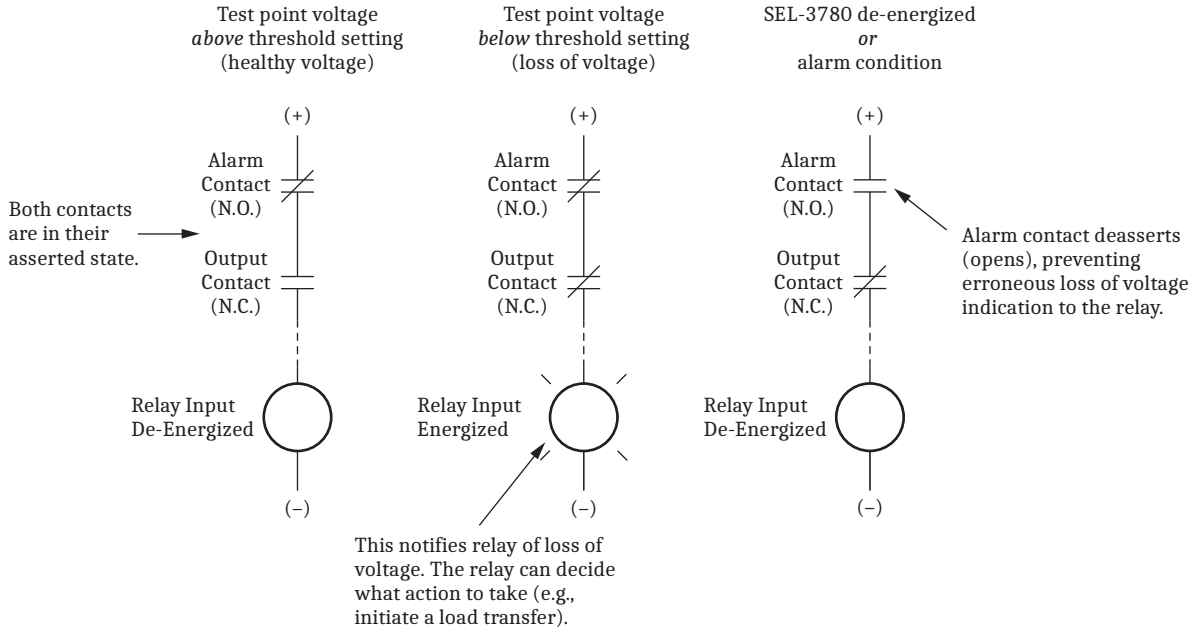


Figure 3.5 Series Output Contact (N.C.) and Alarm Contact (N.O.) for Secure Loss of Voltage Indication

If a calibration routine must be performed again later (see *Section 4: Calibration, Setup, and Test*), follow the instructions in *Install the Control Box* on page 3.1, regardless of whether the loss of voltage indication circuit is connected according to *Figure 3.4* or *Figure 3.5*. The following is a variation of this precautionary procedure:

- Wire a switch in parallel with the contacts in *Figure 3.4* and close the switch to prevent any erroneous indication of a loss of voltage condition.
- Wire a switch in series with the contacts in *Figure 3.5* and open the switch to prevent any erroneous indication of a loss of voltage condition.

Again, *Figure 3.5* is more of a "fail-safe" design, in that if there is loss of dc control voltage for the circuit (e.g., due to an open circuit somewhere in the wiring), the relay input remains de-energized and the relay perceives no loss of voltage indication (and thus takes no action).

Install the Phase Sensors

⚠CAUTION
Use in accordance with normal safe operating procedures. These instructions are not intended to replace or supersede existing safety or operating requirements. Only trained qualified personnel should install the phase sensors.

Test point phase sensors are hardwired to the control box as a three-phase set for capacitive test points or as a three-phase set for BIPs. For added safety, a hook eye molded into each phase sensor allows you to install the phase sensor by using industry-standard hot-line tools, such as a shotgun-style hot stick. Perform the following steps:

Step 1. Remove the protective cap from the test point.

Step 2. Clean and dry test point.

Step 3. Use a silicone dielectric grease to *lightly* coat the rubber portion of the separable connector termination.

IMPORTANT: Sensor cables are factory hardwired to the control box and phase sensors. Do not cut the sensor cables. Do not modify the length of the sensor cables.

Step 4. Install the phase sensors by mounting the rubber boot over the test point. Be careful not twist the boot more than necessary; doing so can cause the spring to contact the rubber boot, resulting in misoperation.

Step 5. Train and secure the phase sensor cables and the I/O cable to prevent accidental flashover from sources of high voltage during normal system operation and when high voltage is present during operation of the separable connector system.

Adapter Ring Installation

NOTE: You must install adapter rings in capacitive test point sensors before installing on Elastimold elbows with test points for the SEL-3780 to detect the presence of system voltage.

NOTE: Elastimold 15, 25, and 35 kV elbows with molded test points require the adapter rings. Complete Steps A–D.

Elbow capacitive test point size varies by manufacturer. SEL has created phase sensors that fit most elbow test points designed to IEEE 386. For Elastimold elbows with capacitive test points, insert the included adapter rings into each phase sensor to provide a physical fit and electrical compatibility.

Follow steps in *Figure 3.6* to install the adapter ring (if required).

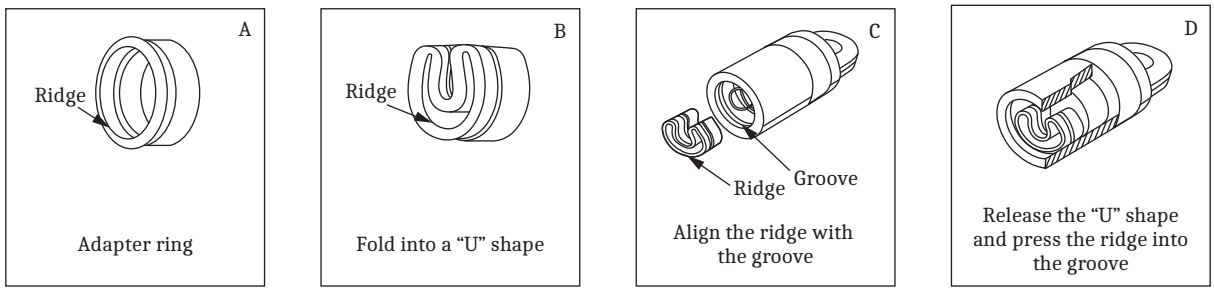


Figure 3.6 Adapter Ring Installation

Sealing Kit for BIPs

NOTE: Do not overtighten the clamp.

⚠CAUTION
Use in accordance with normal safe operating procedures. These instructions are not intended to replace or supersede existing safety or operating requirements. Only trained qualified personnel should use the sealing kit.

For subsurface applications where the BIP will be submerged underwater, use the sealing kit (915900589) for the BIP to seal the phase sensor to the BIP. Apply the stainless-steel clamp around phase sensor while it is installed on the BIP. Tighten the clamp until you see a slight compression around the band.

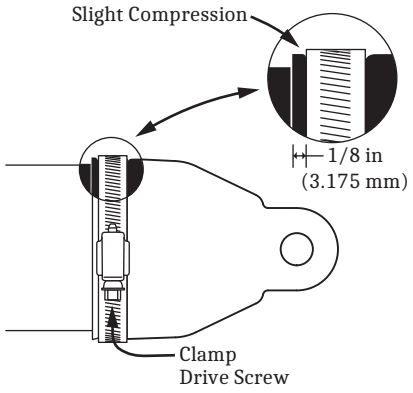


Figure 3.7 Applying the BIP Sealing Kit

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SECTION 4

Calibration, Setup, and Test

The SEL-3780 is settable through two selector switches on the user interface. Use the **MODE SELECTOR** switch to calibrate the sensors and set the operating mode. Use the **VOLTAGE LOSS THRESHOLD SELECTOR** switch to set the voltage loss threshold.

NOTE: The unit recognizes the **MODE SELECTOR** switch selection after approximately 2 seconds of delay.

The SEL-3780 has three operating modes: **CALIBRATE**, **3 PHASE LOSS**, and **ANY PHASE LOSS**. You can easily adapt to application needs by using the field-accessible user interface to access these configurable modes (see *Figure 4.1*).

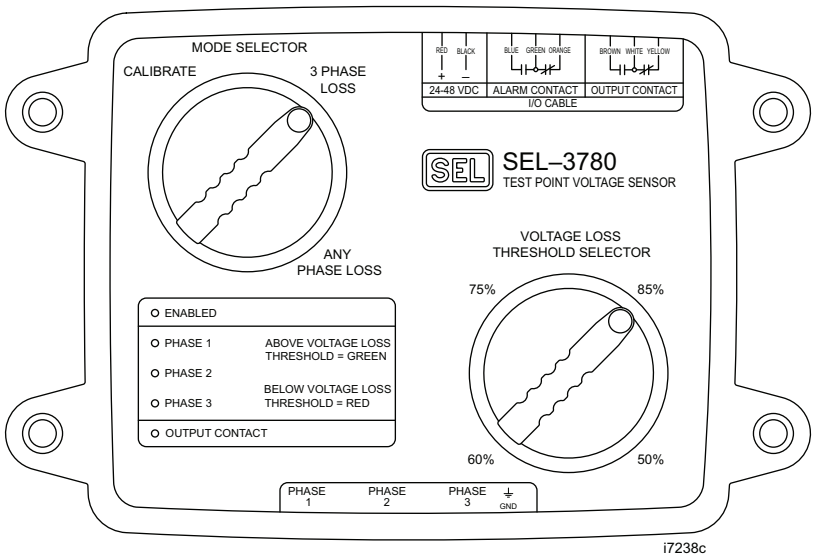


Figure 4.1 SEL-3780 Operating Modes and Threshold Settings

Calibrate the Sensor

NOTE: The contacts operate when the SEL-3780 switches into and out of the calibrate mode. Follow the guidance in *Install the Control Box* on page 3.1 to lockout/isolate the distribution equipment before and throughout calibration.

NOTE: Calibration typically completes within several seconds but may take as long as 30 seconds.

NOTE: The distribution elbows with test points must be energized to successfully calibrate the phase sensor.

NOTE: If the SEL-3780 was previously calibrated on a different system configuration, calibrate the unit to the new system configuration.

Phase sensors must be properly connected to the capacitive test point or BIP and the distribution elbow; see *Section 3: Installation and Connections*. The SEL-3780 must be turned on and distribution equipment must be energized to calibrate the SEL-3780. After turning on the SEL-3780, installing the phase sensors, energizing the distribution equipment, and setting the **MODE SELECTOR** switch, you must calibrate the sensor.

The SEL-3780 out of the box is in an uncalibrated state with the **MODE SELECTOR** switch set to **3 PHASE LOSS**. If the **MODE SELECTOR** switch is in the **CALIBRATE** position when the SEL-3780 starts up, the unit will *not* go through a calibration routine but will instead indicate on the front-panel LEDs its previous calibration status, which can be one of the following:

- Previously uncalibrated, as indicated by the flashing red **ENABLED** LED (refer to the Uncalibrated table shown in *Figure 4.2*)
- Previously calibrated, as indicated by the flashing green **ENABLED** LED (refer to the Successful Calibration table shown in *Figure 4.2*)

If you switch the **MODE SELECTOR** switch to **3 PHASE LOSS** or **ANY PHASE LOSS**, the front-panel LEDs appear as one of the following:

- Previously uncalibrated, as indicated by the flashing red **ENABLED** LED (refer to the Uncalibrated table shown in *Figure 4.2*)
- Previously calibrated, as indicated by the solid green **ENABLED** LED (refer to the Previously Calibrated table shown in *Figure 4.2*)

You must switch the **MODE SELECTOR** switch to the **CALIBRATE** position from another position to begin the calibration cycle. If the **MODE SELECTOR** switch is already in the **CALIBRATE** position, you must first turn the **MODE SELECTOR** switch clockwise to another mode (**3 PHASE LOSS** or **ANY PHASE LOSS**), remain in this position for more than 2 seconds, then turn the **MODE SELECTOR** switch back (counterclockwise) to the **CALIBRATE** position to begin calibration. Turn the **MODE SELECTOR** switch counterclockwise to the **CALIBRATE** position to begin the calibration cycle. While in **CALIBRATE** mode, once calibrated, **PHASE 1**, **PHASE 2**, **PHASE 3**, and the **ENABLED** LED flash green to indicate successful calibration.

After an unsuccessful calibration attempt, the SEL-3780 will indicate the phase(s) that it was unable to calibrate to by flashing each **PHASE** LED red. If the SEL-3780 was unable to calibrate for other reasons, the **PHASE** LEDs will turn off. Refer to *Figure 4.2* for details on **CALIBRATE** mode LED behavior.

If the SEL-3780 loses its input dc power and then power is restored, the stored calibration set points in nonvolatile memory become the starting point for the average voltage calculation (discussed in *Voltage Tracking* on page B.2).

⚠CAUTION
Use in accordance with normal safe operating procedures. These instructions are not intended to replace or supersede existing safety or operating requirements. Only trained qualified personnel should calibrate the sensor.

If the SEL-3780 does not calibrate, use the following steps:

Step 1. Check that the test point and phase sensors are clean and free of debris.

Step 2. Remove and reapply any phase sensors with flashing red **PHASE** LED.

Step 3. Check that the system phase-to-ground voltage is within device specifications.

Step 4. Ensure that the elbow outer surface is solidly grounded.

Step 5. Attempt to recalibrate the device.

If the device will still not calibrate after performing all steps, refer to *Technical Support* on page ix in the *Preface*.

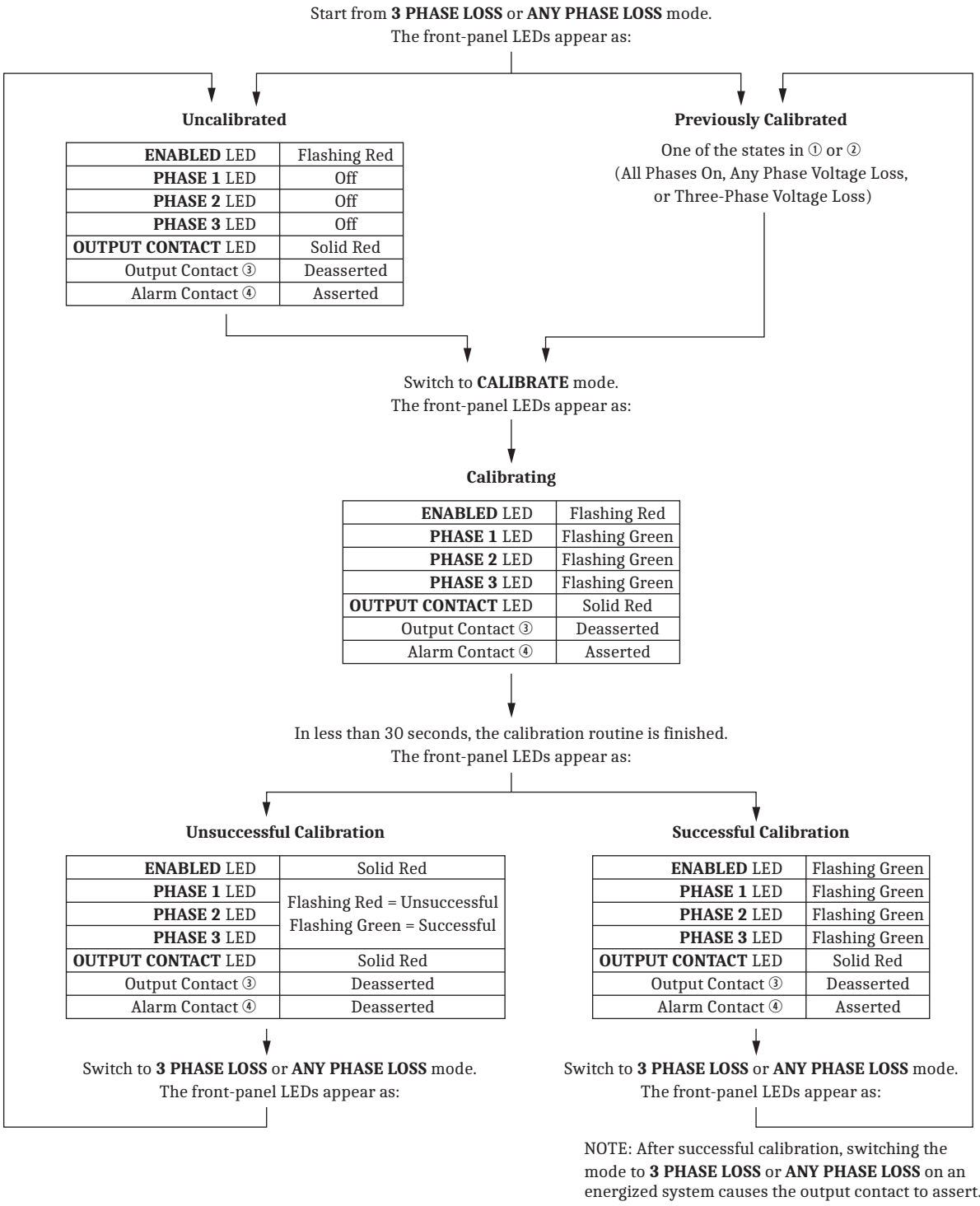
Set the Voltage Loss Threshold

The SEL-3780 voltage loss threshold setting is accessible via the **VOLTAGE LOSS THRESHOLD SELECTOR** switch. There are four voltage loss thresholds: 50, 60, 75, and 85 percent of phase-to-ground voltage. Only one voltage loss threshold can be active at any given time (see *Event Detection (Loss-of-Voltage/Low Voltage)* on page B.3). The voltage presence threshold is automatically set to 5 percent (±1%) above the voltage loss threshold. (e.g., when the voltage loss threshold equals 85 percent, the voltage presence threshold will nominally be 90 percent of the system voltage).

Use the **VOLTAGE LOSS THRESHOLD SELECTOR** switch to set the voltage loss threshold setting. Turn the **VOLTAGE LOSS THRESHOLD SELECTOR** switch clockwise or counterclockwise to one of the four voltage loss threshold settings.

The **VOLTAGE LOSS THRESHOLD SELECTOR** switch setting has no bearing on the calibration routine or subsequent voltage tracking. It only affects the voltage loss threshold calculation, which in turn determines if a loss-of-voltage or low-volt-

age event is detected (which affects the operation of the output contact shown in *Table 3.1* and the **PHASE** LEDs shown in *Table 4.1* and *Table 4.2*). Thus, the **VOLTAGE LOSS THRESHOLD SELECTOR** switch setting can be changed at any time.



① see *Table 4.1*; ② see *Table 4.2*; ③ see *Table 3.1*; ④ see *Table 3.2*.

Figure 4.2 Flowchart for the Calibration Process and the LED Behavior

Set the Operating Mode

NOTE: The device will not operate correctly if it is not successfully calibrated.

NOTE: *Appendix B: Calibration Details, Voltage Tracking, and Event Detection* provides background information concerning the calibration procedure and the subsequent normal operation of the SEL-3780. This appendix also explains the voltage tracking capability of the SEL-3780 and the resultant dynamic voltage loss threshold (and the effect of the **VOLTAGE LOSS THRESHOLD** setting).

After successful calibration, set the operating mode for normal operation. Once the operating mode is set, the SEL-3780 will indicate distribution voltage loss and presence via LEDs and the output contact.

The SEL-3780 has two operating modes: **3 PHASE LOSS** and **ANY PHASE LOSS**. To set the operating mode, turn the **MODE SELECTOR** switch clockwise or counterclockwise until the dot points to the intended operating mode and you feel the switch mechanically click into position.

If the SEL-3780 mode switch is set to one of the two operating modes and the alarm contact (see *Table 3.2*) has deasserted, note the operating mode and refer to *Technical Support* on page ix in the *Preface*.

Operating Mode

Any Phase Voltage Loss

When the **MODE SELECTOR** switch is set to **ANY PHASE LOSS**, any detected voltage loss less than the set threshold on any one or more phases causes the SEL-3780 to indicate the voltage loss. The following occurs (see *Table 4.1*):

- The **PHASE** LEDs turn solid red for phases that detect the loss.
- The **OUTPUT CONTACT** LED turns solid red.
- The output contact deasserts.

Table 4.1 ANY PHASE LOSS Mode—LED and Contact States

	All Phase On	Any Phase Voltage Loss	Three-Phase Voltage Loss
ENABLED LED	Solid Green	Solid Green	Solid Green
PHASE 1 LED	Solid Green	Note[a]	Solid Red
PHASE 2 LED	Solid Green	Note[a]	Solid Red
PHASE 3 LED	Solid Green	Note[a]	Solid Red
OUTPUT CONTACT LED	Solid Green	Solid Red	Solid Red
Output Contact[b]	Asserted	Deasserted	Deasserted
Alarm Contact[c]	Asserted	Asserted	Asserted

[a] Any voltage loss of less than three phase results in the corresponding PHASE LEDs (for phases that detect the loss) turning solid red while the other PHASE LEDs remain solid green.

[b] See *Table 3.1*.

[c] See *Table 3.2*.

Three-Phase Voltage Loss

When the **MODE SELECTOR** switch is set to **3 PHASE LOSS**, detected voltage loss that is less than the set threshold on all three phases causes the SEL-3780 to indicate the voltage loss. The following occurs (see *Table 4.2*):

- All **PHASE** LEDs turn solid red.
- The **OUTPUT CONTACT** LED turns solid red.
- The output contact deasserts.

Table 4.2 3 PHASE LOSS Mode—LED and Contact States

	All Phase On	Any Phase Voltage Loss	Three-Phase Voltage Loss
ENABLED LED	Solid Green	Solid Green	Solid Green
PHASE 1 LED	Solid Green	Note[a]	Solid Red
PHASE 2 LED	Solid Green	Note[a]	Solid Red
PHASE 3 LED	Solid Green	Note[a]	Solid Red
OUTPUT CONTACT LED	Solid Green	Solid Green	Solid Red
Output Contact[b]	Asserted	Asserted	Deasserted
Alarm Contact[c]	Asserted	Asserted	Asserted

[a] Any voltage loss of less than three phase results in the corresponding PHASE LEDs (for phases that detect the loss) turning solid red, while the other PHASE LEDs remain solid green.

[b] See *Table 3.1*.

[c] See *Table 3.2*.

Voltage Tracking Warning

While in any operating mode, the SEL-3780 alarms to indicate a voltage tracking warning when any of the following conditions are met (after a 60-second qualification time):

- The voltage is greater than 140 percent and less than or equal to 150 percent of the average voltage.
- The voltage is greater than or equal to 50 percent and less than 60 percent of the average voltage.
- These conditions cause the alarm contact to deassert and the **PHASE** LEDs corresponding to the tracking warning to flash red. The SEL-3780 continues to track voltage and monitors distribution system conditions for voltage loss.

Voltage Tracking Error

While in any operating mode, the SEL-3780 alarms to indicate a voltage tracking error when any of the following conditions are met (after a 60-second qualification time):

- The voltage is greater than 150 percent of the average voltage.
- The voltage is less than 50 percent of the average voltage.

These conditions cause the **ENABLED** LED to flash red, the alarm contact to deassert, and the **PHASE** LEDs corresponding to the tracking error to flash red. The SEL-3780 stops monitoring distribution system conditions for voltage loss until the error is addressed or the voltage conditions normalize.

A tracking warning or tracking error condition may indicate issues with the test point or system voltage. To solve these issues, use the following steps:

Step 1. Remove sensors and ensure the test points are clean and dry.

Step 2. If the sensors are for capacitive test points and the test point are Elastimold, ensure the adapter ring are correctly installed.

Step 3. Ensure that the phase sensor is the right type for the application. Capacitive test point sensors and BIP sensors are not interchangeable, so match BIP sensors with BIP and capacitive test point sensors with capacitive test points.

Step 4. Remove and reseat the phase sensors.

Step 5. Run the calibration procedure again. If the problem persists, contact technical support for assistance (see *Technical Support* on page ix in the *Preface*).

Self-Test Error

The SEL-3780 continuously monitors itself for internal errors. While in any operating mode, if the **OUTPUT CONTACT** LED is flashing red and all other LEDs are solid red, the device has experienced an internal error. Contact technical support for assistance (see *Technical Support* on page ix in the *Preface*).

Test the SEL-3780 (Optional)

⚠CAUTION
Use in accordance with normal safe operating procedures. These instructions are not intended to replace or supersede existing safety or operating requirements. Only trained qualified personnel should test the SEL-3780.

NOTE: For an installed and calibrated devices operating in the **3 PHASE LOSS** or **ANY PHASE LOSS** mode on an energized system, the output contact operates when one or more phase sensors are disconnected. Follow the guidance to lockout/isolate the distribution equipment. See *Install the Control Box* on page 3.1.

Successful testing of the SEL-3780 requires that the device is already calibrated, the operating mode is set to **3 PHASE LOSS** or **ANY PHASE LOSS**, and the distribution system is energized. Simulate voltage loss conditions by safely removing the phase sensors from test points. The **3 PHASE LOSS** mode requires all three phase sensors to be removed from test points to operate the output contact. The **ANY PHASE LOSS** mode requires at least one phase sensor to be removed from the test point to test the output contact.

Test 3 PHASE LOSS Mode

⚠CAUTION
Sealing clamps must be removed before testing phase sensors with basic insulating plugs (see *Figure 3.7*). If sealing clamps are already installed, de-energize the system and safely remove the sealing clamps before testing. Only trained qualified personnel should remove the phase sensors.

Step 1. Verify that the output contact is asserted and the **OUTPUT CONTACT** LED and the **PHASE** LEDs are solid green.

Step 2. Safely remove all three phase sensors from the test points.

Step 3. Verify that the output contact deasserts, the **OUTPUT CONTACT** LED and the **PHASE** LEDs are solid red.

Step 4. Reapply all three sensors.

Step 5. Verify that the output contact is asserted and the **OUTPUT CONTACT** LED and the **PHASE** LEDs are solid green.

If the output contact, **OUTPUT CONTACT** LED, or **PHASE** LEDs do not match the previous steps, contact technical support for assistance (see *Technical Support* on page ix in the *Preface*).

Test ANY PHASE LOSS Mode

⚠CAUTION
Sealing clamps must be removed before testing phase sensors with basic insulating plugs (see *Figure 3.7*). If sealing clamps are already installed, de-energize the system and safely remove the sealing clamps before testing. Only trained qualified personnel should remove the phase sensors.

Step 1. Verify that the output contact is asserted and the **OUTPUT CONTACT** LED and the **PHASE** LEDs are solid green.

Step 2. Safely remove the **PHASE 1** sensor from its test point.

Step 3. Verify that the output contact deasserts and the **OUTPUT CONTACT** LED and the **PHASE 1** LED are solid red.

Step 4. Reapply the **PHASE 1** sensor to the test point.

Step 5. Verify that the output contact is asserted and the **OUTPUT CONTACT** LED and the **PHASE** LEDs are solid green.

Step 6. Repeats *Step 2* through *Step 5* for the remainder of the phases.

If the output contact, **OUTPUT CONTACT** LED, or **PHASE** LEDs do not match the previous steps, contact technical support for assistance (see *Technical Support* on page ix in the *Preface*).

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APPENDIX A

Firmware and Manual Versions

Firmware

The firmware version number is after the R, and the date code is after the D. For example, the following is firmware version number R101, date code January 26, 2022.

FID=SEL-3780-R101-V0-Z000000-D20220126

Revision History

Table A.1 lists the firmware versions, revision descriptions, and corresponding instruction manual date codes. The most recent firmware version is listed first.

Items marked with "[Cybersecurity]" may affect cybersecurity in your application and should be evaluated for potential security impact.

Table A.1 Firmware Revision History

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-3780-R101-V0-Z000000-D20220126	➤ Initial version.	20220217

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.2 lists the instruction manual versions and revision descriptions. The most recent instruction manual version is listed first.

Table A.2 Instruction Manual Revision History (Sheet 1 of 2)

Date Code	Summary of Revisions
20240229	**Section 1** ➤ Updated *Figure 1.1: SEL-3780 Overview*. ➤ Updated *Features*. ➤ Updated *Figure 1.2: SEL-3780 User Interface*. ➤ Updated *Type Tests* in *Specifications*. **Section 3** ➤ Updated *Install the Control Box*. ➤ Added *Figure 3.1: Installation of an SEL-3780 Within the Pad-Mount Enclosure* and *Figure 3.2: Installation of SEL-3780 Within a Vault*. ➤ Added *Ground the Control Box*. ➤ Updated *Inside the Control Box*, *Connect the Contacts,* and *Install the Phase Sensors*.

Table A.2 Instruction Manual Revision History (Sheet 2 of 2)

Date Code	Summary of Revisions
	Section 4 ➤ Updated *Figure 4.1: SEL-3780 Operating Modes and Threshold Settings*.
20220831	**Section 1** ➤ Updated *Figure 1.1: SEL-3780 Overview*. ➤ Updated *Options* to include 15.2 m (50 ft) eight-conductor I/O cable.
20220520	**Preface** ➤ Updated *Overview*. **Section 1** ➤ Updated *Overview, Features, User Interface,* and *Specifications*. **Section 2** ➤ Added section. **Section 3** ➤ Updated *Inside the Control Box*, *Connect the Contacts,* and *Install the Phase Sensors*. **Section 4** ➤ Updated *Calibrate the Sensor, Set the Voltage Loss Threshold,* and *Set the Operating Mode.* ➤ Added *Test the SEL-3780 (Optional)*. **Appendix B** ➤ Updated *Calibration Routine Details and Normal Operation, Voltage Tracking* and *Event Detection (Loss-of-Voltage/Low Voltage).*
20220307	**Preface** ➤ Updated *General Safety Marks* and *Other Safety Marks*. **Section 1** ➤ Updated *Specifications*. **Appendix A** ➤ Added *Firmware*.
20220217	➤ Initial version.

APPENDIX B

Calibration Details, Voltage Tracking, and Event Detection

Calibration Routine Details and Normal Operation

The calibration routine shown in *Figure 4.2* simultaneously and independently calibrates each phase sensor to the attached test point. This independent calibration feature allows for different test point capacitances due to different elbow manufacturers, production variation, etc. Thus, if a particular elbow is later replaced, you must initiate the calibration routine again (performed on all three phases at the same time).

You must connect all three phase sensors to the energized test points for the calibration routine to execute successfully. The resultant calibration set points are stored in nonvolatile memory and thus are retained if the SEL-3780 loses its input dc power.

The calibration routine demonstrated in *Figure B.1* (only a single phase is shown) first consists of effectively averaging the power system voltage over a number of seconds (no longer than 30 seconds) and deriving an initial average voltage of 7.24 kV. This 7.24 kV value is effectively the calibration set point for the given phase. The derived calibration set points for the other two phases may be different because of primary system voltage differences amongst phases and the aforementioned test point capacitance variation.

After the calibration routine in *Figure B.1* successfully finishes, switch the **MODE SELECTOR** switch to either **ANY PHASE LOSS** or **3 PHASE LOSS** so that the SEL-3780 can operate normally (monitoring primary system voltage for occurrences of voltage loss/low voltage). With the **VOLTAGE LOSS THRESHOLD SELECTOR** switch set at 60 percent, the following occurs:

- Initial voltage loss threshold = 4.34 kV = (60% / 100%) • 7.24 kV (initial average voltage)
- 7.24 kV (initial actual voltage) > 4.34 kV (initial voltage loss threshold)
- The output contact shown in *Table 3.1* asserts, indicating normal conditions (no voltage loss/low voltage)

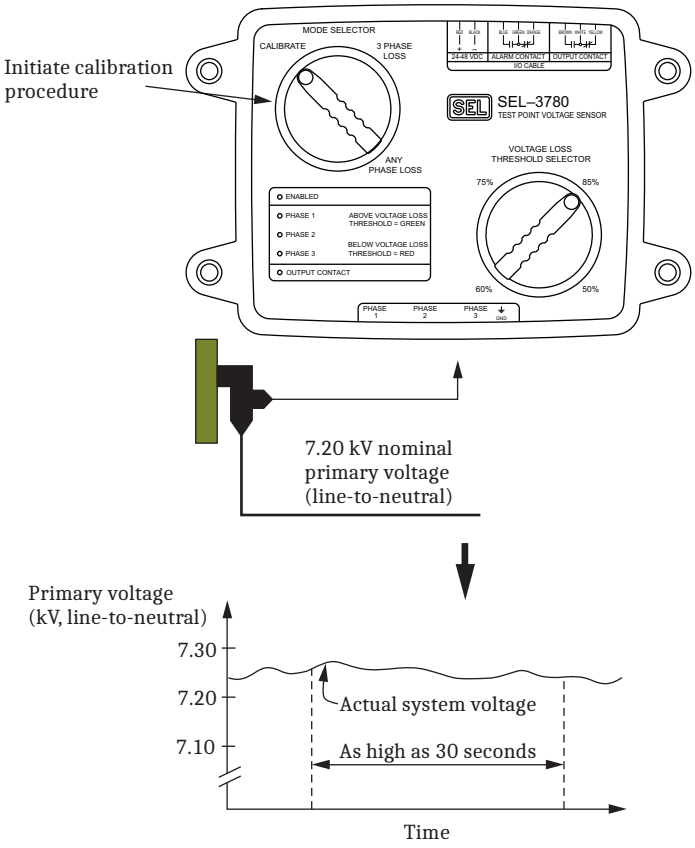

Figure B.1 Derive Calibration Set Point (Initial Average Voltage)

Voltage Tracking

Primary system voltage can vary throughout the day, month, or year because of loading, switching, capacitor bank connection, voltage regulator operation, etc. Thus, the average voltage (initially derived as 7.24 kV from the calibration procedure in *Figure B.1*) must be adjusted over time so that a realistic voltage loss threshold is always available. This is accomplished with a continuing average voltage calculation (after the calibration routine is finished) that more slowly adjusts to the change in primary system voltage. Any momentary or transient voltage change is effectively filtered out and does not affect this continuing average voltage calculation.

Figure B.2 shows the more slowly changing average voltage (starting at 7.24 kV from the calibration procedure in *Figure B.1*) that is governed by an effective time constant that adjusts to 95 percent of primary system voltage after 15 minutes. For demonstration purposes (not necessarily realistic), the primary system voltage is shown jumping from 7.24 kV to 7.50 kV (and remains at 7.50 kV). After 15 minutes, the following occurs:

- Average voltage at time t1 = 7.49 kV = 7.24 kV + (95% / 100%) • (7.50 kV – 7.24 kV)
- Voltage loss threshold at time t1 = 4.49 kV = (60% / 100%) • 7.49 kV (average voltage at time t1)

- 7.50 kV (actual voltage at time t1) > 4.49 kV (voltage loss threshold at time t1)
- The output contact shown in *Table 3.1* remains asserted, indicating normal conditions (no voltage loss/low voltage)

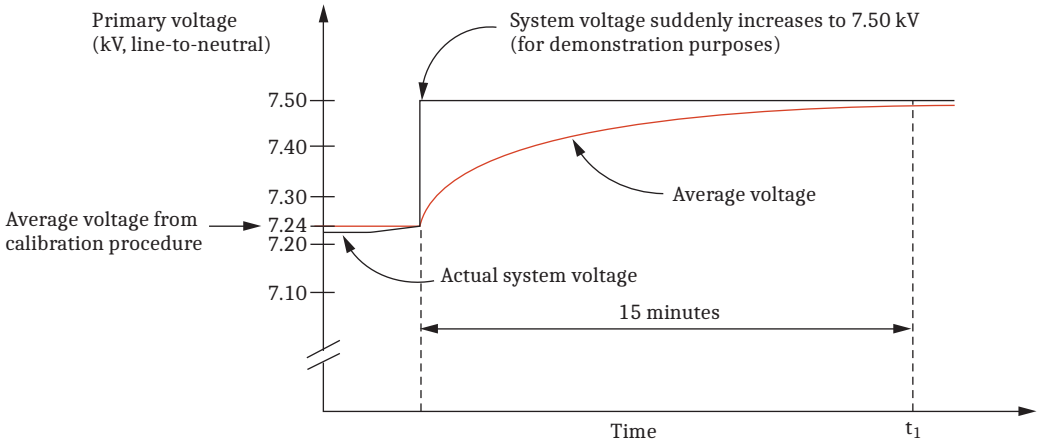

Figure B.2 Response of Average Voltage Value to a Sudden Voltage Change

Event Detection (Loss-of-Voltage/Low Voltage)

If at time t1 in *Figure B.2* a low voltage condition on the primary system suddenly occurs (e.g., actual voltage falls to 2.25 kV; assume it occurs on all phases), the following occurs:

- 2.25 kV (actual voltage slightly after time t1) < 4.49 kV (voltage loss threshold slightly after time t1)
- The output contact shown in *Table 3.1* now deasserts, indicating the detection of a loss-of-voltage or low-voltage event (see *Table 4.1* and *Table 4.2*)

With the primary system voltage now less than the calculated voltage loss threshold of 4.49 kV, the average voltage (which cannot change fast anyway) is now frozen at 7.49 kV and thus the voltage loss threshold remains at the following:

- Frozen voltage loss threshold = 4.49 kV = (60% / 100%) • 7.49 kV (frozen average voltage)

For the average voltage calculation to later become unfrozen, the actual voltage has to ascend an additional 5 percent higher than the **VOLTAGE LOSS THRESHOLD SELECTOR** switch setting (which is set at 60 percent in this example):

- 5% hysteresis voltage loss threshold = 4.89 kV = [(60% + 5%) / 100%] • 7.49 kV (frozen average voltage)

Once the actual voltage exceeds this 5 percent hysteresis voltage loss threshold (actual voltage > 4.89 kV; assume it occurs on all phases), the following occurs:

- The average voltage calculation becomes unfrozen and starts processing again (governed by the effective time constant that adjusts to 95 percent of primary system voltage after 15 minutes)
- The output contact shown in *Table 3.1* asserts again (the low-voltage condition no longer exists; see *Table 4.1* and *Table 4.2*)

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