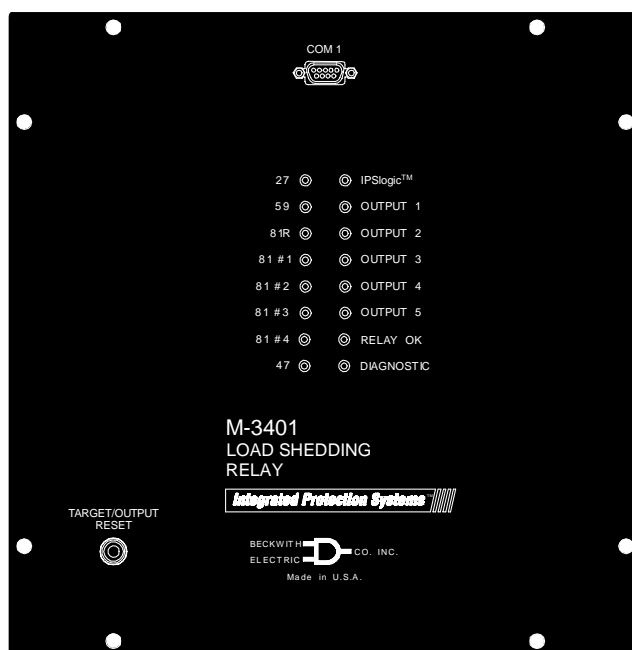


# Load Shedding Relay M-3401

## Integrated Protection System®



*M-3401 Standard Panel*



*M-3401 Vertical Panel (Optional)*



*M-3401 Horizontal Panel (Optional)*

- **Voltage Collapse Mitigation providing 4-step undervoltage and 4-step underfrequency load shedding functions**
- **Undervoltage blocking and negative sequence overvoltage blocking for system faults provides load shedding security**
- **Local and remote serial communications (MODBUS Protocol) for monitoring and control functions**
- **5 programmable outputs and 2 programmable inputs**

## M-3401 Load Shedding Relay

### Protective Functions

- 4-Step Phase undervoltage (27) protection, single-phase and positive sequence
- 4-Step Phase undervoltage, selectable as single phase or positive sequence responding, with Negative sequence overvoltage and three phase undervoltage supervision
- Phase overvoltage (59) protection
- Four-step over/under frequency (81) protection
- Rate of Change of Frequency (81R) protection
- IPSlogic™ takes the contact INPUT status and function status and generates OUTPUTS by employing (OR, AND, and NOT) boolean Logic and a timer.

### Standard Features

- 5 programmable outputs, 2 programmable inputs, and 1 self-test output
- Oscillographic recording (COMTRADE file format)
- Time-stamped sequence of events (SOE) recording for 32 events
- Metering of Voltage and Frequency
- One RS-232 port (COM1) on front and one RS-232 or 485 port (COM2) on rear
- M-3812 IPScom® For Windows™ Communications Software
- MODBUS protocol
- Supports both 50 and 60 Hz applications
- Relay voltage inputs can be directly connected (no VT required) for voltages  $\leq 480$  V ac
- Continuous Self-Diagnostics


### Optional Features

- M-3801D IPSplot® PLUS Oscillograph Analysis Software
- Horizontal and Vertical panel mount versions available (see Figures 2 and 4)

**PROTECTIVE FUNCTIONS**

Device Number	Function	Setpoint Ranges	Increment	Accuracy
<b>Phase Undervoltage</b>				
27	Pickup #1, #2, #3, #4	4 to 100%*	0.1%	±0.5 V or ±0.5%
	Time Delay #1, #2, #3, #4	1 to 8160 Cycles	1 Cycle	±2 Cycles**
Supervision				
47S	Pickup	4 to 100%*	0.1%	±0.5 V or ±0.5%
	Time Delay	1 to 8160 Cycles	1 Cycle	±2 Cycles**
27S	Pickup	4 to 100%*	0.1%	±0.5 V or ±0.5%
	Time Delay	1 to 8160 Cycles	1 Cycle	±2 Cycles**
* Of nominal voltage.				
** When RMS (total waveform) is selected, timing accuracy is ≤20 cycles or ±1%				
27 element response is selectable as positive sequence voltage or phase-to-phase voltage.				
<b>Negative Sequence Overvoltage</b>				
47	Pickup #1, #2	4 to 100%*	0.1%	±0.5 V or ±0.5%
	Time Delay #1, #2	1 to 8160 Cycles	1 Cycle	±2 Cycles
* Of nominal voltage.				
<b>Phase Overvoltage</b>				
59	Pickup #1, #2	100 to 150%*	0.1%	±0.5 V or ±0.5%
	Time Delay #1, #2	1 to 8160 Cycles	1 Cycle	±2 Cycles**
* Of nominal voltage.				
** When RMS (total waveform) is selected, timing accuracy is ≤20 cycles or ±1%				
<b>Over/Under Frequency</b>				
81	Pickup #1, #2, #3, #4	50.00 to 67.00 Hz (40.00 to 57.00 Hz*)	0.01 Hz	±0.03 Hz
	Time Delay #1,#2, #3, #4	2 to 65,500 Cycles	1 Cycle	±2 Cycles or ±0.01%
*This range applies to 50 Hz nominal frequency models.				
The pickup accuracy applies to 60 Hz models at a range of 57 to 63 Hz, and to 50 Hz models at a range of 47 to 53 Hz. The accuracy is ±0.15 Hz for a range of 52 to 57 Hz and 63 to 67 Hz (for 60 Hz nominal) and 42 to 47 Hz and 53 to 57 Hz (for 50 Hz nominal).				
<b>Rate of Change of Frequency</b>				
81R	Pickup #1, #2	0.10 to 20.00 Hz/Sec.	0.01 Hz/Sec.	±0.05 Hz/Sec. or ±5%
	Time Delay #1, #2	3 to 8160 Cycles	1 Cycle	+ 20 Cycles
	Negative Sequence Voltage Inhibit	0 to 99%	1%	±0.5%

**PROTECTIVE FUNCTIONS (cont.)**

<b>Device Number</b>	<b>Function</b>	<b>Setpoint Ranges</b>	<b>Increment</b>	<b>Accuracy</b>
<b>IPSlogic™</b>				
	IPSlogic uses element trip commands, control/status input state changes, communication points, output contact close signals to develop 2 programmable logic schemes.			
	Time Delay #1–#2	1 to 8160 Cycles	1 Cycle	±1 Cycle or ±1%
<b>Nominal Settings</b>				
	Nominal Voltage	50 to 500 V*	1 V	—
	VT Configuration	Line-Line/Line-Ground/Line-Ground-to-Line-Line**		
	Seal-in Delay	2 to 8160 Cycles	1 Cycle	±1 Cycle or ±1%

\* Maximum measured range for (59) function setting is ≤ 600 V.

\*\* When line-ground-to-line-line is selected, the relay internally calculates the line-line voltage from the line-ground voltages for all voltage-sensitive functions. When line-ground-to-line-line selection is applied, the nominal voltage selection should be the line-line nominal voltage (not line-ground nominal voltage).

## Description

The M-3401 Load Shedding Relay provides voltage load shedding, frequency load shedding or supervised voltage or frequency load shedding to assist in voltage collapse mitigation. The M-3401 Load Shedding Relay can be integrated into load shedding schemes that are part of an Energy Management System (EMS), or into automatic load shedding schemes as defined by the IEEE Power System Relaying Committee, Substation Protection Subcommittee, Working Group K-12.

In load shedding as part of EMS application, a control signal is sent to multiple remote switches at participating blocks of customers to interrupt loads for predetermined intervals. This method of load shedding can be manually performed by dispatchers at the EMS control station, or they may be automatic from the EMS using the logic, measurement and intelligence of the M-3401.

In the Automatic Load Shedding scheme where voltage instability is caused by sudden loss of critical transmission equipment or VAR generating equipment (i.e. very short collapse time), the M-3401 provides the means to quickly arrest fast voltage drop by disconnecting selected large blocks of customer load allowing voltage to recover.

The security of an undervoltage load setting scheme is increased with multiple phase detection rather than single phase, proper time coordination between fault clearing and the time delay for load shedding and also by using various supervision techniques that prevent nuisance tripping for voltage conditions that do not lead to collapse. This M-3401 offers three-phase line to line or line to ground configuration, optimal pickup/seal-in time delays from 2 to 8160 cycles, and negative sequence voltage (47S) as well as undervoltage (27S) supervisory functions that ensure security and reliable operation.

To ensure that all data is collected during a load-shedding event the M-3401 has oscillographic recording, storing 180 cycles of all measured parameters. Additionally, the M-3401 has a Sequence of Events (SOE) recorder built-in to capture and store a total of 32 events with 1mSec resolution time stamp.

## Undervoltage Load Shedding

Area undervoltage can occur when there is a lack of reactive support for the load. This lack of reactive support manifests itself as an undervoltage condition, with the undervoltage most severe at the load area requiring the reactive support. As load in the transmission systems are approximately symmetrical on all three phases, the undervoltage condition is seen on all three phases. If the power system voltage profile over the system is viewed as a plane, the undervoltage event from lack of reactive support can be conceptualized as a depression from the 1.0 pu level nominal) to some lower level, with the lowest point the area of highest reactive support requirement.

A method of gaining selectivity for load shedding is to employ multiple time undervoltage elements. In that manner, the localized areas with the lowest voltage (highest reactive power support requirements) are shed first.

When implementing an undervoltage load shedding scheme, it must be secure from asymmetrical voltage depressions occurring from unbalanced faults; single phase-to-ground, phase-to-phase, and phase-phase to phase-ground faults as well as three-phase faults and complete system de-energizations.

- Asymmetrical voltage depressions occurring from single to phase-to-ground, phase-to-phase, and phase-phase to ground faults are detected by using a negative sequence overvoltage element (47S) as a supervision. Typically set to 0.05 to 0.1 pu of nominal voltage, if the adjustable threshold is exceeded, the undervoltage load shedding is blocked.
- Three-phase faults that decrease the voltage symmetrically across all three phases, as well as complete de-energizations of the parts of the power system due to fault clearing or other sectionalizing, are detected by using undervoltage supervision (27S) on all phases. The undervoltage supervision is typically set lower than the lowest survivable undervoltage that could occur from lack of reactive support before the entire system voltage collapses, typically from 0.9 to 0.7 pu. If any phase voltage is lower than the adjustable setting, it is assumed that the condition is from a fault (any type, including three-phase) or complete de-energization of that part of the system.

## M-3401 Load Shedding Relay

### Metering

The relay provides metering of voltages and frequency.

*Metering Accuracies are:*

**Voltage:**  $\pm 0.5$  V or  $\pm 0.5\%$ , whichever is greater (Range 0 to 600 V)

**Frequency:**  $\pm 0.03$  Hz (from 57 to 63 Hz for 60 Hz models; from 47 to 53 Hz for 50 Hz models)

### Oscillographic Recorder

The oscillographic recorder provides comprehensive data recording of all monitored waveforms, input contacts and output contacts, storing up to 120 cycles of data. The total record length is configured for one or two partitions. A programmable post trigger delay (5 to 95%) is incorporated to capture breaker operation. The oscillograph is triggered either remotely using the serial interface, or designated status input signals or M-3401 programmable output operations. Storage of oscillographic records is nonvolatile, and will be retained even without power, as long as the on-board battery is healthy.

Oscillographic data can be downloaded via serial communication in Common Format For Transient Data Exchange (COMTRADE) format as specified by IEEE Standard C37.111-1999.

### Sequence of Events

A total of 32 nonvolatile events can be stored. The recorded information includes the function(s) operated, the function(s) picked up, input/output contact status and time stamp. The events can be retrieved through the communications port. After the 32nd event is stored, additional events result in the oldest event being dropped (FIFO). The information is time-stamped to 1 ms resolution.

### Calculations

The M-3401 uses discrete fourier transform (DFT) algorithm on sampled (32 times per cycle) voltage signals to extract fundamental frequency phasors for calculations. The 59/27 function, when set for RMS measurement, uses a time domain algorithm to calculate the voltage magnitude.

### Power Input Options

Nominal	Range	Burden
12/24 V dc	9 to 36 V dc	<5 VA
48 V dc	36 to 75 V dc	<5 VA
120 V ac/125 V ac	85 to 150 V ac/V dc	<5 VA

### Sensing Inputs

*3 Voltage Inputs:* Rated nominal voltage of 69 V ac to 480 V ac, 60 Hz (50 Hz user configurable). Will withstand 600 V continuous voltage. Source voltages may be line-to-ground or line-to-line connected. Phase sequence ABC/ACB is selectable. Voltage transformer burden less than 0.25 VA at 120 V ac.

### Control/Status Inputs

The control/status inputs, INPUT1 and INPUT2, can be programmed to block any of the M-3401 functions and trigger the oscillograph recorder. The control/status inputs accept only dry contacts and are internally wetted (9 V dc) by the relay's power supply. A minimum current of 1.3 mA is required to avoid spurious triggering of the input.

## Output Contacts

The five programmable output relays, each with a contact, are rated as per ANSI/IEEE C37.90-1989 for tripping: make 30 A for 0.2 seconds.

The hardware configuration consists of the following:

- 1 self-test alarm output contact (form 'c') with a rating of 8 A at 120 V ac, 5 A at 30 V dc, 125 V dc 0.15 A resistive, 0.1 A inductive.
- 2 (form 'a') contacts which carry 8A, break 6A at 120 V ac, break 0.1A at 125 V dc, inductive break at 0.1A.
- 3 (form 'c') contacts with a rating of 8A at 120 V ac, 5A at 30 V dc, 125 V dc 0.15A resistive, 0.1A inductive.

Any of the M-3401 protective functions can be individually programmed to activate the five programmable outputs. The user can configure the five programmable outputs to either energize or de-energize to issue an output command.

The outputs (excluding the self-test) can have two modes of operation, LATCHING and NORMAL. The LATCHING mode requires an operator intervention to deactivate the outputs after the condition for operation has been removed. In the NORMAL mode, when the condition for tripping has been removed, the output(s) will deactivate automatically after the corresponding seal-in timers have expired.

## IPSlogic™

This feature can be programmed utilizing the IPScom® Communications Software. IPSlogic takes the contact input status and function status, and by employing (OR, AND, and NOT) boolean logic and a timer, can activate an output or change setting profiles.

## Target/Status Indicators and Controls

The **RELAY OK** LED reveals proper cycling of the microprocessor. The **DIAGNOSTIC** LED provides indication of the error code (when flashing). The **OSC TRIGGER** LED indicates that the oscillograph has been triggered. The remaining LEDs are used to indicate which protective function(s) have been tripped. **OUTPUT 1** and **OUTPUT 2** are used to indicate the status of the output contacts. The output LEDs will illuminate when the output contact relays are tripped. The **TARGET/OUTPUT RESET** button resets the target LEDs if the conditions causing the operation have been removed. Holding the **TARGET/OUTPUT RESET** button displays the present pickup status of the M-3401 functions. The **TARGET/OUTPUT RESET** button will deactivate the tripped output contact if the **LATCHING** mode was selected. (If the seal in timer has already expired, the output contact will deactivate immediately.)

## Communication

Communications ports include a front panel RS-232 port and a rear port user configurable to RS-232 or RS-485. The RS-232 ports are connected physically with a DB-9 connector and the RS-485 port utilizes 4-wire interface mounting screw terminals.

M-3812 IPScom® For Windows™ utilizing the MODBUS communications protocol in RTU mode, implements serial, byte-oriented asynchronous communication with the M-3401 and provides the following functions:

- Interrogation and modification of setpoints
- Time-stamped sequence of events information for the 32 most recent events
- Real-time metering of all quantities measured
- Downloading of recorded oscillographic data
- Relay Setup

## Tests and Standards

### Voltage Withstand

#### *Dielectric Withstand*

IEC 60255-5 3,500 V dc for 1 minute applied to each independent circuit to earth  
3,500 V dc for 1 minute applied between each independent circuit

■ **NOTE:** 1,500 V dc for power supply voltage options (12, 24, 48 V dc inputs).

#### *Impulse Voltage*

IEC 60255-5 Power supply input voltages, 120 V ac/125 V dc:  
5,000 V pk, +/- polarity applied to each independent circuit to earth  
5,000 V pk, +/- polarity applied between each independent circuit  
1.2 by 50  $\mu$ s, 500 ohms impedance, three surges at 1 every 5 seconds

Power supply input voltages, 12, 24, 48 V dc:  
3,000 V pk, +/- polarity applied to each independent circuit to earth  
3,000 V pk, +/- polarity applied between each independent circuit  
1.2 by 50  $\mu$ s, 500 ohms impedance, three surges at 1 every 5 seconds

#### *Insulation Resistance*

IEC 60255-5 > 100 Megaohms

### Electrical Environment

#### *Electrostatic Discharge Test*

EN 60255-22-2 Class 4 (8 kV)—point contact discharge

EN 60255-22-2 Class 4 (15kV)—air discharge

#### *Fast Transient Disturbance Test*

EN 60255-22-4 Class A (4 kV, 2.5 kHz)

ANSI/IEEE 2,500 V pk oscillatory applied to each independent circuit to earth  
C37.90.1- 2,500 V pk oscillatory applied between each independent circuit  
2002 4,000 V pk Fast Transient burst applied to each independent circuit to earth  
4,000 V pk Fast Transient burst applied between each independent circuit  
5,000 V pk Fast Transient applied to each independent circuit to earth  
5,000 V pk Fast Transient applied between each independent circuit

■ **NOTE:** The signal is applied to the digital data circuits (RS-232, RS-485) through capacitive coupling clamp.

ANSI/IEEE 80-1000 Mhz @ 35 V/m  
C37.90.2

#### *Output Contacts*

ANSI/IEEE Make 30 A for 0.2 seconds, off for 15 seconds for 2,000 operations, per Section 6.7.1,  
C37.90.0 Tripping Output Performance Requirements

## Atmospheric Environment

### Temperature

IEC 60068-2-1 Cold, -20° C  
IEC 60068-2-2 Dry Heat, +70° C  
IEC 60068-2-78 Damp Heat, +40° C @ 93% RH

## Mechanical Environment

### Vibration

IEC 60255-21-1 Vibration response Class 1, 0.5 g  
Vibration endurance Class 1, 1.0 g

### Shock

MIL-STD-810C Method 516.2, Procedure 1, 11 ms, 15 g, 1/2 sine pulse, 3 pulses per axis

## Compliance

cULus-Listed per 508 – Industrial Control Equipment  
– Industrial Control Equipment Certified for Canada CAN/CSA C22.2 No. 14-M91  
cULus-Listed Component per 508A Table SA1.1 Industrial Control Panels

## Physical

### Panel Mount

**Size:** 12.20" high x 12.00" wide x 2.56" deep (30.99 cm x 30.48 cm x 7.27 cm)

**Approximate Weight:** 5 lbs, 11 oz (2.11 kg)

**Approximate Shipping Weight:** 9 lbs, 13 oz (4.48 kg)

### Horizontal/Vertical Panel Mount

**Size:** 3.46" high x 10.50" wide x 11.63" deep (8.8 cm x 26.7 cm x 29.54 cm)

**Approximate Weight:** 6 lbs, 4 oz (2.84 kg)

**Approximate Shipping Weight:** 10 lbs, 4 oz (10.7 kg)

## Recommended Storage Parameters

**Temperature:** 5° C to 40° C

**Humidity:** Maximum relative humidity 80% for temperatures up to 31° C, decreasing to 31° C linearly to 50% relative humidity at 40° C.

**Environment:** Storage area to be free of dust, corrosive gases, flammable materials, dew, percolating water, rain and solar radiation.

See M-3401 Instruction Book, Appendix D, Layout and Storage for additional information.

## Patent & Warranty

The M-3401 Load Shedding Relay is covered by U.S. Patent 5,592,393.

The M-3401 Load Shedding Relay is covered by a five year warranty from date of shipment.

## External Connections

M-3401 external connection points are illustrated in Figure 1, Standard Panel Layout External Connections and Figure 2 for the optional Horizontal and Vertical Panel External Connection Layouts.

*Specification is subject to change without notice.*

# M-3401 Load Shedding Relay

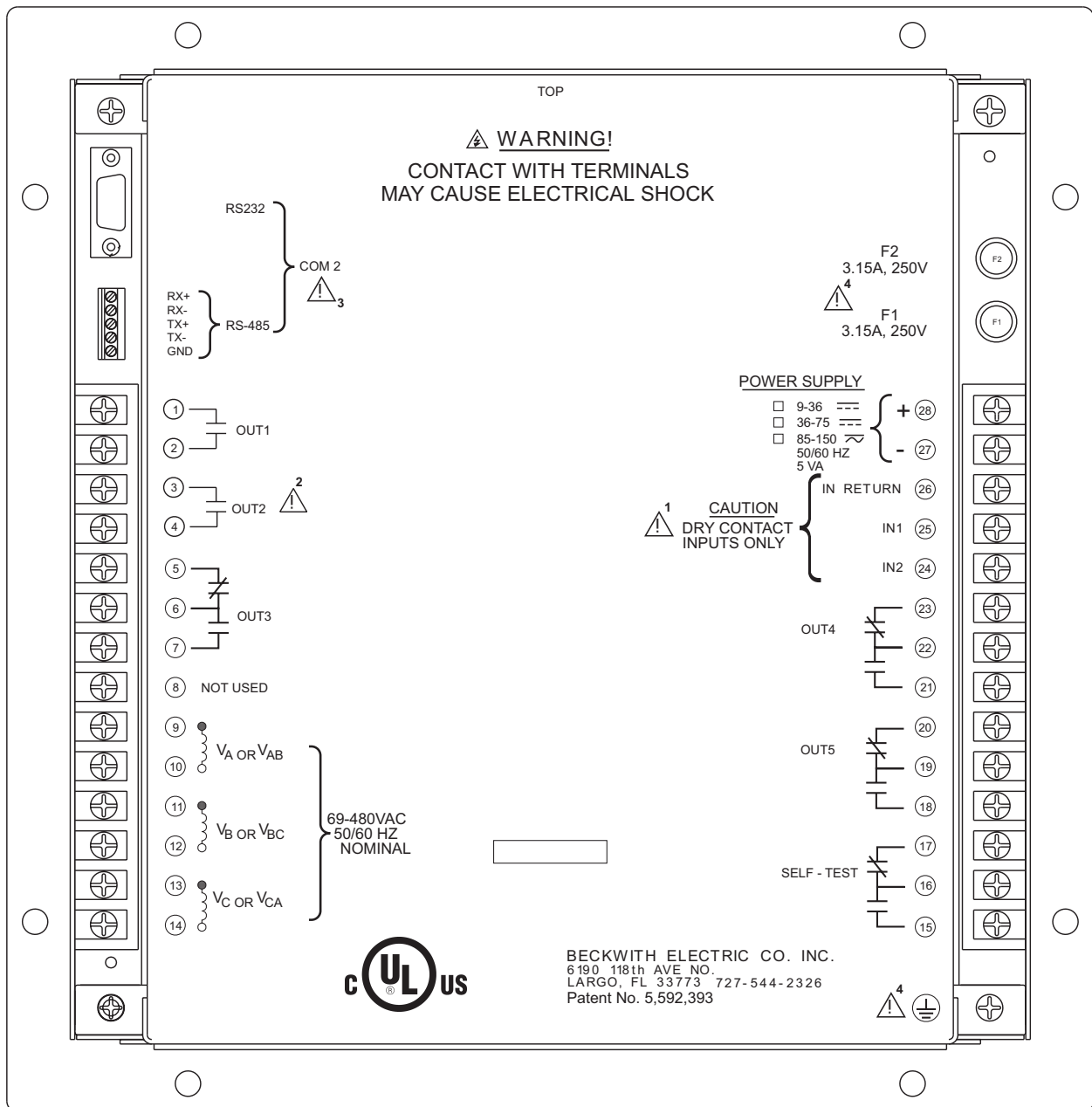


Figure 1 Standard Panel Layout External Connections (Elevation View)

■ **NOTES:** ⚠

1. See M-3401 Instruction Book, Section 2.3, External Connections.
2. See M-3401 Instruction Book, Section 3.1, Relay Configuration, Output Contact Mode.
3. See M-3401 Instruction Book, Section 2.8, Relay Remote Communication Setup (PC), COM2 Configuration.
4. See M-3401 Instruction Book, Section 2.3, External Connections.

# M-3401 Load Shedding Relay

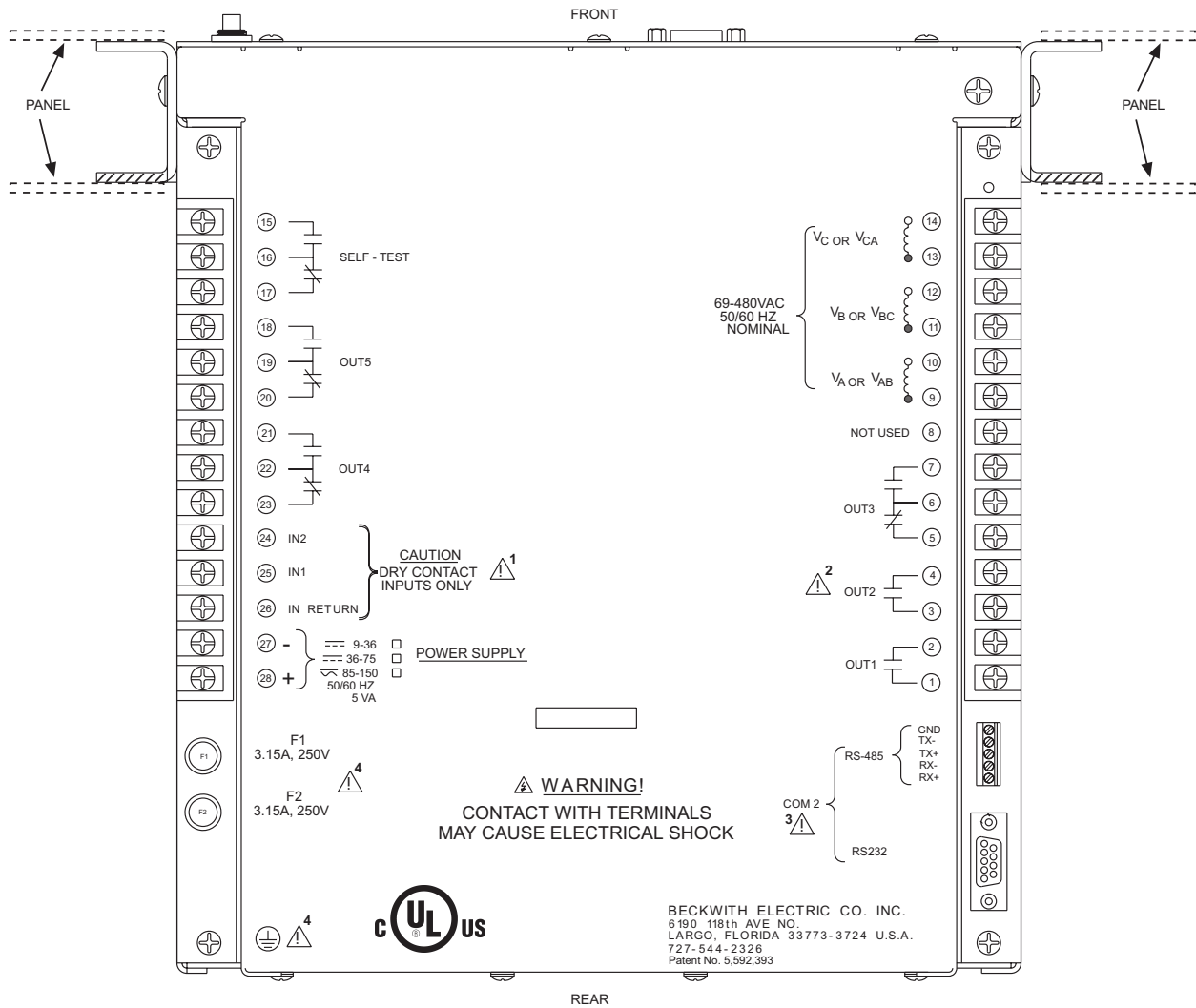


Figure 2 Optional Horizontal and Vertical Panel External Connection Layout (Plan View)

■ NOTES:

1. See M-3401 Instruction Book, Section 2.3, External Connections.
2. See M-3401 Instruction Book, Section 3.1, Relay Configuration, Output Contact Mode.
3. See M-3401 Instruction Book, Section 2.8, Relay Remote Communication Setup (PC), COM2 Configuration.
4. See M-3401 Instruction Book, Section 2.3, External Connections.

# M-3401 Load Shedding Relay

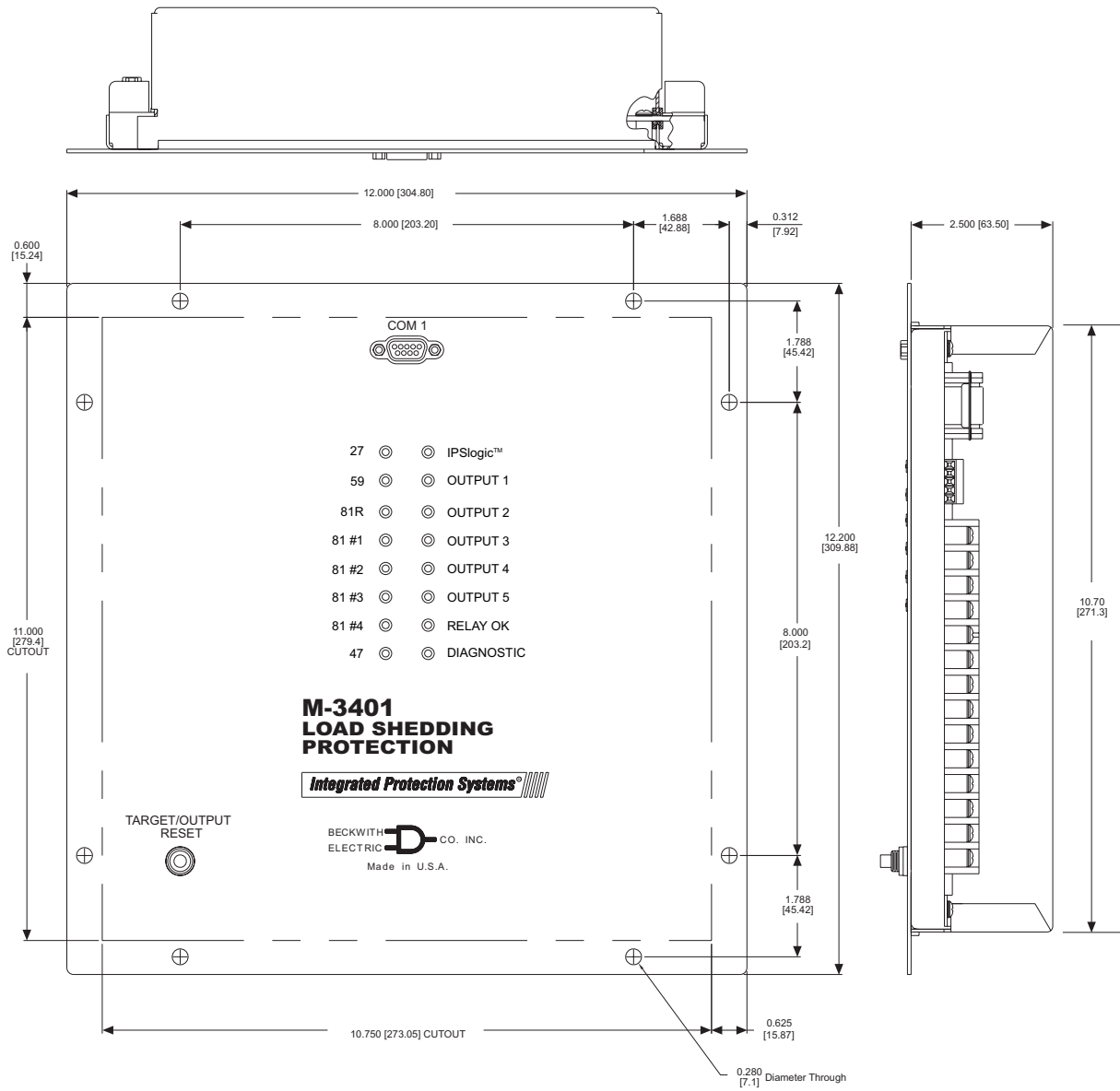


Figure 3 Standard Panel Mounting Dimensions

# M-3401 Load Shedding Relay

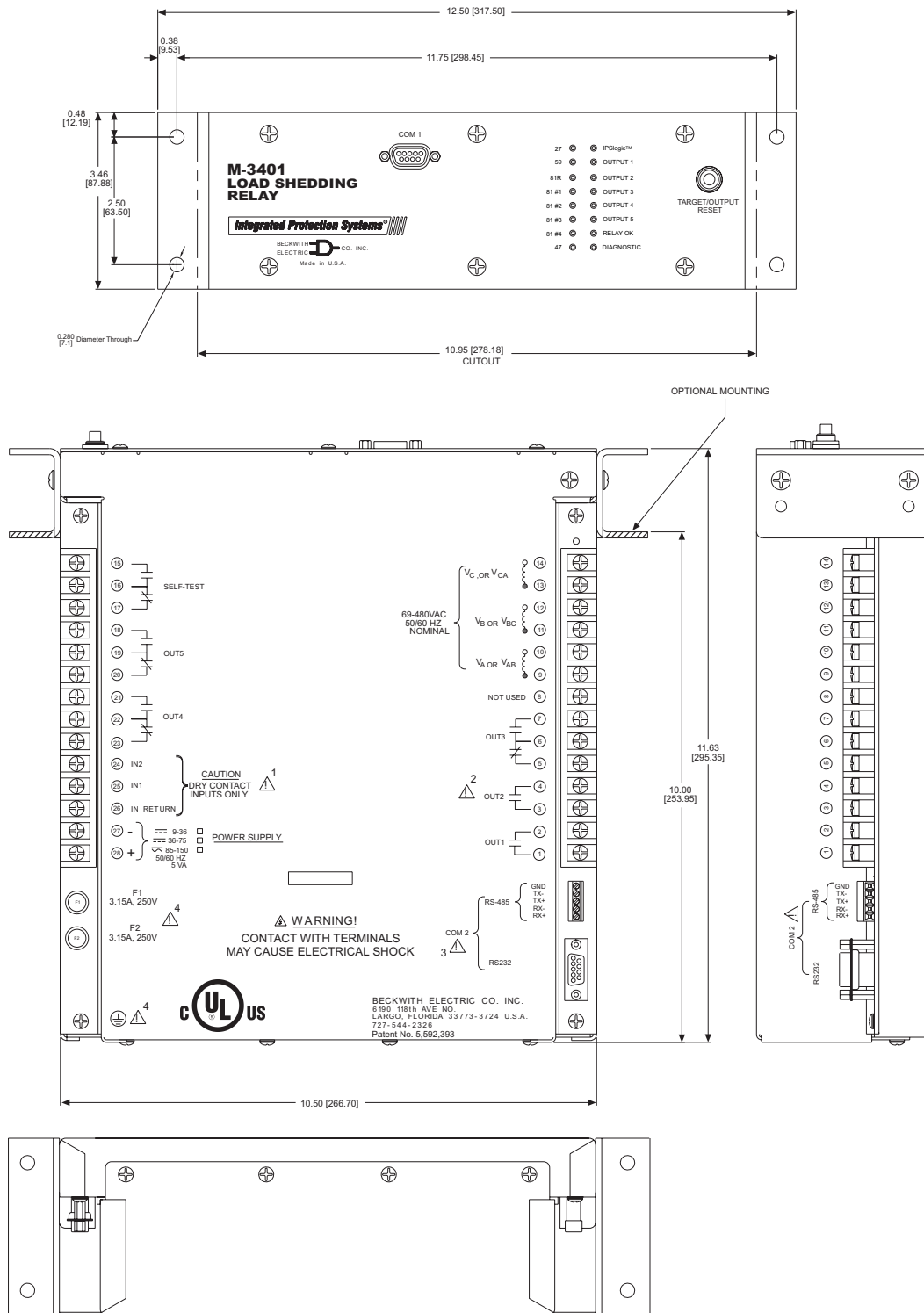


Figure 4 Optional Horizontal/Vertical Panel Mounting Dimensions

■ NOTES:

1. See M-3401 Instruction Book, Section 2.3, External Connections
2. See M-3401 Instruction Book, Section 3.1, Relay Configuration, Output Contacts Mode.
3. See M-3401 Instruction Book, Section 2.8, Relay Remote Communication Setup (PC), COM2 Configuration
4. See M-3401 Instruction Book, Section 2.3, External Connections.

## M-3401 Load Shedding Relay

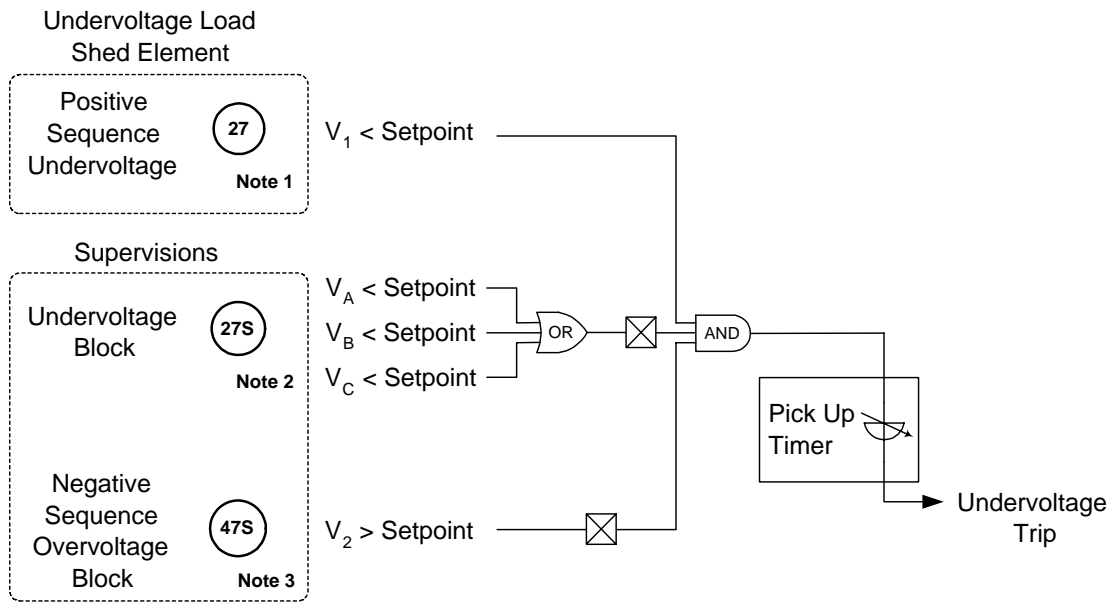


Figure 5 Positive Sequence Undervoltage Element

### NOTES:

1. The undervoltage load shed element is selectable as either positive sequence undervoltage or three phase undervoltage.
2. The 27S supervises and blocks undervoltage load shedding when the system is de-energized or during three-phase faults.
3. The 47S supervises and blocks undervoltage load shedding during single and two-phase faults.

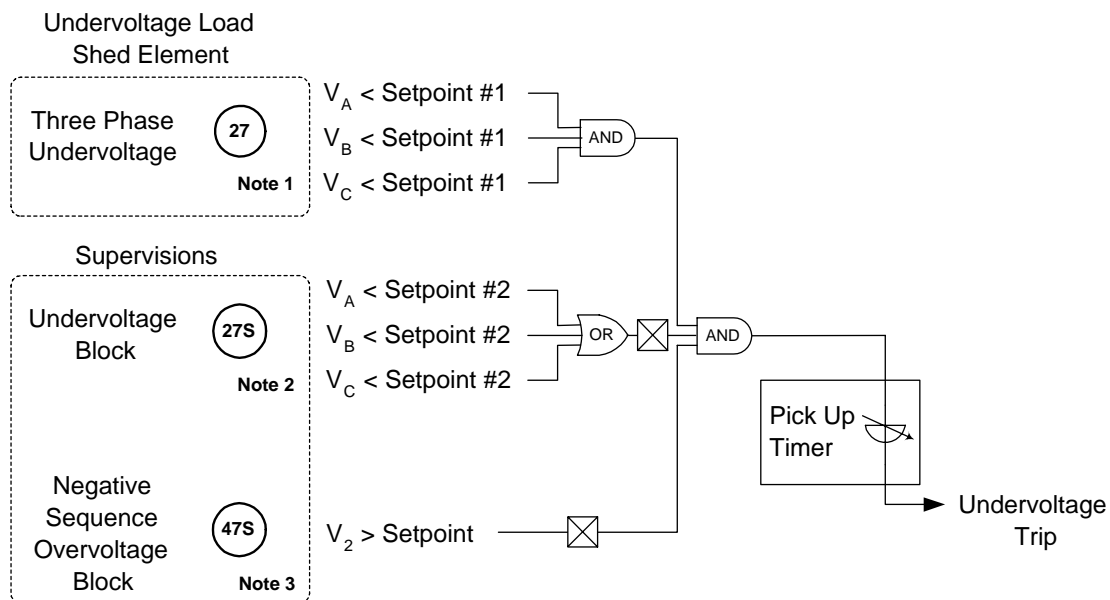


Figure 6 Three Phase Undervoltage Element

### NOTES:

1. The undervoltage load shed element is selectable as either positive sequence undervoltage or three phase undervoltage.
2. The 27S supervises and blocks undervoltage load shedding when the system is de-energized or during three-phase faults.
3. The 47S supervises and blocks undervoltage load shedding during single and two-phase faults.

M-3401 Load Shedding Relay

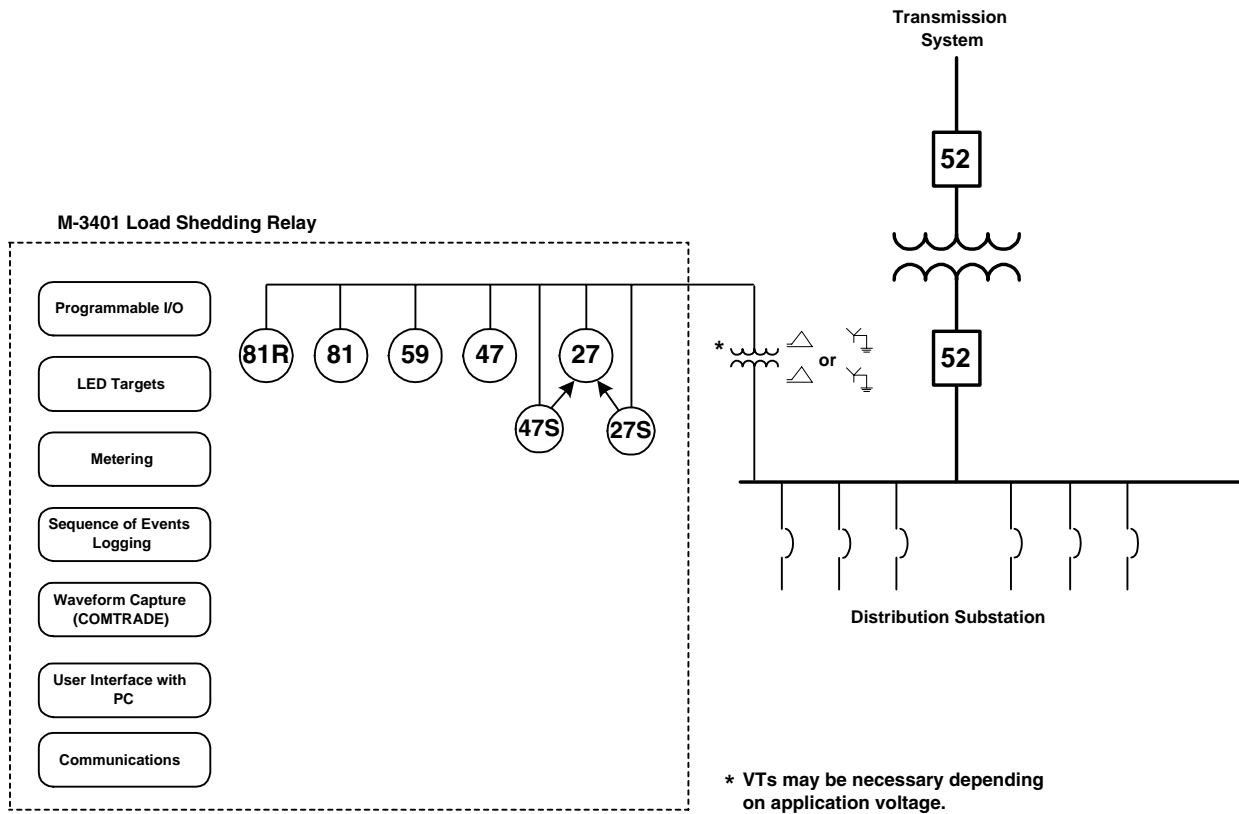


Figure 7 Typical One-Line Diagram Load Shedding - Distribution

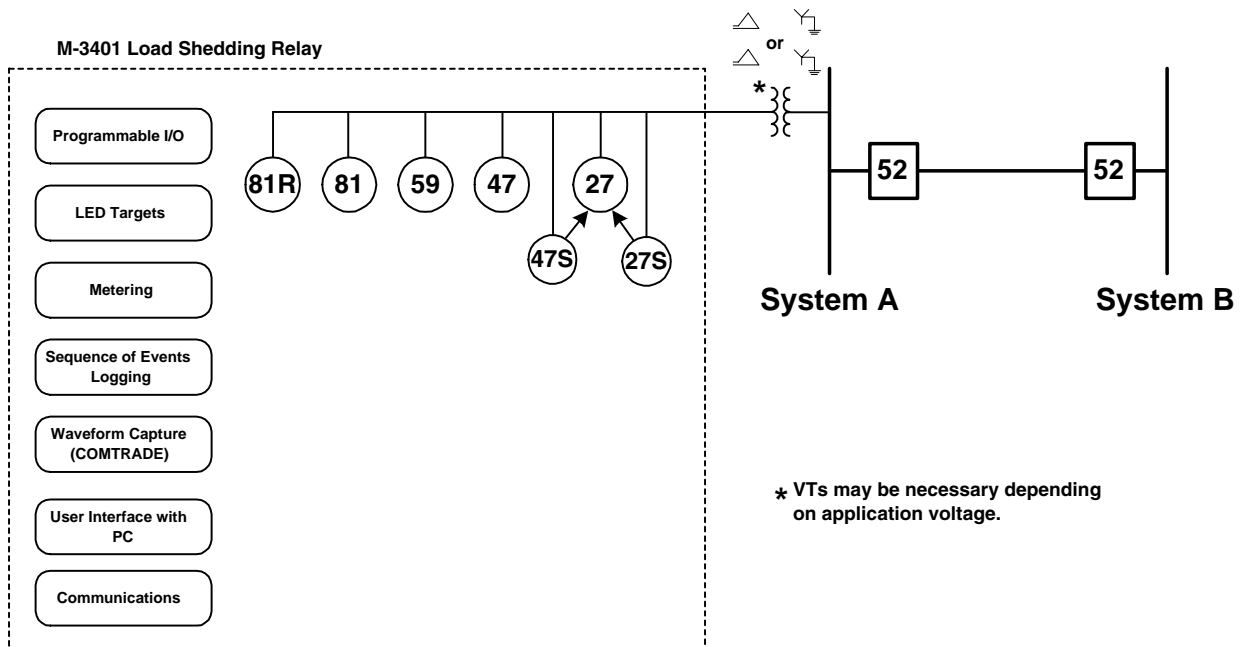


Figure 8 Typical One-Line Diagram Load Shedding - Transmission/Sub-transmission

# M-3401 Typical Connection Diagram

- ① Alternate VT connection, phase voltages
- ② VTs are not necessary if the Nominal Rated Interconnection Voltage is  $\leq 480$  V ac.

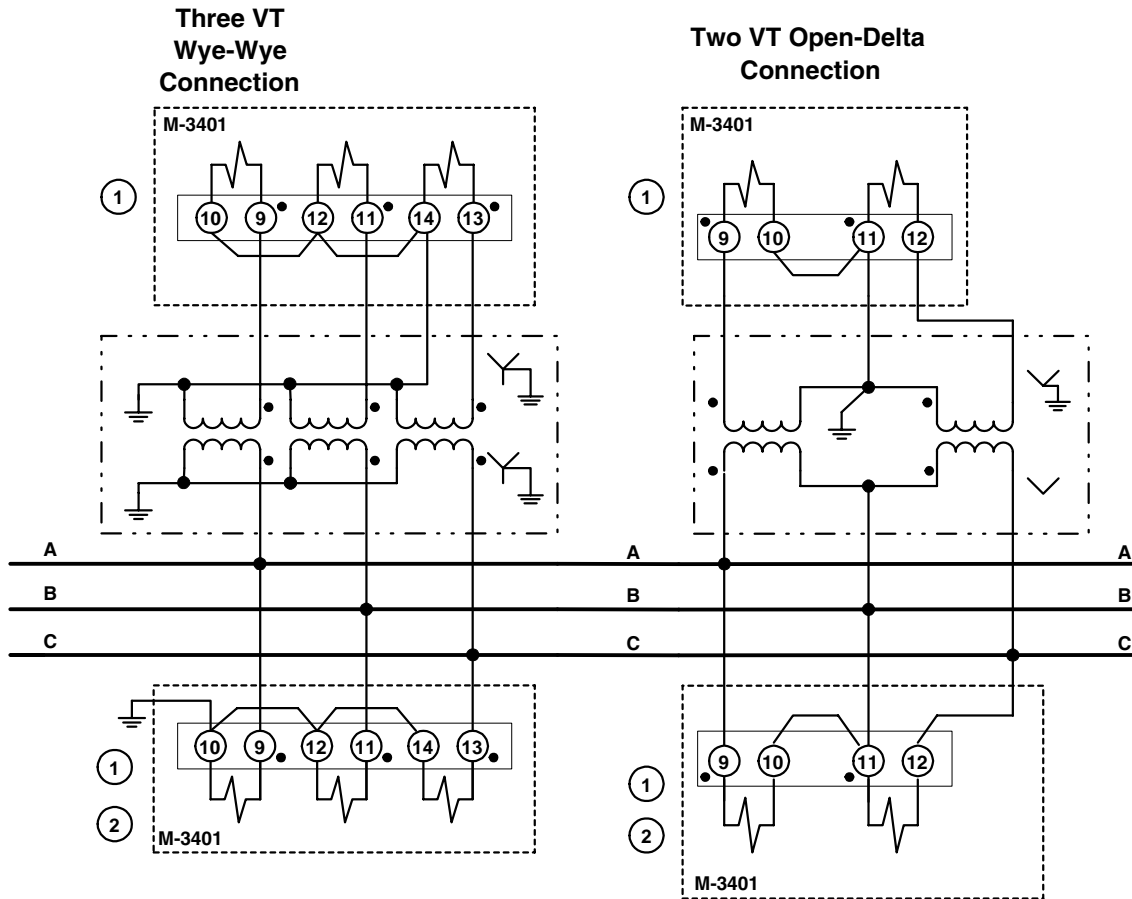


Figure 9 Typical Three-Line Diagram Load Shedding Application



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