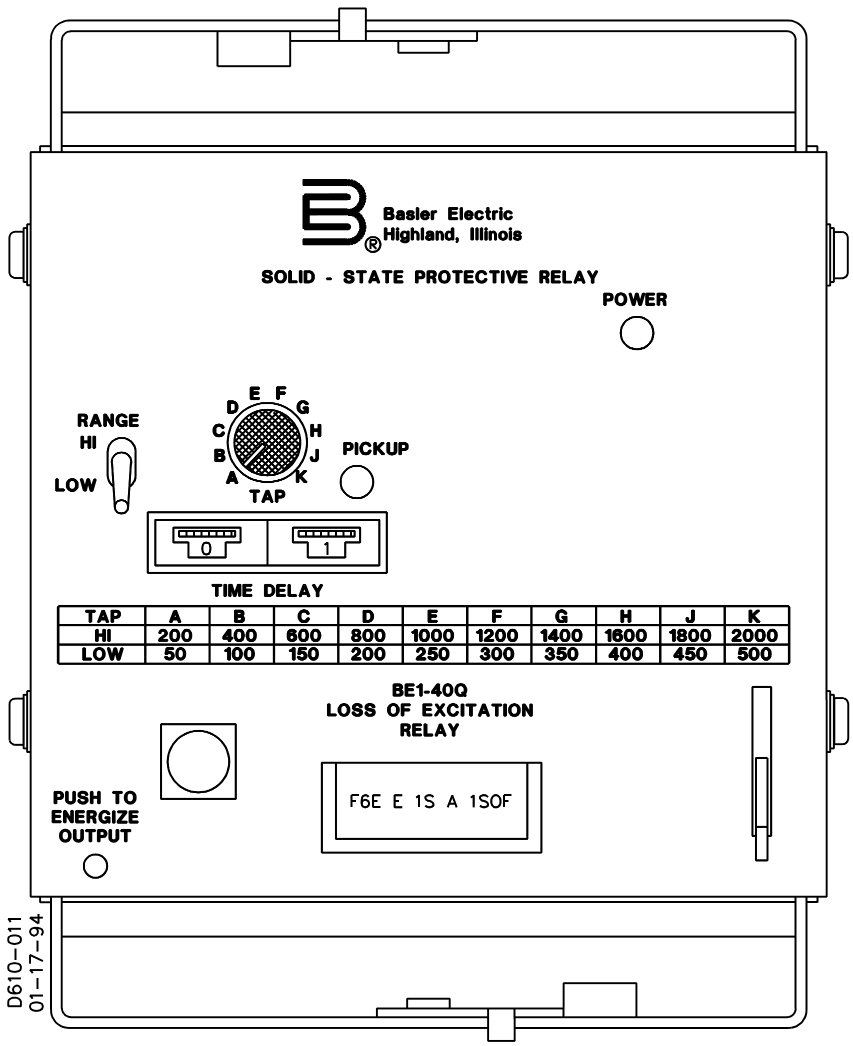
INSTRUCTION MANUAL

FOR
LOSS OF EXCITATION RELAY
BE1-40Q



TAP	A	B	C	D	E	F	G	H	J	K
HI	200	400	600	800	1000	1200	1400	1600	1800	2000
LOW	50	100	150	200	250	300	350	400	450	500

Basler Electric

Publication Number: 9 1715 00 990
Revision: K 02/01

INTRODUCTION

This Instruction Manual provides information concerning the operation and installation of BE1-40Q Loss of Excitation Relays. To accomplish this, the following is provided.

- Specifications
- Functional characteristics
- Installation
- Operational Tests
- Mounting Information

WARNING

To avoid personal injury or equipment damage, only qualified personnel should perform the procedures presented in this manual.

First Printing: January 1986

Printed in USA

February 2001

It is not the intention of this manual to cover all details and variations in equipment, nor does this manual provide data for every possible contingency regarding installation or operation. The availability and design of all features and options are subject to modification without notice. Should further information be required, contact Basler Electric Company, Highland, Illinois.

BASLER ELECTRIC
ROUTE 143, BOX 269
HIGHLAND, IL 62249 USA
http://www.basler.com, info@basler.com
PHONE 618-654-2341 **FAX 618-654-2351**

CONTENTS

CONTENTS- Continued

SECTION 1 • GENERAL INFORMATION

APPLICATION

General

Loss of excitation protection is applied on nearly all synchronous generators. Reduced or complete loss of excitation can cause loss of synchronism, instability and, possibly, damage to the generator from overheating. Many modern excitation systems include minimum-excitation limiters to prevent underexcitation; however, loss of excitation protective relays are still applied as backup to these automatic controls. BE1-40Q Loss of Excitation Relays provide this protection by monitoring the field excitation (measuring the magnitude and direction of var flow) and tripping the generator before serious damage to the generator can occur.

Synchronous generators in parallel are normally operated in the overexcited (lagging) region which allows generation of reactive power (vars). Although the field excitation may be safely adjusted to cause the generator to absorb vars (leading), this is usually avoided because stability is unreliable under this condition.

When field excitation is not sufficient to maintain the terminal voltage of an interconnected generator, the system will attempt to supply reactive power to excite the generator. If the system cannot supply the required vars, the weakened field may allow the rotor to slip poles during disturbances such as load changes or faults, causing loss of synchronism.

When the system can supply the necessary vars, the generator will act as an induction generator, drawing excitation from the system. The machine voltage will remain above the setting of undervoltage relays, but the current induced by the rotor slip will flow in the damper (amortisseur) windings. The excessive heating caused by the current flow reduces machine life exponentially.

Under either condition, BE1-40Q Relays will detect the increased vars at the generator terminals as a loss of excitation and trips the generator to prevent loss of synchronism or excessive heating within the generator.

Capability Curves

Generator manufacturers supply capability curves that specify the operating limits of a particular machine (similar to those shown in Figure 1-1). The curves are derived from the heating characteristics that occur on the stator end iron, the stator winding, and the rotor winding. Plotted on the complex power plane, real power P (kW) is on the horizontal axis and reactive power Q (var) is on the vertical axis.

An additional limit is often included on these curves, as shown in Figure 1-2. Here, the steady state stability limit further defines the safe operating limit of the generator. If the stability limit is exceeded, an out-of-step condition can occur due to loss of synchronism.

BE1-40Q Operating Characteristics

BE1-40Q relay characteristics closely follow the generator capability curves. The response characteristic is represented by a line eight degrees from horizontal, placed above the most restrictive limit of normal operation. As shown in Figure 1-3, the attendant intercept of the line on the Q axis (at -0.4 per unit vars in this example) is used to establish the pickup of the relay. A front panel rotary switch is used to set the TAP setting. Refer to *Section 5, Setting And Testing* for specific information on determining the pickup setting.

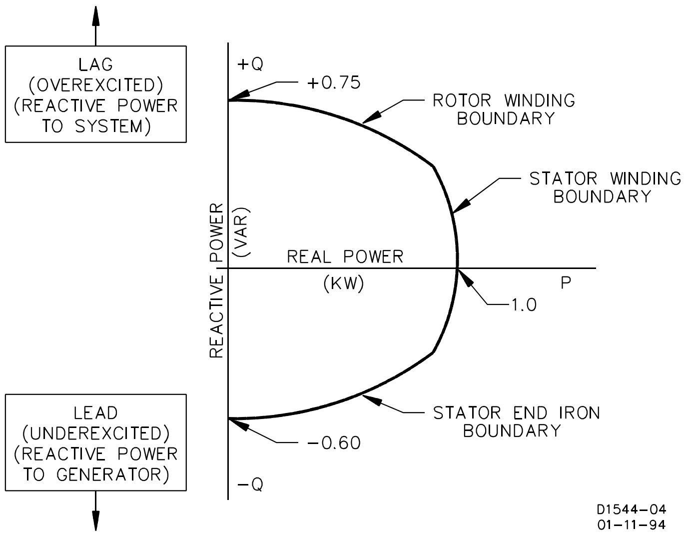


Figure 1-1. Typical Generator Capability Curve

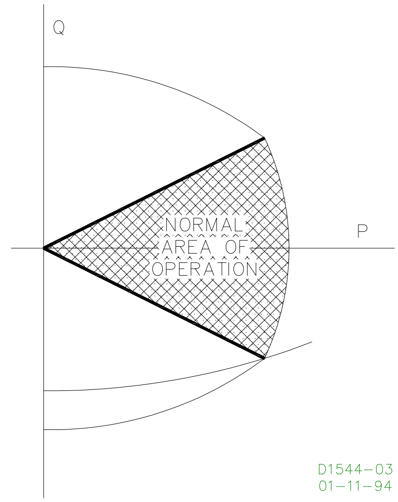


Figure 1-2. Normal Operation with Steady State Stability Limit

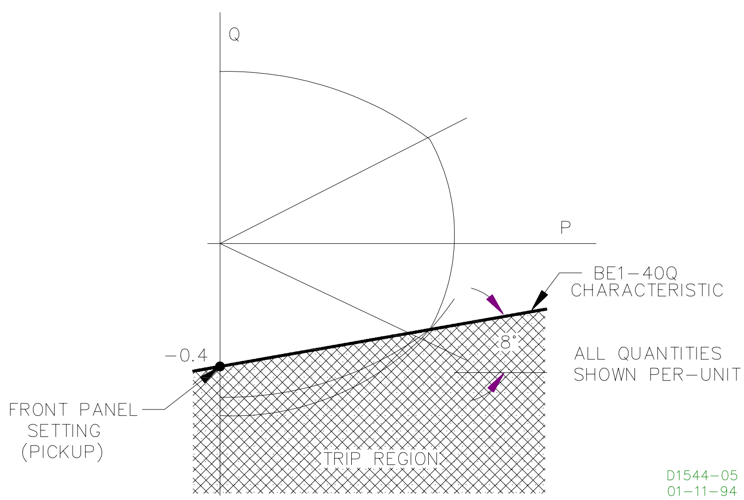


Figure 1-3. An Example of BE1-40Q Relay Operating Characteristics

Time Delay

A time delay is included in BE1-40Q Relays to prevent misoperation for transient conditions such as power swings due to synchronizing or external fault clearing. A definite time delay of 0.1 to 9.9 seconds can be set on the front panel thumbwheels in increments of 0.1 second. Setting both thumbwheels to 0 causes an instantaneous trip signal to be sent when the TAP setting is exceeded. Refer to Section 5 for specific setting information.

MODEL AND STYLE NUMBER DESCRIPTION

BE1-40Q Loss of Excitation Relays electrical characteristics and operational features are defined by a combination of letters and numbers that make up the style number. The model number, together with the style number, describe the options included in a specific device, and appear on the front panel, drawout cradle, and inside the case assembly. Upon receipt of a relay, be sure to check the style number against the requisition and the packing list to ensure that they agree.

Style number identification chart (Figure 1-4) defines the electrical characteristics and operational features included in BE1-40Q relays. For example, if the style number were **F3E E10 B1S2F**, the device would have the following:

(F) - 60 Hz single-phase current sensing.
(3) - 120 Vac, 4 to 200 W.
(E) - One output relay with normally open contacts.
(E1) - Definite timing.
(0) - Operating power derived from 48 Vdc.
(B) - One current operated target.
(1) - Push-to-energize output (pushbutton).
(S) - Power supply status output.
(2) - One auxiliary output relay with normally closed contacts.
(F) - Semi-flush mounting.

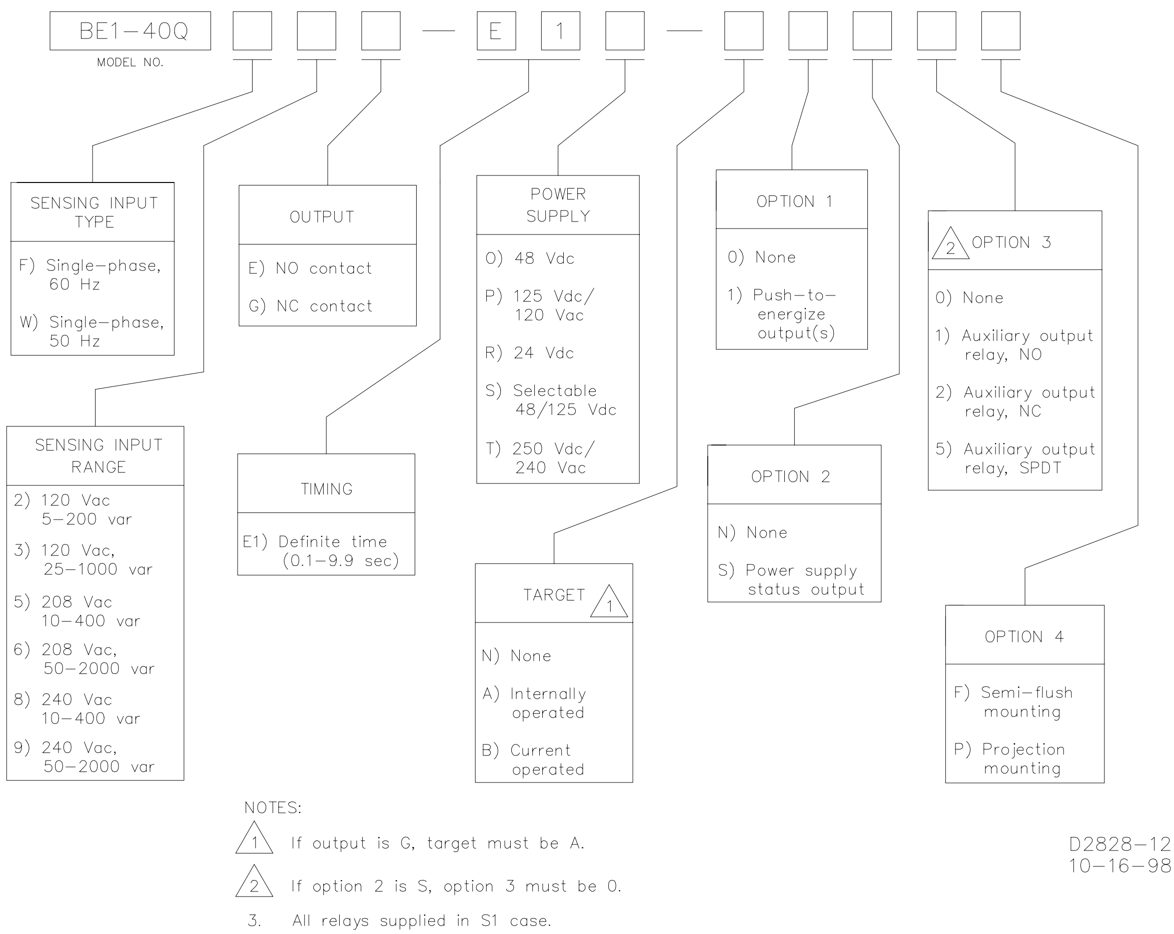


Figure 1-4. Style Number Identification Chart

SPECIFICATIONS

Current Sensing

Unit is designed to operate from the secondary of a standard current transformer rated at 5 A, 50 and 60 Hz (based on configuration). Internal current sensing transformers are rated at 10 A continuous, 15 A for 1 minute, and 200 A for 1 second.

Current Sensing Burden

Maximum sensing burden is less than 0.1 ohm at pickup over the frequency range of 45 to 65 Hz.

Voltage Sensing

Three line-to-line voltage sensing inputs are available: 120, 208, and 240 Vac (nominal). Each have a burden that is less than 1 VA over the frequency range of 45 to 65 Hz.

Pickup Range

Refer to Table 1-1.

Table 1-1. Pickup Setting

SENSING INPUT TYPE	NOMINAL VOLTS	SENSING INPUT RANGE	PICKUP SETTING (in secondary vars)										
			TAP	A	B	C	D	E	F	G	H	J	K
F & W	120	3	HI	100	200	300	400	500	600	700	800	900	1000
			LOW	25	50	75	100	125	150	175	200	225	250
F & W	208 & 240	6 & 9	HI	200	400	600	800	1000	1200	1400	1600	1800	2000
			LOW	50	100	150	200	250	300	350	400	450	500

Pickup Accuracy

±2% of the front panel setting or ±0.1 var, whichever is greater for a power factor angle of -90°.

Dropout

Not less than 95% of actual pickup.

Time Delay Range

Definite time delay is adjustable by two front panel thumbwheels over a range of 01 to 99 (0.1 to 9.9 seconds) in increments of 0.1 seconds. A setting of 00 enables instantaneous operation.

Timing Accuracy

Shown in Figure 1-5. Note that each curve is slightly offset by a factor that represents integration time. Repeatability is within ±5% or 25 milliseconds, whichever is greater.

Power Supply

Power for the internal circuitry may be derived from a variety of ac or dc power sources, as shown in Table 1-2.

Output Circuits

Output contacts are rated as follows:

Resistive:

120/240 Vac — Make 30 A for 0.2 seconds, carry 7 A continuously, and break 7 A.

250 Vdc — Make 30 A for 0.2 seconds, carry 7 A continuously, and break 0.3 A.

Inductive:

120/240 Vac, 125/250 Vdc — Make 30 A for 0.2 seconds, carry 7 A continuously, and break 0.3 A. (L/R = 0.04).

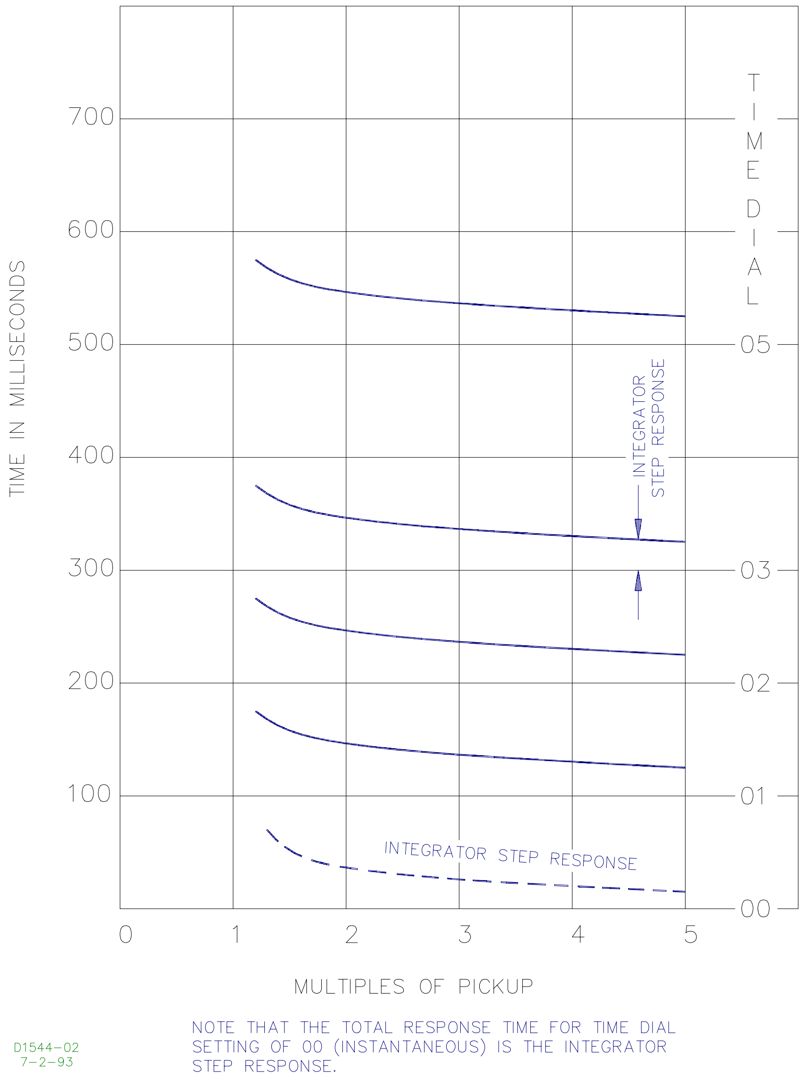


Figure 1-5. Relay Response Time for Typical Time Dial Settings

Table 1-2. Power Supply Options and Burdens

Type	Nominal Input Voltage	Input Voltage Range	Burden at Nominal
O (Mid Range)	48 Vdc	24 to 150 Vdc	5.0 W
P (Mid Range)	125 Vdc 120 Vac	24 to 150 Vdc 90 to 132 Vac	5.2 W 15.1 VA
R (Low Range)	24 Vdc	12† to 32 Vdc	5.1 W
S(Mid Range)	48 Vdc 125 Vdc	24 to 150 Vdc 24 to 150 Vdc	5.0 W 5.2 W
T (High Range)	250 Vdc 240 Vac	62 to 280 Vdc 90 to 270 Vac	5.2 W 14.0 VA

NOTE:

† Type R power supply initially requires 14 Vdc to begin operating. Once operating, the voltage may be reduced to 12 Vdc and operation will continue.

Target Indicators

Function targets may be specified as either internally operated, or current operated by a minimum of 0.2 ampere through the output trip circuit. When current operated, the output circuit must be limited to 30 amperes for 0.2 seconds, 7 amperes for 2 minutes, and 3 amperes continuously.

Radio Frequency Interference (RFI)

Maintains proper operation when tested for interference in accordance with IEEE C37.90.2-1987, *Trial-Use Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers*.

Isolation

In accordance with IEC 255-5 and ANSI/IEEE C37.90-1989 one minute dielectric (high potential) tests as follows:,

All circuits to ground:	2121 Vdc.
Input to output circuits:	1500 Vac or 2121 Vdc.

Shock

In standard tests, the relay has withstood 15 g in each of three mutually perpendicular planes without structural damage or degradation of performance.

Vibration

In standard tests, the relay has withstood 2 g in each of three mutually perpendicular planes, swept over the range of 10 to 500 Hz for a total of six sweeps, 15 minutes each sweep, without structural damage or degradation of performance.

Surge Withstand Capability

Qualified to ANSI/IEEE C37.90.1-1989, *Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems*.

UL Recognition

UL Recognized per Standard 508, UL File No. E97033. Note: Output contacts are not UL Recognized for voltages greater than 250 volts.

Fast Transient

Qualified to ANSI/IEEE C37.90.1-1989. *Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems.*

Operating Temperature

-40°C (-40°F) to +70°C (+158°F).

Storage Temperature

-65°C (-85°F) to +100°C (+212°F).

Weight

13.5 pounds (6.12 kg) maximum.

Case Size

S1. (Dimensions are provided in *Section 4, Installation*.)

SECTION 2 • HUMAN-MACHINE INTERFACE

CONTROLS AND INDICATORS

Table 2-1 lists and briefly describes the operator controls and indicators of the BE1-40Q Overexcitation Relay. Reference the call-out letters to Figure 2-1.

Table 2-1. Controls and Indicators

Letter	Control or Indicator	Function or Indicator
A	**TAP** Switch	A ten-position rotary switch sets the pickup point when used in conjunction with the **RANGE** Switch (see I). Pickup levels (in vars) are labeled on the Tap Range Chart (see G).
B	**PICKUP** Indicator	LED illuminates to indicate that the pickup level has been exceeded.
C	**POWER** Indicator	LED illuminates to indicate that the relay power supply is functioning properly.
D	Target Reset Lever	Linkage extends through bottom of front cover to reset the target indicator.
E	Target Indicator (Optional)	Magnetically latching indicator is tripped to red to indicate that the output relay either has been energized (internally operated) or that a minimum of 0.2 amperes has flowed through the contacts (current operated).
F	**PUSH-TO-ENERGIZE** (Optional)	Momentary pushbutton is accessible through the front panel and used to test the output relay and verify system wiring.
G	Tap Range Chart	Provides an index of reactive power levels (in vars) that correspond to the **TAP** Switch positions.
H	**TIME DELAY** Selectors	Two thumbwheel switches select the trip time delay. The left thumbwheel represents seconds; the right thumbwheel represents tenths of a second. A **TIME DELAY** setting of 00 indicates instantaneous trip time.
I	**RANGE** Switch	Two-position switch selects the reactive power range (**HI** or **LOW**) desired.

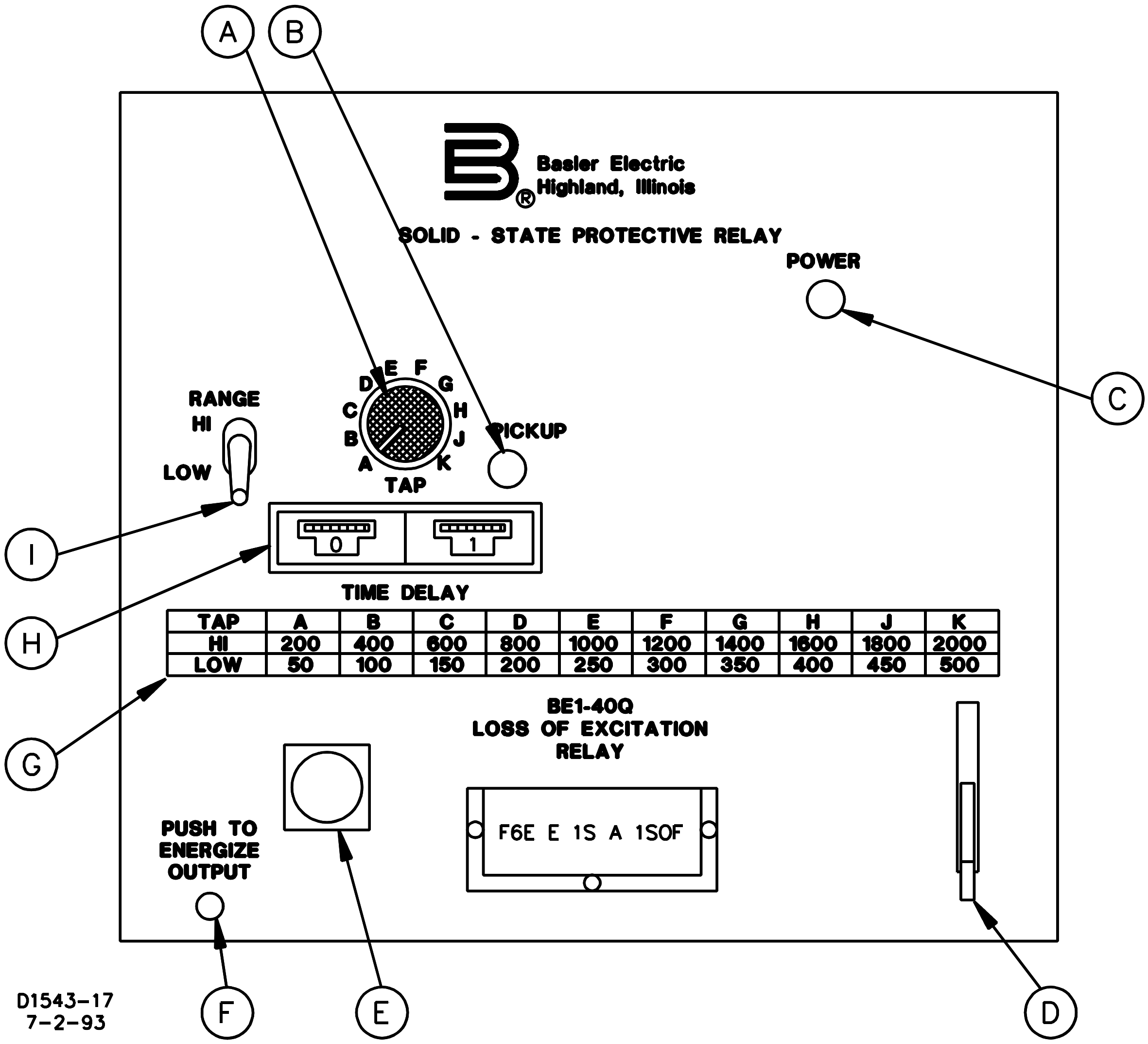


Figure 2-1. Location of Controls and Indicators

SECTION 3 • FUNCTIONAL DESCRIPTION

GENERAL

BE1-40Q Loss of Excitation Relays are static devices that respond to the relation of voltage to current magnitudes of the monitored circuit. As such they are sensitive to phase rotation. All connections shown in this manual assume ABC rotation.

FUNCTIONAL DESCRIPTION

Refer to Figure 3-1 to follow the functional description of the BE1-40Q Loss of Excitation Relay.

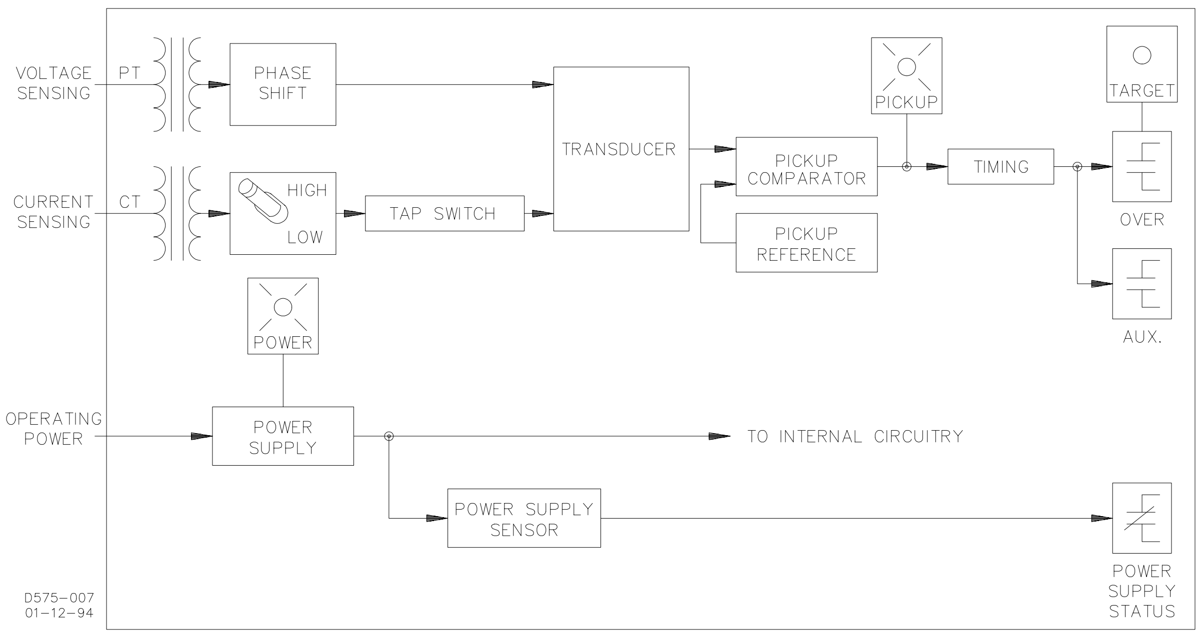


Figure 3-1. Functional Block Diagram

Voltage Sensing

The monitored voltage input is derived from a system voltage transformer connected phase-to-phase. An internal voltage transformer (PT) provides isolation and reduces the nominal value of the voltage sensing input (i.e., 120, 208, or 240 Vac) to internal circuitry requirements.

Phase Shift

Since the voltage input, V_{AB}, leads the sensed input current, I_B, by an angle of 150° for a unity power factor condition, the voltage phasor is internally shifted 68° in a lagging direction (delayed) to achieve the relay response characteristics. The resultant I_{TRIP} leads the polarizing voltage V_{POL} by 8° (when the system power factor angle (θ) is equal to —90°), as shown in Figure 3-2.

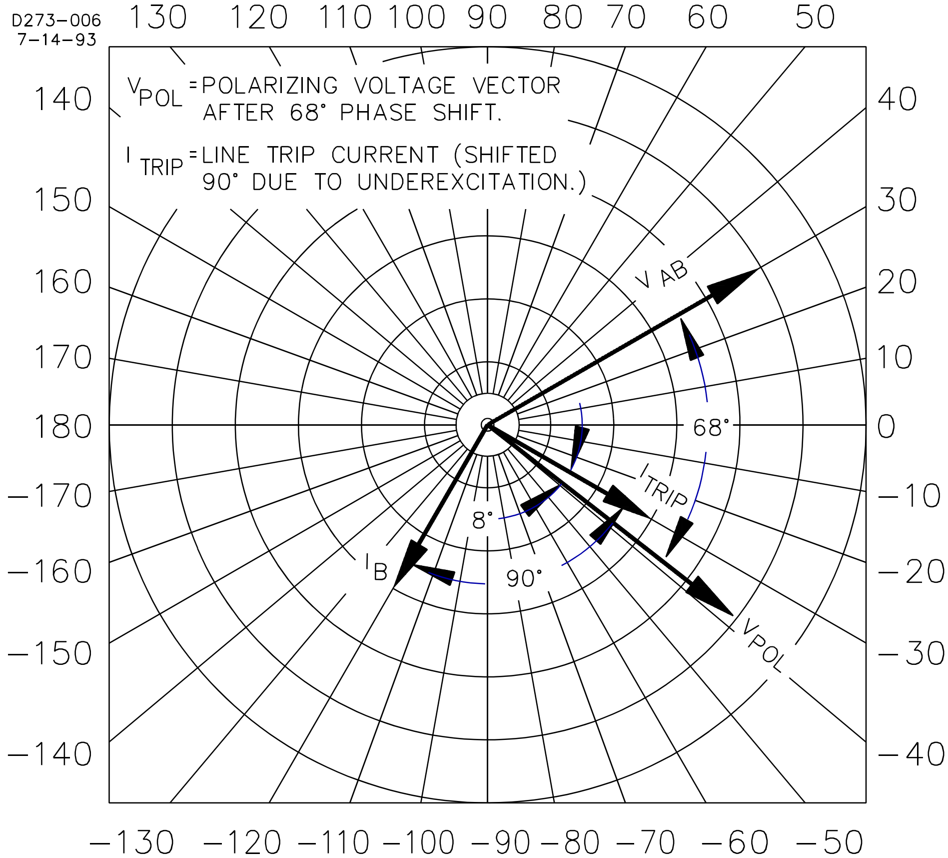


Figure 3-2. Phase Shift Example

The response of the relay is:

$$\text{Front Panel Pickup Setting} = \left(\frac{V_{AB}(I_B)}{\sqrt{3}}\right)\left(\frac{\sin(8^{\circ} \overset{\text{or}}{-} \theta)}{\cos 8^{\circ}}\right) \tag{3.1}$$

$$I_B = \left(\frac{\text{Front Panel Pickup Setting}}{V_{AB}}\right)\left(\frac{\sqrt{3}\cos 8^{\circ}}{\sin(8^{\circ} - \theta)}\right) \tag{3.2}$$

Where:

V_{AB} = phase A to phase B voltage magnitude
I_B = phase B current magnitude
θ = system power factor angle = (voltage angle) - (current angle)

Current Sensing

The monitored current is derived from the secondary of a system current transformer rated nominal five amperes. An internal current transformer (CT) provides isolation and scaling for proper relay operation. The front panel HI/LOW RANGE Switch uses the tapped secondary of the internal CT for range selection to increase pickup stability.

Note that when the connection plugs (paddles) are removed, the CT inputs are shorted.

HI/LOW RANGE Switch

The front panel HI/LOW RANGE switch selects which secondary winding of the internal CT is connected to the TAP Switch and thus the measurement circuitry. The position of this switch may be changed while sensing current is present. The effect of this switch, in conjunction with the TAP switch, is shown in the

Specifications, Table 1-1, and on the front panel tap range chart.

TAP Switch

The front panel TAP switch selects the pickup setting (in single-phase vars), depending on the position of the HI/LOW RANGE switch, as shown in Table 1-1. The TAP switch selects the resistive burden value that is placed across the output of the internal sensing input CT. The resistive burden establishes the scaling of the internal signal that represents the input current value.

Transducer

The transducer consists of a multiplier and integrator. The multiplier and associated control circuits produce an output that is representative of the product of the scaled current input and the scaled, phase-shifted voltage input signal. The output waveform of the multiplier is an instantaneous value; therefore, the output is integrated to develop a signal that represents the average var value. The integrator response time is a function of the pickup multiple, as shown in Section 1, *Specifications*.

Comparator

The signal representing the single-phase var value is compared with the pickup reference. When the reference value is exceeded, the PICKUP LED indicator is illuminated and timing is initiated.

Timing

A definite time delay is initiated when the monitored var level exceeds the pickup reference. A calibrated frequency generating circuit, in conjunction with counter circuits and the front panel TIME DELAY thumbwheel switches, establishes the definite time delay interval.

Time delay is adjustable from 0.1 to 9.9 seconds in 0.1 second intervals. A setting of 00 enables instantaneous (no intentional time delay) operation. Timing is instantaneously reset if the var level reduces to less than the pickup setting.

For a complete description of timing accuracy, refer to *Specifications* in Section 1.

Outputs

Defined by the style number, the output relay may have either a normally open (NO) or normally closed (NC) configuration. The normally open output contact option is required when current operated targets are desired.

In addition, an auxiliary output contact may be provided which is specified by style number as NO, NC, or SPDT. If an auxiliary contact is provided, then the power supply status output is not available.

Targets

A magnetically-latching target indicator may be provided for the output contact as an option. This target is actuated upon relay trip and may be either internally operated or current operated. An internally operated target may be specified with either a normally open or normally closed output contact. When a current operated target is desired, the output contact must be specified with a normally open configuration. The current operated target requires a minimum of 0.2 amps flowing through the output relay contacts. The target indicator must be reset with the manual target reset lever.

PUSH-TO-ENERGIZE OUTPUT Pushbutton

A small pushbutton switch may be provided as an option to allow testing the primary output contact and (if present) the auxiliary output contact. To prevent accidental operation, the pushbutton is recessed behind the front panel and is depressed by inserting a thin, non-conducting rod through an access hole in the front panel.

Power Supply

Basler Electric enhanced the power supply design for unit case relays. This new design created three, wide range power supplies that replace the five previous power supplies. Style number identifiers for these power supplies have not been changed so that customers may order the same style numbers that they ordered previously. The first newly designed power supplies were installed in unit case relays with EIA date codes 9638 (third week of September 1996). Relays with a serial number that consists of one alpha character followed by eight numerical characters also have the new wide range power supplies. A benefit of this new design increases the power supply operating ranges such that the 48/125 volt selector is no longer necessary. Specific voltage ranges for the three new power supplies and a cross reference to the style number identifiers are shown in the following table.

Table 3-1. Wide Range Power Supply Voltage Ranges

Power Supply	Style Chart Identifiers	Nominal Voltage	Voltage Range
Low Range	R	24 Vdc	12† to 32 Vdc
Mid Range	O, P, S	48, 125 Vdc, 120 Vac	24 to 150 Vdc, 90 to 132 Vac
High Range	T	125, 250 Vdc, 120, 240 Vac	62 to 280 Vdc, 90 to 270 Vac

† 14 Vdc is required to start the power supply.

Relay operating power is developed by the wide range, isolated, low burden, flyback switching, solid state power supply. Nominal ±12 Vdc is delivered to the relay internal circuitry. Input (source voltage) for the power supply is not polarity sensitive. A red LED turns ON to indicate that the power supply is functioning properly.

Power Supply Status Output

A normally closed output relay may be provided, whose contact remains open when energized by the presence of nominal voltage at the output of the power supply. If the power supply voltage fails or falls below requirements, the power supply status output relay will deenergize, closing its contact.

A shorting bar is included in the relay case so that the status output terminals can provide a remote indication that the BE1-40Q Relay has been withdrawn from its case or taken out of service by removing the connection plug.

If the power supply status output is provided, then auxiliary output contacts are not available.

SECTION 4 • INSTALLATION

GENERAL

When not shipped as part of a control or switchgear panel, relays are shipped in sturdy cartons to prevent damage during transit. Immediately upon receipt of a relay, check the model and style number against the requisition and packing list to see that they agree. Visually inspect the relay for damage that may have occurred during shipment. If there is evidence of damage, immediately file a claim with the carrier and notify the Regional Sales Office, or contact the Sales Representative at Basler Electric, Highland, Illinois.

In the event the BE1-40Q Relay is not to be installed immediately, store it in the original shipping carton in a moisture and dust free environment. See Section 5 for further information. When the relay is to be placed in service, it is recommended that the Operational Test Procedure (Section 5) be performed prior to installation.

RELAY OPERATING PRECAUTIONS

Before installation or operation of the relay, note the following precautions:

1. A minimum of 0.2 A in the output circuit is required to ensure operation of current operated targets.
2. The relay is a solid-state device. If a wiring insulation test is required, remove the connection plugs and withdraw the cradle from its case.
3. When the connection plugs are removed, the relay is disconnected from the operating circuit and will not provide system protection. Always be sure that external operating (monitored) conditions are stable before removing a relay for inspection, test, or service.
4. Be sure the relay case is hard wired to earth ground using the ground terminal on the rear of the unit. It is recommended to use a separate ground lead to the ground bus for each relay.

DIELECTRIC TEST

In accordance with IEC 255-5 and ANSI/IEEE C37.90-1989, one-minute dielectric tests (high potential) may be performed as follows:

All circuits to ground:	2121 Vdc.
Input to output circuts:	1500 Vac or 2121 Vdc.

MOUNTING

Because the relay is of solid-state design, it does not have to be mounted vertically. Any convenient mounting angle may be chosen. Relay outline dimensions and panel drilling diagrams are supplied in Figures 4-1 through 4-9.

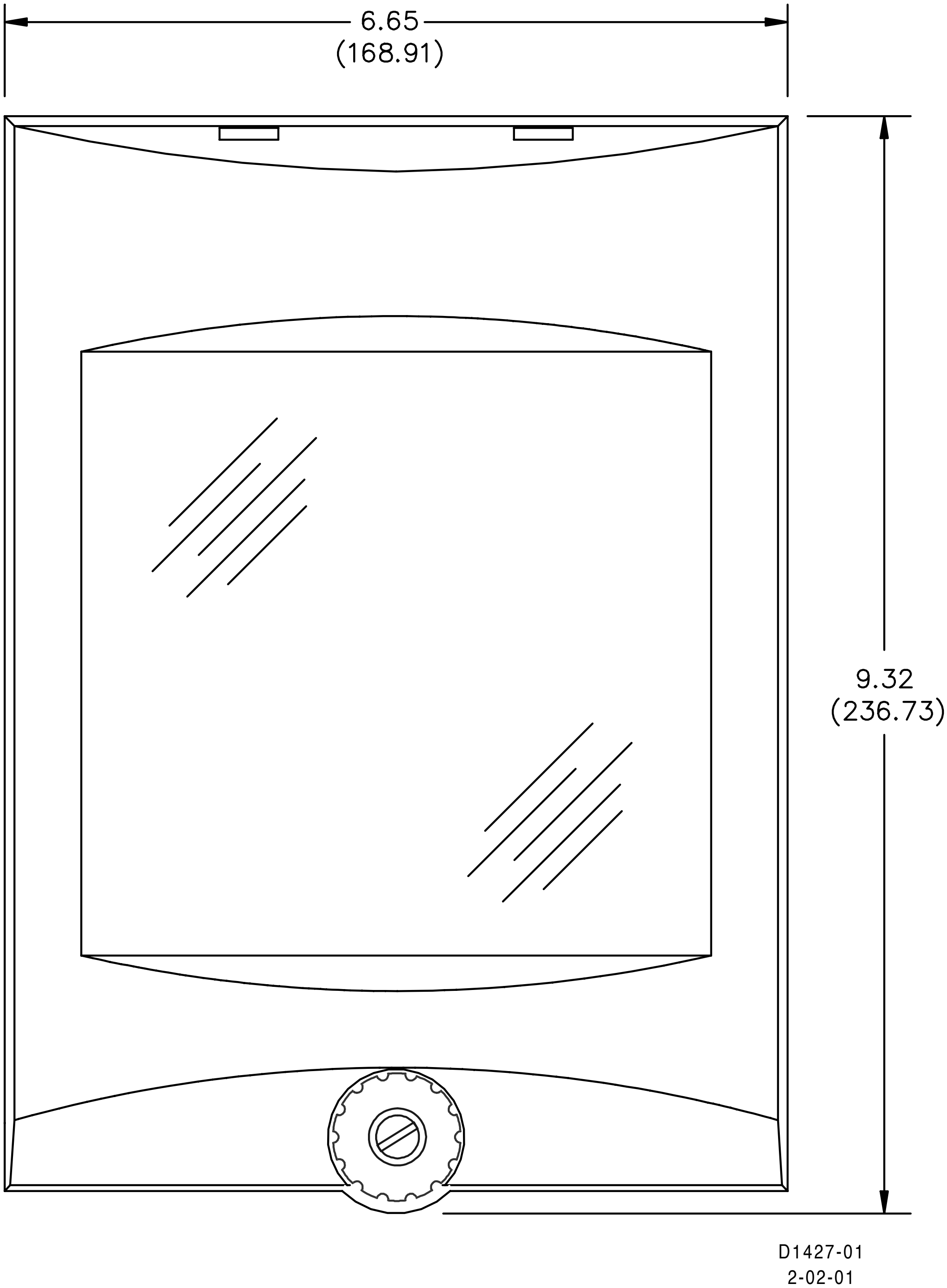


Figure 4-1. S1 Case, Outline Dimensions, Front View

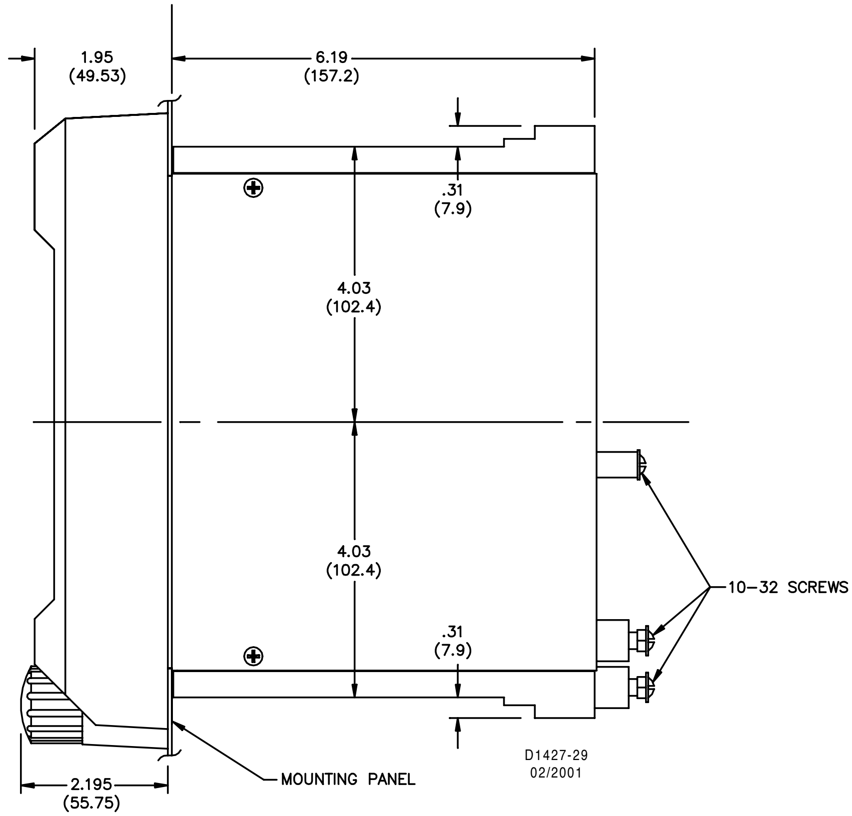


Figure 4-2. S1 Case, Single-Ended, Semi-Flush Mounting, Outline Dimensions, Side View

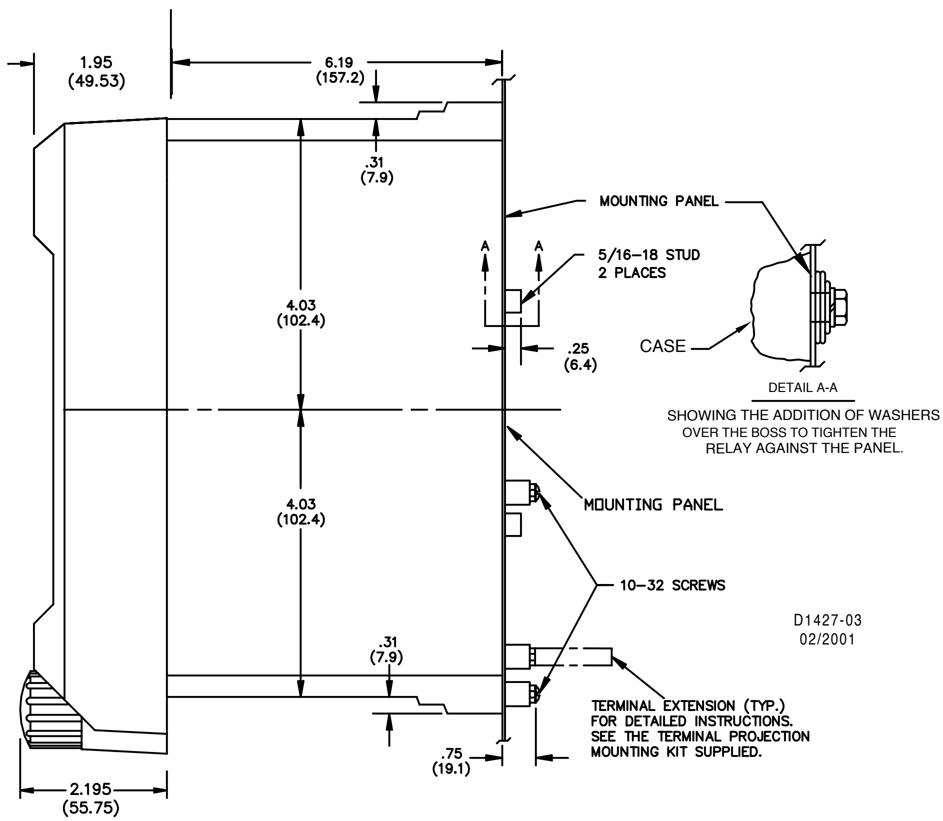


Figure 4-3. S1 Case, Single-Ended, Projection Mounting, Outline Dimensions, Side View

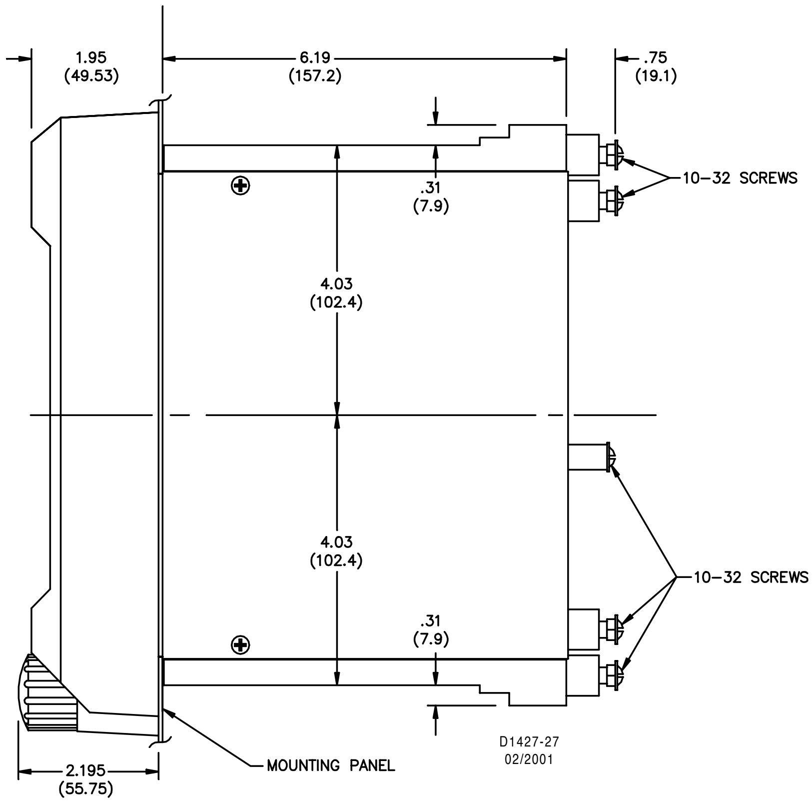


Figure 4-4. S1 Case, Double-Ended, Semi-Flush Mounting, Outline Dimensions, Side View

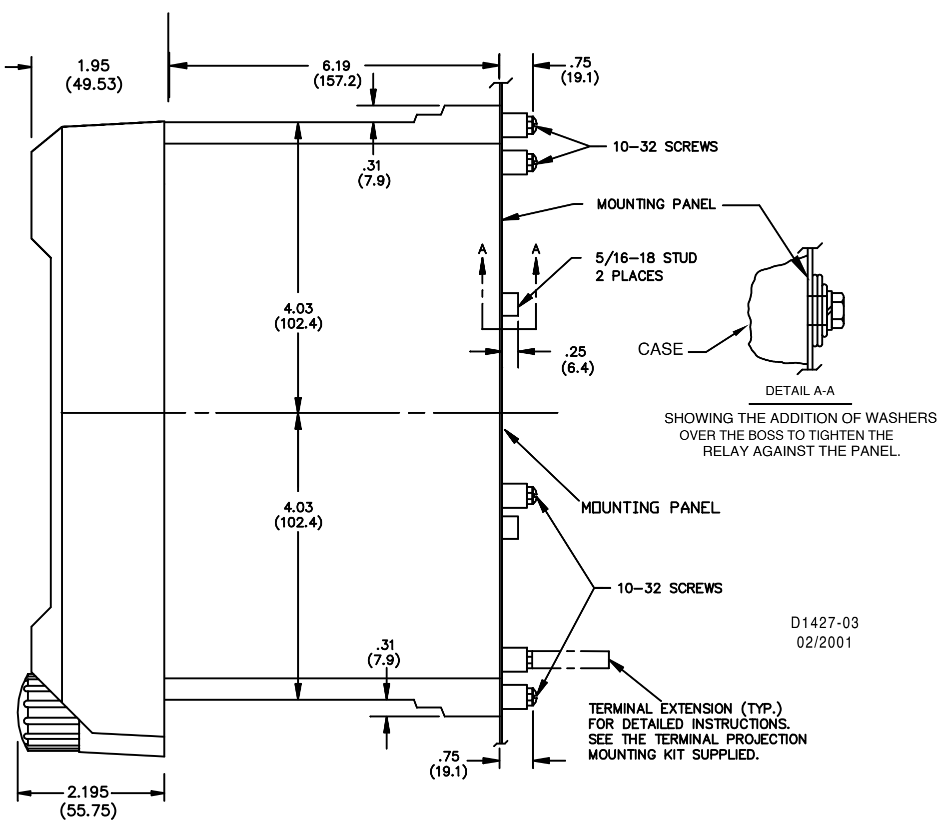


Figure 4-5. S1 Case, Double-Ended, Projection Mounting, Outline Dimensions, Side View

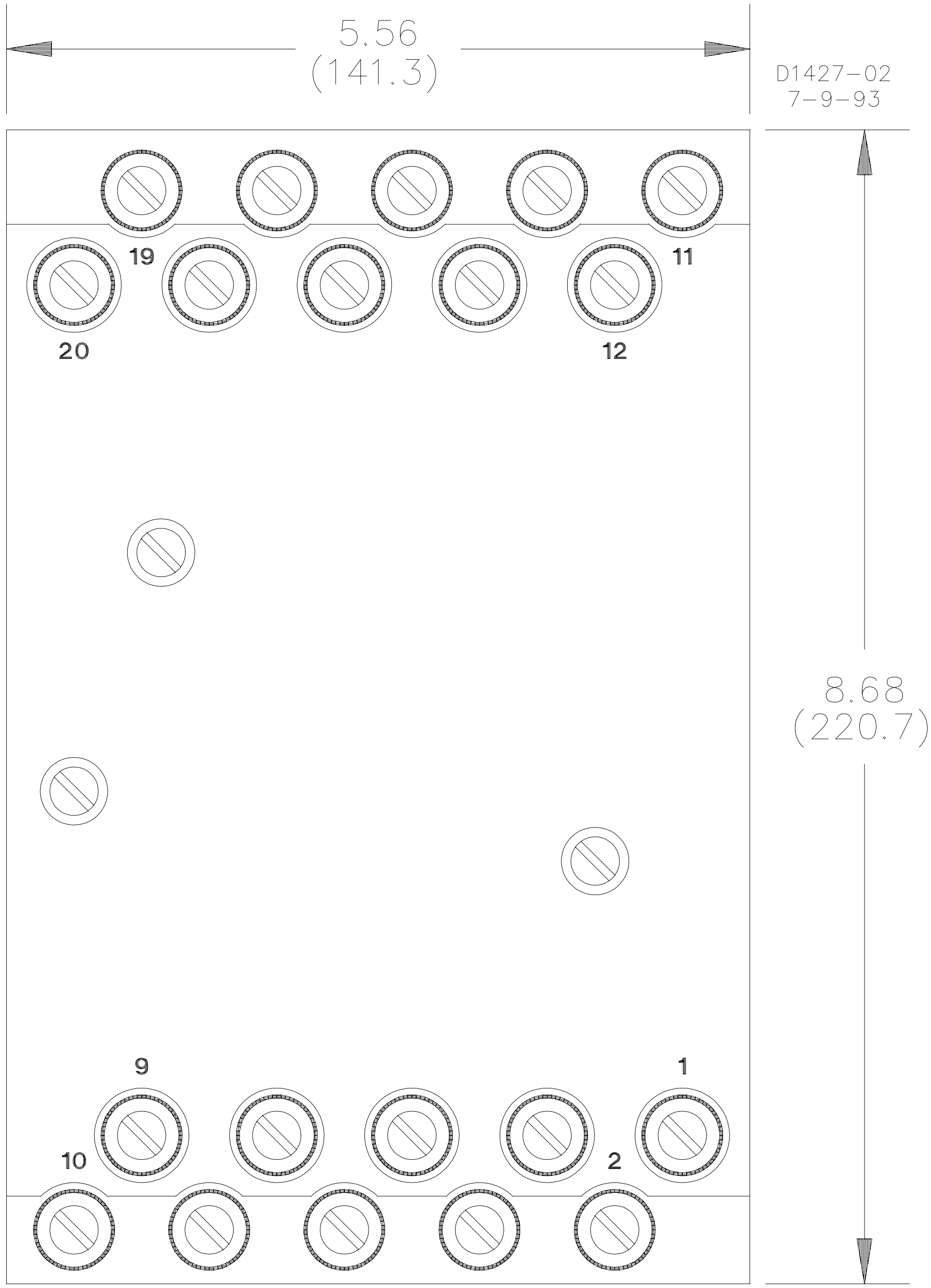


Figure 4-6. S1 Case, Outline Dimensions, Rear View

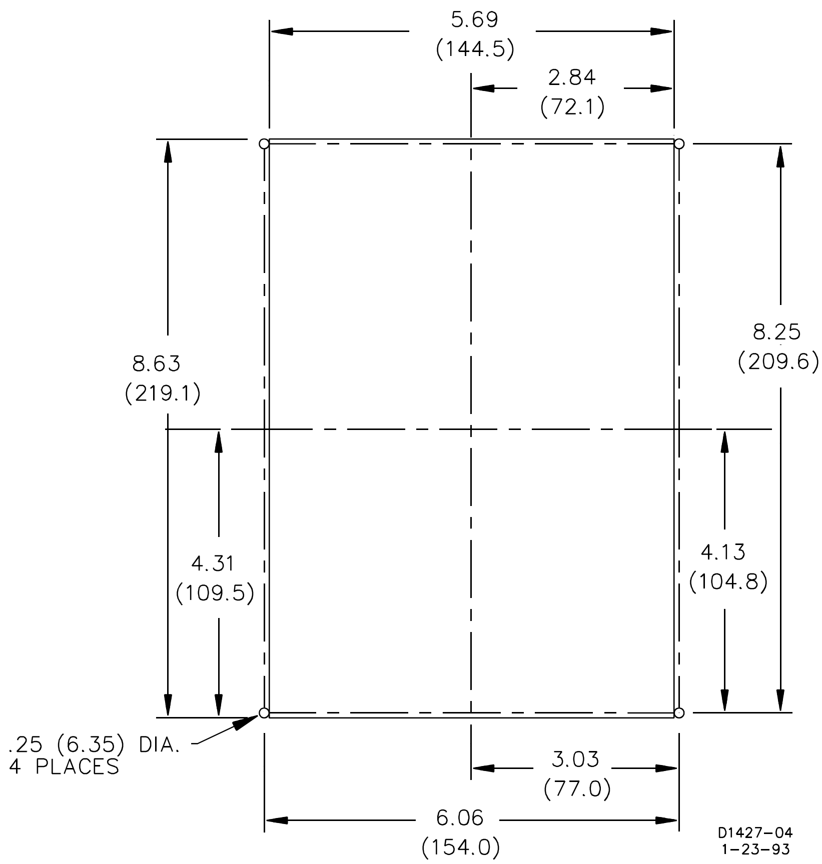


Figure 4-7. S1 Case, Panel Drilling Diagram, Semi-Flush Mounting

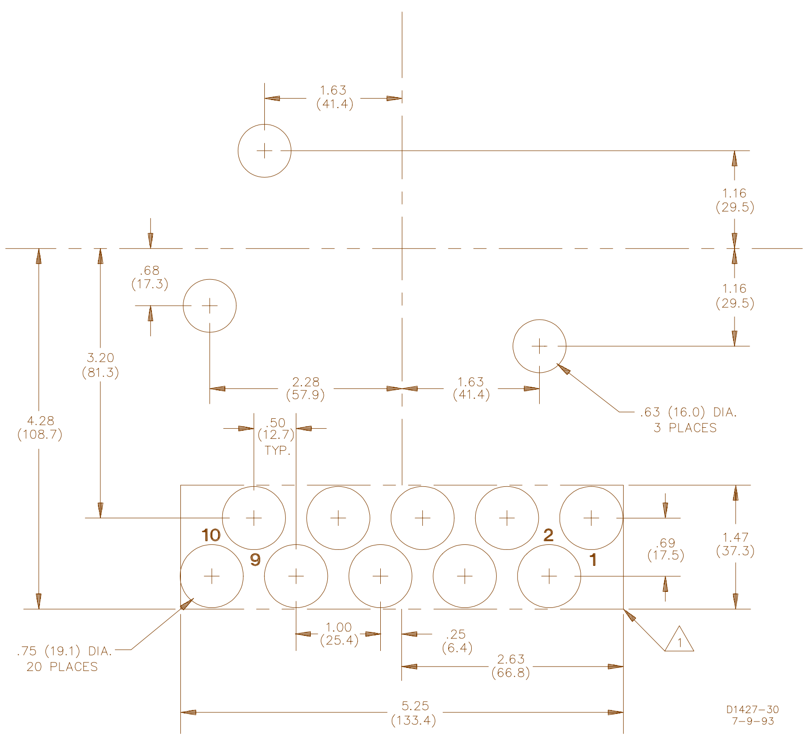


Figure 4-8. S1 Case, Single-Ended, Panel Drilling Diagram, Rear View (Projection Mounting)

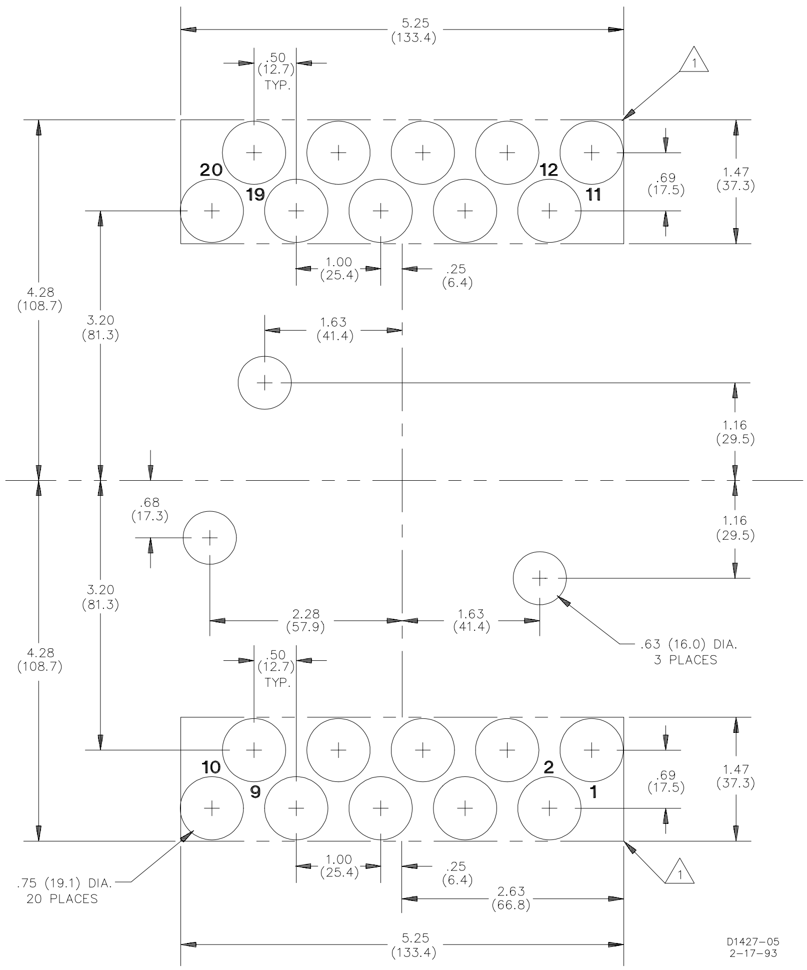


Figure 4-9. S1 Case, Double-Ended, Panel Drilling Diagram, Rear View (Projection Mounting)

CONNECTIONS

Incorrect wiring may result in damage to the relay. Except for the ground wire, connections should be made with minimum wire size of 14 AWG. For the ground wire, refer to the following note. Typical sensing input connections are shown in Figure 4-10. Typical output connections are shown in Figure 4-11. Internal wiring diagrams are shown in Figures 4-12 through 4-14. All connections shown in this manual assume ABC rotation.

NOTE

Be sure the relay case is hard-wired to earth ground with no smaller than 12 AWG copper wire attached to the ground terminal on the rear of the relay case. When the relay is configured in a system with other protective devices, it is recommended to use a separate lead to the ground bus from each relay.

Relay circuitry is connected to the case terminals by removable connection plugs (1 plug for 10-terminal cases and 2 plugs for 20 terminal cases). Removal of the connection plug(s) opens the normally open trip contact circuits and shorts the normally closed trip contact circuits before opening the power and sensing circuits. The CT inputs are shorted when the plug(s) are removed.

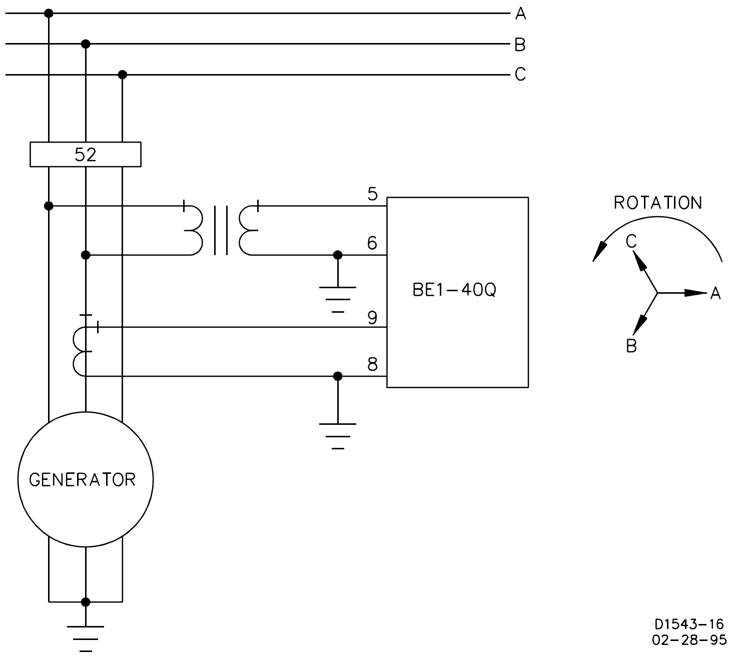


Figure 4-10. Sensing Input Connections

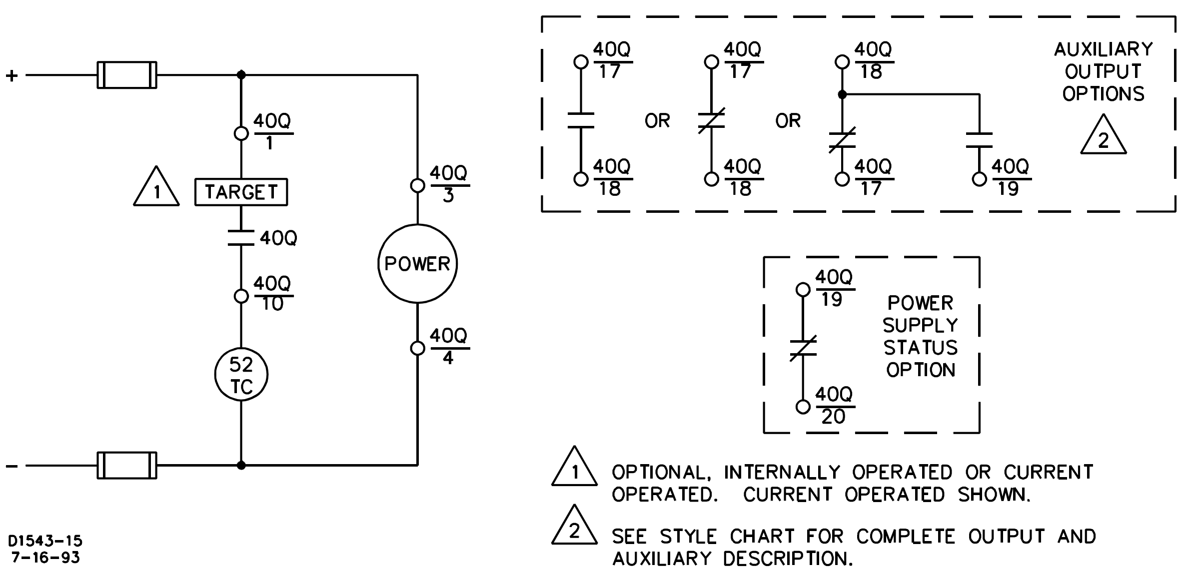


Figure 4-11. Output Connections

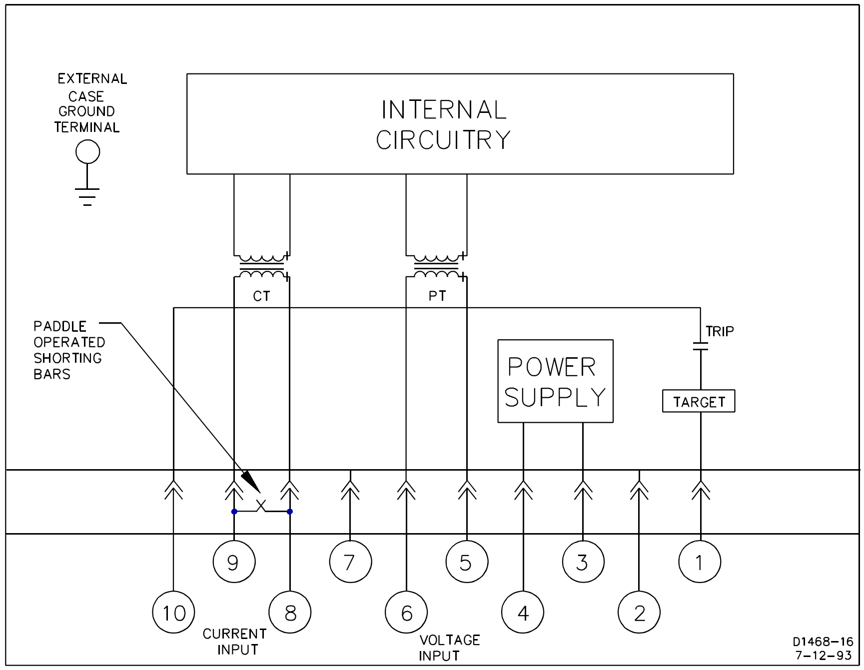


Figure 4-12. Interconnection With Current Operated Targets

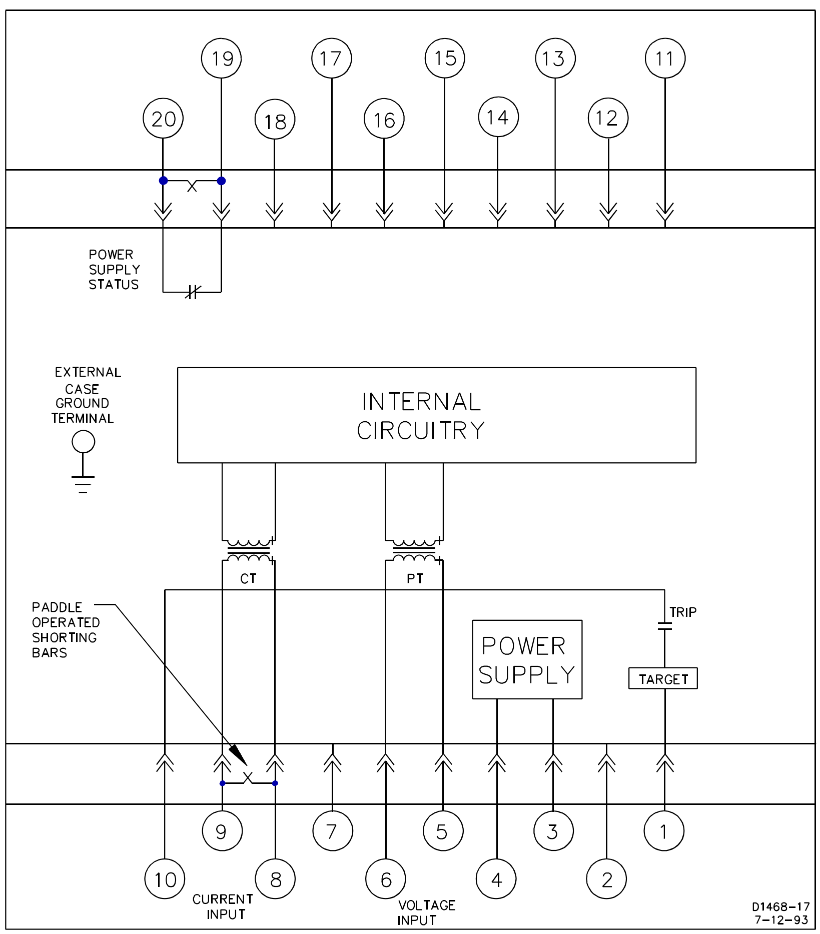


Figure 4-13. Interconnection With Current Operated Targets and Power Supply Status Output

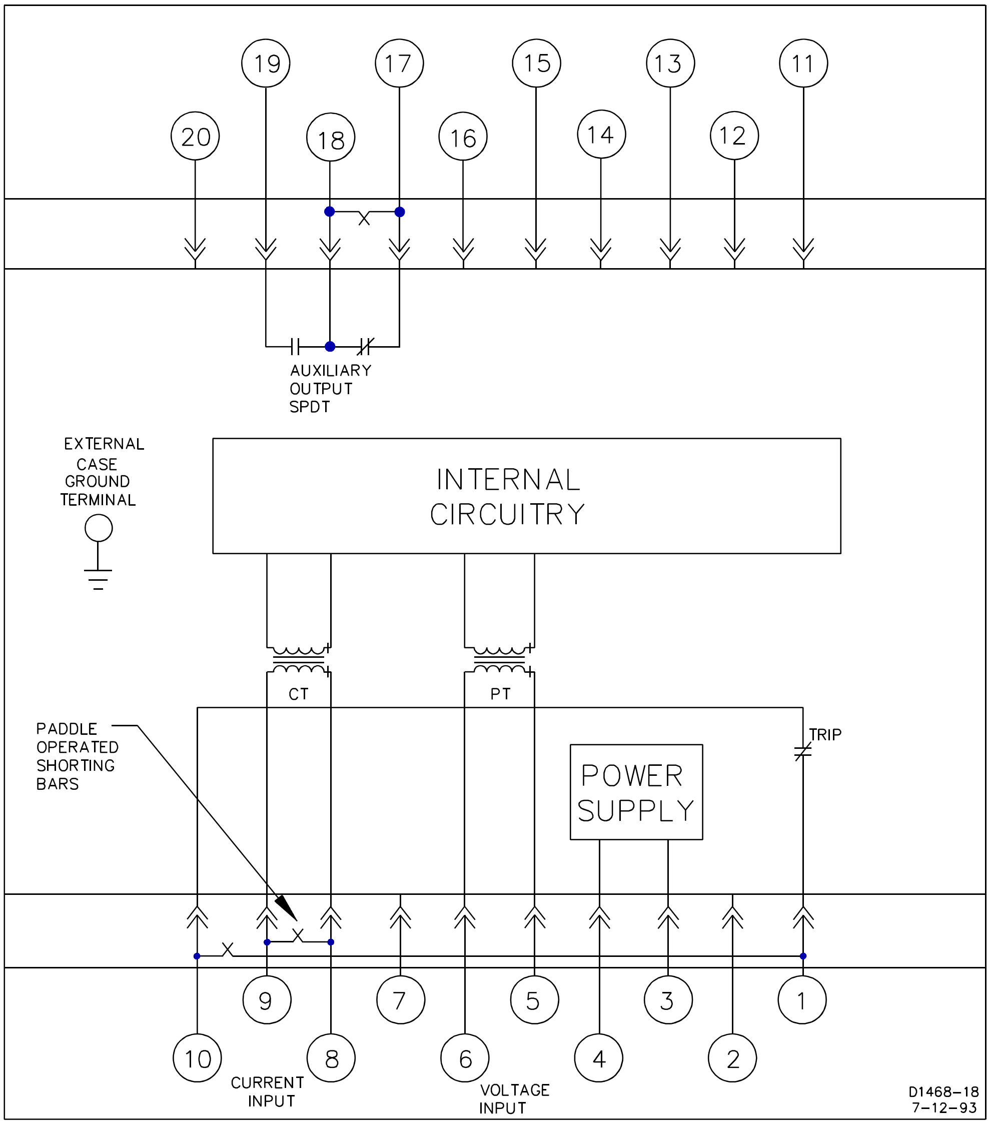


Figure 4-14. Interconnection With Internally Operated Target and Auxiliary Output Contacts (SPDT)

SECTION 5 • SETTING AND TESTING

SETTING

Setting the pickup value of BE1-40Q Relays is facilitated by using the capability curves supplied by the generator manufacturer as shown previously in the examples in Section 1. The figure for relay operating characteristics is repeated here as Figure 5-1. Note that the line representing the relay characteristic is positioned on the curve 8° from horizontal and just above the point where the steady state stability limit arc intersects the capability curve. (The 8° slope applies to all BE1-40Q Relays.)

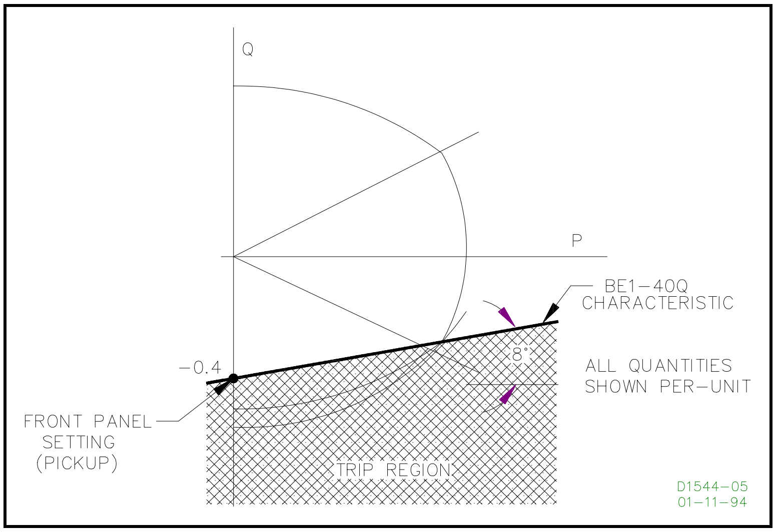


Figure 5-1. An Example of BE1-40Q Relay Operating Characteristics

The pickup setting is determined by the point where the BE1-40Q characteristic intersects the Q axis in per unit (pu) quantities. Therefore, for the example shown in Figure 5-1, the pickup is -0.4 pu. The actual per unit pickup setting for your relay is determined by your specific application.

Per Unit Conversion Example

The per unit quantity is converted to a TAP Switch setting by the procedure described in the following example.

Given:

Rated power = 100 MVA
Rated voltage = 12.8 kV
CT ratio = 5000/5
PT ratio = 12800/120

Step 1. Determine the desired primary vars.

$$\begin{aligned} \text{Three-phase primary vars} &= 0.4 \times \text{rated power} \\ &= 0.4 \times 100 \text{ MVA} \\ &= 40 \text{ Mvar} \\ \text{Single-phase primary vars} &= 13.33 \text{ Mvar} \end{aligned} \tag{4.1}$$

Step 2. Determine the desired primary current.

$$\begin{aligned}\text{Primary current} &= (\text{single-phase primary var})\left(\frac{\sqrt{3}}{V_{LL}}\right)\\ &= (13.33\ \text{Mvar})\left(\frac{\sqrt{3}}{12800}\right) \qquad (4.2)\\ &= 1804\ \text{A}\end{aligned}$$

Step 3. Specify a BE1-40Q Relay having a nominal sensing range of 120 V_{LL} (for a PT ratio of 12800/120).

Step 4. Determine the desired secondary current.

$$\begin{aligned}\text{Secondary current} &= \frac{\text{primary current}}{\text{CT ratio}}\\ &= \frac{1804}{5000/5} \qquad (4.3)\\ &= 1.8\text{A}\end{aligned}$$

Step 5. Determine the pickup.

$$\begin{aligned}\text{Pickup} &= \frac{V_{relay}}{\sqrt{3}} \times I_{relay}\\ &= \frac{120}{\sqrt{3}} \times 1.8 \qquad (4.4)\\ &= 125\\ &= \text{Low Range, TAP position E (Table 1-1)}\end{aligned}$$

OPERATIONAL TEST PROCEDURE

BE1-40Q Loss of Excitation Relays operation and calibration can be verified by the following operational test procedure. Test results obtained from this procedure may not fall within specified tolerances because of inaccuracies in test equipment. When evaluating results, consider the inherent error of the test equipment. Test equipment should be accurate within one percent or better.

Pickup Verification

Step 1. Connect the test circuit as shown in Figure 5-2. Apply appropriate operating power, depending on the power supply option (refer to the Style Number Identification Chart in Section 1), to terminals 3 and 4. The POWER LED should light.

Step 2. For relay styles with target indicators, actuate the target reset lever to insure that the target is reset.

Step 3. For a setting of 25 var, make the following front panel adjustments on the BE1-40Q Relay:

RANGE Switch - LOW position
TAP Switch - Position A (minimum)
TIME DELAY Switches - 10 (1.0 second)

Step 4. If equipped with a power supply status output relay (option 2-S), verify that the contact is open when external power is applied. Remove input power and verify that the status contacts close. Reapply external power.

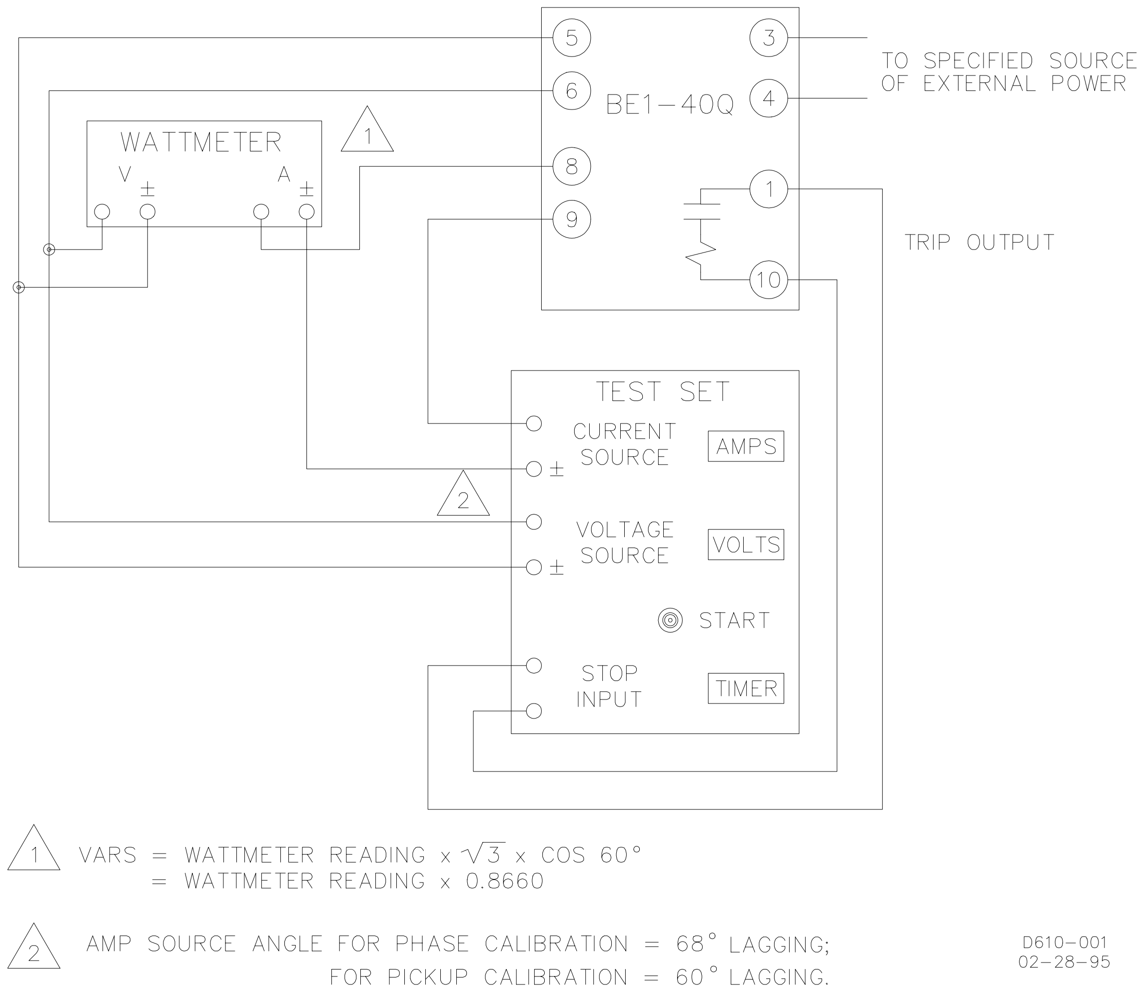


Figure 5-2. Test Circuit Connections

Step 5. Adjust the voltage source to the nominal value of the sensing input as designated by the second digit of the style number. (Refer to Table 5-1.)

Table 5-1. Nominal Sensing Input Voltage

Second Digit of Style Number	Nominal Ac Voltage
3	120
6	208
9	240

Step 6. Adjust the phase of the current source to produce an output that lags the voltage input by 60°.

Step 7. Slowly increase the magnitude of the current source until the PICKUP LED lights. On units with target indicators, the indicator should operate.

NOTE

Equation 4.5 applies only to Step 8 of the Pickup Verification Test Procedure. For the pickup response of the BE1-40Q Relay, see Equation 3.1.

Step 8. Note the indicated voltage and current, and calculate the actual pickup value as defined by:

$$\text{pickup} = \frac{V_{relay}}{\sqrt{3}} \times I_{relay} \tag{4.5}$$

Compare the result with Table 1-1. Reset the target indicator, if present.

Step 9. Repeat Steps 7 and 8 for each TAP setting, verifying both the HI and LOW RANGE setpoints. The pickup tolerance should be ±2% of the front panel setting or 0.1 var, whichever is greater.

Timing Verification

Step 1. Connect the test circuit as shown in Figure 5-2.

Step 2. Connect a timer to record the time interval from application of the test current that will be applied in Step 6, to the change of state of the output relay. If a normally open contact has been selected, a trip will occur when the contact closes; normally closed contacts will open to trip.

Step 3. Make the following front panel adjustments on the BE1-40Q Relay:

RANGE Switch - LOW position
TAP Switch - Position A (minimum)
TIME DELAY Switches - 10 (1.0 second)

Step 4. Apply appropriate operating power, depending on the power supply option, to terminals 3 and 4. The POWER LED should light.

Step 5. Adjust the voltage source to the nominal value of the sensing input as designated by the second digit of the style number.

NOTE
The test current given in Table 5-2, below, is twice the pickup current.

Step 6. Adjust the current source to produce a 60° lagging current that steps from zero magnitude to the test current value shown in Table 5-2.

Table 5-2. Test Current

Second Digit of Style Number	Nominal Ac Voltage	Pickup Current	Test Current
3	120	0.361 A	0.722 A
6	208	0.416 A	0.832 A
9	240	0.361 A	0.722 A

Step 7. The actual time delay should be 1.0 second ±5%.

Step 8. Adjust the TIME DELAY Switches to a setting of 55 (5.5 seconds), and repeat Steps 6 and 7. The time delay should be 5.5 seconds ±5%.

Step 9. Adjust the TIME DELAY Switches to a setting of 99 (9.9 seconds), and repeat Steps 6 and 7. The time delay should be 9.9 seconds ±5%.

Relay Characteristics Verification

Preliminary

Step 1. Connect the test circuit as shown in Figure 5-2.

Step 2. Adjust the BE1-40Q Relay for the desired pickup value as specified by the generator application or the test setup capabilities.

Step 3. Adjust the TIME DELAY switches to a minimum value (e.g., 0.1, 0.2, or 0.3 seconds).

Step 4. Adjust the voltage source to the nominal value of the sensing input as designated by the second digit of the style number, at a leading phase angle of 150°.

Characteristics Data

Step 1. Adjust the current source phase angle for each of the values indicated in Table 5-3. Record the magnitude of current required to receive each pickup indication. To measure pickup for each phase angle setting, slowly increase the current magnitude from zero or a value less than the pickup value until the PICKUP LED lights and an output contact operation occurs.

NOTE

With the test setup as specified, the current source phase angle setting simulates a leading power factor angle, i.e., $\theta < 0$.

Table 5-3. Current Magnitudes Required for Pickup

Current Source Phase Angle Setting (Degrees)	Equivalent System Power Factor Angle (θ) In Degrees	Current Magnitude Required for Pickup (Amps)
+20	-20	
+30	-30	
+40	-40	
+50	-50	
+60	-60	
+70	-70	
+80	-80	
+90	-90	
+100	-100	
+110	-110	
+120	-120	

Step 2. With the above recorded data, calculate P (watts) and Q (vars), as follows, for each recorded pickup value.

$$P = \frac{V_{LL}}{\sqrt{3}}(I_L)\cos\theta \quad (4.6)$$

$$Q = \frac{V_{LL}}{\sqrt{3}}(I_L)\sin\theta \quad (4.7)$$

Where:

V_{LL} = voltage measured in the test setup of Figure 5-2,
I_L = current measured in the test setup of Figure 5-2,

θ = the (-) angle setting of the current source.

> **NOTE**
>
> If V = | V | ∠α and I = | I | ∠β,
>
> Then:
>
> Real power (P) = | V | x | I | cos(α - β),
>
> Reactive power (Q) = |V| x | I | sin(α - β), and
>
> System power factor angle (θ) = α - β

Step 3. The results from the above calculations can now be plotted on a graph of the complex power plane.

Graph Example

Given:

Relay style number is BE1-40Q F3E E1P B1S1F. (Reference the Style Number Identification Chart, Figure 1-4.)

Pickup is set to 125. (Reference Table 1-1.)

Test results are obtained as given in Step 1. For this example, we are using the data shown in columns [1] and [2] of Table 5-4, below.

Step 1. Calculate P and Q for a current phase angle of 20° (θ = -20°).

$$P = \frac{120}{\sqrt{3}}(3.806)\cos(-20°) = 247.8\ \text{W} \qquad (4.8)$$

$$Q = \frac{120}{\sqrt{3}}(3.806)\sin(-20°) = -90.18\text{vars} \qquad (4.9)$$

Note that the above results for a phase angle of -20° have been entered in Table 5-4, columns [3] and [4], first row. Similarly, the values of P and Q can be solved for the other phase angles of column [1].

Step 2. Finally, the data from Table 5-4 is shown plotted on the complex power plane shown in Figure 5-3. A blank graph is provided as Figure 5-4.

Table 5-4. Data for the Hypothetical Graph of Figure 5-3

[1]		[2]	[3]	[4]
Current Source Phase Angle Degrees	System Phase Angle θ	Current Magnitude for Pickup (Amps)	Real Power (Watts)	Reactive Power (Vars)
+20	-20	3.806	247.76	-90.18
+30	-30	2.902	174.12	-100.53
+40	-40	2.404	127.60	-107.07
+50	-50	2.107	93.82	-111.81
+60	-60	1.927	66.75	-115.62
+70	-70	1.827	43.28	-118.92
+80	-80	1.788	21.51	-121.98
+90	-90	1.804	0.00	-125.00
+100	-100	1.879	-22.60	-128.18
+110	-110	2.024	-47.95	-131.74
+120	-120	2.267	-78.54	-136.04

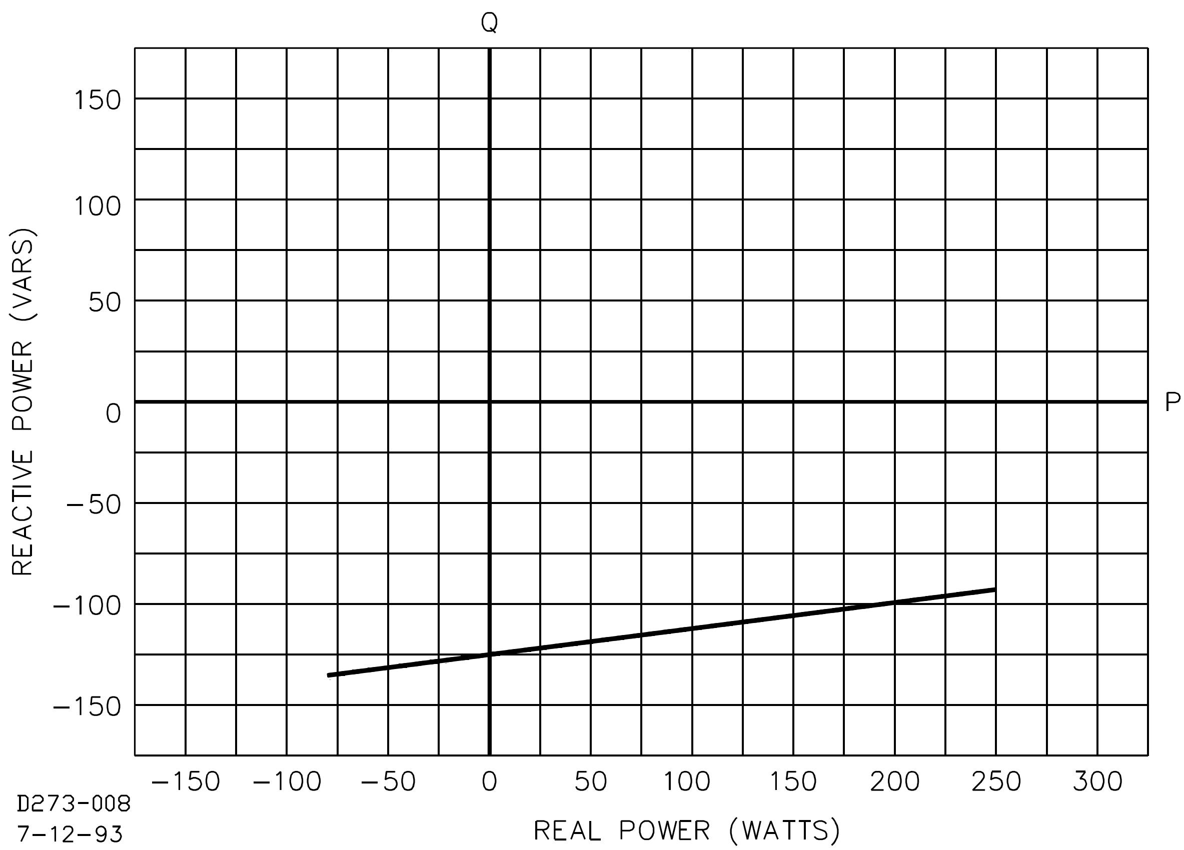


Figure 5-3. BE1-40Q Relay Characteristics Plotted on Complex Power Plane

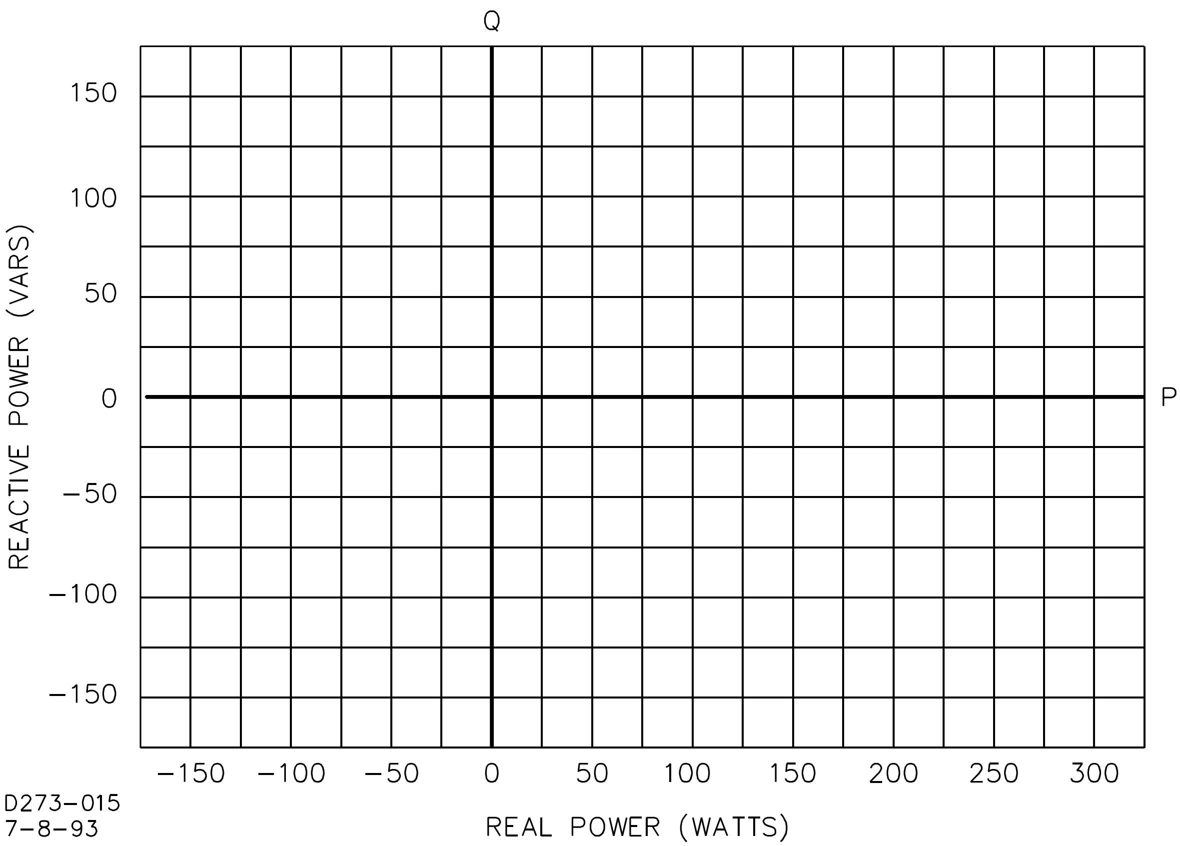


Figure 5-4. Blank Graph

SECTION 6 • MAINTENANCE

GENERAL

BE1-40Q Loss of Excitation Relays require no preventive maintenance other than a periodic operational test (refer to Section 5 for operational test procedure). If the relay fails to function properly, and factory repair is desired, contact the Customer Service Department of the Power Systems Group, Basler Electric, for a return authorization number prior to shipping.

IN-HOUSE REPAIR

In-house replacement of individual components may be difficult and should not be attempted unless appropriate equipment and qualified personnel are available.

> **CAUTION**
>
> Substitution of printed circuit boards or individual components does not necessarily mean the relay will operate properly. Always test the relay before placing it in operation.

When complete boards or assemblies are needed, the following information is required.

1. Relay model and style number
2. Relay serial number
3. Board or assembly
   a) Part number
   b) Serial number
   c) Revision letter
4. The name of the board or assembly.

STORAGE

This protective relay contains aluminum electrolytic capacitors which generally have a life expectancy in excess of 10 years at storage temperatures less than 40° C. Typically, the life expectancy of the capacitor is cut in half for every 10°C rise in temperature. Storage life can be extended if, at one-year intervals, power is applied to the relay for a period of thirty minutes.

TEST PLUG

Test plugs (Basler part number 10095 or G.E. part number XLA12A1) provide a quick, easy method of testing relays without removing them from their case. Test plugs are simply substituted for the connection plugs. This provides access to the external stud connections as well as to the internal circuitry.

Test plugs consist of black and red phenolic moldings with twenty electrically separated contact fingers connected to ten coaxial binding posts. Fingers on the black side are connected to the inner binding posts (black thumb nuts) and tap into the relay internal circuitry. Fingers on the red side of the test plug are connected to the outer binding posts (red thumb nuts) and also connect to the relay case terminals.

When testing circuits connected to the bottom set of case terminals, the test plug is inserted with the numbers 1 through 10 facing up. Similarly, when using the test plug in the upper part of the relay, the numbers 11 through 20 are faceup. It is impossible, due to the construction of the test plug, to insert it with the wrong orientation.

SECTION 7 • MANUAL CHANGE INFORMATION

CHANGES

Substantive changes in this manual to date are summarized in the following table.

Table 7-1. Manual Change Information

Revision	Summary Of Changes	ECA/ECO	Date
A	Figure 3-3 added; editing changes made to clarify specifications; two articles added to Section 4, entitled, “Setting the Pickup” (page 4-5) and, “Relay Characteristic Verification” page 4-7.	10562	11-22-88
B	Minor corrections and editing.	10621	11-22-88
C	Figure 3-2 corrected; equations on page 4-8 restated for clarification; arithmetical errors corrected in the example given on page 4-8; Table 4-2 corrected; Figure 4-3 was reformatted; Figure 4-7 revised to clarify installation.	11090	06-16-89
D	Equations 4.1 through 4.4 put into standard form by removing negative sign from the angle theta.	11154	08-08-89
E	Legend of Figure 3-2 corrected. Page 3-1 (under “Phase Shift”): 68° was 52°.	11645	09-04-90
F	Pages 1-3, 1-5 (Style Chart), 1-7 2-1 (Item H), 4-4 (step 3), 4-7 (Step 3): Time delay range is 0.1 to 9.90 seconds, adjustable in increments of 0.1 seconds. This was previously unclear or (in some cases) erroneous. Page 1-8: RFI specification added. Pages 1-6, 5-1: minor editing.	11826	01-10-91
G	Deleted references to mho characteristic. Corrected Figure 4-3 (Sensing Input Test Setup), current sensing input terminals 8 and 9 were reversed on earlier versions; renumbered equations; updated format; and added new internal connection diagrams Figures 4-3 through 4-5, added new mounting diagrams Figures 4-6 through 4-14. Added new Section 5, *Setting and Testing*, moved appropriate data from Section 4 into Section 5, and changed Sections 5 and 6 to Sections 6 and 7.	13492	01-11-94
H	Changed *Section 1, General Information, Specifications, Output Circuits* and *Isolation*. Added phase rotation sensitivity information to *Section 3, Functional Description*. Changed *Section 4, Installation, Dielectric Test*, to reflect specification changes. Corrected Figure 4-1 and changed Figure 5-2, note 2. Corrected typographical error in *Table 5-4, Reactive Power (Vars), +120.* Corrected typographical error in *Section 6, Maintenance, General.*	14962	03-01-95

Revision	Summary Of Changes	ECA/ECO	Date
J	Corrected Voltage Sensing in *Specifications* from "Each have a burden that is less than 0.1 ohm over the" to "Each have a burden that is less than 1 VA over the." Deleted 500 Vdc from *Resistive Output Circuits*. Deleted all references to Service Manual. Updated Style Number Identification Chart by changing Power Supply Type T from "230 Vac" to "240 Vac." Added new power supply information to Specifications and Section 3 starting with "Basler Electric enhanced the power supply design..." Changed the format of the manual.	1033	10-27-98
K	Updated S1 case drawings in Section 4 to the most recent drawings.	12241	02-07-01