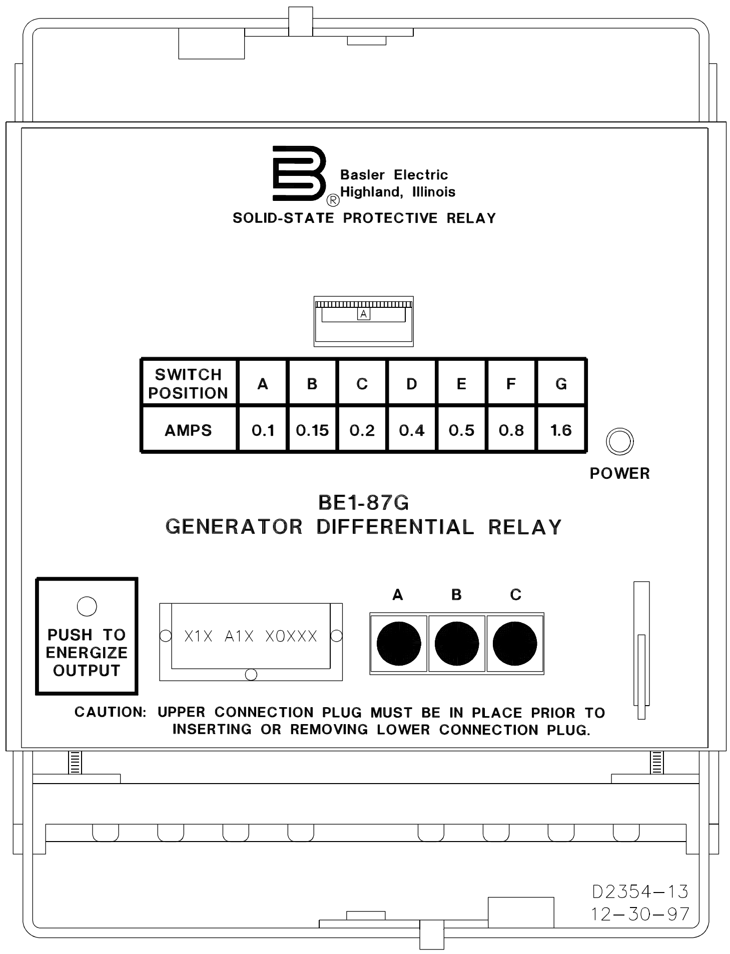
INSTRUCTION MANUAL

FOR

VARIABLE PERCENTAGE DIFFERENTIAL RELAY

BE1-87G



Basler Electric

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INTRODUCTION

This manual provides information concerning the operation and installation of the BE1-87G Variable Percentage Differential Relay. To accomplish this, the following is provided.

- **Specifications**
- **Functional description**
- **Mounting information**
- **Setting procedure/example.**

W A R N I N G !

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

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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.

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SECTION 5 TESTING AND SETTING - Continued

SECTION 1 • GENERAL INFORMATION

DESCRIPTION

BE1-87G Variable Percentage Differential relays are single- or three-phase solid state devices designed to provide selective, high-speed, differential protection for generators, motors and shunt reactors.

Differential relaying selectivity is based on the ability of a relay to distinguish between an internal fault (within the protected zone) and an external fault. Under normal operating conditions the current into the protected zone equals the current out of the protected zone with a net operating current equal to zero. Internal faults upset this balance and result in a difference between the input and output currents. External faults have relatively little effect on the balance because the protected zone input current still equals the output current. Therefore, by comparing the currents on both sides of the protected element or zone and detecting when these currents are not equal, a differential relay acts to isolate the element or zone from the system with unsurpassed effectiveness.

BE1-87G Variable Percentage Differential relays typically trip a lockout relay (86) which in turn trips the generator breaker and, when present, the field and/or neutral breakers.

APPLICATION

BE1-87G Variable Percentage Differential relays are recommended for the following specific applications when used with current transformers (CT) with an accuracy class of either C20 or better or T20 or better.

- Generators: any terminal voltage and a rating of 1000 kVA and above.
- Generators: any kVA rating and a terminal voltage of 5 kV and above.
- Generators: a terminal voltage of 2200 V or higher, and a rating of more than 500 kVA.
- Motors: rated 1500 horsepower and above.
- As primary protection on shunt reactors for transmission lines.
- Generator ground differential

Differential relaying is the most selective form of fault protection which may be applied to the individual elements or zones of ac power systems. Various types of differential relays and relaying systems have evolved to take advantage of the differential principle.

WARNING

Relays manufactured prior to July 22, 1991 (EIA date code symbol 9129 and previous) do **NOT** have case jumpers between terminals 7 and 8 (single phase units). This also applies to three phase relays terminals 7 and 8, terminals 13 and 14, and terminals 17 and 18. Exercise **CAUTION** when grounding or testing current transformer circuits connected to these terminals.

Typical application schemes are shown in Figures 1-1 and 1-2.

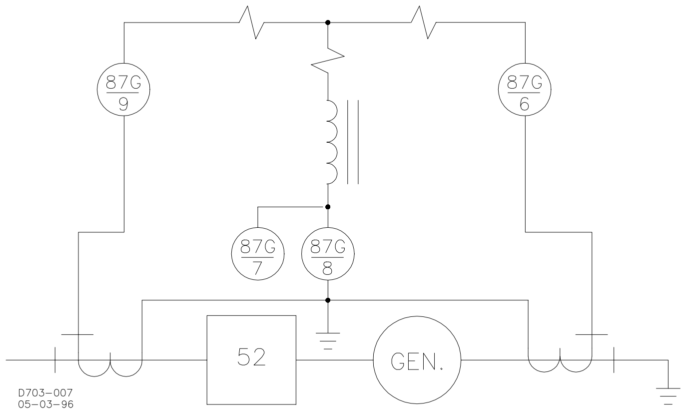


Figure 1-1. Typical Single-Phase Application Scheme

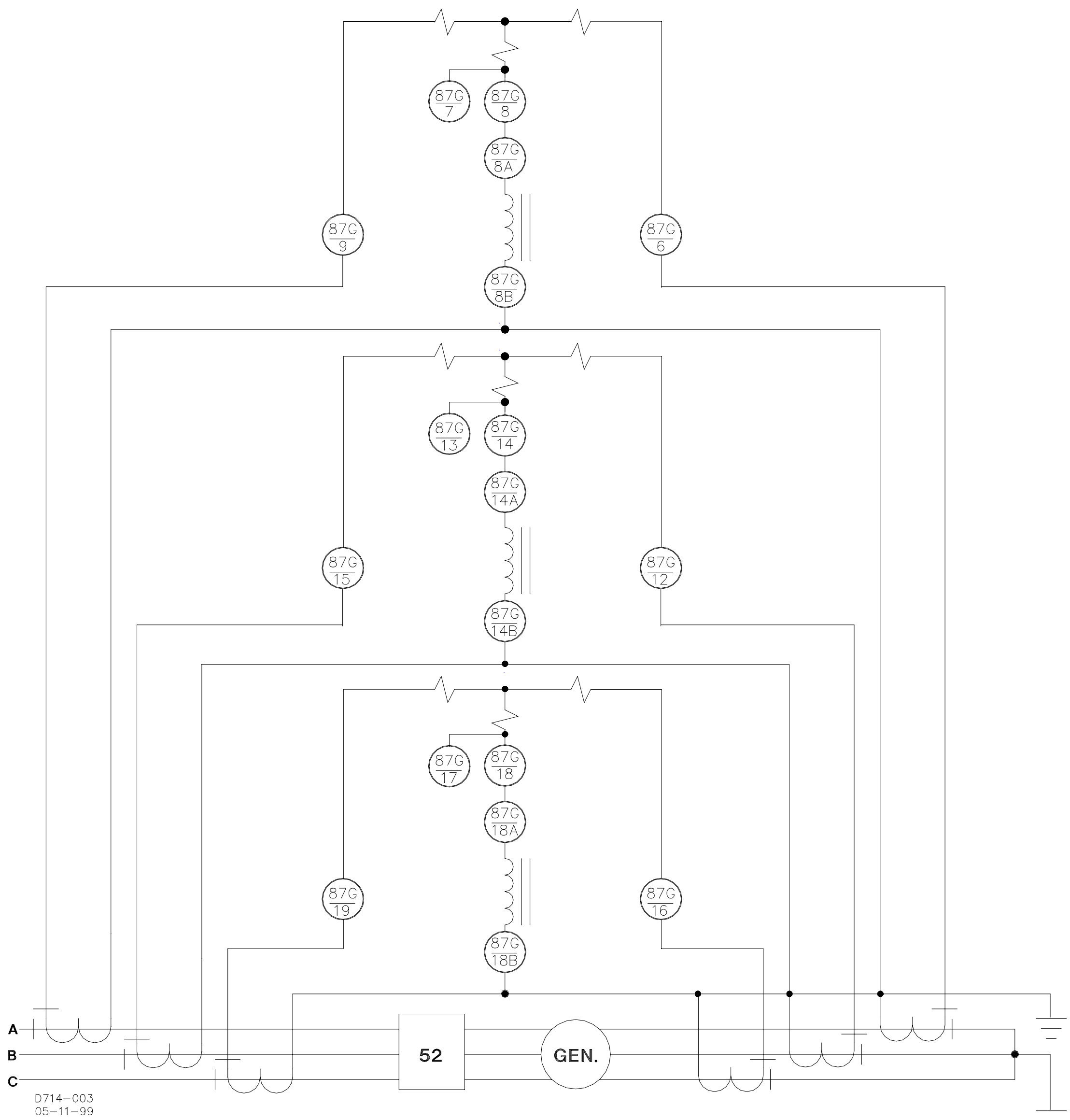


Figure 1-2. Typical Three-Phase Application Scheme

Variable Restraint Characteristic

At high current levels, the inevitable difference in the saturation characteristics between current transformers indicates a need for a compensating decrease in relay sensitivity. The design of the BE1-87G provides a restraint factor that is proportional to input current when the restraining current (I_R) is greater than nominal (five amperes for sensing input type one or one ampere for sensing input type two). The BE1-87G compares the protected zone sensed input and output currents. The lesser of the two sensed current levels becomes the restraining current. The difference between the two sensed currents (the operating current) is compared to a reference established by the sensitivity setting, and adjusted by an amount proportional to the restraining current. This makes the BE1-87G more sensitive to low current internal faults, and less sensitive to external faults with high levels of through current.

When the restraining current is at nominal (five amperes for sensing input type one or one ampere for sensing input type two) or less, the relay trips if the differential current exceeds the relay setting (I_S). But when the restraining current is greater than nominal, the overall sensitivity is a combination of the front panel setting and the restraint factor.

Design Highlights

Some of the many advantages of the solid-state BE1-87G Variable Percentage Differential Relay are summarized as follows.

- Seven sensitivity levels on each of the two sensing input ranges. The seven levels allow compensation for CT mismatch and provide the flexibility and adaptability necessary for many special applications such as split winding generator protection.
- Stabilizing reactor. Minimizes dissimilar performance of system CTs. Reactor can be located on the back of the relay or remotely from the BE1-87G for flexibility of system installation.
- Variable restraint. The variable restraint characteristic allows increased sensitivity to low current internal faults while providing increased security against high levels of through current caused by external faults.
- Single- or three-phase availability. Either configuration is available in the Basler Electric S1 drawout case.
- High-Speed Operation. The BE1-87G operates in 30 milliseconds for fault levels of 10 times the sensitivity setting. This high-speed operation minimizes potential damage to the protected equipment. Response characteristics for sensing input ranges 1 and 2 are shown in Section 5, *Testing And Setting* the relay.

MODEL AND STYLE NUMBER

The electrical characteristics and operational features included in a specific relay are defined by a combination of letters and numbers which constitutes the device's style number. The style number together with the model number describe the features and options in a particular device and appear on the front panel, drawout cradle, and inside the case assembly. The model number BE1-87G designates the relay as a Basler Electric Class 100, Variable Percentage Differential Relay.

Style Number Example

Figure 1-3 illustrates the style number identification chart with features and options for BE1-87G relays. For example, if the style number were BE1-87G GlE AlJ AOCOF the device would have the following:

BE1-87G	Model Number
G	Three-phase sensing input
1	Sensing range switch selectable for 0.1, 0.15, 0.2, 0.4, 0.5, 0.8, or 1.6 A
E	Normally open output relay
A1	Instantaneous timing
J	Operating power derived from 125 Vdc or 100/120 Vac
A	Internally operated targets (one per phase)
0	No option 1 available
C	Push-to-energize outputs (pushbuttons)
0	No auxiliary output contacts
F	Semi-flush mounting

Style Number Identification Chart

Figure 1-3 is the Style Number identification Chart for the BE1-87G Variable Percentage Differential relay.

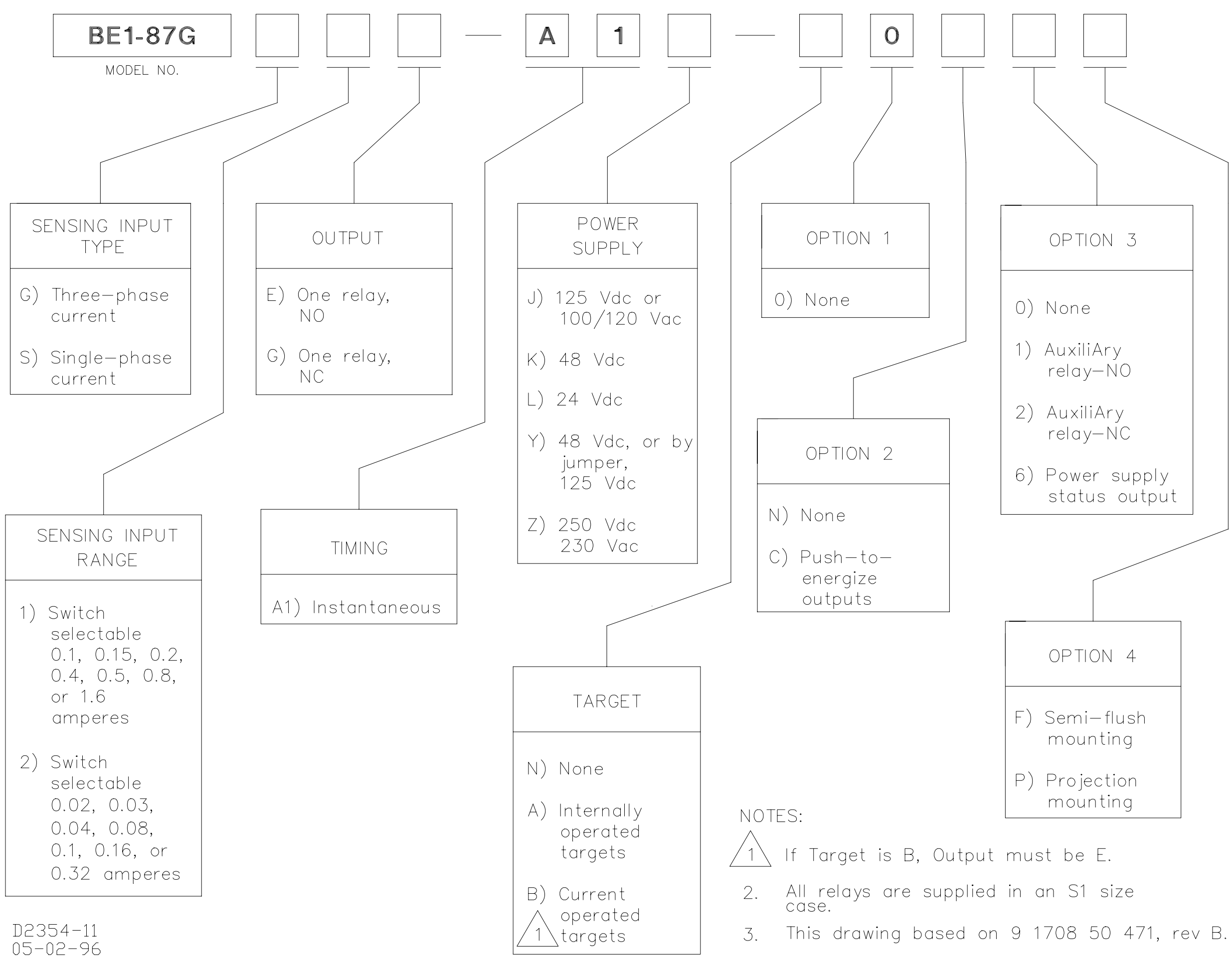


Figure 1-3. Style Number Identification Chart

SPECIFICATIONS

BE1-87G relays are available in single-phase and three-phase configurations, and with the following features and capabilities.

Current Sensing Inputs

(5 Ampere) — Nominally rated at 5 amperes, with a range of 45 to 65 hertz. Maximum current per input: 10 amperes continuous, 250 amperes for 1 second.

(1 Ampere) — Nominally rated at 1 ampere, with a range of 45 to 65 hertz. Maximum current per input: 2 amperes continuous, 50 amperes for 1 second.

Current Sensing Burden

(5 Ampere) — Burden is less than 0.05 ohms per input.

(1 Ampere) — Burden is less than 0.25 ohms per input.

Stabilizing Reactor — Refer to Section 4 for stabilizing reactor impedance characteristic curves.

I^2t Rating

(5 Ampere) — 65 amperes for 1 second at 70° C ambient, ($I^2t = 4225$).

(1 Ampere) — 13 amperes for 1 second at 70° C ambient, ($I^2t = 4225$).

Pickup Control — A front panel control permits minimum differential (operate) currents to be selected. This sensitivity is constant for restraint currents less than the nominal current (5 or 1 amperes). Actual operating characteristics are shown in graph format in Section 5, *Testing And Setting* the relay.

(5 Ampere) — Minimum differential (operate) current = 0.1, 0.15, 0.2, 0.4, 0.5, 0.8, or 1.6 amperes. The ideal operating characteristic is approximated by the following equations.

where

I_R is the restraint current, defined as the lesser of the input currents.
I_{OP} is the operate current
I_S is the front panel setting

For $I_R \le 5$ amperes: $I_{OP} = I_S$
For $I_R > 5$ amperes: $I_{OP} = I_S + 0.5(I_R - 5)$

(1 Ampere) — Minimum differential (operate) current = 0.02, 0.03, 0.04, 0.08, 0.10, 0.16, or 0.32 ampere. The ideal operating characteristic is approximated by the following equations.

For $I_R \le 1$ ampere: $I_{OP} = I_S$
For $I_R > 1$ ampere: $I_{OP} = I_S + 0.5(I_R - 1)$

Pickup Accuracy

(5 Ampere) — For $I_R \le 5$ amperes, ±5% of the operate pickup characteristic or 25 milliamperes whichever is greater. Actual operating characteristics are shown in graph format in Section 5, *Testing And Setting* the relay.

For $I_R \rangle$ 5 amperes, up to a maximum of 20 amperes, ±8% of the operate pickup characteristic or 150 milliamperes, whichever is greater. Actual operating characteristics for pickup values between 5 and 20 amperes are shown in graph format in Section 5, *Testing And Setting* the relay.

Pickup Accuracy
(1 Ampere)

For $I_R \leq 1$ ampere, ±5% of the operate pickup characteristic or 25 milliamperes whichever is greater. Actual operating characteristics are shown in graph format in Section 5, *Testing And Setting* the relay.

For $I_R \rangle$ 1 amperes, up to a maximum of 4 amperes, ±8% of the operate pickup characteristic or 150 milliamperes, whichever is greater. Actual operating characteristics for pickup values between 1 and 4 amperes are shown in graph format in Section 5, *Testing And Setting* the relay.

Dropout

Greater than 90% of operate characteristic.

Timing

Less than 30 milliseconds at 10 times pickup setting; 70 milliseconds maximum. See Section 5, *Testing And Setting* the relay, for the pickup response timing curve.

Power Supply

Power for the internal circuitry may be derived from ac or dc external power sources as indicated in Table 1-1.

Table 1-1. Power Supplies

Type	Nominal Input Voltage	Input Voltage Range	Burden at Nominal (Maximum)
K (Mid Range)	48 Vdc	24 to 60 Vdc	5.0 W
J (Mid Range)	125 Vdc 120 Vac	62 to 150 Vdc 90 to 132 Vac	5.5 W 14.5 VA
L (Low Range)+	24 Vdc	12 to 32 Vdc	5.5 W
Y (Mid Range)	48 Vdc 125 Vdc	24 to 60 Vdc 62 to 150 Vdc	5.5 W 6.0 W
Z (High Range)	250 Vdc 230 Vac	140 to 280 Vdc 190 to 270 Vac	7.0 W 20.0 VA

+ Type L power supplies may initially require 14 Vdc to begin operating. Once operating, the voltage may be reduced to 12 Vdc and operation will continue.

Output Contacts

Output contacts are rated as follows.

Resistive:

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

125/250 Vdc — Make and carry 30 amperes for 0.2 seconds, carry 7 amperes continuously, and break 0.3 ampere.

Inductive:

120/240 Vac, — Make and break 0.1 A (L/R = 0.04).
125/250 Vdc — Make and break 0.1 A (L/R = 0.04).

Targets

Magnetically latched, manually reset target indicators may be optionally selected as either internally operated or current operated. Current operated targets require a minimum of 0.2 ampere through the output trip circuit and are rated at 30 amperes for 1 second, 7 amperes for 2 minutes, and 3 amperes continuously.

Isolation	In accordance with ANSI/IEEE C37.90, one minute dielectric (high potential) tests as follows: All circuits to ground: 2121 Vdc Input to output circuits: 1500 Vac or 2121 Vdc
Surge Withstand Capability	Qualified to ANSI/IEEE C37.90.1-1989 *Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems*.
Fast Transient	Qualified to ANSI/IEEE C37.90.1-1989.
Impulse Test	Qualified to IEC 255-5.
Radio Frequency Interference (RFI)	Maintains proper operation when tested for interference in accordance with IEEE C37.90.2, Trial-Use Standard Withstand Capability of Relay systems to Radiated Electromagnetic Interference from Transceivers.
Temperature	<u>Operating Range</u> -40°C (-40°F) to 70°C (158°F) <u>Recommended Storage Range</u> -65°C (-85°F) to 100°C (212°F).
Shock	15 g in each of three mutually perpendicular planes.
Vibration	2 g in each of three mutually perpendicular planes swept over the range of 10 to 500 hertz for a total of six sweeps, 15 minutes each sweep.
Weight	3-phase: 19.2 pounds maximum. 1-phase: 14.3 pounds maximum.
Case Size	All units are supplied in an S1 size case.

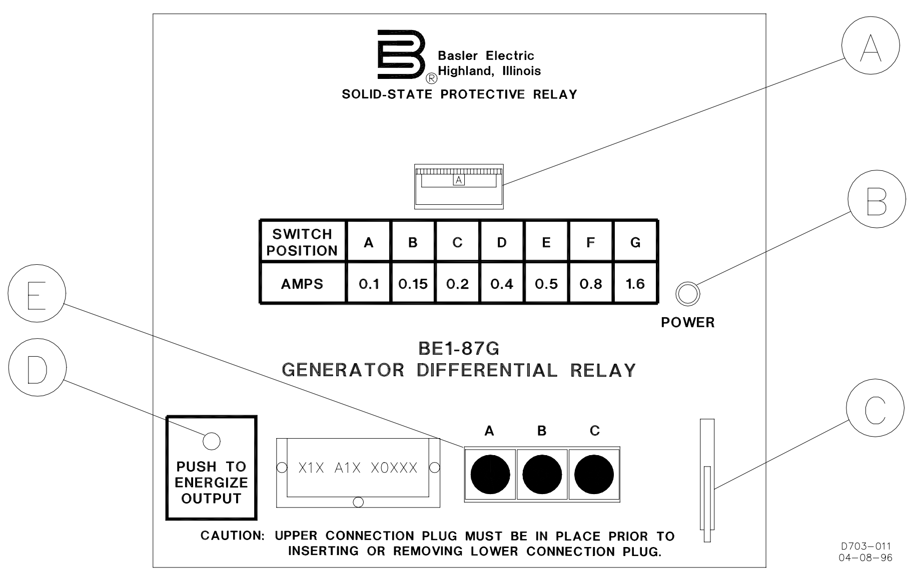
SECTION 2 • HUMAN MACHINE INTERFACE (Controls And Indicators)

DESCRIPTION

Table 2-1 lists and briefly describes the BE1-87G Variable Percentage Differential Relay operator controls and indicators. Reference the call-out letters to Figure 2-1.

Table 2-1. BE1-87G Controls and Indicators (Refer to Figure 2-1)

Locator	Control or Indicator	Function
A	Sensitivity Switch	Establishes reference for the operating current. It is a seven position thumbwheel switch labeled A through G. The chart below the switch relates the switch position to the operating current required for tripping when the restraint current is ≤ nominal (five amperes, sensing input range one, and one ampere, sensing input range two).
B	**Power** Indicator	LED illuminates to indicate power supply is operating.
C	Target Reset Lever **(Optional)**	Linkage extends through bottom of front cover to reset magnetically latching target indicators.
D	**PUSH-TO-ENERGIZE** Switch (Optional)	A momentary contact pushbutton switch accessible by inserting a 1/8" diameter non-conducting rod through the front panel. Operates the output and auxiliary relays.
E	Target Indicators (Optional)	Magnetically latching indicators which indicate the associated phase that has caused a trip.



NOTE: Above panel for 3⌀ units only.

Figure 2-1. Location of Controls and Indicators, BE1-87G, Sensing Input Range 1

SECTION 3 • FUNCTIONAL DESCRIPTION

GENERAL

BE1-87G Variable Percentage Differential Relays are static devices that protect motors and generators by providing an output signal when incoming current does not match outgoing current by a predetermined but variable limit. The functional block diagram in Figure 3-1 illustrates the overall operation of the BE1-87G Variable Percentage Differential Relay. Note that it may be configured to monitor either single-phase or three-phase. Phases B and C, when present, are functionally identical to Phase A.

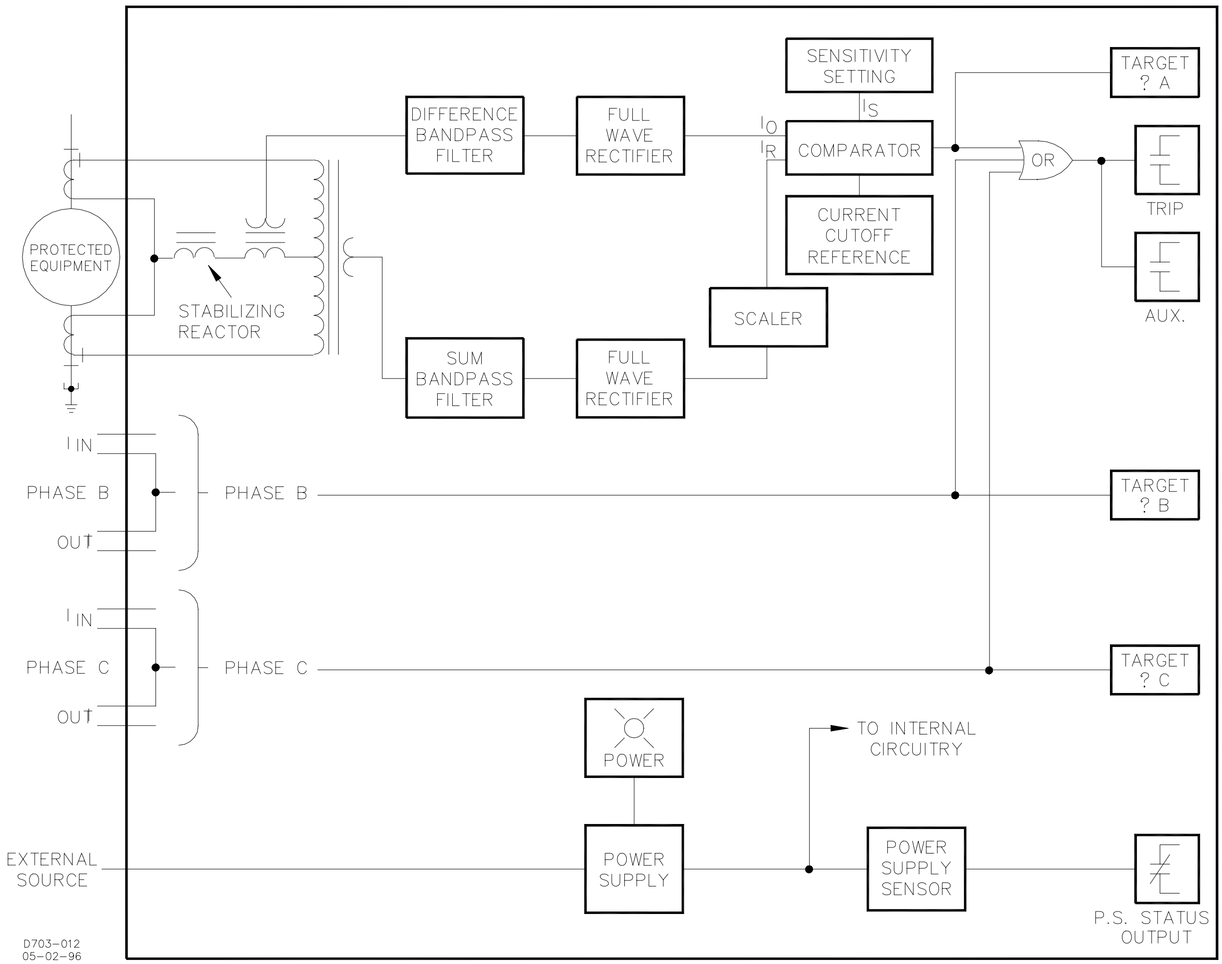


Figure 3-1. Functional Block Diagram

FUNCTIONAL DESCRIPTION

The following paragraphs describe the Relay circuit functions illustrated in Figure 3-1.

Current Transformers

Two standard system CTs with secondary windings to match sensing input range one or range two (five ampere and one ampere nominal), one transformer on each side of the protected machine, supply sensing current for each monitored phase. The sensing currents are applied to the respective input transformers of the relay which provide system isolation and determine the differential and sum currents. These CTs are gapped to withstand DC offset.

Stabilizing Reactor

To minimize dissimilar performance of the system CTs, the stabilizing reactor acts as a stabilizing impedance during external faults. Stabilizing reactors are current rated based on time and ambient temperature (refer to *Section 1, Specifications*). See Figures 3-2 and 3-3 for the stabilizing reactor impedance characteristics.

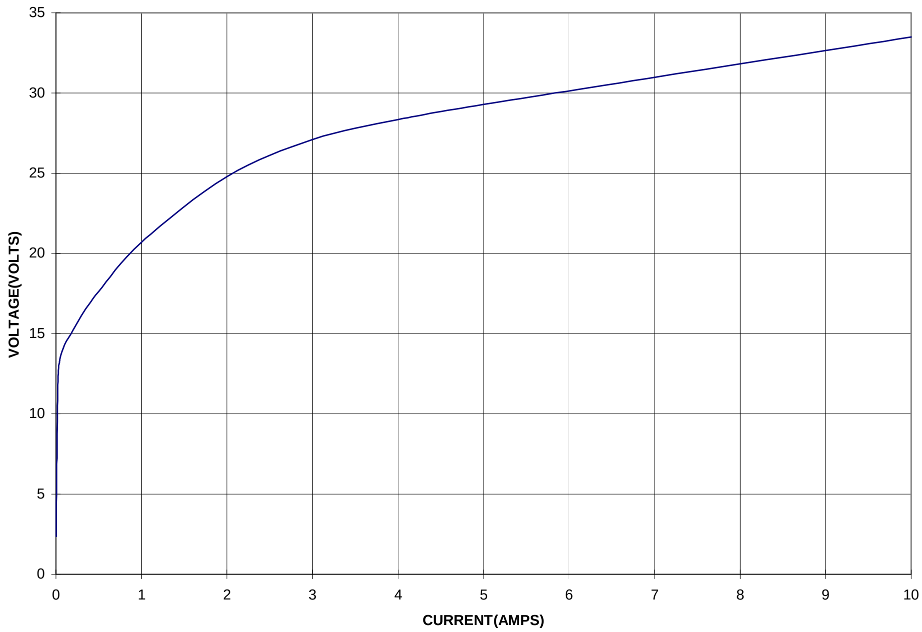


Figure 3-2. Sensing Input Range 1 (5 Ampere), Stabilizing Reactor Impedance Characteristics

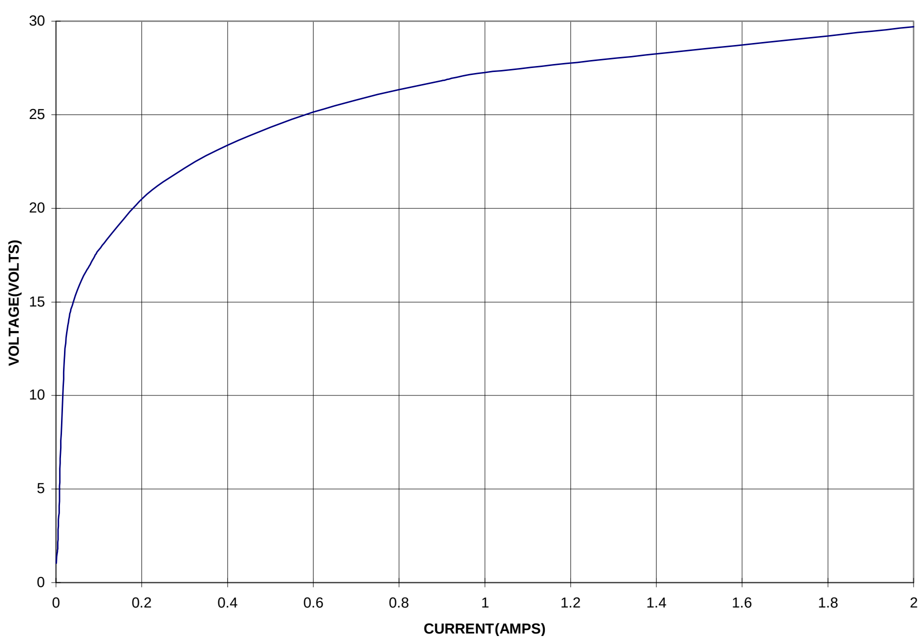


Figure 3-3. Sensing Input Range 2 (1 Ampere),Stabilizing Reactor Impedance Characteristics

Bandpass Filters

Outputs from the relay transformers are filtered to eliminate the third harmonic and to minimize the effect of DC offset caused by CT saturation (as may occur during synchronization or asymmetrical faults).

The output of the difference bandpass filter is applied to a full wave rectifier. The rectifier scales the differential and applies the output to the comparator as the operating current (I_{OP}) signal .

The output of the sum bandpass filter is also applied to a full wave rectifier. The scaled sum of the two inputs represents the restraint current (I_R). The restraint current is scaled for a 50% slope above nominal input current (five amperes input range one and one ampere input range two).

Comparator

The comparator provides the variable percentage characteristic of the relay as follows:

- When I_R is less than nominal (five amperes input range one and one ampere input range two), the comparator provides an output signal whenever the operate current (I_{OP}) exceeds the front panel sensitivity setting I ($_S$).
- When I_R is greater than nominal (five amperes input range one and one ampere input range two), the front panel sensitivity threshold is increased by adding to it a scaled value representing 1/2 of I_R minus nominal (five amperes input range one and one ampere input range two).

Outputs

In the three-phase model, the outputs of the comparators are OR'd so that the coil of the output relay is energized if the current difference of any monitored phase exceeds the variable percentage limit. When the current difference falls below 90% of the variable percentage threshold, the output relay resets.

Targets (Optional)

If the relay is equipped with targets, the target associated with the phase or phases with excessive differential current is tripped.

Depending on the style number (TARGET Option A or B), a unit may contain either internally operated or current operated targets. Internally operated targets are actuated in conjunction with the output relay. Current operated targets require a minimum of 0.2 ampere in the output circuit for actuation. Both types are magnetically latching devices and must be manually reset by use of the reset lever.

Push-To-Energize (Optional)

The unit may be equipped (Option 2-C) with a momentary pushbutton that is accessible through the front panel. To prevent accidental operation of this switch, it is recessed behind the front panel of the relay and is actuated by inserting a thin non-conducting rod through an access hole in the panel. When pushed, the switch operates the output relays and internally operated targets. Current operated targets will activate if the required 0.2 ampere of minimum current is present.

Power Supply Status Output (Optional)

The power supply status output relay (Option 3-6) has normally closed (NC) output contacts. This relay is energized upon power-up and the NC contacts open. Normal relay operating voltage maintains the power supply status output relay continually energized and its output contacts open. If the power supply output voltage falls below the requirements for proper operation, the power supply status output relay de-energizes, closing the NC output contacts.

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 Identifier	Nominal Voltage	Voltage Range
Low Range	L	24 Vdc	12† to 32 Vdc
Mid Range	J, K, Y	48, 125 Vdc, 120 Vac	24 to 150 Vdc 90 to 132 Vac
High Range	Z	125, 250 Vdc, 120, 240 Vac	62 to 280 Vdc 90 to 270 Vac

† 14 Vdc 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.

SECTION 4 • INSTALLATION

GENERAL

When not shipped as part of a control or switchgear panel, the 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 relay is not to be installed immediately, store the relay in its original shipping carton in a moisture and dust free environment. When relay is to be placed in service, it is recommended that the operational test procedure in Section 5, *Testing And Setting*, be performed prior to installation.

DIELECTRIC TEST

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

All circuits to ground:	2828 Vdc
Input to output circuits:	2000 Vac or 2828 Vdc

MOUNTING

Relay

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 shown in Figures 4-1 through 4-7. Numbers in parentheses indicate metric dimensions (millimeters). All other dimensions are in inches.

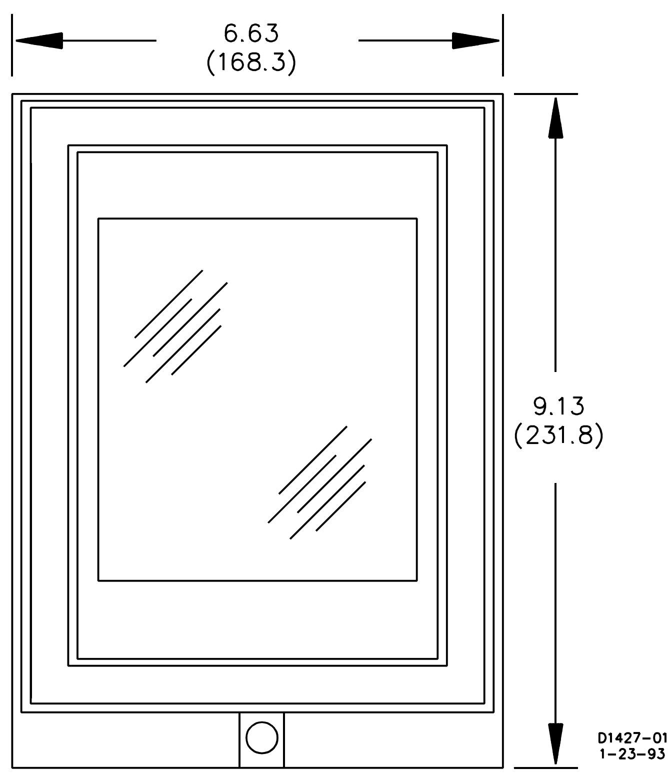


Figure 4-1. S1 Case, Outline Dimensions, Front View

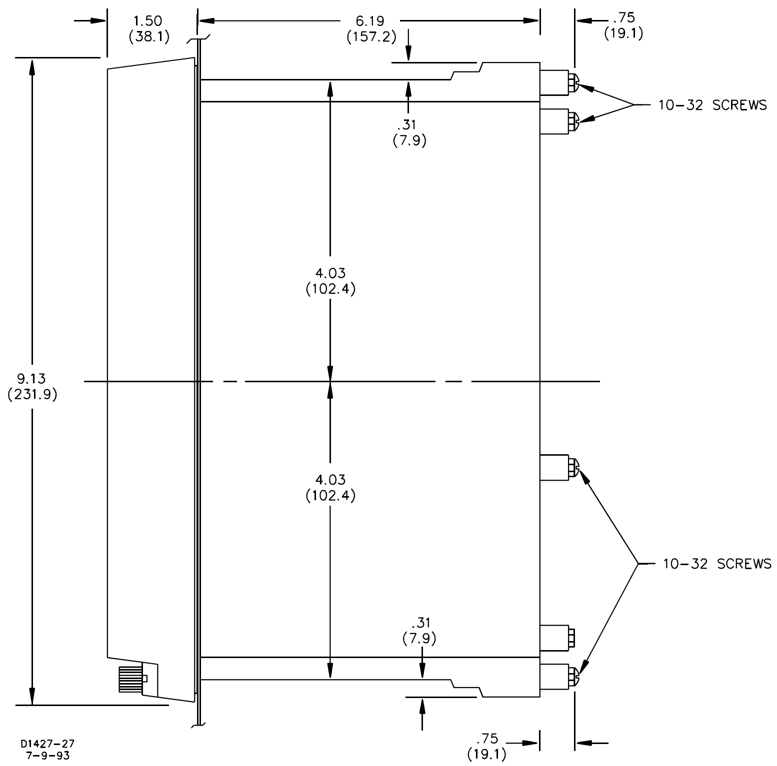


Figure 4-2. S1 Case, Double-Ended, Outline Dimensions, Semi-Flush Mounting, Side View

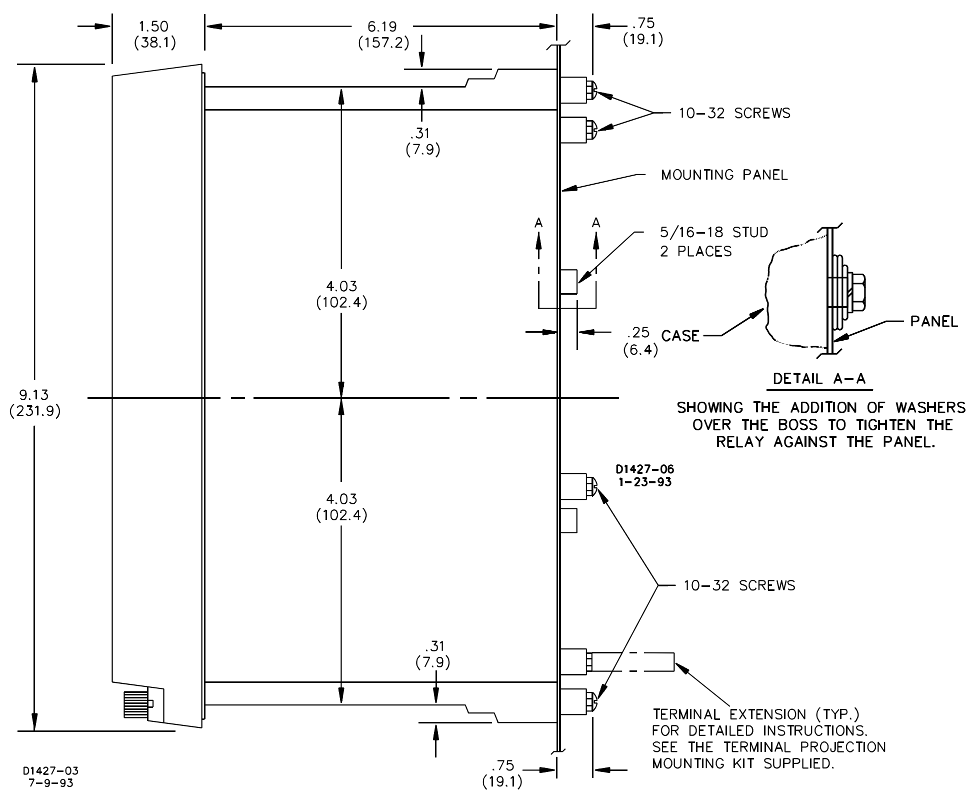


Figure 4-3. S1 Case, Double-Ended, Outline Dimensions, Projection Mounting, Side View

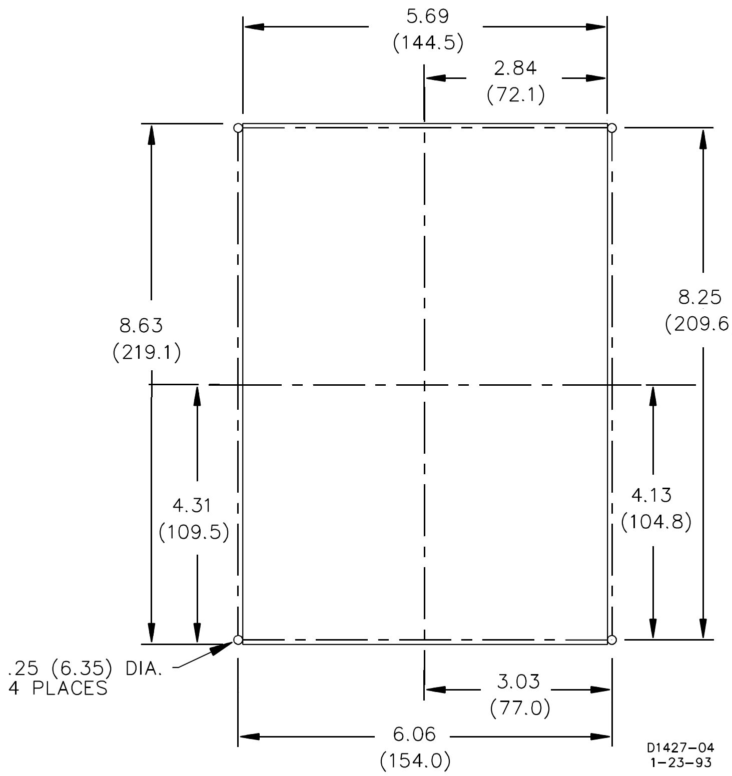


Figure 4-4. S1 Case, Double-Ended, Panel Drilling Diagram, Semi-Flush Mounting

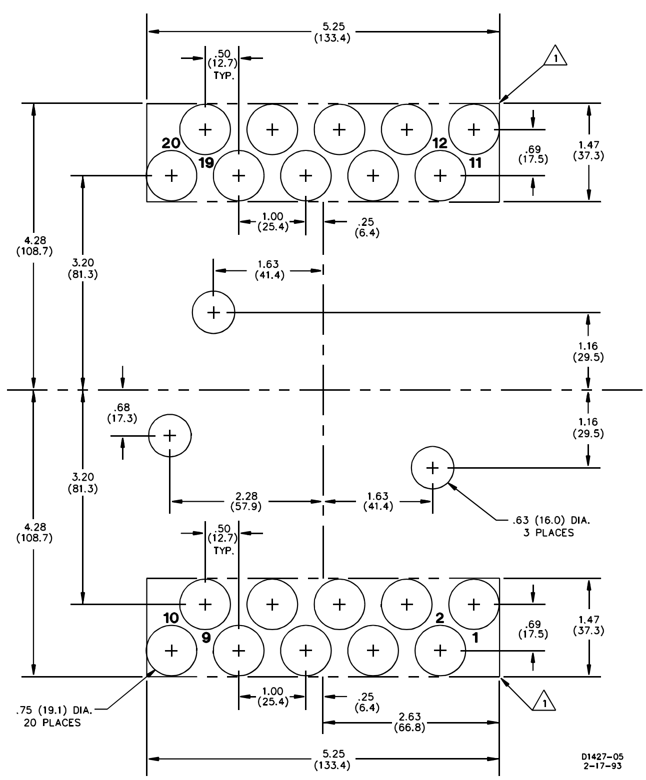


Figure 4-5. S1 Case, Double-Ended, Panel Drilling Diagram, Projection Mounting, Rear View

Stabilizing Reactor

The stabilizing reactor for a three-phase relay is mounted on the rear of the relay. For projection mounting or convenience, the stabilizing reactor can be removed and relocated. Rewire in accordance with the procedures and illustrations in this section. To remove the stabilizing reactor, remove four screws holding the reactor to the mounting plate. To remove the mounting plate, remove two five-sixteenths by eighteen, hex head bolts. The stabilizing reactor outline dimensions and panel drilling diagrams are shown in Figures 4-6 and 4-7.

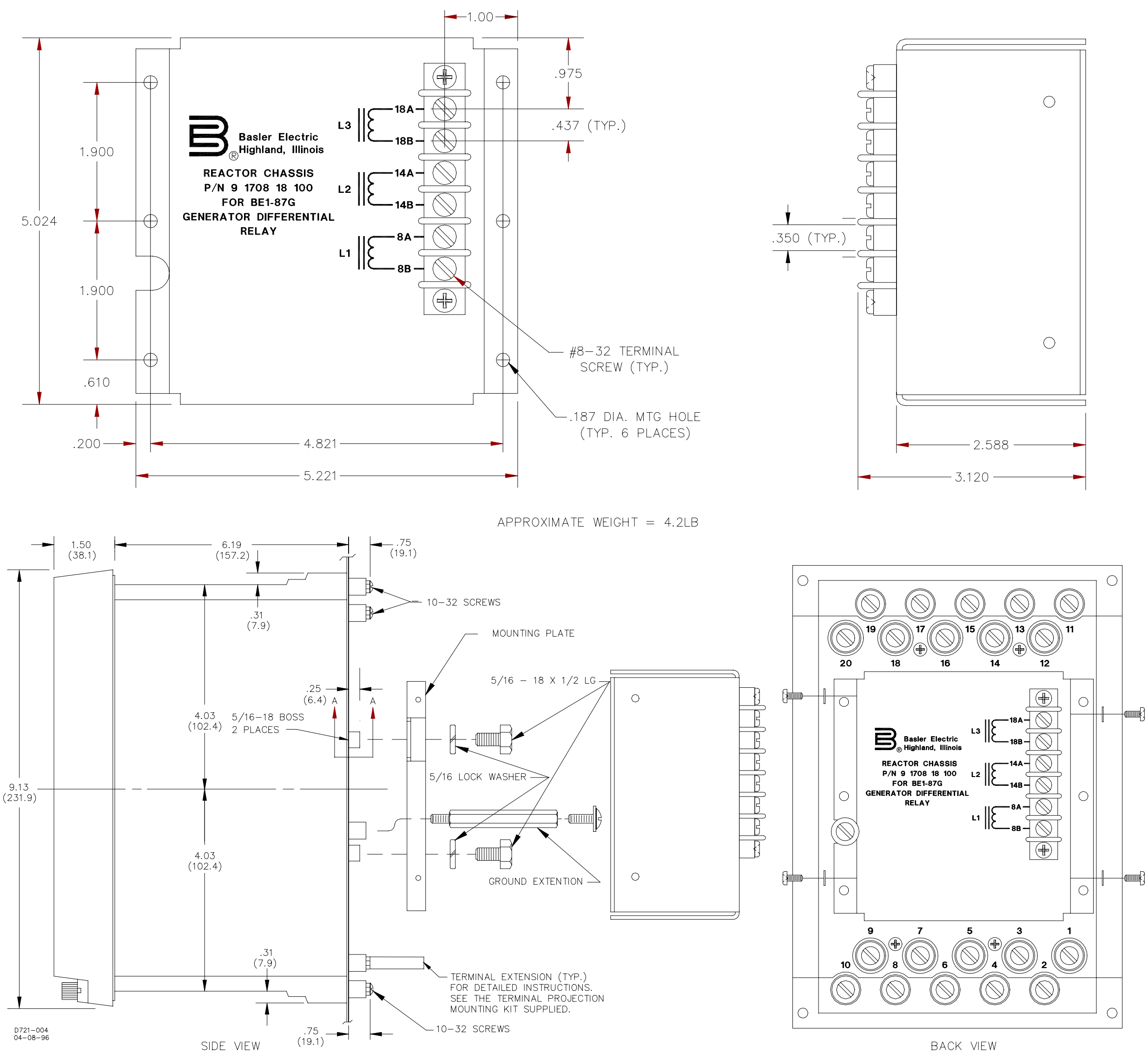


Figure 4-6. Outline Dimensions for External Reactor Chassis 9 1708 18 100

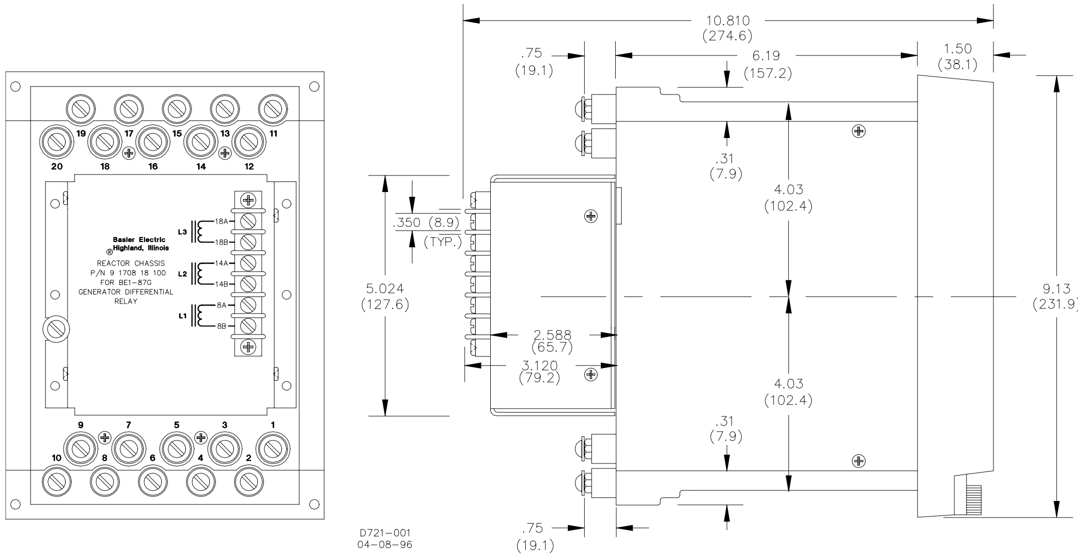


Figure 4-7. S1 Case And Reactor, Outline Dimensions (Semi-Flush Mounting)

CONNECTIONS

Incorrect wiring may result in damage to the relay. Be sure to check model and style number against the options listed in the Style Number Identification Chart before connecting and energizing a particular relay.

WARNING

Relays manufactured prior to July 22, 1991 (EIA date code symbol 9129 and previous) do **NOT** have case jumpers between terminals 7 and 8 (single phase units). This also applies to three phase relays terminals 7 and 8, terminals 13 and 14, and terminals 17 and 18. Exercise **CAUTION** when grounding or testing current transformer circuits connected to these terminals.

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.

Except as noted above, connections should be made with minimum wire size of 14 AWG. Typical dc control connections are shown in Figure 4-8. Sensing input connections are shown in Figures 4-9 and 4-10. Terminals 7, 13, and 17 are provided for convenience and to insure compatibility with earlier versions of the relay. Figures 4-11 and 4-12 are typical internal connection diagrams.

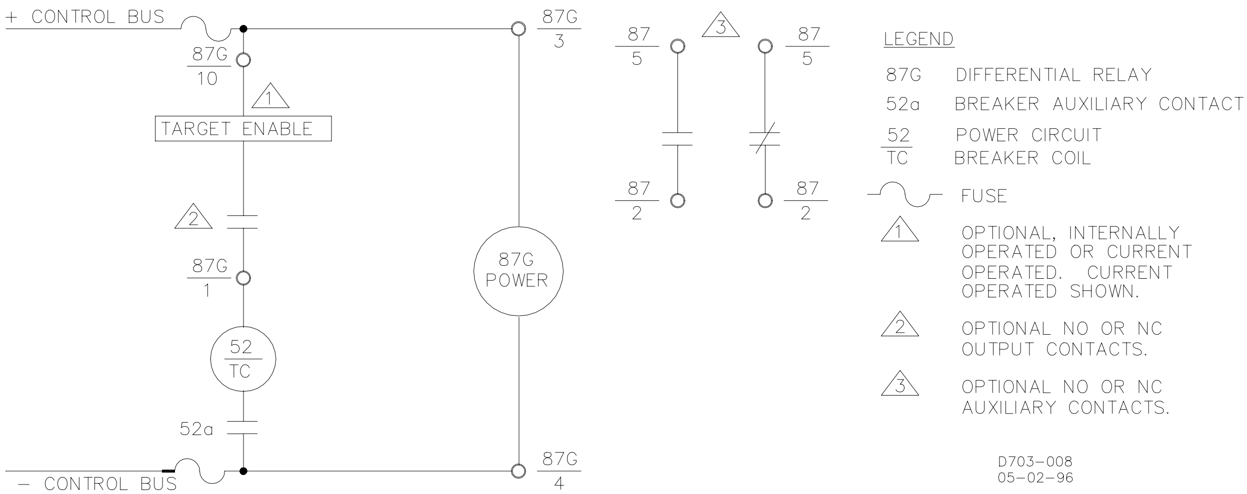


Figure 4-8. Typical DC Control Connections

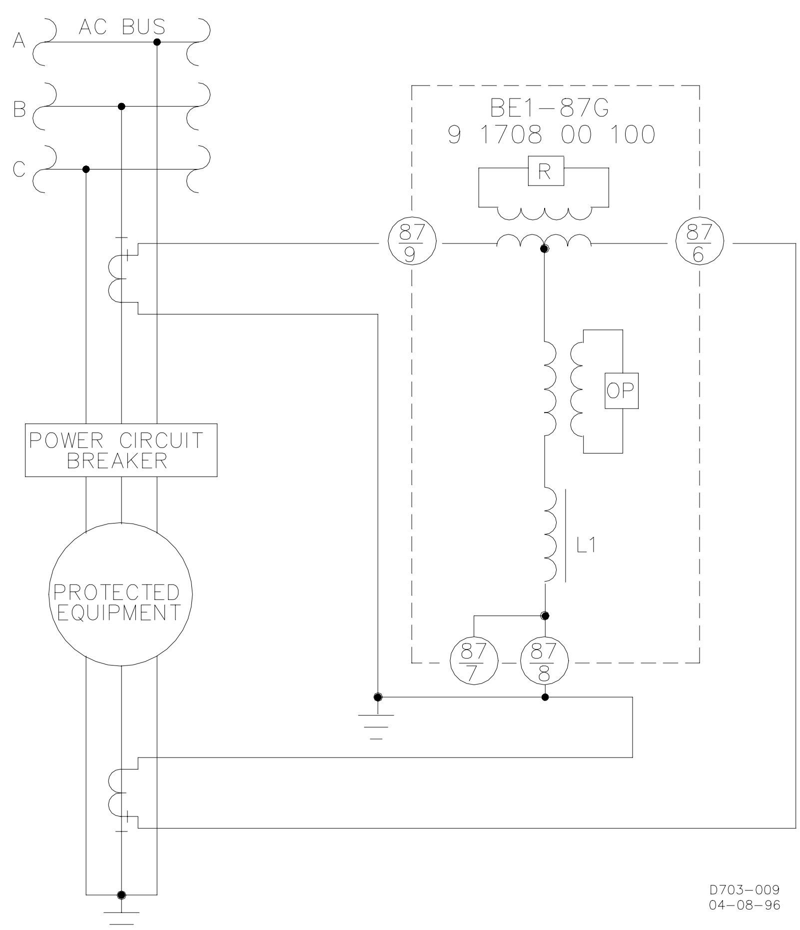


Figure 4-9. Single-Phase Sensing Input Connections

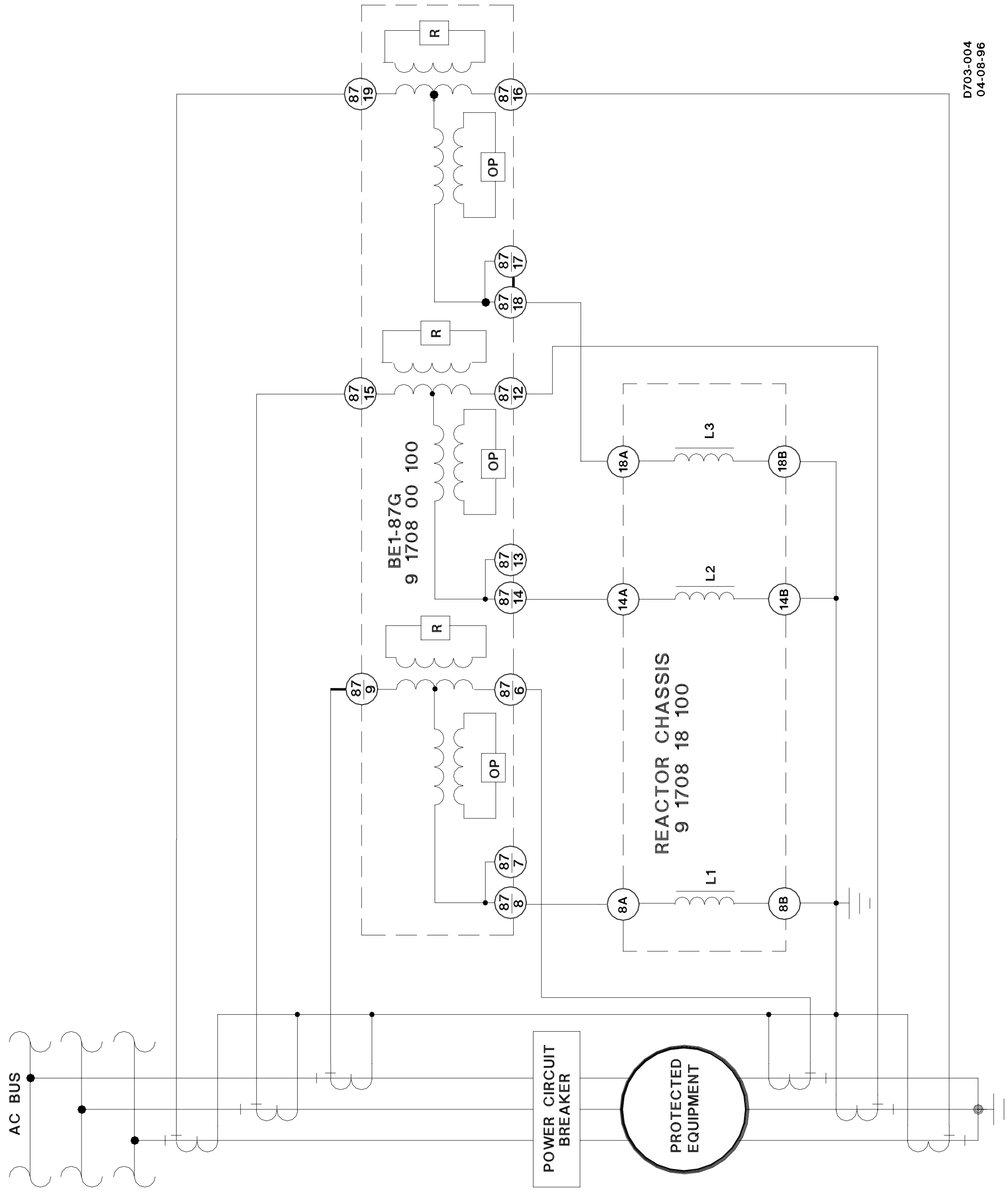


Figure 4-10. Three-Phase Sensing Input Connection

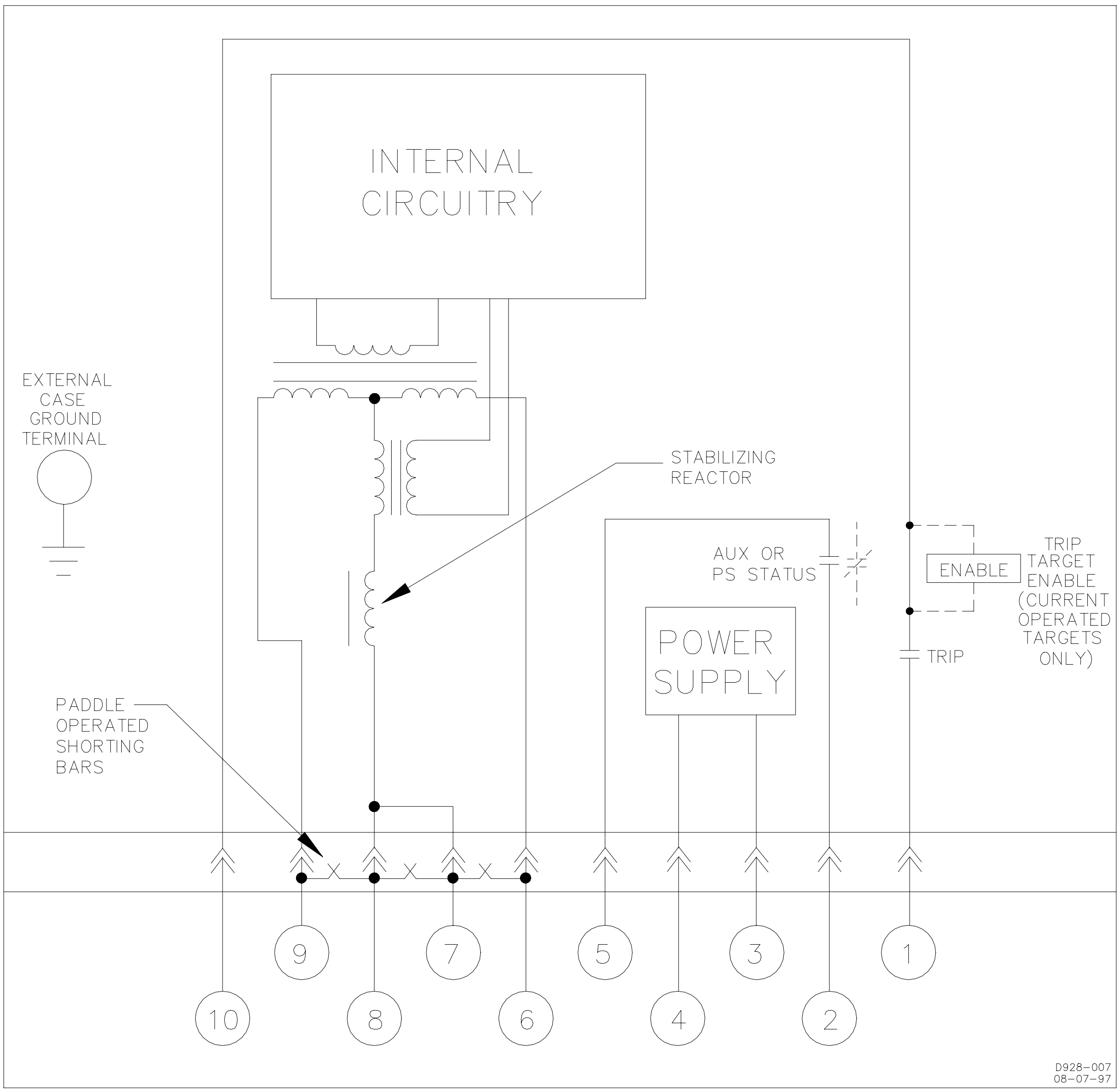


Figure 4-11. Single-Phase Internal Connection Diagram

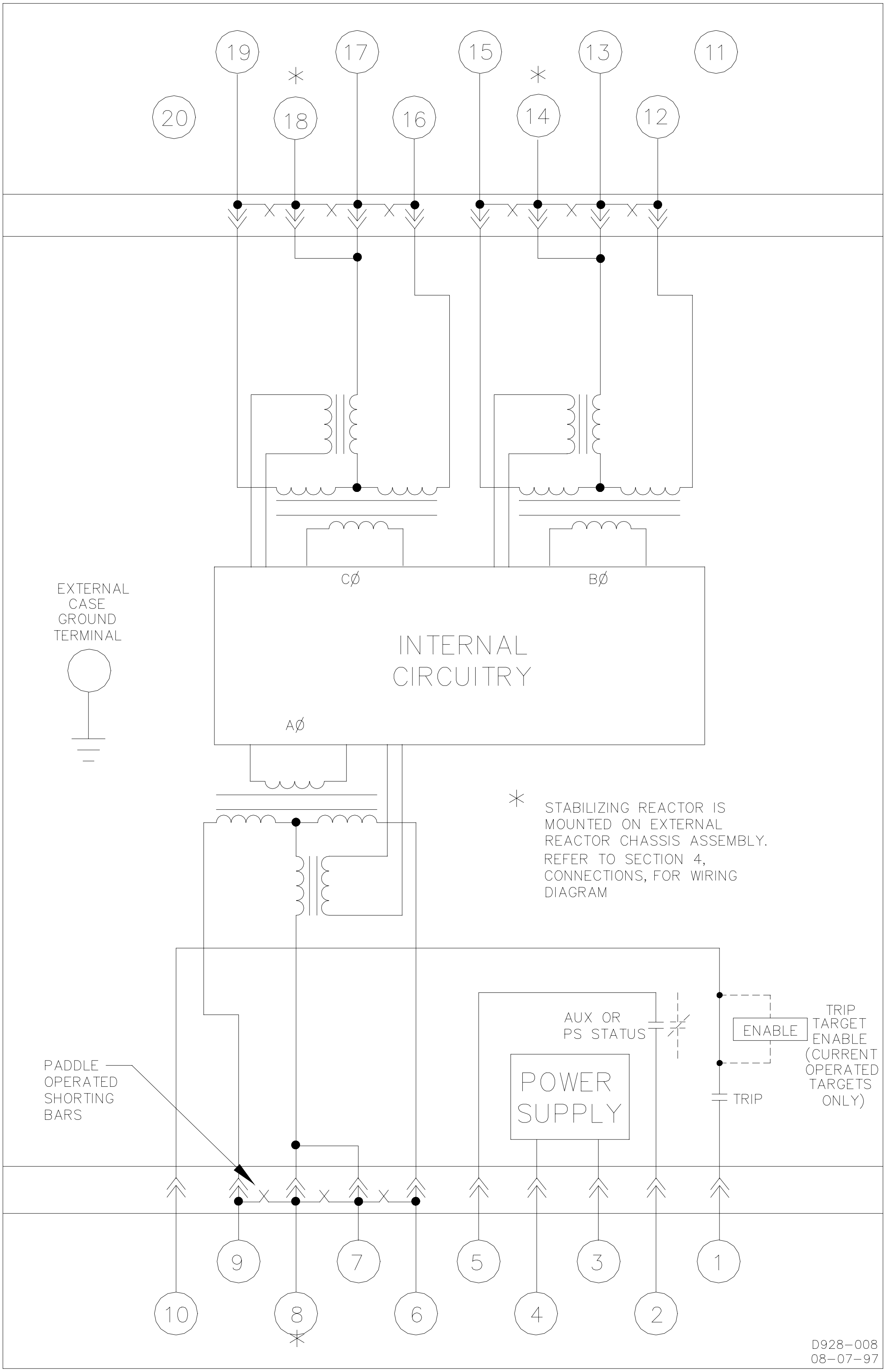


Figure 4-12. Three-Phase Internal Connection Diagram

SECTION 5 • TESTING AND SETTING

GENERAL

Proper operation of the relay may be confirmed by performing the operational test procedures in this Section. In the event the relay is not to be installed immediately, store the relay in its original shipping carton in a moisture and dust free environment.

RELAY OPERATING PRECAUTIONS

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

1. A minimum of 0.2 ampere 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.

> **CAUTION**
> To avoid false tripping on three phase units, upper connection plug must be in place prior to inserting or removing lower connection plug.

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 and ANSI/IEEE C37.90, one minute dielectric (high potential) tests as follows.

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

EQUIPMENT REQUIRED

Because of the speed and sensitivity of this relay, it is necessary that the accuracy and stability of the test equipment be appropriate to test the sensitivity switch settings. For example, this switch at the most sensitive setting (0.1 ampere) is monitoring a current difference that is only 1% for a sensing input of 10 amperes.

- Two Multi-Amp SSR-78, or one Doble F2500, or suitable substitute
- Digital voltmeter accurate to within 1% or better
- Digital ammeter accurate to within 1% or better
- Variable AC/DC ()-250 V) power supply (operating power input)
- DC power supply (for current operated targets)

OPERATIONAL TEST PROCEDURE

The following procedure verifies operation of the relay. Terminal numbers are referenced to the operational test setup in Figure 5-1. Three-phase units may be tested one phase at a time because all phases are OR'd together at the output.

> **WARNING**
>
> During testing, do **NOT** apply or generate continuous operate current greater than three amperes. If the operate current is greater than three amperes, a temperature increase in the reactor may result and cause insulation breakdown.

> **NOTE**
>
> Because of the reactance of the stabilizing reactors, the burden may be too high for large values of operate current with solid state test sets. Stabilizing reactor L1 may be shorted out in single-phase relays by placing a jumper on TP-1 and TP-2 on the lower magnetics shield board. The jumper should be capable of carrying five amperes of operate current. Figure 5-2 shows the location of the lower magnetics shield board assembly and Figure 5-3 shows test point locations. In three-phase relays, current sources may be connected directly to the upper and lower terminals (6-9 and 12-19) to bypass the external reactor chassis.

Restraint current supplied to any one relay input must not exceed either of the following conditions.

- 10 amperes continuous or 250 amperes for 1 second (sensing input range one)
- 2 amperes continuous or 50 amperes for 1 second (sensing input range two)

Whenever this current level is exceeded, provisions must be made to cut off the sensing current as the relay trips.

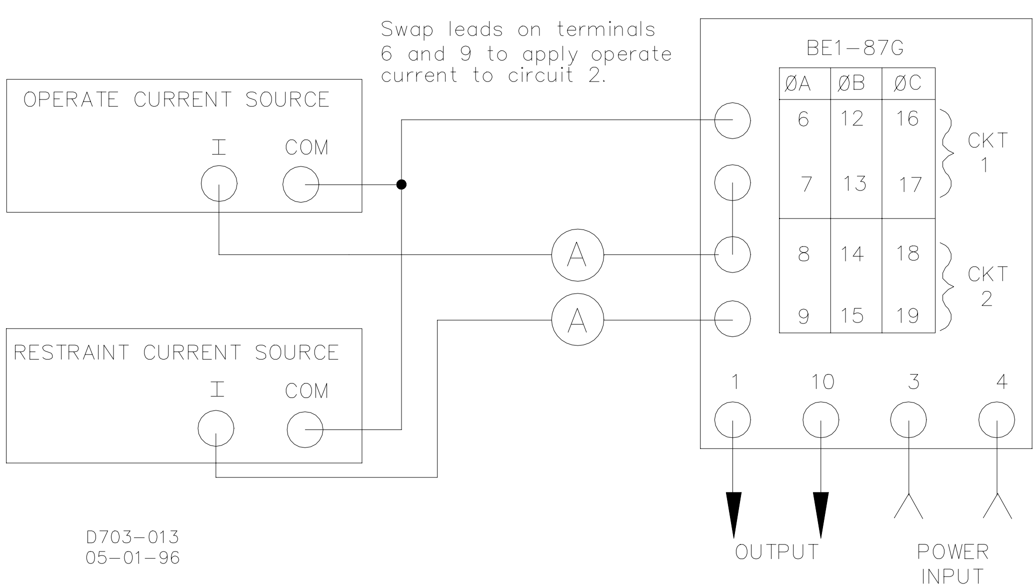


Figure 5-1. Operational Test Setup

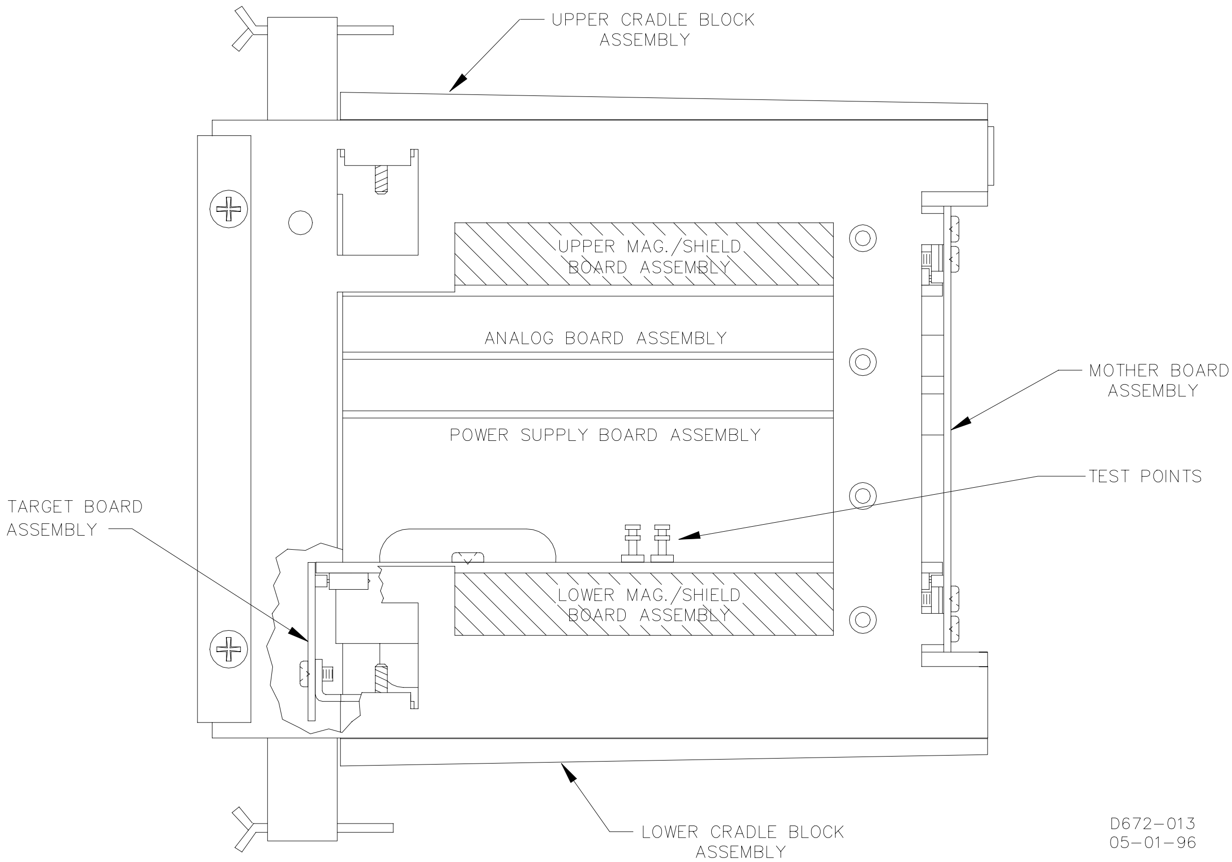
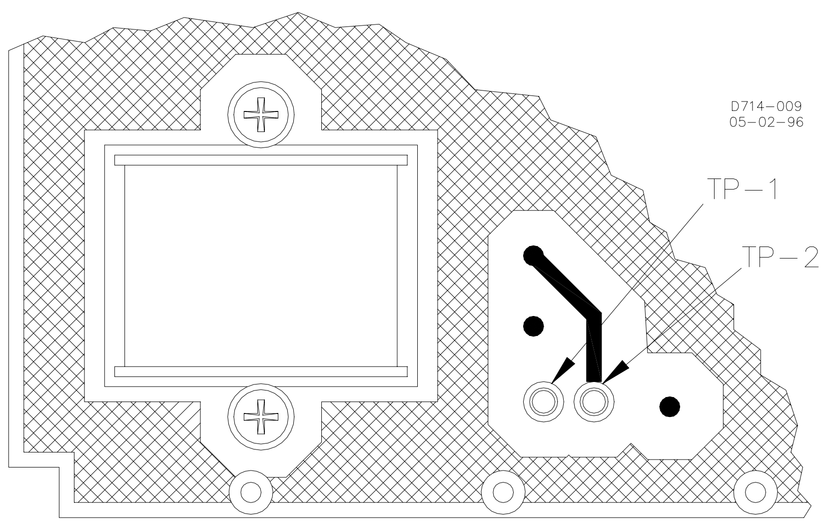


Figure 5-2. Location of Assemblies (Single Phase Only)



NON-COMPONENT SIDE OF LOWER MAGNETICS/SHIELD BOARD

Figure 5-3. TP-1 and TP-2 on Single Phase Relays

Single-Phase Trip And Dropout Test

Step 1. Connect the test setup for phase A in accordance with Figure 5-1.

Step 2. Set the sensitivity switch to A.

Step 3. Apply appropriate power input voltage to terminals 3 and 4.

Step 4. Using a regulated current source that is independently adjustable, apply the restraint current (0.1 ampere, sensing input range 1 or 0.02 ampere, sensing input range 2) to phase A terminals 6 and 9.

Step 5. Slowly increase the operate current source to phase A terminals 6 and 8 until the relay trips. Trip should occur at (0.1 ampere, sensing input range 1 or 0.02 ampere, sensing input range 2), ±(5% or 25 milliamperes), whichever is greater.

NOTE
Output contacts may be NC or NO, depending on style of relay. Check continuity at terminals 1 and 10 with relay tripped and not tripped to assure correct response for the type of contacts specified.

Step 6. Slowly decrease the operate current source until dropout. Reset must occur at a value of current that is greater than or equal to 90% of I_s (sensitivity switch setting value).

Step 7. Repeat steps 2 through 6 for the other sensitivity switch settings. If desired, a sufficient number of trip points may be taken to verify any or all of the performance curves shown in Figure 5-4. For $I_R \leq$ nominal (5 amperes, sensing input range 1 or 1 ampere, sensing input range 2), the tolerance is ±(0.05 I_{OP} or 25 milliamperes, whichever is greater.) For $I_R \rangle$ nominal up to a maximum of 20 amperes (sensing input range 1) or 4 amperes (sensing input range 2), the tolerance is ±0.08 I_{OP} on the characteristic curve or 150 milliamperes, whichever is greater. See Figures 5-4 through 5-7 for the operating characteristic curves and trip response timing curve.

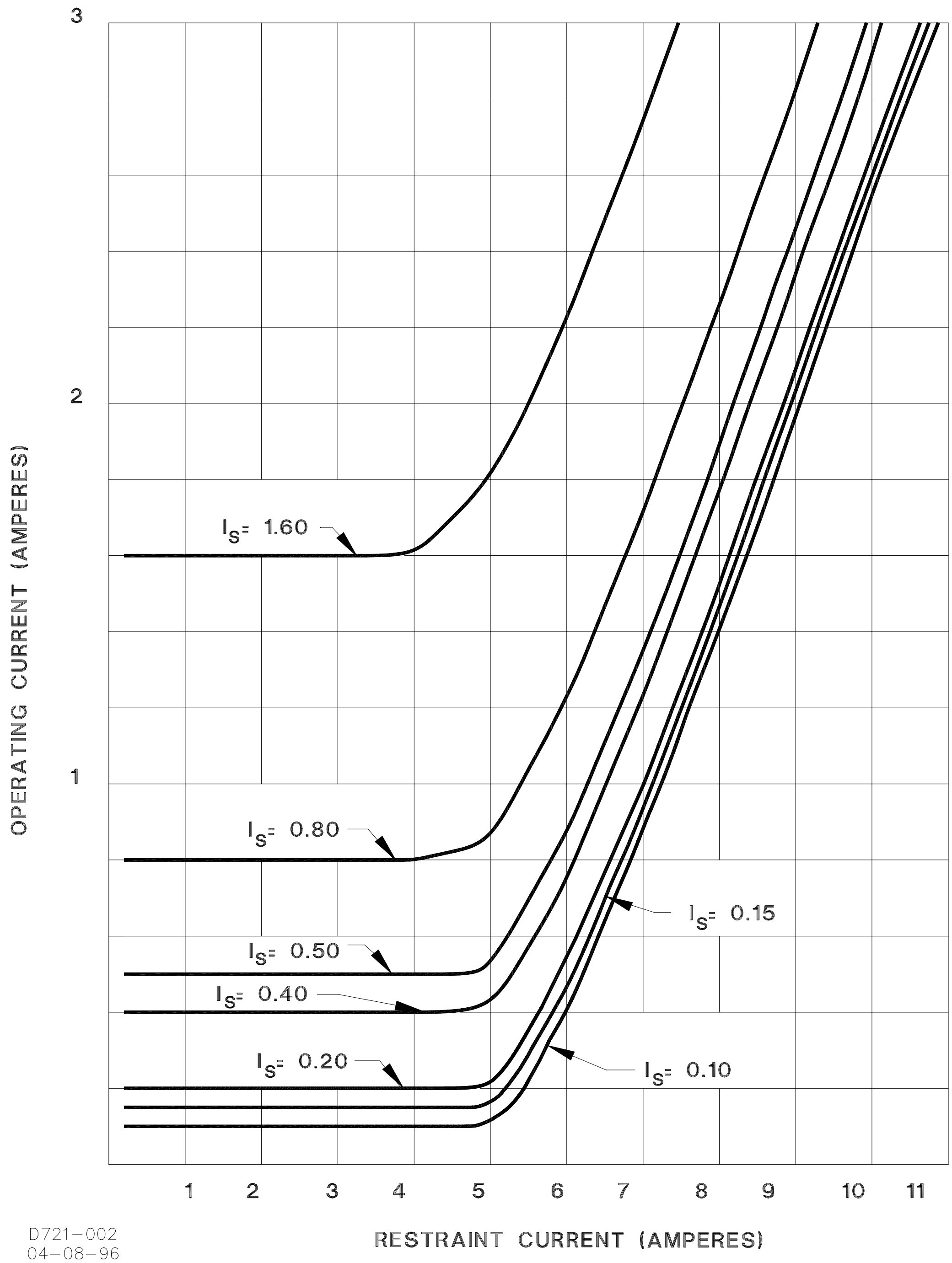


Figure 5-4. Sensing Input Range 1, Operating Characteristics

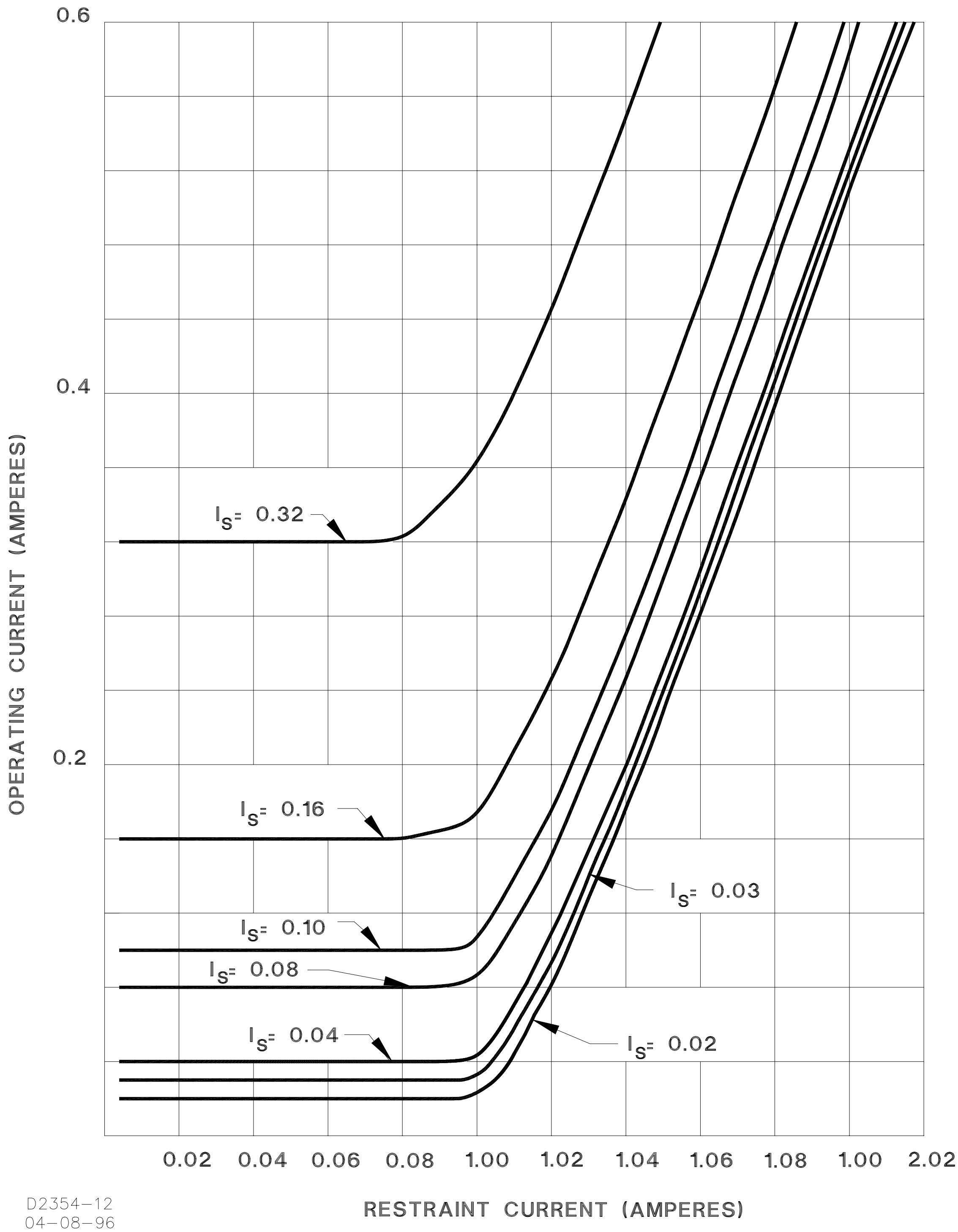


Figure 5-5. Sensing Input Range 2, Operating Characteristics

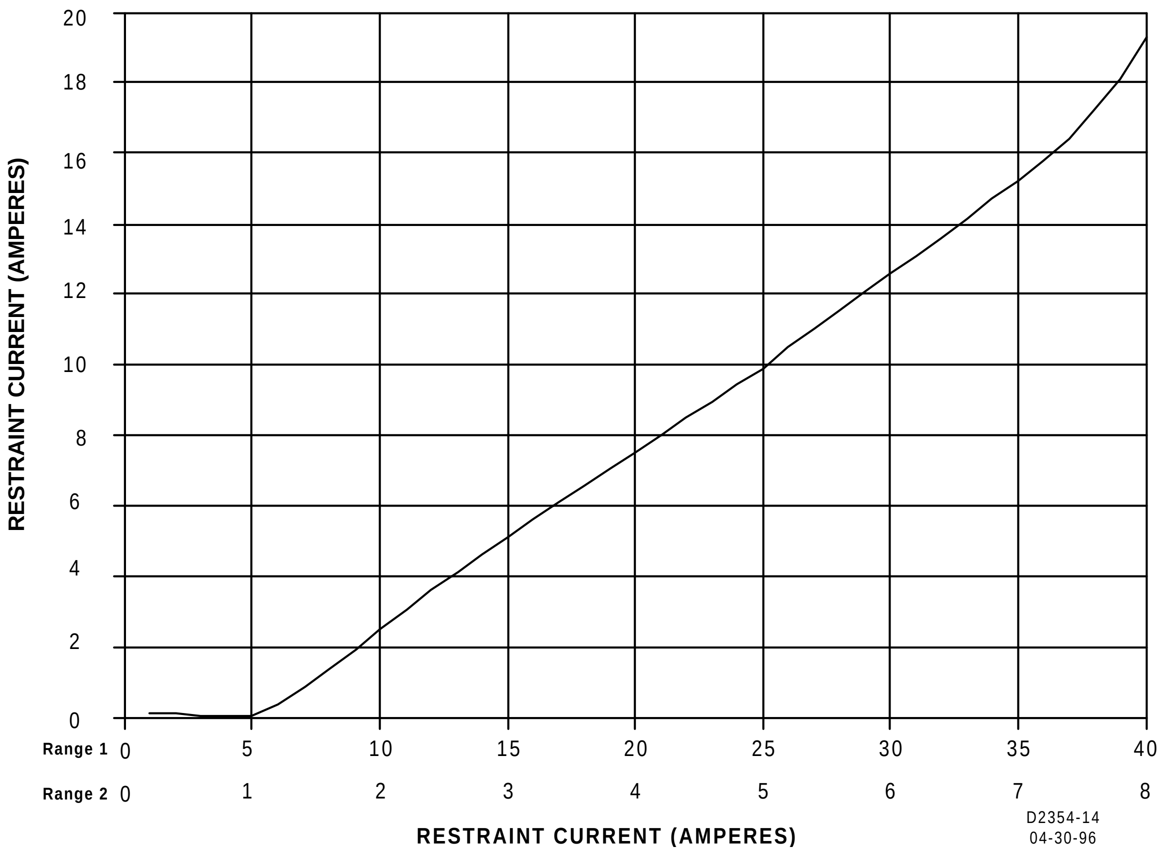


Figure 5-6. Extended Restraint Operating Characteristic

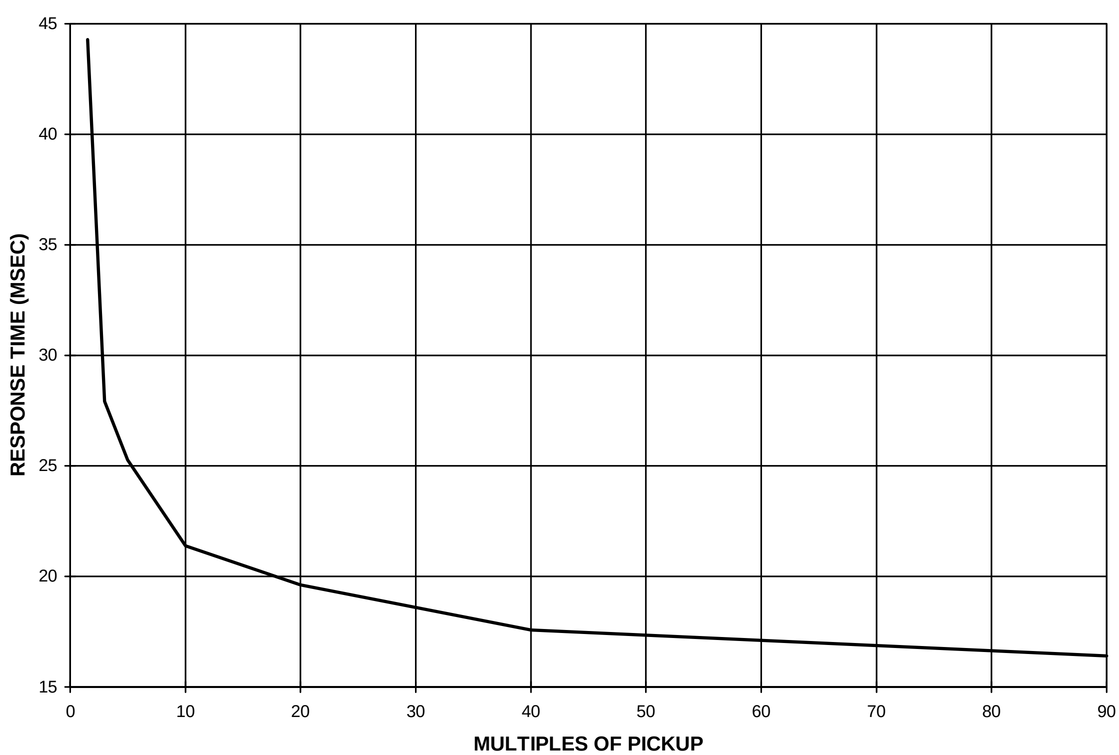


Figure 5-7. Pickup Response Timing

Terms for Calculations

I''_d Subtransient current

N Total number of CT turns

N_a Number of CT turns in use (for multi-ratio type)

R_l One-way lead resistance, in ohms

R_r Relay restraint circuit resistance, in ohms

R_w CT winding resistance, in ohms.

> **NOTE**
> Sensing Input Range 1: If R_w is unknown, assume $R_w = 0.003 * N_a$
>
> Sensing Input Range 2: If R_w is unknown, assume $R_w = 0.01 * N_a$

R_t Total CT burden = $R_l + R_r + R_w$ (for phase faults and switching)

$= 2R_l + 2R_r + R_w$ (for external ground faults)

SFR Saturation factor ratio = $[(Vce)_1/(Vce)_2]*[(R_t)_2/(R_t)_1]$ (If SFR is < 1, use 1/SFR)

Vc CT accuracy-class voltage rating

Vce Effective CT accuracy-class voltage rating = Vc (N_a/N)

X''_d Subtransient reactance

CT Quality

CTs should have an accuracy class of either C20 or better or T20 or better.

Burden Limit

The CTs should be operating below the knee point under symmetrical current conditions --i.e. no "ac saturation". For a generator, ac saturation should not occur for the maximum external fault current. For a motor, ac saturation should not occur during starting. For a shunt reactor, high current fundamental-frequency currents won't flow unless the reactor becomes faulted.

Assuming a maximum current of 20 times CT rating: **$R_t < 0.007Vce$** **(1)**

where V_{knee} = 70% of Vce and 20 X 5 A nominal rating = 100 A so that

$$R_t = V_{knee} / I\ max = 0.7\ Vce / 100\ A = 0.007\ Vce$$

Relative CT Performance

Table 5-1 lists the recommended minimum pickup settings to provide security during external faults and switching.

Phases B And C, Trip And Dropout Test

Step 1. If the relay is a 3-phase relay, repeat steps 1 through 7 for phases B and C.

Target Test

If relay is equipped with targets, check for correct operation of each phase when relay is tripped, and for manual reset.

> NOTE
> If option B (current operated) targets are specified, the target is only operable when a minimum of 0.2 ampere is present in the output circuit (terminals 1 and 10).

Auxiliary Output Test

If an Auxiliary output (Option 3-2 or 3-3) is present, check outputs at terminals 2 and 5 (either NC or NO as specified) when relay is tripped.

Push To Energize Output Test

If a PUSH TO ENERGIZE switch (Option 2-C) is present, verify correct operation by depressing the switch and observing that the output and auxiliary relays cycle (terminals 1 and 10 and terminals 2 and 5 respectively.)

Power Supply Status Output Test

Step 1. If power supply status output (Option 3-6) is present, verify correct operation by applying appropriate voltage to the power input, placing the unit in a powered-up condition, verifying that the power supply status output contacts are energized open (terminals 2 and 5).

Step 2. Remove input power and verify that the power supply status output contacts close.

SETTING THE RELAY

General

This paragraph provides recommendations for selecting the current sensitivity switch setting. Figures 5-4 and 5-5 show how this setting corresponds to the operating current pickup over the restraint current range.

Assuming that the CTs on both sides of the zone (generator, motor or reactor) perform identically, operating current will be equal to zero. The sensitivity setting serves to accommodate dissimilar CT performance, resulting from differences in CT quality, burden, and core remanence.

During normal operation, the pickup on the flat part of the operating characteristics (refer to Figures 5-4 and 5-5) must exceed the difference in steady-state CT errors. The relay must also override the error differences in the presence of dc components developed by external faults or switching. Currents will be offset during external faults on generator applications, during motor starting, and during switching of shunt reactors.

Out-of-phase synchronizing of machines will also produce offset components. These so-called dc components will produce significant CT saturation. For high-current faults, the relay relies on the 50% slope characteristic to override large operating currents. Significant operating current can also be developed at restraint levels that fall on the flat part of the characteristic if the offset component persists. The sensitivity setting needs to be above this operating current.

Table 5-1. Recommended Pickup Settings

Vce (Lower Value)	SFR				
	1	1.5	2	3	4
20	0.2	0.4	0.5	0.8	1.6
50	0.2	0.4	0.4	0.5	0.8
100	0.2	0.2	0.4	0.4	0.5
200	0.1	0.1	0.2	0.4	0.5
>200	0.1	0.1	0.2	0.4	0.5

Note: Use next higher setting if CTs are a mix of C classification and T classification.

The saturation factor ratio, SFR, represents an index of the relative performance of the two sets of CTs. This performance is a function of the relative quality of the CTs (Vce), the relative burdens (R_t), and neglecting the remanence. **If SFR is < 1, then use 1/SFR for SFR.**

Setting Example Number One

Select the pick-up setting for the motor application in Figure 5-8. In this application, the settings need to be based on the probability of significant dissimilar CT saturation due to the very slowly decaying dc component of the starting current. Since the motor is not grounded, no ground current can flow during starting of an unfaulted motor. Therefore, one-way lead burden is used to determine the total CT burden. Each phase CT carries just the burden for the lead for that phase.

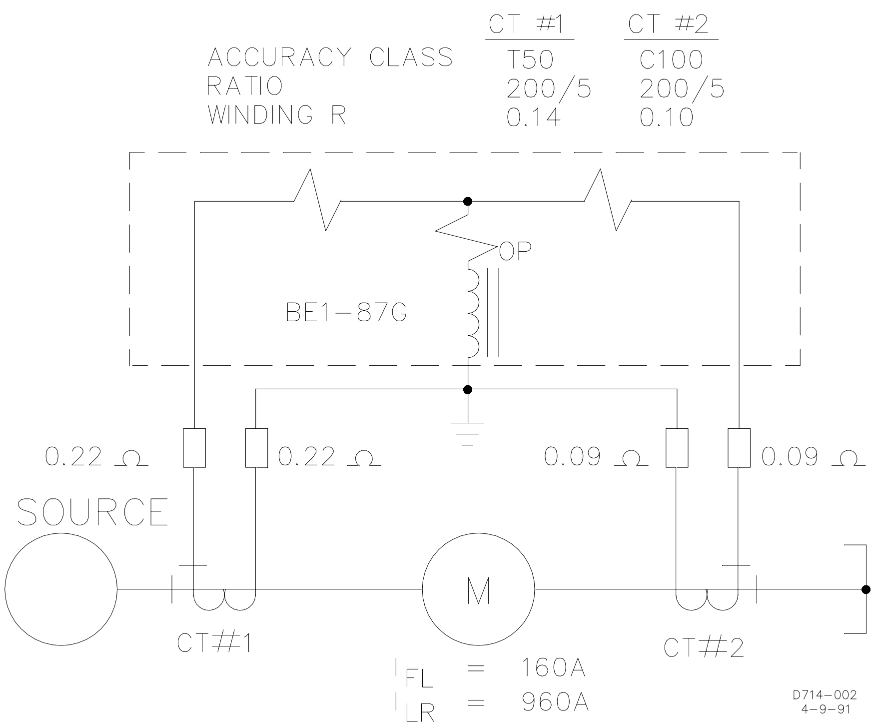


Figure 5-8. Motor Differential Application

$(R_t)_1 = R_l + R_w = 0.22 + 0.14 = 0.36$; $(Vce)_1 = 50$; $R_t < 0.007(Vce)_1 = 0.35$

$(R_t)_2 = 0.09 + 0.10 = 0.19$; $(Vce)_2 = 100$; $R_t < 0.007(Vce)_2 = 0.7$

Inequality **(1)** is met with CT #2, but not with CT #1. However, since the locked rotor current is only 4.8 times CT rating [vs. the assumption of 20 times rated for inequality **(1)**], the application is suitable.

SFR = (100/50)*(0.36/0.19) = 3.8

Using the SFR 4 column of Table 5-1, a 0.8 ampere setting is indicated. However, based on the note accompanying this table, choose the next higher setting of 1.6, because CT #1 has a T classification, and CT #2 has a C classification. The T classification indicates that the CT has significant secondary leakage inductance which somewhat degrades the transient performance. This is a concern during motor starting because a slowly decaying offset component develops in at least one phase.

Setting Example Number Two

Select the pick-up setting for the generator application in Figure 5-9. In this application, the settings need to be based on the probability of significant dissimilar CT saturation during an external fault. Since the generator is resistance grounded, the three-phase fault current will be much larger than the ground fault level. Moreover, the resistor will rapidly dampen any offset-current component. Accordingly, determine the subtransient current (I''_d).

$$I''d = \frac{\frac{1000}{4.16\times\sqrt{3}}}{0.15\times 200} = \frac{138.8}{30} = 4.6 \times CT\ rating$$

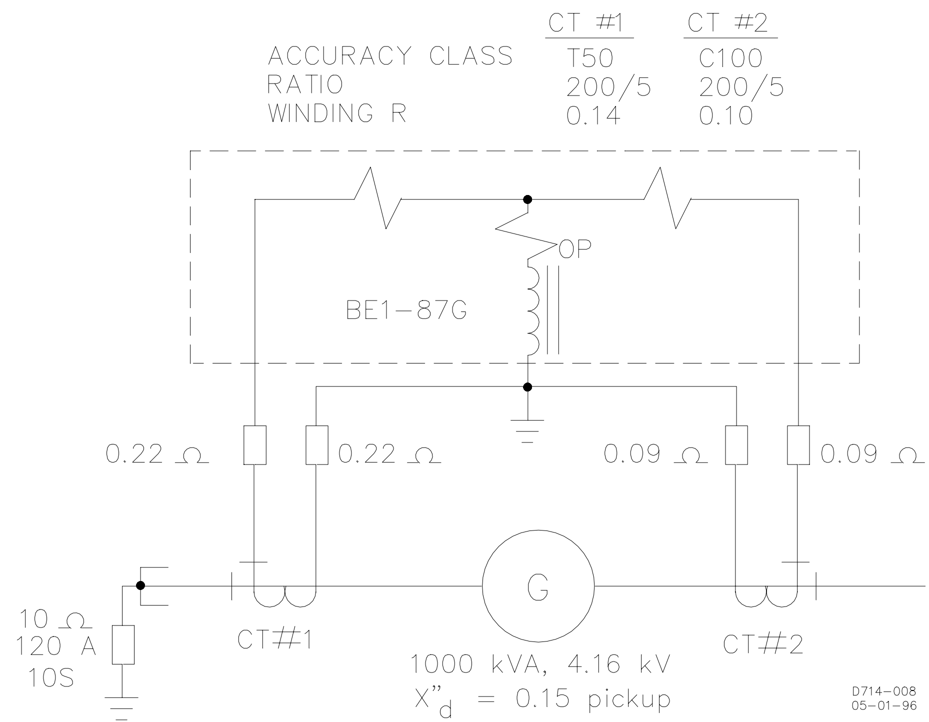


Figure 5-9. Generator Differential Application

Since the three-phase fault is involved, one-way lead burden is used to determine the total CT burden. Each phase CT carries just the burden for the lead for that phase.

$(R_t)_1 = R_l + R_w = 0.22 + 0.14 = 0.36$; $(Vce)_1 = 50$; $R_t < 0.007(Vce)_1 = 0.35$

$(R_t)_2 = 0.09 + 0.10 = 0.19$; $(Vce)_2 = 100$; $R_t < 0.007(Vce)_2 = 0.7$

Inequality **(1)** is met with CT #2, but not with CT #1. However, since the maximum external fault current is only 4.6 times CT rating [vs. the assumption of 20 times rated for inequality **(1)**], the application is suitable.

SFR = (100/50)*(0.36/0.19) = 3.8

Using the SFR 4 column of Table 5-1, a 0.8 ampere setting is indicated. However, based on the note accompanying this table, choose the next higher setting of 1.6, because CT #1 has a T classification, and CT #2 has a C classification. The T classification indicates that the CT has significant secondary leakage inductance which somewhat degrades the transient performance. This is a concern during motor starting because a slowly decaying offset component develops in at least one phase.

SECTION 6 • MAINTENANCE

GENERAL

BE1-87G Variable Percentage Differential Relays require no preventive maintenance other than a periodic operational test (refer to Section 5 for the operational test procedures). If 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.

Where special components are involved, Basler Electric part numbers may be obtained from the number stamped on the component or assembly, the schematic, or parts list. These parts may be ordered directly from Basler Electric. 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.

SECTION 7 • MANUAL CHANGE INFORMATION

SUMMARY AND CROSS REFERENCE GUIDE

This section contains information concerning the previous editions of the manual. The substantive changes to date are summarized in Table 7-1.

Table 7-1. BE1-87G Changes

Revision	Summary Of Changes	ECA/ECO/Date
A	Added qualifications to specifications listing, revised isolation test and dielectric test.	05-12-86/7820
B	Grammatical changes to specifications, changed comparator functional description and operational test procedure.	10-07-86/8199
C	Added Power Supply Status Output Option 3-6	03-13-87/8485
D	Physically removed Power ON/OFF switch and added stabilizing reactor. Added illustrations for typical connections, sensing input connections, test setup, extended operational characteristics, and pickup response timing. Added table for current sensing burden and functional description of stabilizing reactor, setting the relay, and setting the relay example.	03-06-91/11227
E	Changed Figure 1-1 and 1-2, and added Warning pages 1-1 and 4-2.	07-17-91/12091
F	Changed pickup accuracy for I_R > 5 A from 30 A, ±5% to 20 A, ±8% of the operate pickup characteristic or 150 mA, whichever is greater.	07-30-91/12100
G	Added I^2t rating of Stabilizing Reactor and new Figure 4-1, Stabilizing Reactor Impedance Characteristics.	10-17-91/12223
H	Added sensing input range 2 (one ampere nominal) to the available models. Changed high speed operation from 20 milliseconds to 30 milliseconds. Changed all connection diagrams to include ground connections where applicable. Added internal connection diagrams. Corrected Table 1-1 Clarified *Setting Example* for motor differential application, and added *Setting Example Number Two*, generator differential application. Divided *Section 4* into two sections. The new *Section 5*, is *Testing And Setting* the relay.	05-03-96/15555
J	Reformatted manual to current standards. Page 1-2, corrected Figure 1-2. Page 1-4, last paragraph, changed “Terminals 7, 13, and 14 are provided for convenience . . .” to “Terminals 7, 13, and 17 are provided for convenience . . .”. Corrected Figures 4-11 and 4-12. Updated this section to show changes.	05-12-99/4392