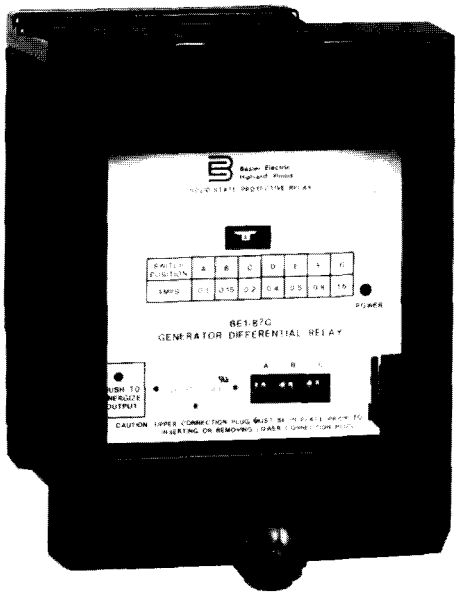

BE1-87G
VARIABLE PERCENTAGE DIFFERENTIAL RELAY

The BE1-87G is a single or three-phase solid-state variable percentage differential relay designed to provide selective, high-speed, differential protection for generators, motors, and shunt reactors.

ADVANTAGES

- Single or three-phase relays available.
- Variable percentage characteristic.
- Low operating burden.
- Balancing impedance in CT inputs provides excellent security during external faults or other transients.
- High speed operation.
- Seven sensitivity settings cover the range of 0.1 to 1.6A or 0.02 to 0.32A.
- Pickup accuracy within ±5% of the operate characteristic.
- Qualified to the requirements of
  - IEEE C37.90.2 for Radio Frequency Interference (RFI)
  - IEEE C37.90.1-1990 for Fast Transient and Surge Withstand Capability
  - IEC 255-5 and ANSI C37.90.1978 for Impulse and Dielectric tests.
- UL recognized under Standard 508, UL File #E97033.
- Five year warranty.

ADDITIONAL INFORMATION

INSTRUCTION MANUAL
Request Publication 9170800990

STANDARDS, DIMENSIONS & ACCESSORIES
Request Bulletin SDA

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APPLICATION

BASIC PRINCIPLES

Differential relaying is the most selective form of fault protection that 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.

The BE1-87G is a single or three-phase solid-state variable percentage differential relay designed to provide selective, high-speed differential protection for generators, motors, and shunt reactors.

The selectivity of differential relaying is based on the ability of the 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 current in still equals the current out of the protected zone. 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.

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

RESTRAINT CHARACTERISTICS

At high current levels, the inevitable difference in the saturation characteristics between current transformers requires a compensating decrease in relay sensitivity. The design of the BE1-87G provides a restraint factor that is proportional to input current.

Specifically, the BE1-87G compares the two sensed currents (in and out) to determine which is less. This lower current level becomes the restraining current. The difference between the two sensed currents (I_0) is compared to a reference established by the sensitivity setting and adjusted by an amount proportional to the restraining current. (The typical ratio is given in the formula on page 3.) This makes the BE1-87G more sensitive to low current internal faults, for which the relay should operate, and less sensitive to external faults with high levels of through current for which the relay should not operate.

THE VARIABLE PERCENTAGE PRINCIPLE

Figure 1 plots the tripping characteristics of two typical constant-percentage relays (one with a 10% slope, the other 25%). These are superimposed over the variable percentage characteristic of the BE1-87G relay to illustrate the improvement in sensitivity and security.

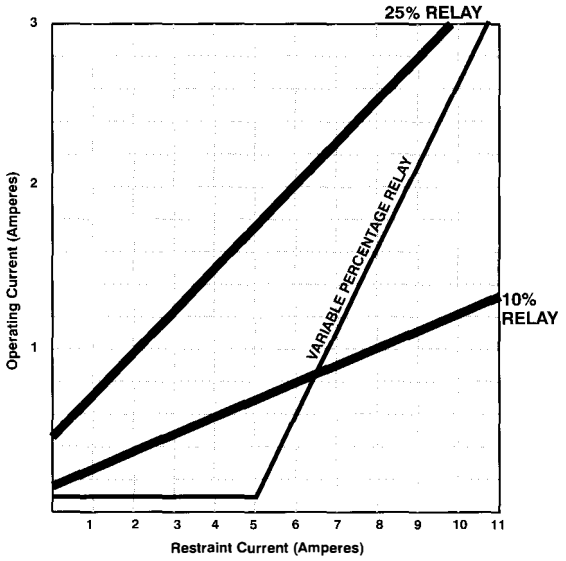


Figure 1 - Constant Percentage vs. Variable Percentage

In contrast to constant percentage relays, the BE1-87G's operating requirements are defined over two regions of the total operating range based on the level of the restraining current (I_R). When the restraining current is five amperes or less, the relay trips when the differential current exceeds the relay setting (I_S). But when the restraining current is greater than five amperes, the overall sensitivity is a combination of the front panel setting and the restraint factor.

For external faults, the system CTs will usually saturate to some extent. A stabilizing impedance in the relay design will force the CTs to perform more similarly under such conditions, thus reducing false "operate" current sensed by the relay. This, together with the variable percentage characteristic, provides security against false tripping.

SPECIFIC APPLICATIONS

The BE1-87G Variable Percentage Differential Relay is recommended for the following specific applications.

- Generators: Any terminal voltage, and a rating of 1000 kVA and above.
- Generators: Any kVA rating and a terminal voltage of 5kV and above.

APPLICATION, continued

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

DESIGN HIGHLIGHTS

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

- Seven sensitivity levels: from 0.1-1.6A or from 0.02A to 0.32A. Allows compensation for slight CT mismatch and provides 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 mounted remotely on three-phase units for flexibility of system installation.
- Minimum restraint: Using the smaller of the input currents as the restraint means a more accurate appraisal of the through current. This allows greater sensitivity while maintaining selectivity.
- Variable restraint characteristic (vs. constant 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 can be provided in a Basler Electric S1 drawout case.
- High-Speed Operation: The BE1-87G operates in 30 milliseconds for fault levels of 10 times the sensitivity setting, thus minimizing potential damage to the protected equipment.

SPECIFICATIONS

FUNCTIONAL DESCRIPTION

The specifications on these pages define the many features and options that can be combined to exactly satisfy an application requirement. The block diagram, Figure 2, illustrates how the various standard features and options function together.

INPUTS

Differential Current Sensing

System current transformers with nominal 5A secondaries supply the differential relay's input transformers with either single-phase or 3-phase currents, depending upon option selected. (See Figure 2.) These input currents are converted to analog voltages that are bandpass filtered, then presented to the current difference detector. The output of the latter, which represents the current difference between I_{in} and I_{out}, is then full-wave rectified and presented to the comparator as the operate current (I_0).

The two sensed inputs are also applied to a circuit that determines which input is smallest. This signal, after full-wave rectification, represents restraint current (I_R). However, I_R has no effect on determining the trip point until the lesser input exceeds approximately 5A. The ideal trip point occurs when:

$$I_0 = I_S \text{ for } I_R \leq 5 \text{ A}$$

$$I_0 = I_S + 0.5\,(I_R - 5) \text{ for } I_R > 5 \text{ A}$$

where,

I_0 is the operate current (i.e., the difference between inputs)

I_S is the front panel sensitivity setting

I_R is the restraint current (and is the lesser of two input currents)

The comparator implements the above equation and causes an output signal whenever the measured operate current is greater than the limit defined by Figure 3. If three phases are specified, the outputs of three comparators are ORed to determine a trip condition. If equipped with targets, the phase initiating the output will be indicated by a tripped target.

Sensing Burden

The steady state burden is always less than 1VA. Table 1 shows the values in ohms.

Frequency	50	60
Burden per Phase	25 + j1.5 ohms	25 + j1 ohms

Table 1 - Sensing Burden (Typical)

POWER SUPPLY INPUTS

One of three wide range power supply types may be selected to provide internal operating power. They are described in Table 2 on page 4.

SPECIFICATIONS, continued

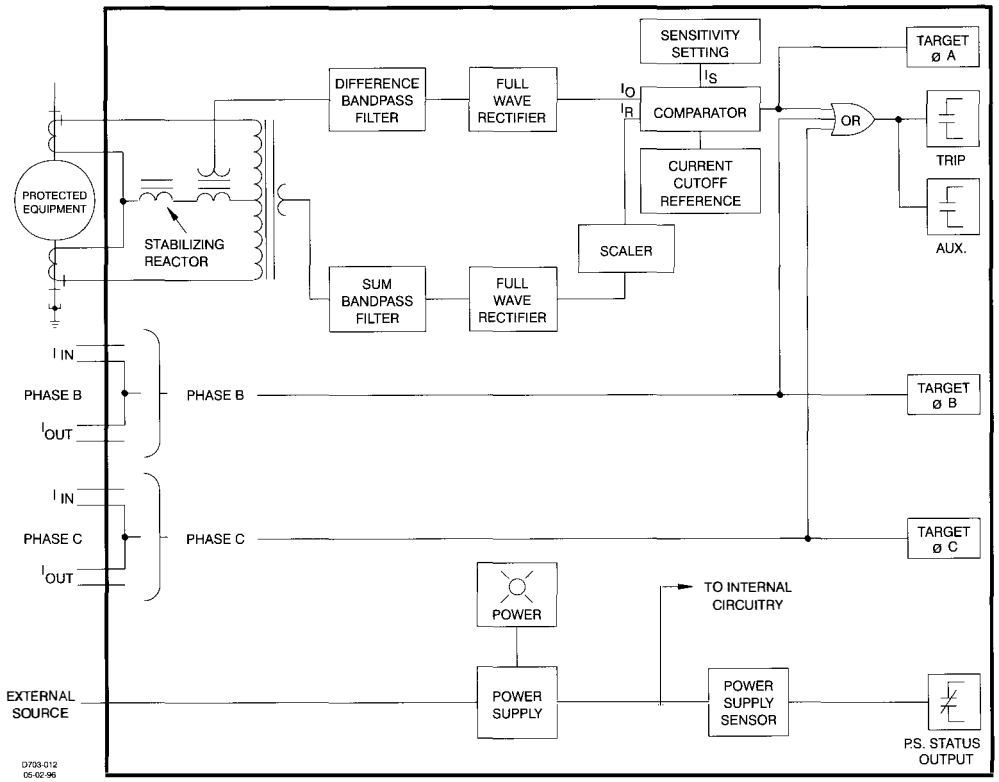


Figure 2 - Functional Block Diagram

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

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

Table 2 - Power Supply Options

POWER SUPPLY STATUS OUTPUT

The power supply output relay is energized and its NC output contact is opened when power is applied to the relay. Normal internal relay operating voltage maintains the power supply status output relay in a continuously energized state with its output contact open. If the power supply output voltage falls below the requirements of proper operation, the power supply output relay is de-energized, closing the NC output contact.

PICKUP ACCURACY

The ideal characteristic is graphically illustrated in Figure 3.

DROPOUT RATIO

The dropout ratio is greater than 90% of the sensitivity setting.

TRIP TIME CHARACTERISTICS

Trip time characteristics are shown in Figure 4.

OUTPUTS

Output contacts are rated as follows:

SPECIFICATIONS, continued

Resistive

120/240 Vac - make 30 A for 0.2 seconds, carry 7 A continuously, break 7 A.

250 Vdc - make and carry 30 A for 0.2 seconds, carry 7 A continuously, break 0.3 A.

Inductive

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

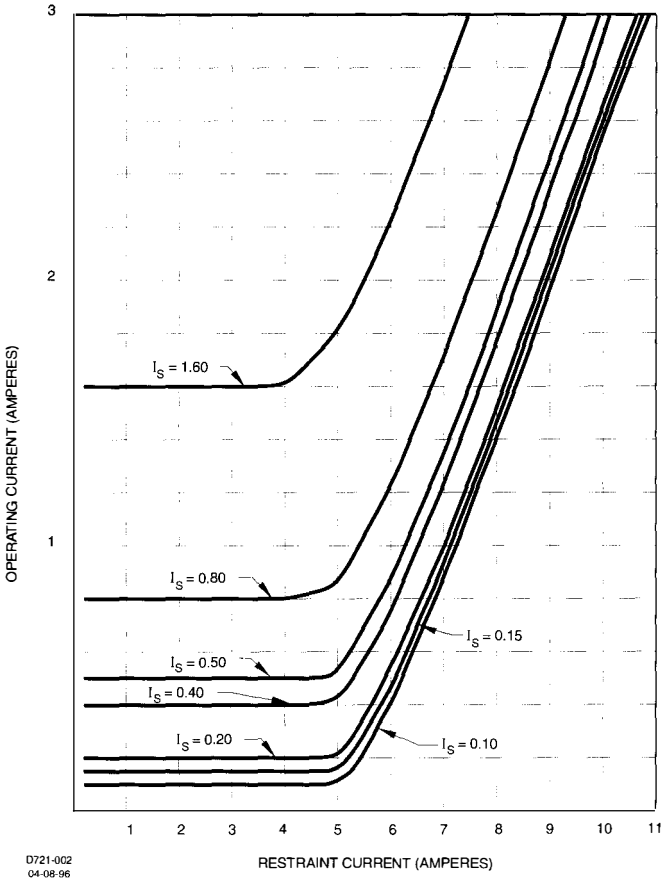


Figure 3 - Sensing Input Range 1, Operating Characteristics

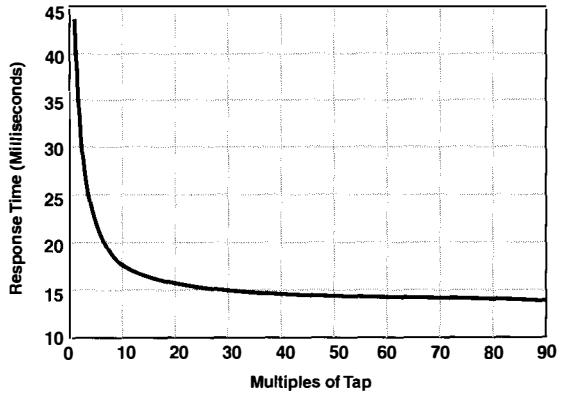


Figure 4 - Trip Delay Characteristics (Typical)

Push-to-Energize (Optional)

The unit may be equipped with a momentary pushbutton that is accessible through the front panel. To prevent accidental operation of this switch, if 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 0.2A of minimum current is present.

TARGET

Magnetically latched, manually reset, target indicators are optionally available to indicate that an output has tripped. Either internally operated or current operated targets may be specified. Current operated targets require 0.2 A in the output trip circuit to actuate, and trip circuit current must not exceed 30 A for 1 second, 7 A for 2 minutes, and 3 A continuous. Current operated targets may be selected only when normally open (NO) output contacts have been specified.

SURGE WITHSTAND CAPABILITY

Qualified to IEEE C37.90.1-1989 *Surge Withstand Capability Test* and IEC 255-5 *Impulse Test and Dielectric Test*.

MECHANICAL

Operating Temperature Range
-40°C to 70°C (-40°F to 158°F)
-65°C to 100°C (-85°F to 212°F)

Shock

In standard tests, the relay has withstood 15g in each of three mutually perpendicular axes.

Vibration

In standard tests, the relay has withstood 2g in each of three mutually perpendicular axes swept over the range of 10 to 500 Hz for a total of six sweeps, 15 minutes for each sweep.

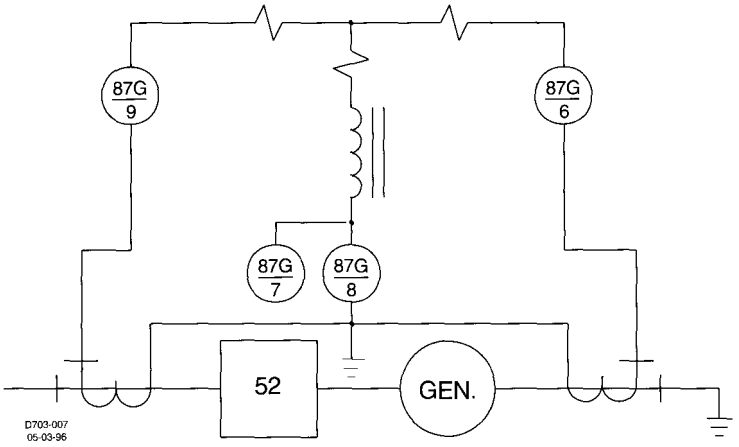
Weight

Single phase: 14.3 lbs., 6.48 kg.
Three phase: 19.2 lbs., 8.70 kg.

Case Size

S1: 6.65"W x 9.32"H x 9.40"D

CONNECTIONS



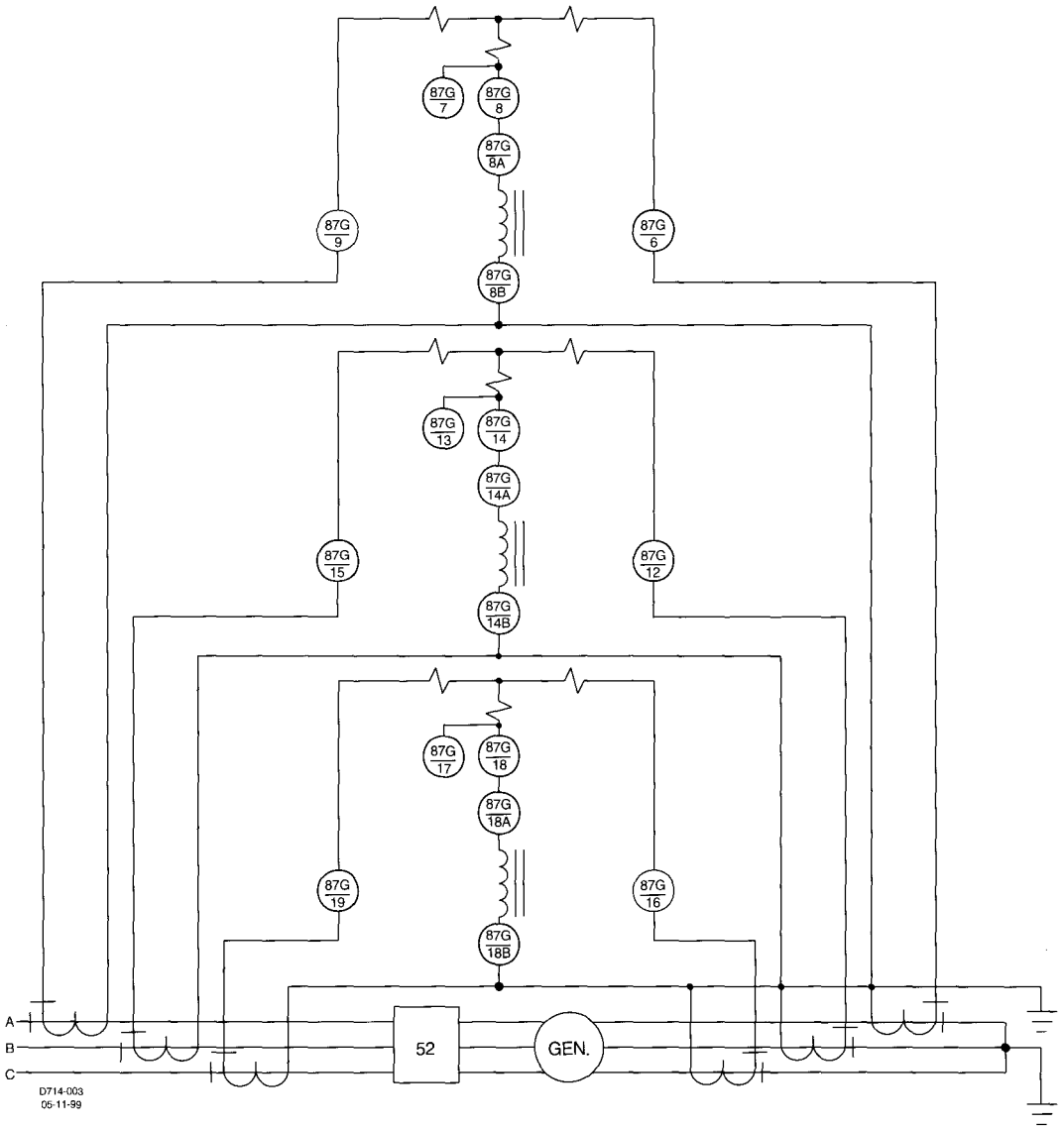


Figure 5 - Typical Single-Phase and Three-Phase Application Schemes

CONNECTIONS, continued

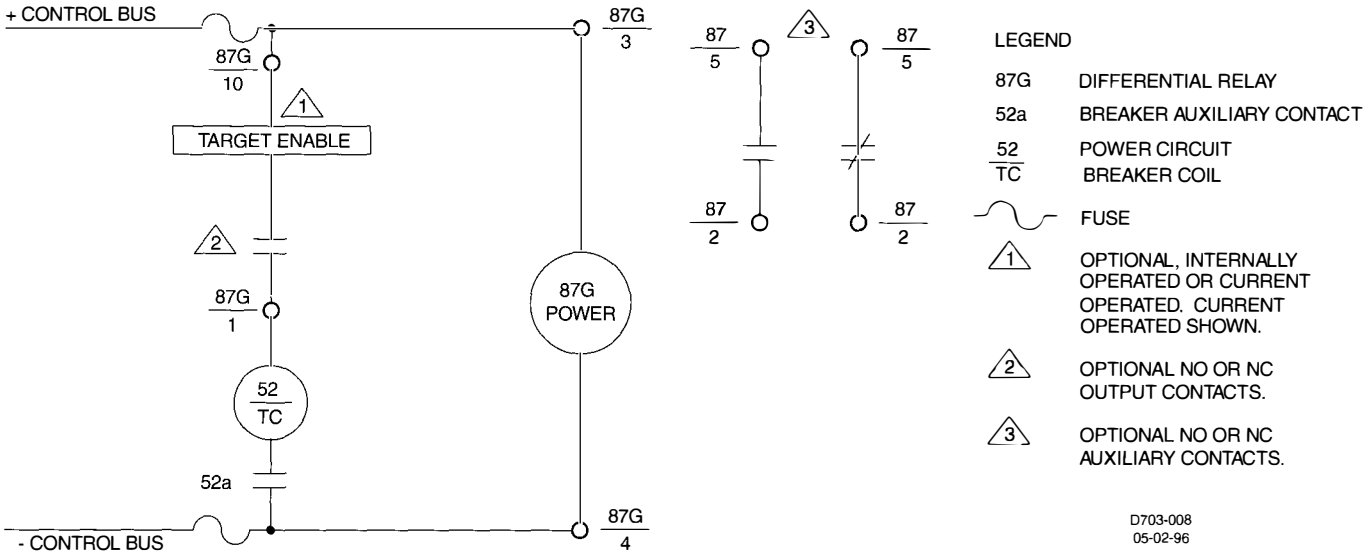


Figure 6 - Typical DC Control Connections

ORDERING

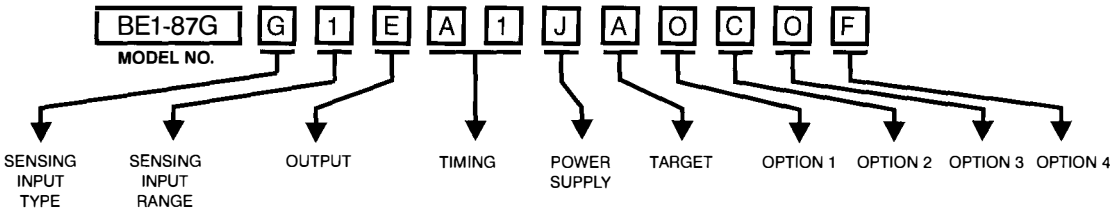
MODEL NUMBER
BE1-87G Variable Percentage Differential Relay

STYLE NUMBER
The style number appears on the front panel, drawout cradle, and inside the case assembly. This style number is an alphanumeric combination of characters identifying the features included in a particular unit. The sample style number below illustrates the manner in which the various features are designated. The Style Number Identification Chart (page 8) defines each of the options and characteristics available for this device.

SAMPLE STYLE NUMBER: G1EA1JAOCOF
The style number above describes a BE1-87G Variable Percentage Differential Relay having the following features.

Sensing Input Type	(G) Three-phase current
Sensing Input Range	(1) Switch selectable
Output	(E) One relay, NO
Timing	(A1) Instantaneous
Power Supply	(J) 125 Vdc or 100/120 Vac external power source
Target	(A) Internally operated, one per phase
Option 1	(O) None
Option 2	(C) Push-to-energize outputs
Option 3	(O) None
Option 4	(F) Semi-flush mounting

Note: The description of a complete relay must include both the model number and the style number.



ORDERING, continued

HOW TO ORDER:

Designate the model number followed by the complete Style Number:

BE1-87G Style No. ☐☐☐☐☐☐☐☐☐☐

Complete the Style Number by selecting one feature from each column of the Style Number Identification Chart and entering its designation letter or number into the appropriate square. (Two squares are used to indicate timing). All squares must be completed.

STANDARD ACCESSORIES:

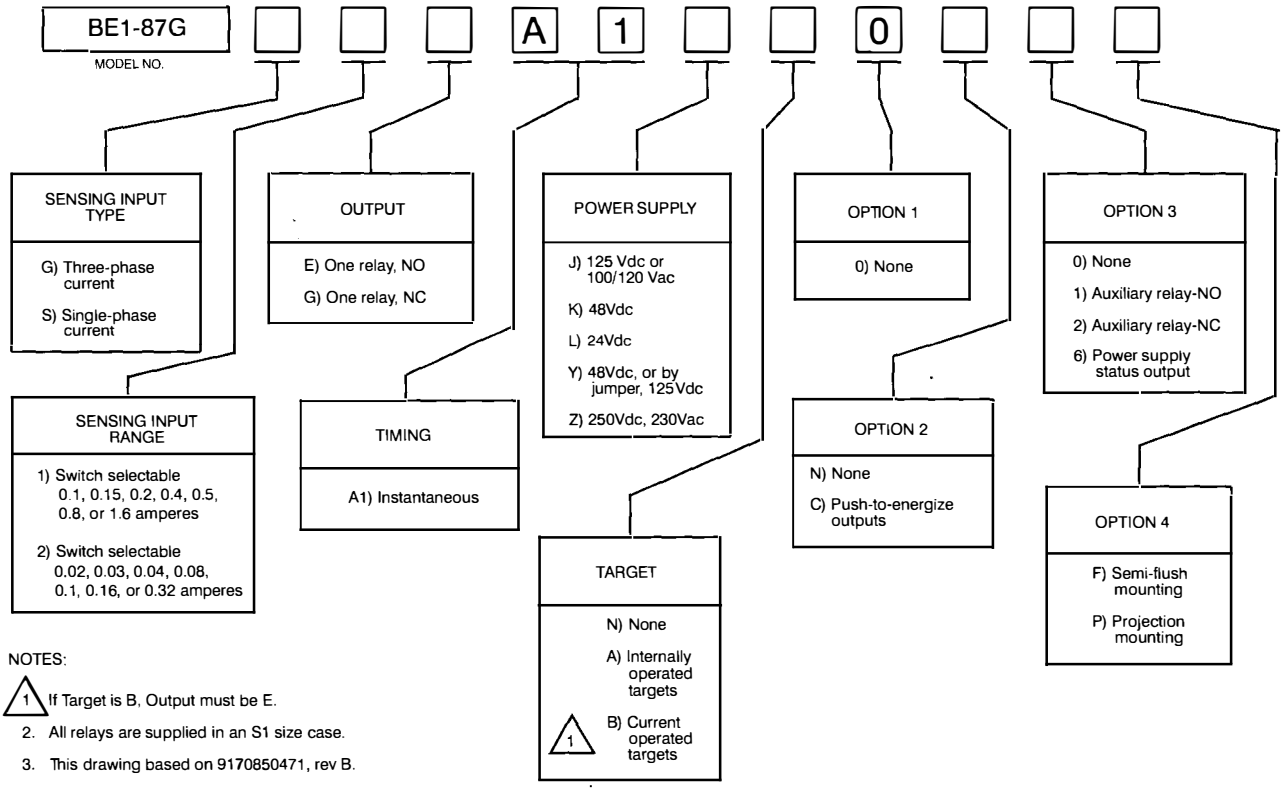
The following standard accessories are available for the BE1-87G Variable Percentage Differential Relay.

Test Plug
To allowing testing of the relay without removing system wiring, order two test plugs, Basler Electric part number 10095.

Extender Board
The Extender Board will permit troubleshooting of the printed circuit boards outside of the relay cradle. Order Basler Electric part number 9165500100.

Stabilizing Reactor
For units shipped prior to 6/1/91, a stabilizing reactor, part number 9170818100, may be added for improved security.

STYLE NUMBER IDENTIFICATION CHART



NOTES:

1. If Target is B, Output must be E.
2. All relays are supplied in an S1 size case.
3. This drawing based on 9170850471, rev B.

Basler Electric

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