INSTRUCTION MANUAL

FOR

BE1-87B

Bus Differential Relay

PVD Retrofit
P/N 9282300111

Basler Electric®

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Preface

This instruction manual provides information about the installation and operation of the BE1-87B Bus Differential Relay. To accomplish this, the following information is provided:

- Control and indicator descriptions
- Application information
- Installation instructions
- Test procedures
- Product specifications

Conventions Used in this Manual

Important safety and procedural information is emphasized and presented in this manual through warning, caution, and note boxes. Each type is illustrated and defined as follows.

Warning!
Warning boxes call attention to conditions or actions that may cause personal injury or death.

Caution
Caution boxes call attention to operating conditions that may lead to equipment or property damage.

Note
Note boxes emphasize important information pertaining to installation or operation.

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Warning!
READ THIS MANUAL. Read this manual before installing, operating, or maintaining the BE1-87B. Note all warnings, cautions, and notes in this manual as well as on the product. Keep this manual with the product for reference. Only qualified personnel should install, operate, or service this system. Failure to follow warning and cautionary labels may result in personal injury or property damage. Exercise caution at all times.

Basler Electric does not assume any responsibility to compliance or noncompliance with national code, local code, or any other applicable code. This manual serves as reference material that must be well understood prior to installation, operation, or maintenance.

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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. Over time, improvements and revisions may be made to this publication. Before performing any of the following procedures, contact Basler Electric for the latest revision of this manual.

The English-language version of this manual serves as the only approved manual version.

Contents

Introduction

The BE1-87B is a single-phase differential relay intended for protection of high-voltage buses and critical medium- and low-voltage buses. Its high-impedance characteristic provides fast, sensitive tripping for all internal faults along with the selectivity to restrain tripping due to faults outside the differential zone.

This version of the BE1-87B is identified by part number 9282300111 and functions as a retrofit for a GE PVD21B or PVD21D differential voltage relay. The BE1-87B is provided in a draw-out cradle assembly that installs, without modification, in an existing M1 PVD case. A relay cover is secured to the case through a cover adapter. Only minor wiring changes are required.

Features and Characteristics

The BE1-87B offers high-speed fault protection, which may be applied to individual elements or zones of ac power systems. It operates in less than 7 milliseconds for fault levels of 1.5 times the current pickup and less than 5.5 seconds for fault levels above six times the current pickup. This high-speed operation minimizes potential damage to the protected equipment. Response characteristics for the sensing input range are shown in the *Testing* chapter.

Standard BE1-87B features include:

- Percent of pickup voltage alarm
- Front panel trip test control
- Front panel LED indicators
- Low-burden power supply for reduced battery load
- Power supply status output contacts
- Relay cover with integrated Reset button plunger

BE1-87B operating characteristics include:

- Single-phase, 5 Aac nominal current sensing
- Jumper-selectable instantaneous or 2-millisecond timing delay
- 48/125 Vac/Vdc nominal control power input

Controls and Indicators

BE1-87B controls and indicators are located on the front panel and the control circuit board.

Front Panel

Front panel controls and indicators are illustrated in Figure 1 and described in the following paragraphs.

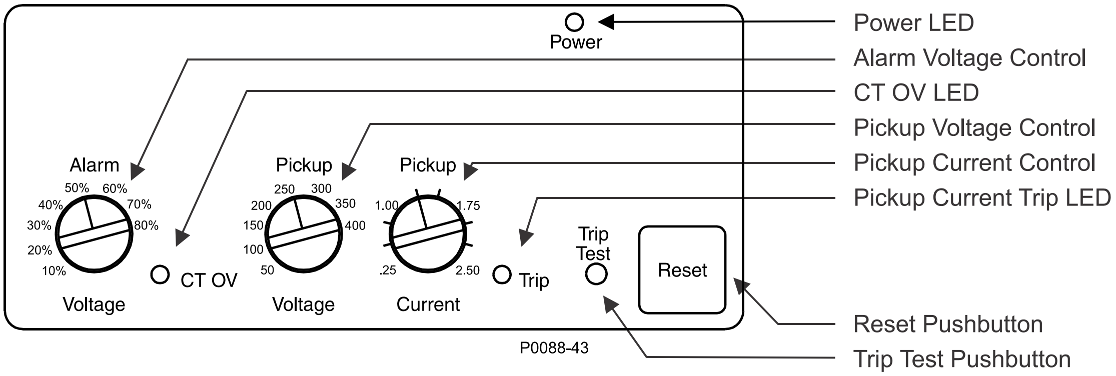

Figure 1. BE1-87B Controls and Indicators

Power LED

This indicator lights when nominal operating power is applied to the relay at terminals 1 (+) and 8 (–).

Alarm Voltage Control and CT OV LED

The Alarm Voltage rotary select switch allows for a setting range of 10% through 80% of the pickup voltage setting in 10% increments. The alarm voltage element detects unbalanced voltages across the sensing inputs of the relay (terminals 4/5 [common] and 6 [+]). If the unbalance voltage exceeds the voltage alarm setting (10 to 80 % of pickup voltage), the CT OV LED lights. When the voltage input falls below the alarm setting, the CT OV LED turns OFF. The response time of the CT OV LED is intentionally slow to prevent nuisance alarms.

Example

With the Alarm Voltage setting at 10% and a Pickup Voltage setting of 150 volts, the CT OV LED will light when the input voltage exceeds 15 volts (0.1 × 150).

Pickup Voltage Control

This rotary control allows for a pickup voltage setting range of 50 to 400 volts rms in 50-volt increments. This sets the voltage at which the back-to-back internal SCRs trigger. The SCRs are triggered when the input voltage exceeds twice the setting of the Pickup Voltage switch to allow for a fully offset voltage signal. Refer to the *Specifications* chapter for input impedance values while not triggered.

Example

With the pickup voltage set at 150 volts rms, the input SCRs will trigger when the input voltage is increased to 300 volts rms (calibration and routine maintenance tests) or when the instantaneous voltage exceeds 2.83 times the rms pickup voltage (fully offset, peak value). Refer to the *Application* chapter for more information.

Pickup Current Control

This rotary control allows for a pickup current setting of 0.25 to 2.50 amperes rms in 0.25 ampere increments. This setting determines the level of current into the sensing input (terminals 4/5 [common] and 6 [+]) that causes the trip output contacts to close and the Trip LED to light. Note that relay operation is based on the instantaneous peak value of the sinusoidal current detected at the sensing input. Refer to the *Specifications* chapter for input impedance values while triggered.

Example

When the Pickup Current Control is set at 1 amperes rms, output contact closure occurs when the current sensing element detects an instantaneous current value of 1.414 amperes.

When the input current decreases below this setting, the output contacts open, but the Trip LED remains lit until the Reset button is pressed. The Trip LED maintains correct status indication even if power is lost and then restored.

Pickup Current Trip LED

This indicator lights when the level of current flowing through the relay sensing input exceeds the setting of the Pickup Current Control. The Pickup Current Trip LED remains lit until the Reset button is pressed. LED status is maintained when the relay is de-energized. When operating power is re-applied, the LED lights and remains lit until the Reset button is pressed.

Reset Pushbutton

Pressing the Reset button turns off the Pickup Current Trip LED.

Trip Test Pushbutton

The Trip Test pushbutton is recessed behind the front panel and is accessed through a small opening. It is actuated by using a nonconductive tool small enough to fit through the front panel. It is used to simulate a trip condition, to verify operation of both output trip contacts, and to verify that the trip LED lights. Upon releasing this pushbutton, the output trip contacts open but the Trip LED remains lit. The test operator must press the reset switch to clear the Trip LED.

Note

The Trip Test pushbutton is functional only when operating power is applied to the relay.

Control Circuit Board

The Intentional Delay jumper is located on the control circuit board (Figure 2) and is used to select either no intentional delay or an intentional delay of 2 milliseconds added to the trip response time. Jumpering pins 1 and 2 provides no intentional delay and jumpering pins 2 and 3 provides the 2-millisecond delay.

The 2-millisecond intentional delay is intended to minimize nuisance tripping due to very brief disturbances such as nearby lightning strikes. The actual time delay obtained is a function of the pickup current. For currents exceeding twice the pickup setting, the intentional time delay is 2 milliseconds. For currents less than twice the pickup setting, the intentional time delay is 7 milliseconds.

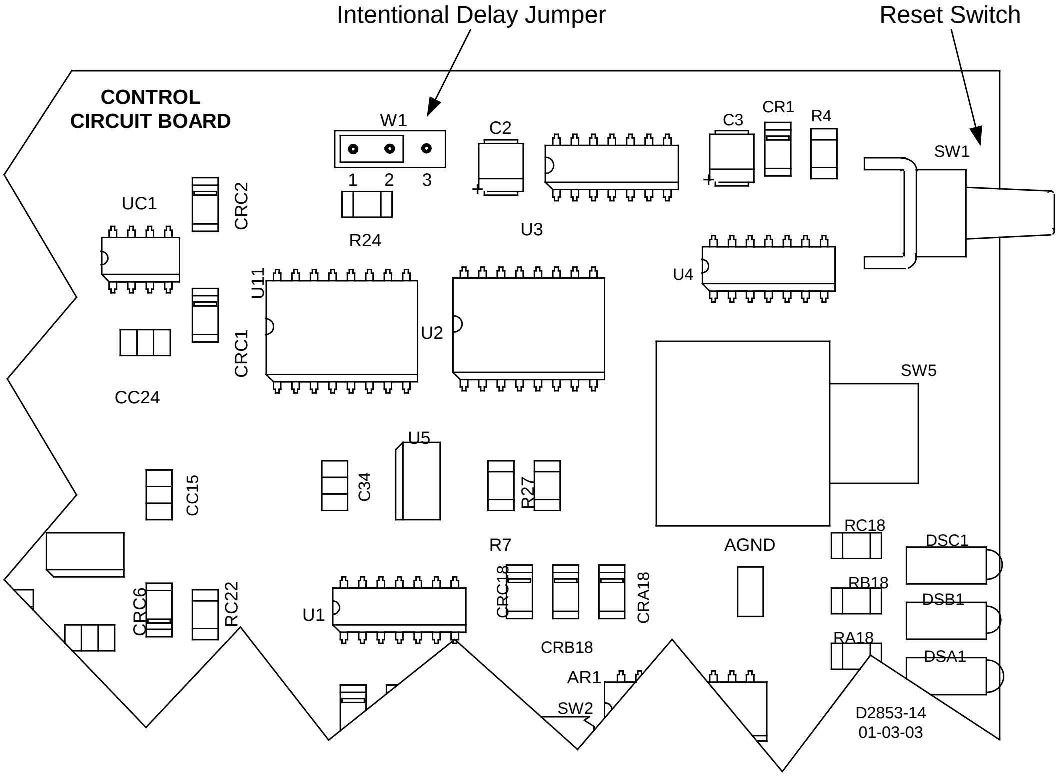

Figure 2. Internal Delay Jumper Location

Installation

Upon receipt of a relay, check the model and part number against the requisition and packing list to ensure that they agree. If there is evidence of shipping damage, file a claim with the carrier and notify Basler Electric.

If the relay will not be installed right away, store it in its original shipping carton in a moisture- and dust-free environment.

Note
This device contains long-life aluminum electrolytic capacitors. For devices that are not in service (spares in storage), the life of these capacitors can be maximized by energizing the device for 30 minutes once per year.

Before placing the BE1-87B in service, consider performing the procedures provided in the *Testing* chapter.

Operating Precautions

- If a wiring insulation test is required, remove the connection plug and withdraw the cradle from its case
- When the connection plug is removed, the relay is disconnected from the operating circuit and will not provide system protection. Always be sure that external operating conditions are stable before removing a relay for inspection, test, or service.
- Terminal 7 of the relay must be connected to earth ground. Each relay should be connected to the ground bus with a separate ground lead.

Relay Components

Relay components include:

- Cradle assembly
- Connection plug
- Cover
- Cover adapter and mounting screws
- Instruction manual

Relay Installation

Select the desired relay settings before placing the relay into service. Changing pickup settings while the relay is in service may cause tripping. Perform the following steps to install the BE1-87B.

1. Select the desired settings on the BE1-87B relay.
2. Remove the existing PVD relay from its case.
3. Attach the relay cover adapter to the PVD case.
    a. Orient the adaptor as shown in Figure 3 with its gasket positioned against the PVD case.
    b. Secure the adaptor with the provided screws at the locations shown in Figure 3. The maximum torque rating for each screw is 30 inch-pounds (3.4 N•m).
4. Place the BE1-87B relay in the case and secure it by closing the cradle latches.
5. Install the connection plug.

6. Install the relay cover.
    a. Position the interlocking bracket at the top of the cover into the mating receptacle at the top of the relay cover adapter.
    b. Secure the cover by tightening the captive fastener at the bottom of the cover.

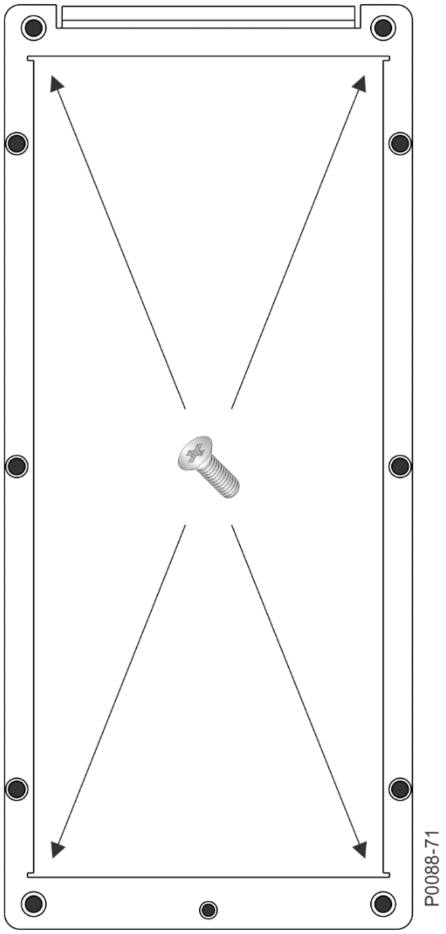

Figure 3. Cover Adaptor Mounting Detail

Relay Connections

Caution

Incorrect wiring may result in damage to the relay.

Note

Be sure the relay case is hard-wired to earth ground with no smaller than 12 AWG copper wire attached to terminal 7 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 wire no smaller than 14 AWG.

Internal connections are shown in Figure 4.

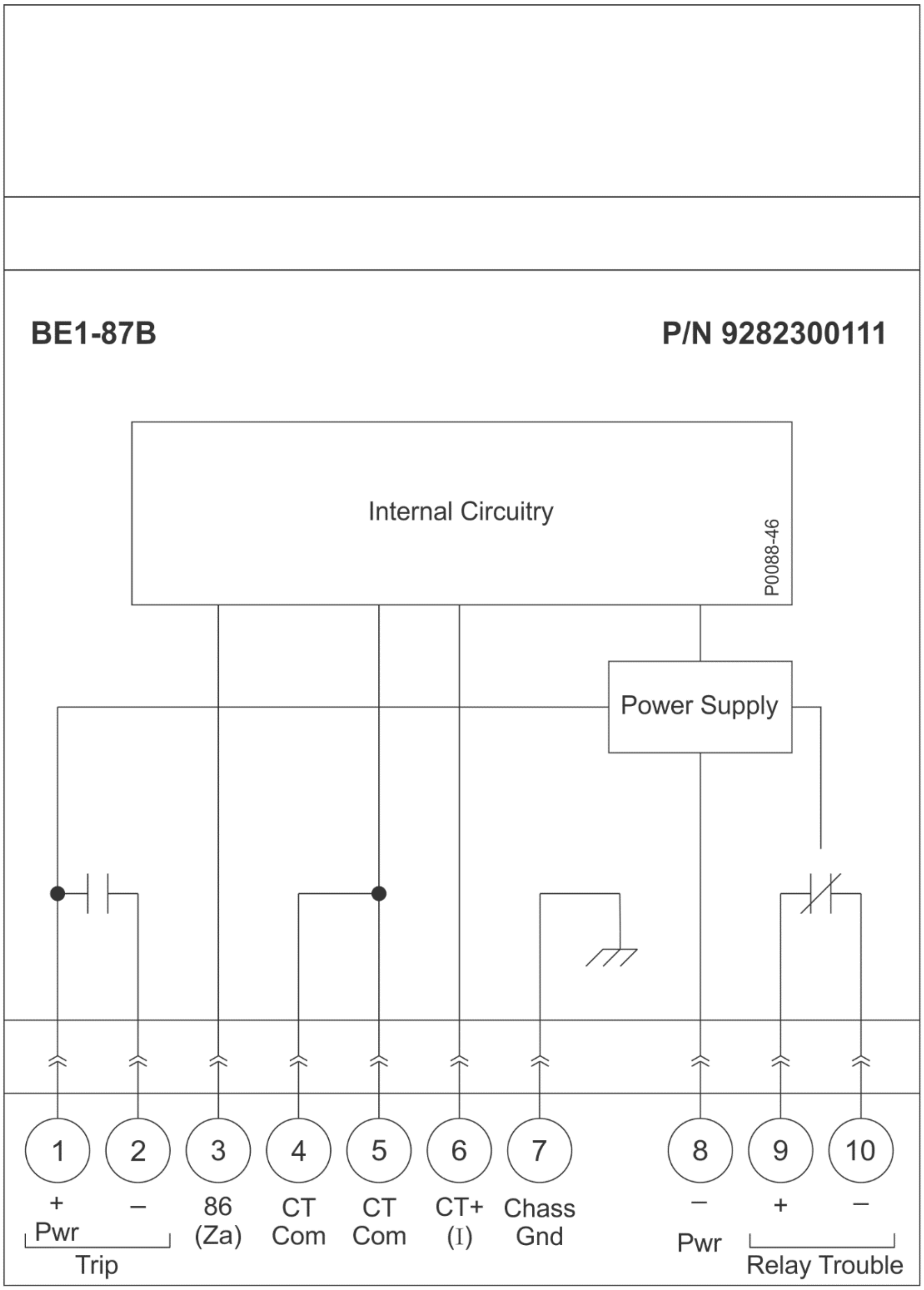

Figure 4. Internal Connections


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Application

The BE1-87B is a solid-state, high-speed, high-impedance differential relay. This relay (part number 9282300111) is a single-phase model that fits an M1 case and replaces a GE PVD relay in most applications with minimal rewiring.

The BE1-87B solid-state, high-speed, high-impedance differential relay is available in single or three-phase models. The relay was specifically designed to provide high-speed differential protection for high voltage buses, critical medium, and low voltage buses. Because of its design and sensitivity, the relay can also be used for shunt reactor protection. While bus schemes require three-phase protection, shunt reactors may be protected with only one single-phase relay for ground faults.

Application

Regardless of the scheme employed or the equipment protected, the following applications apply to the BE1-87B relay.

Application with Lightning Arresters

The BE1-87B is a high-speed relay designed to operate in a half-cycle or less. As a result, applying the relay to a bus with lightning arresters must be addressed. The relay pickup current range is adjustable between 0.25 to 2.5 amperes rms. If lightning arresters will be connected to the bus, use the 2.5 ampere sensitivity setting so as to prevent the possibility of a differential operation during a normal arrester operation. If no lightning arresters are used, start with the 0.5 ampere sensitivity setting and adjust as the application dictates.

Caution
If lightning arresters are added to an existing bus, as might be the case when adding a transformer, be sure to increase the Pickup Current setting of the BE1-87B to the 2.5 ampere setting.

Application with a Lockout Function

Contacts from the lockout relay (86) should be connected across terminals 3 and 6 of the BE1-87B relay to short-circuit the SCRs in the input circuit after a trip output has been initiated. This allows the relay to continue operation as a conventional overcurrent relay and at the same time protect against exceeding the short-time rating of the internal SCRs. The relay can be used in any application where the total secondary current is not more than the current waveform of a fully-offset fault with 215 amperes rms symmetrical available, provided the lockout relay (86) has an operate time of 1 cycle or less (16 milliseconds).

Caution
If the BE1-87B relay control power (power supply voltage) is removed, relay terminals 6 and 4 or 5 should be shorted by pulling the connection plug. If this is not done, the BE1-87B relay could be damaged due to continuous fault current flowing through the relay SCRs.

Current Source for High Impedance Differential Relaying

Predictable current transformer (CT) performance is critical to the effective operation of a high impedance differential scheme. Where practical, the following current transformer guidelines should be applied when using the BE1-87B relay.

- All CTs should be of toroidal design and be fully distributed around the core.
- All CTs should have the same full ratio value and be connected to the full ratio taps.
- All CTs should have the same voltage rating, accuracy class, and thermal rating.
- The CTs should be dedicated to the differential application.
- When adding to an existing differential scheme, at least one set of CTs in the new breaker should be ordered with the same ratio and accuracy class as the differential CTs used in the existing scheme.
- CTs cannot have primary or secondary voltage limiting devices, as the resulting short-circuit could cause an unwanted operation of the differential.

BE1-87B Flexibility

Because of the flexible wide-range design of the BE1-87B, it is possible to apply the relay in situations where the current sensing input circuit is less than ideal. It should be noted, however, that the possibility of less sensitive settings, equipment overvoltage, or false operation could result. Careful review of the following application notes is recommended:

- It is possible to use a mixture of multi-ratio CTs, however, it is essential that the tapped value has the same turns ratio as the other parallel CTs in the circuit. When taps are selected other than full ratio, use the highest available tap setting that will allow all CTs in the scheme to have the same turns ratio. Tap settings other than full ratio require a calculation of the peak voltage developed across the full winding resulting from autotransformer action. The resulting voltage should not exceed the insulation breakdown values of the connected equipment. The equation for this calculation is derived in the paragraph on operating principles in this chapter and repeated in the paragraphs on *Calculation of Settings*.

- All CTs used in the differential circuit should have negligible leakage reactance on the connected taps. Most, if not all, multi-ratio internal, bushing, and column type CTs made in the last 30 years meet this requirement. All CTs wound on toroidal shaped cores meet this requirement if the windings (on the tap used) are completely distributed around the core (consult your CT manufacturer if you have questions). It may be possible to use CTs that do not meet this requirement if the leakage reactance is known. The leakage reactance is added algebraically to the resistance of the CT circuit in question. Less sensitive protection will occur as a result of a higher pickup setting.

- It may be possible, although not recommended, to use the differential circuit CTs jointly for other functions as long as an accurate impedance of the other function is known. The performance of the system under these conditions can be calculated by algebraically adding the other impedance to the CT winding and cable resistance. Less sensitive protection will occur as a result of a higher pickup setting. Also, consideration must be given to the hazards of false operation due to extra connections and errors in testing the added devices. To ensure proper relay setting, all cable and CT secondary winding resistances should be evaluated before a decision is made to add other devices to the BE1-87B CT circuits.

Bus Protection Application

Three single-phase BE1-87B relays and an auxiliary lockout relay (86), provide a complete multi-phase and ground bus fault protection package. Typical external connections to the relays are shown in Figure 5 and Figure 6. The connections are illustrated for a bus with three circuits, but the protection can easily be extended if more circuits are added to the bus. For additional circuits, it is only necessary to connect the CTs associated with the added circuits to the respective junction points and to connect the contacts of the lockout relay in the respective trip circuits. The relay voltage tap setting is based on the maximum voltage that can be developed across the differential junction point during an external fault. Calculation of the maximum voltage is easily made and methods for doing so are given in the paragraph under calculation of settings. A sample calculation for a bus differential scheme is also provided.

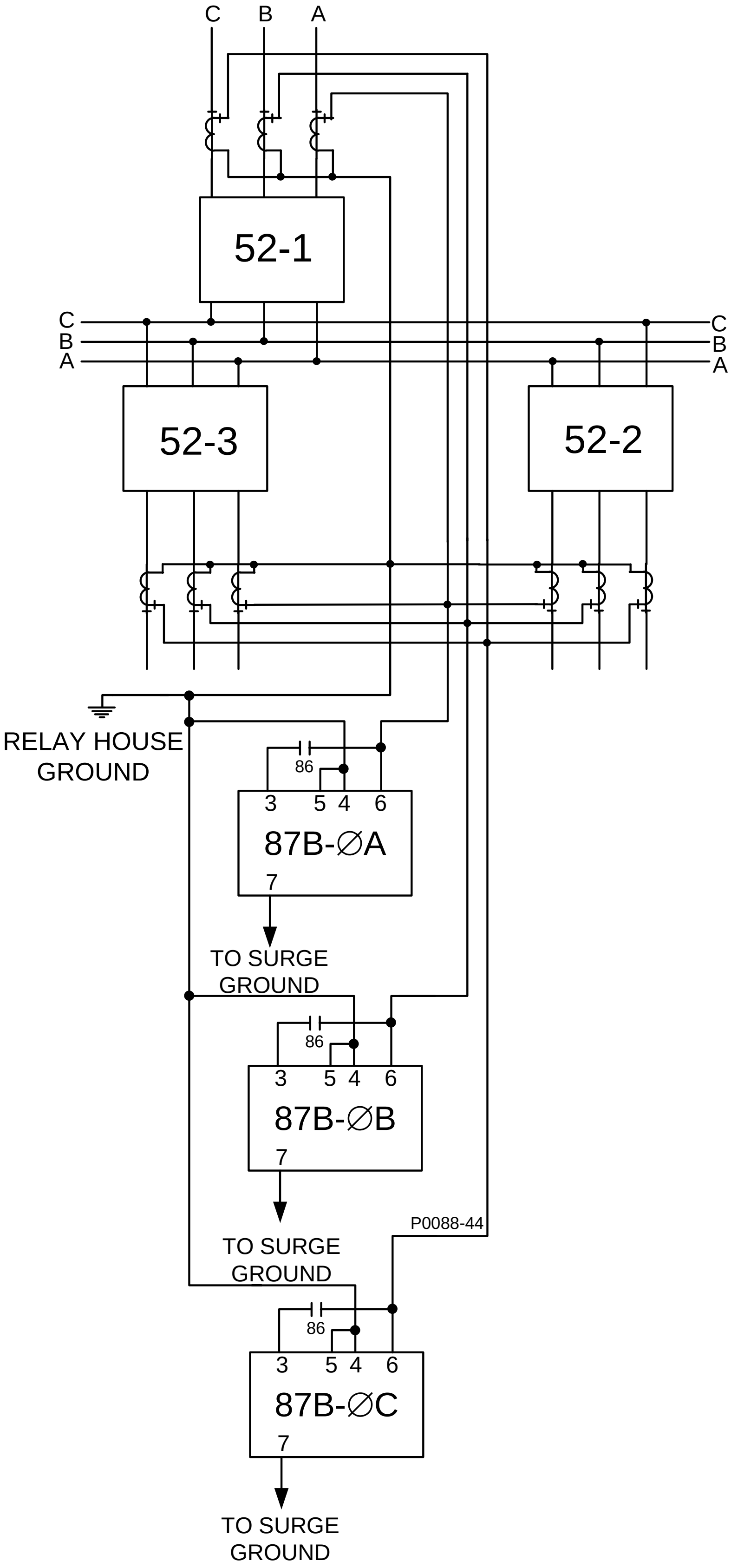


Figure 5. External AC Connections for Bus Protection

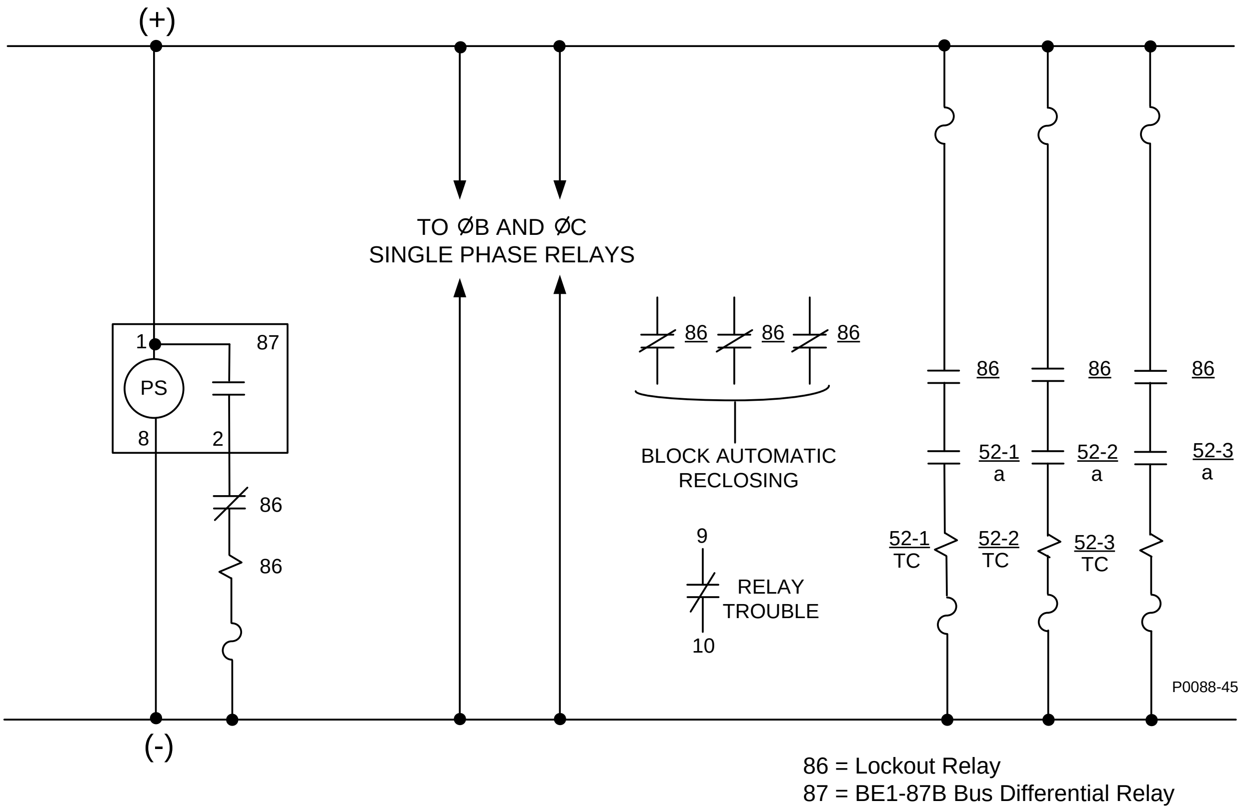


Figure 6. External DC Connections for Bus Protection

Shunt Reactor Protection Application

Differential protection of shunt reactors may be provided by using one single-phase BE1-87B relay or three single-phase relays. Typical ac external connection diagrams for these schemes are shown in Figure 7 and Figure 8. The dc connections will be similar to those shown in Figure 6. Only ground fault protection will be provided when one relay is applied. Application of either three-phase arrangement will provide both multi-phase and phase-to-ground fault protection. Calculation of the voltage tap setting is basically the same as for the bus application. The procedures for calculating the voltage tap setting for either scheme are provided under *Calculation of Settings*.

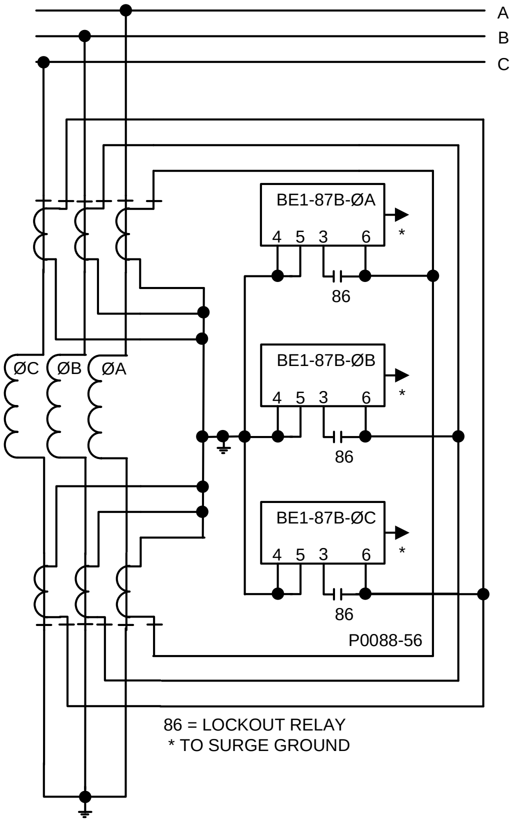


Figure 7. External AC Connections for Shunt Reactor Protection, Multi-Phase and Line-to-Ground Faults

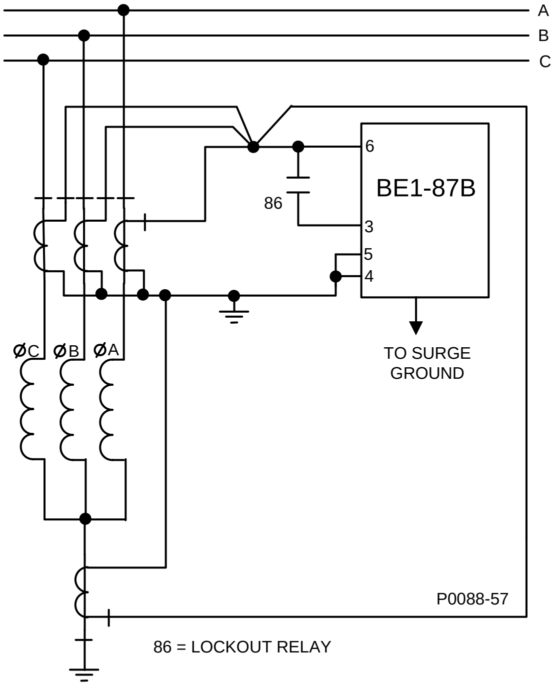


Figure 8. External AC Connections for Shunt Reactor Protection, Ground Faults

Mixing Two Different Ratio CTs

While high-impedance bus protection is best configured with all CTs having a common ratio, it is possible to utilize two different ratio CTs within one bus protection zone. The process by which this is accomplished is detailed in the technical paper *"Bus Protective Relaying, Methods and Application"* located at www.basler.com.

General Settings Guidelines

To obtain the maximum setting sensitivity, the CT loop resistance should be minimized so that the lowest possible voltage setting can be selected. For switchyard applications where there is a large distance between the breaker and the relay panel, it may be desirable to locate the differential junction in the switchyard since the resistance of the fault CT loop may otherwise be too large. To minimize the impedance from the current transformers to the junction point, all the secondary windings should be paralleled in the switchyard and as close as possible to the current transformers. Optimally, the junction point should be equidistant from all current transformers.

Note

The cable resistance from the junction point to the relay is not included as a part of the fault CT loop resistance. It is permissible to locate junction points at the panel, providing that the relay setting gives the desired sensitivity.

Operating Principles

The BE1-87B high impedance, differential relay operates on the instantaneous value of CT secondary voltage to which the relay is connected. All the CTs in the differential circuit must have the same turns ratio. If all CTs have the same turns ratio, the voltage developed across the relay during normal system conditions is very small. The diagram of Figure 5 illustrates typical external ac connections to the relay for use in a bus differential scheme. As shown in the diagram, a typical differential connection is used consisting of the CT circuits from each bus device connected in wye and paralleled at one location (summing point) on a per-phase basis. Three single-phase BE1-87B relays or one three-phase relay provide complete protection of the bus. The relay will generate a trip output when the instantaneous voltage applied across terminals 3 and 6 exceeds the voltage pickup setting (V_{DIFF}) and the fault current is greater than the current sensitivity setting.

External Faults

If the differential protection scheme is to perform satisfactorily, then it must not trip for faults external to the zone of protection. For example, Figure 9 shows a one-line diagram for a three input differential scheme. The BE1-87B must not operate for a fault at F1. Since the CTs in the faulted feeder (CT 3) will see the most current, assume they will saturate completely, thus causing the magnetizing reactance to drop to zero. The total current from the other CTs (CT 1 and 2) is forced through the parallel combination of the high impedance relay (5,000 Ω) and the saturated CT secondary. The saturated CT secondary winding resistance is in series with any resistance of the CT leads and connection cables (the total of which presents a much lower resistance than the 5,000 Ω).

Therefore, nearly all the secondary fault current will flow through the saturated CT. A voltage drop (V_R), caused by the flow of the fault current in this parallel path, will appear across the BE1-87B relay. For this fault, the highest voltage that could be developed at the relay would occur when the associated CT (CT3) saturates completely, and the others (CT1 and CT2) do not saturate at all. When a CT with a distributed toroidal winding (on the tap used) saturates completely, it produces no voltage and the impedance, as seen at the secondary winding, is very nearly equal to the winding resistance (very small impedance). Thus the highest peak voltage that can be developed across the relay during an external fault will be equal to the voltage produced by the total secondary fault current flowing through the control cable resistance plus the winding resistance of the CT associated with the faulted feeder. Refer to the example case in Figure 9 while applying Equation 1.

$$V_{Peak} = 2\sqrt{2}(I_F)(R_S + 2R_L)$$

Equation 1

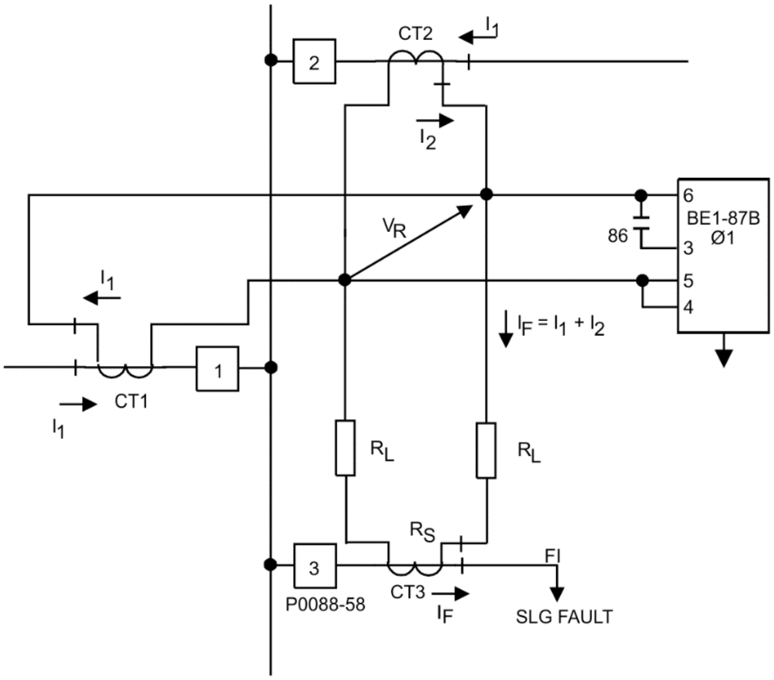
I_F: rms symmetrical value of fault current in the fault CT in secondary amps.
R_S: CT secondary winding resistance plus any lead resistance (at highest expected operating temperature)
R_L: Cable resistance from junction point to CT (at highest expected operating temperature)

Equation 1 yields the peak voltage developed at the relay for a completely offset wave of current having an rms symmetrical value of I_F secondary amperes. Because the BE1-87B relay is calibrated in symmetrical rms volts, Equation 2, which yields the rms voltage value, is used in the paragraphs on *Calculation of Settings*.

$$V_R = I_F(R_S + 2R_L)$$

Equation 2

The pickup voltage of the BE1-87B must be set above this value of rms voltage and above the rms value of the other voltages obtained in a similar manner on all the circuits of the bus. Because the peak voltage is proportional to the fault current, the highest possible value of expected fault current in rms symmetrical amperes should be used in making the evaluation.



Note: CT3 assumed to be completely saturated
R_S = CT secondary winding resistance plus any lead resistance (at highest expected operating temperature)
R_L = cable resistance from junction point to CT (at highest expected operating temperature)
I_F = rms value of the current in the primary of CT3 divided by the secondary turns
V_R = voltage across BE1-87B

Figure 9. Illustration of Single Line-to-Ground Fault at Location F1

Internal Faults

During internal faults on the bus, all of the CTs will be operating into the relatively high impedance of the BE1-87B. Under these conditions, the maximum fundamental frequency voltage that can be produced will be limited to values as dictated by the CT secondary fundamental frequency excitation characteristics. Examination of a typical CT secondary excitation characteristic will show that the available fundamental frequency voltage flattens off beyond the knee of the curve. However, the peak voltages that can be produced are not indicated on the standard excitation curve.

The concept of how the CT responds during an internal fault is given in greater detail in the technical paper *"Bus Protective Relaying, Methods and Application"* located at www.basler.com. Let us summarize the matter to say that, for internal faults, the peak voltages will always be greater than indicated by the average, and will continue to increase in magnitude as the excitation is increased. Because the peak voltages during internal faults will be much greater than the peak voltages experienced during external faults, and because the BE1-87B relay operates as a function of the instantaneous voltage, the relay can be set to be selective between internal and external faults. An indication of the peak voltages that a CT can produce can be determined by a simple modification to the CT secondary excitation characteristic.

The modification is shown by the lines CPB in Figure 10, which now define the excitation characteristics as a function of the peak voltages. Studies have shown that the peak voltages produced will be at least equal to or greater than those established by the modified characteristics. These characteristics are useful in determining the minimum internal fault for which the relay will operate. The method for making the modifications, and their uses in determining the sensitivity, are provided in the *Calculation of Settings, Minimum Fault to Trip* sub-section in this chapter.

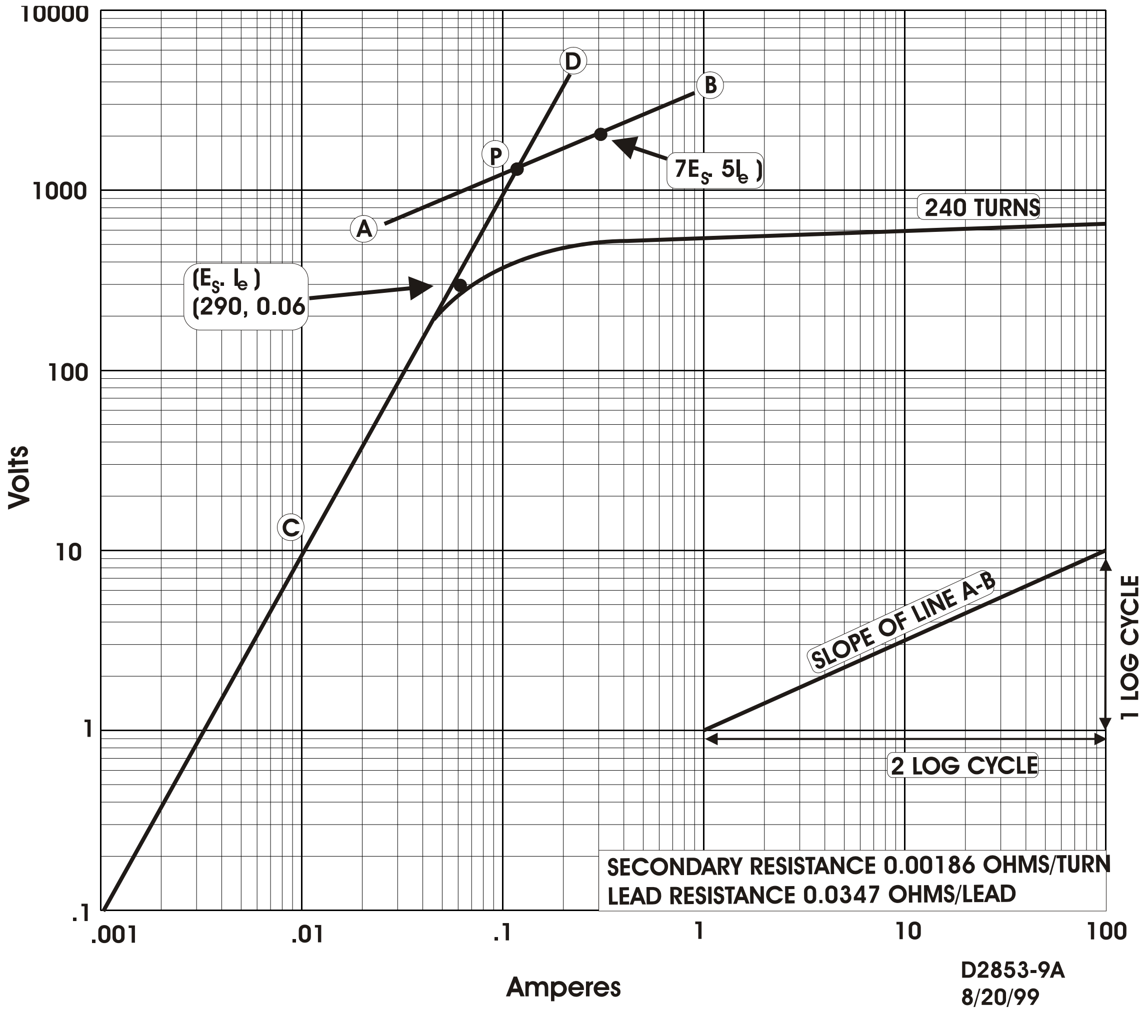


Figure 10. Typical Secondary Excitation for 1200/5 Bushing Current Transformer

Figure 11 illustrates, in simplified form, the internal connections of the BE1-87B relay. When an internal fault occurs, the peak voltage developed in the secondary of the feeder CTs will appear across the relay input network via phase A, phase B, or phase C. Under normal conditions, while operating power is available to the relay, the SCR firing is accomplished via the voltage sensing circuitry by the pulse amplifier. When the SCRs fire, the CT circuits will be shorted and the total secondary fault current will flow through the SCR circuits and the primary of current transformer T1. If the total secondary fault current, and hence the primary current of T1 is above the pickup level of the relay, a trip output will be provided via the output relay.

When relay operating power is not available, the BE1-87B can no longer trip the output contacts. However, the SBS (silicon bilateral switch) circuitry provides voltage protection for the SCRs and the relay internal circuitry. When the peak voltage exceeds the switching voltage of the SBS, it will conduct, causing the corresponding SCR to be triggered to the ON condition. During subsequent half cycles, the SCRs will be triggered alternately. Note that the SBS, across the SCRs, exhibits high impedance in the OFF state and will turn ON and conduct when a switching voltage above the relay maximum setting is reached. The SBS acts only as a failsafe, triggering the SCRs in the event control power (power supply voltage) is lost and a fault has occurred.

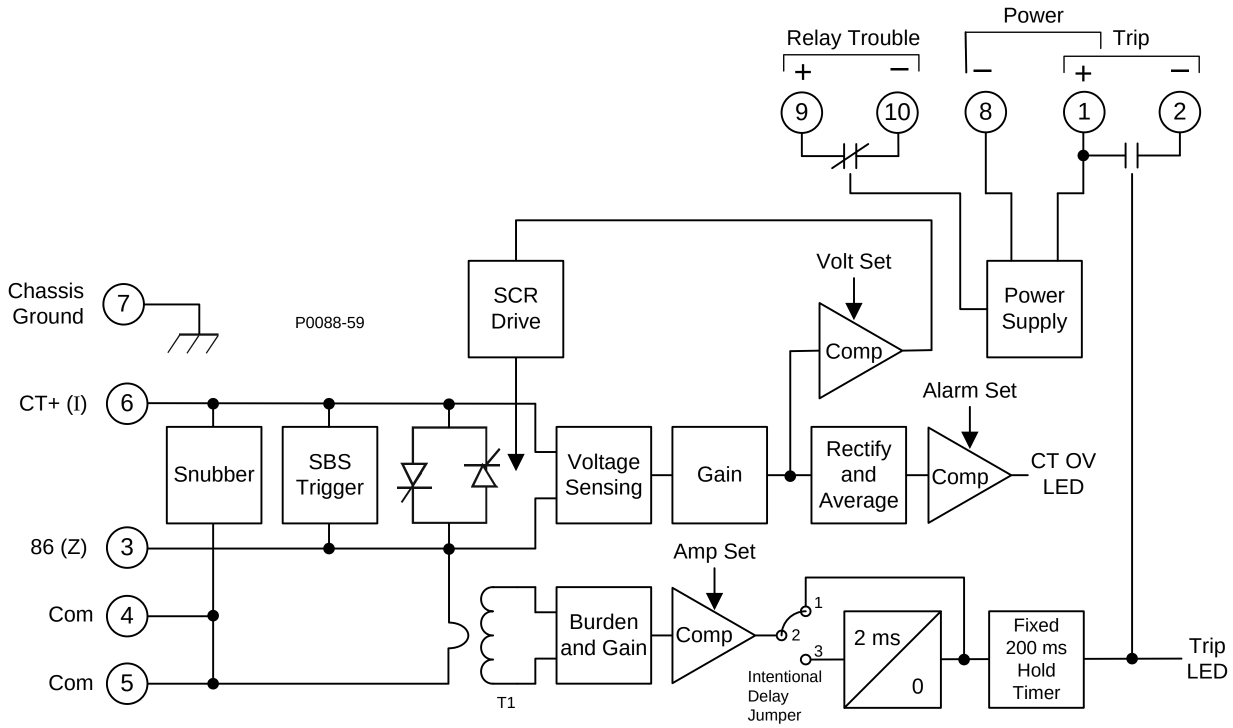


Figure 11. Simplified Internal Connection Diagram for BE1-87B Relay

For convenience, the BE1-87B relay voltage settings are calibrated in terms of rms symmetrical volts and all calculations for settings are made in terms of rms symmetrical quantities. The relay responds to the instantaneous value of applied voltage, and this maximum instantaneous value can be two times the square root of two or 2.83 times V_{DIFF} for fully offset waveforms. As soon as the relay operates, the shorting action of the SCR path reduces this voltage to a very low level. Thus, the maximum peak voltage that can be produced in the differential circuit will be limited to the value calculated in Equation 3.

$$V_R = 2\sqrt{2}(V_{DIFF}) = (2.83)(V_{DIFF})$$

Equation 3

V_R	maximum instantaneous peak voltage that can be developed in the differential circuit
V_{DIFF}	BE1-87B voltage set point in rms symmetrical volts
$(2\sqrt{2})$	conversion of rms symmetrical volts to corresponding peak volts of a fully offset voltage wave

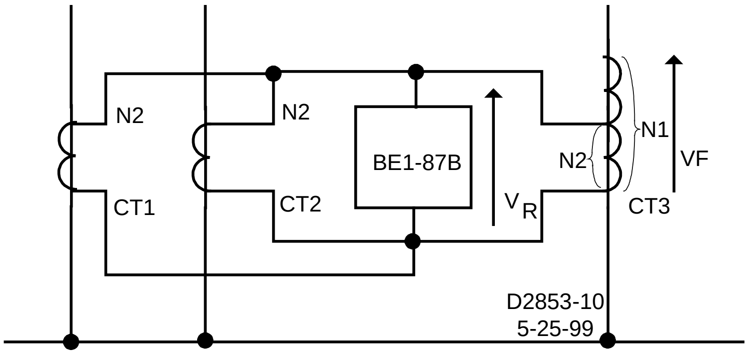
Where CTs with taps set on other than the full winding are involved, the voltage developed across the full winding of these CTs can be greater than the differential circuit voltage as a result of the autotransformer action. For example, consider the simple circuit of Figure 12. The voltage in the differential circuit, and consequently across CT1 and CT2, will be limited to V_R. But the voltage across the full winding of CT3 will be greater by the ratio of the total number of turns of the CT to the actual turns used. See Equation 4.

$$V_F = \frac{N_1}{N_2}(V_R) = \frac{(2.83)(V_{DIFF})(N_1)}{N_2}$$

Equation 4

V_F: voltage across the full winding
N_1: total number of CT secondary turns
N_2: number of CT secondary turns used, i.e. tap settings
2.83: $(2\sqrt{2})$ (peak value of fully offset wave)

The voltage across the full winding (V_F) should not exceed the insulation breakdown of the connected equipment. The value of the actual peak voltage that can be produced for any relay tap setting and mixed multi-ratio CT combination may be evaluated using Equation 4.



$$VF = \frac{N1}{N2} VR$$

V_F = VOLTAGE DEVELOPED ACROSS FULL WINDING
V_R = MAXIMUM INSTANTANEOUS VOLTAGE
NI = TOTAL NUMBER OF CT TURNS
N2 = NUMBER OF CT TURNS USED (TAP SETTING)

Figure 12. Voltage Appearing Across Full Winding of CT

Characteristics

Operation of the BE1-87B relay is initiated as a function of the instantaneous voltage developed across terminals 5 and 7 (single-phase model) of the relay. However, an output will not be produced unless the total secondary fault current that flows through the relay after the SCRs fire is greater than the pickup current setting. In this fashion both voltage and current are required to produce an output. The voltage selector switch setting and current selector switch setting determine the voltage and current requirements needed to produce an output.

Differential Voltage Pickup

The BE1-87B pickup voltage selector switch allows for a setting range of 50 to 400 volt rms symmetrical in 50-volt increments. This sets the voltage level at which the back to back internal SCRs will trigger. The SCRs will trigger whenever the instantaneous value of the applied voltage is equal to twice the peak value of the rms symmetrical pickup voltage setting. Refer to Equation 3.

Note

Voltage V_R is equal to the peak voltage of a fully offset voltage wave having an rms symmetrical value equal to the pickup voltage selector switch setting. Because of this the SCRs will fire whenever an rms symmetrical voltage greater than twice the voltage selector switch setting is applied, or whenever the corresponding peak voltage is exceeded on an instantaneous basis as in the case of an internal fault. When the SCRs fire, provided the total secondary fault current that flows in the relay is greater than the pickup current setting, the relay will produce an output.

Differential Pickup Current

Pickup current is defined as the rms value of a symmetrical sinusoidal current that must flow into the BE1-87B in order to provide a contact output. The BE1-87B has a pickup current selector switch that allows for a range of 0.25 to 2.5 amperes rms in 0.25 ampere increments. However, the relay internally operates off of the instantaneous peak of this sinusoidal current. For example, if the relay is set at 1 amp, the current sensing element monitors for instantaneous current riding above 1.414 amps.

Alarm Voltage Pickup

The BE1-87B is equipped with a differential voltage alarm function. The function is used to detect steady state voltage imbalances across the input sensing circuit of the relay (terminals 5 and 7). The setting range for the alarm pickup is 10% to 80% of the rms differential voltage pickup setting (V_{DIFF}) in increments of 10%. When the rms voltage across the sensing input terminals exceeds the voltage pickup setting times the voltage alarm percentage setting (V_{DIFF} x % set), the CT OV LED lights. When the input voltage falls below the alarm voltage threshold, the CT OV LED turns off. The response time of the LED is intentionally slow to prevent nuisance alarms (approximately one second).

Example

A relay with a differential pickup voltage (V_{DIFF}) setting of 200 volts rms symmetrical and an imbalance alarm voltage setting of 10%, will alarm at 20 volts rms (200 x 0.1 = 20 volts).

Trip Test Pushbutton

The Trip Test pushbutton is recessed behind the front panel and is accessed through a small opening. Insert a small, nonconductive tool through the front panel to depress the Trip Test pushbutton. Trip test simulates a trip condition and verifies the operation of both output trip contacts and the trip LED. Upon releasing the Trip Test pushbutton, the trip output contacts will reset, but the LED remains lit. To clear the Trip LED indication, press the Reset button.

Caution

Activation of the Trip Test button will trip the lockout device (86) and the bus breakers unless appropriate steps are taken.

Power LED

This LED lights when normal operating power is applied to relay terminals 15 and 16.

Intentional Delay Jumper

A user-settable jumper is located on the Control circuit board and is used to select either no intentional delay (jumper position 1 to 2) or an intentional delay (jumper position 2 to 3) added to the trip response time.

The 2-millisecond intentional delay is intended to minimize nuisance tripping due to very short disturbances such as nearby lightning strikes.

Actual intentional time delay is a function of pickup current. For currents exceeding twice the pickup setting, intentional time delay is 2 milliseconds. For currents less than twice the pickup setting, intentional time delay is 7 milliseconds.

Operating Times

The BE1-87B operates in less than 7 milliseconds (half cycle) for faults 1.5 times the current pickup. The BE1-87B operates in less than 5.5 milliseconds for fault levels above 6 times the current pickup. High-speed operation minimizes potential damage to the protected equipment. Refer to the *Specifications* chapter for illustrations of response times.

Hold Timer

The BE1-87B has a fixed hold timer (200 milliseconds) that prevents the Trip output relay contacts from opening prematurely.

Calculation of Settings

The BE1-87B relay is set based on the maximum possible voltage that can be produced in the differential circuit as a result of a fault external to the zone of protection. Determination of the maximum voltage for this condition is subject to simple calculations, and thus, the relay setting is easily determined. The relay has a setting range 50 to 400 volts rms in 50-volt steps.

It is first necessary to calculate the maximum voltage that can be produced in the differential circuit for an external fault. Once that value is determined, the appropriate voltage setting can be selected. If a mixture of multi-ratio CTs is used (not recommended) or if the CTs are applied on taps other than full ratio, calculations must be performed to determine if excessive voltages will be produced across the full winding of the CT. Last, the minimum internal fault for which the relay will just operate will be calculated.

Calculation of Voltage Differential Settings

The minimum acceptable differential voltage setting can be determined using Equation 5.

$$V_{DIFF} = 1.25(R_S + PR_L)\frac{I_F}{N}$$

Equation 5

V_{DIFF}: minimum acceptable voltage tap setting. Since V_{DIFF} in general will not come out exactly equal to one of the available settings, the next higher setting should be used. The available voltage settings are 50 to 400 volts rms in 50-volt increments.
R_S: dc resistance of fault CT secondary windings and leads to the CT makeup box (at maximum expected operating temperature).
R_L: single conductor dc resistance of the current circuit cable for a one-way run from the differential junction point to the fault CT makeup box (at maximum expected operating temperature).
P: one (1.0) for three-phase faults and (2.0) for single-phase to ground faults.
I_F: maximum external fault current in the fault CT in primary symmetrical rms amperes.
N: CT ratio.
1.25: margin for safety.

The following comments may be made with respect to the evaluation of Equation 5.

- It is only necessary to calculate three-phase and single-phase-to-ground faults. If the results yield a satisfactory application, the application will also be satisfactory for multi-phase faults.
- For single-phase-to-ground faults, the differential circuit is such that the CT secondary fault current will flow through both of the fault CT cables; thus the multiplier P must be set equal to two. On the other hand, the CT secondary currents during a balanced three-phase fault will result in 0 current in the return cable; thus only the one-way cable resistance is involved, and P is set equal to one.
- If the single-phase-to-ground fault current at a given location is greater than or equal to the three-phase fault current, the calculations need only be made for the single-phase-to-ground faults.
- The resistance of the CTs and connecting cables will increase with increasing temperature; therefore, if adequate margin is to be maintained at all times, Equation 5 should be evaluated using resistance values corresponding to the maximum expected operating temperature (see *Sample Calculation* in this chapter).

The methods to be used in calculating the voltage tap setting using Equation 5 will to some extent be dependent on the type of application. The following paragraphs discuss different areas in which the BE1-87B relay may be applied.

Bus Protection

Two methods are outlined for evaluating Equation 5 in order to determine an appropriate relay voltage tap setting.

Method 1 offers a simplified conservative approach to the problem and requires that Equation 5 be evaluated only once. With this method, it is assumed that a single-phase-to-ground fault with a current magnitude equal to the maximum interrupting rating of the breaker occurs on the feeder associated with the CT having the longest cable run from the differential junction point. Under these assumptions, the effect of the fault current, I_F, is maximized, and so is the effect of cable resistance, because the highest value of resistance is used and P is set equal to 2. Thus, the highest possible value of V_{DIFF} will be obtained.

Method 2 offers an exact approach but requires that Equation 5 be evaluated a number of times in order to obtain the maximum V_{DIFF}. With this method, calculations must be made for the maximum single-phase-to-ground fault and the maximum three-phase fault just off each of the n feeders on the bus. Therefore, Equation 5 must be evaluated 2n times using the associated value of cable resistance and P = 1 or P = 2, as required.

In general, method 2 will produce a lower voltage tap setting than method 1, but method 1 is simpler to utilize. The user should begin with method 1. If the voltage setting resulting from the use of this method results in adequate sensitivity, a unique advantage is realized in that the setting does not require recalculation following future changes in the power system that result in higher fault current magnitudes. If the sensitivity resulting from the use of method 1 does not prove adequate, then method 2 should be used. Each method is outlined below.

Method 1 (Simplified Conservative Approach)

a. Use the maximum interrupting rating of the circuit breaker as the maximum single-phase-to-ground symmetrical fault current (I_F).
b. R_L is based on the distance from the differential junction point to the most distant CT.
c. Calculate V_{DIFF} substituting the values of current and resistance from a and b and set P = 2.
d. Select the highest available voltage setting that just accommodates the voltage calculated in c above.

Method 2 (Exact Approach)

a. Determine the maximum three-phase and single-phase-to-ground fault currents for faults just off each of the n breakers on the bus.
b. R_L is the one-way dc resistance of the cable from the associated CT to the differential junction point.
c. For each breaker in turn, calculate V_{DIFF} separately, utilizing the associated maximum external three-phase symmetrical fault current in the fault CT, with P = 1 and the maximum external single-phase-to-ground symmetrical fault current in the fault CT, with p = 2.
d. Use the highest V_{DIFF} resulting from the calculations and select the next highest available voltage setting that just accommodates this value.

Shunt Reactor Protection

Depending on the type of protection required, shunt reactors may be protected by the BE1-87B relay in one of two ways (see Figure 7 and Figure 8). Since the shunt reactors contribute no current to an external fault, Equation 5 should be evaluated using the highest magnitude of current that can flow in the reactor under any system condition, exclusive of a fault in the reactor. If the differential junction point is located near the reactors, the resistance of the CT connecting cables can probably be ignored, and Equation 5 need only be evaluated using the CT resistance and the maximum expected current. If the cable resistance cannot be ignored, use the maximum expected reactor current and P = 2. After a value of V_{DIFF} has been calculated, select the next higher available voltage setting that just accommodates this voltage.

Application with Mixed Multi-Ratio CTs

Where CTs are used on other than their full windings, (not recommended) the application should be evaluated after a voltage setting has been selected to determine that excessive voltages are not developed across the full windings of these CTs as a result of autotransformer action. It is desirable to limit the peak value of the voltage to less than the insulation breakdown of the connected equipment. Refer to Equation 4 under Operating Principles for information on how to calculate the peak voltage across the full winding.

See Figure 12 for an illustration of terms from Equation 4. If V_F is less than the insulation breakdown, and if the current rating of the CT is not exceeded, the application is permissible. Equation 4 should be evaluated for the CT having the highest N1/N2 ratio. If the condition of Equation 4 is met for this CT, then it will also be met for the remaining CTs.

Current Element Setting

The setting of the current element is based upon four factors:

1. The current setting needs to be set so that the relay will operate at minimum fault levels. The main application where this will be of concern will be when one wishes to ensure operation of the relay for ground faults on impedance grounded systems. This matter is discussed in the *Minimum Fault to Trip* sub-section.
2. The current setting should be set high when there are surge arresters in the zone of protection. This factor was discussed in the *Application with Lightning Arresters* sub-section.
3. The third factor is hard to quantify. It is possible for noise to be induced on the bus differential CT circuit by the magnetic fields generated by out-of-zone fault currents. This includes magnetic fields generated by both the primary fault currents and by secondary fault currents where CT leads are in the same conduit at the differential relay CT leads. Due to the high impedance of the bus differential circuit, the induced voltage can be high enough to cause the relay voltage element to transiently pick up. However, this induced voltage cannot carry any appreciable current after the BE1-87B SCRs are turned on. If the BE1-87B voltage element operates but current in the CT string remains low (less than the BE1-87B current element setting) after the SCRs turn on, the relay will not trip. Hence, the current element is set at some level that will prevent induced pickup of the relay for this condition. A typical setting for this purpose is 0.5 amperes.

Minimum Fault to Trip (Voltage Element)

Note

In this sensitivity analysis, relay impedance is rounded to 5,000 Ω for simplicity and the algebraic addition of current magnitudes rather than a more exact phasor addition of currents is used. A comparison of the simplified calculation approach to the more exact calculation approach results in a minimum fault sensitivity value that is higher than when the more exact approach is used. Hence, the simplified approach is a more conservative method for finding minimum sensitivity.

After the differential voltage setting has been established, a check should be made to determine the minimum internal fault current that will just cause the voltage element of the relay to operate. This current level should be compared to the current element setting. The greater of these two quantities determines the relay minimum fault-to-trip. The minimum fault-to-trip should be less than the bus minimum fault duty. This will be an issue mainly with impedance-grounded systems. Equation 6 can be used to determine the minimum internal fault current required for a particular tap setting.

$$I_{MIN} = \left[\sum_{x=1}^{n} (I)x + I_R \right] N$$

Equation 6

I_{min}: minimum rms symmetrical internal fault current required to operate the BE1-87B relay
n: number of CTs (number of circuits)
I: secondary excitation current of individual CT at a voltage equal to (V_{DIFF})
I_R: current in the relay at pickup setting
N: CT ratio on tap used

The excitation currents, (I)1, (I)2…(I)n will be a function of the peak voltages that can be produced in the secondary of the respective CTs. It is possible to determine the currents with the aid of the secondary excitation characteristic for the respective CT. But it is first necessary to modify the characteristics so that they are plotted as a function of the peak voltages that can be produced. The procedure for doing so is provided in the following paragraphs.

1. Determine the knee point coordinates of the standard excitation curve (E_S and Ie). These points will be indicated on the given characteristic, or they can be found graphically by determining the point where a 45-degree line is tangent to the knee of the excitation curve.
2. Use Equation 7 to calculate and plot the following point on the same sheet with the excitation curve:

$$V = (7)\ (E_S)$$

$$I = (5)\ (Ie)$$

Equation 7

3. Draw a line having a slope of ½ through the point (V, I) calculated and plotted in step 2. A slope of ½ corresponds to one log cycle on the vertical axis (voltage) and two log cycles on the horizontal axis (current) (See line A-B in Figure 10).
4. Extend the lower part of the excitation curve in a straight line until it intersects line A-B drawn in step 3 (see line C-D in Figure 10).

The curve (CPB) formed by these two lines now represents the modified excitation characteristics as a function of the peak voltages that can be produced. After the curve has been drawn, use Equation 8 to calculate the following corresponding excitation current I.

$$V_S = 2\sqrt{2}\ (V_{DIFF})$$

Equation 8

V_S: voltage coordinate for determining I
V_{DIFF}: differential voltage setting of the BE1-87B

Note

The first term in Equation 6 reduces the nI if all the CTs have the same characteristics. The second term in Equation 6 represents the current (I_R) drawn by the relay just at the operating point. It can be calculated as follows:

$$I_R = \frac{(2)(V_{DIFF})}{5000}$$

Equation 9

Sample Calculation

The various steps for determining the setting of the BE1-87B in a typical bus application will be demonstrated with the aid of a worked example. Assume the protected zone includes five breakers, all rated at 69 kV, 1,500 MVA, and 1,200 amperes, with a maximum interrupting rating of 12,500 amperes. The excitation curve for the 1200/5 bushing CTs in these breakers is shown in Figure 10.

A current sensitivity setting of 0.5 amperes will be used. The voltage tap setting will be determined by using Method 1 described in the preceding paragraphs. The value of R_S from Figure 10 is (0.0019) (240)

+ 2 (0.0347) = 0.525 Ω. It is assumed that this resistance corresponds to the maximum expected operating temperature. It is further assumed that the longest CT cable run is 442 feet, and number 10 AWG copper wire is used. The one-way cable resistance at 25°C is 0.450 Ω. The resistance value of the wire at 25°C or at any temperature T1 may be corrected to any temperature T2 by means of .

$$RT2 = \left[1 + \rho 1\left(T2 - T1\right)\right]RT1$$

Equation 10

RT2:	Resistance in ohms at T2, degrees C
RT1:	Resistance in ohms at T1, degrees C
ρ1:	Temperature coefficient of resistance at T1

For standard annealed copper, ρ1 = 0.00385 at T1 = 25°C. If the maximum expected operating temperature is assumed to be 50°C, then the following applies.

RT2 = [1 + 0.00385 (50-25)] 0.450

= (1.096) (0.450) = 0.493 Ω

Substituting the various quantities in Equation 5 yields:

V_{DIFF} = 1.25 [.524 + 2 (0.493)] 12500/240

= 98.31 volts

Since 98.31 volts is not an exact equal to one of the V_{DIFF} settings, select the next higher available setting, which is 100 volts.

V_{DIFF} = 100 volts

Since the CTs are all used on the full winding (suggested practice), there is no need to check that excessive voltages will be produced in the CT circuits. Now that the V_{DIFF} setting has been selected, the sensitivity may be calculated following the procedure outlined in the section under *Minimum Fault to Trip*.

From Figure 10, the knee point coordinates E_S and Ie, are 290 volts and 0.06 ampere. From Equation 7:

V = (7) (E_S) = (7) (290) = 2,030 volts

I = (5) (Ie) = (5) (0.06) = 0.30 ampere

Plot this point (V, I) on the graph of Figure 10 and draw the lines A-B and C-D. This gives the modified secondary excitation characteristics. Calculate the voltage V_S using Equation 8.

V_S = (V_{DIFF})

= 2.83 (100)

= 283 volts

From the modified curve, the current Ie corresponding to V_S = 283 volts is 0.05 ampere.

The relay current from Equation 9 is:

$$I_R = \frac{(2)(V_{DIFF})}{5000}$$

$$I_R = \frac{(2)(100)}{5000} = 0.04 \text{ amperes}$$

The sensitivity of the relay voltage element or the minimum fault level of the voltage element from Equation 6 is:

I_{min} = [(5) (.05) + 0.04] (240) = 70 amperes.

With the relay set at 0.25 amperes sensitivity, 60 amperes of primary current are required to produce 0.25 ampere secondary from the 1200/5 CTs. Therefore, the minimum current sensitivity of the relay is 60 amperes primary. If a higher minimum current sensitivity is used, the minimum current required for pickup will be correspondingly higher. For example, with a 1200/5 CT ratio, 120 amperes of primary current are required to produce 0.50 ampere secondary with the relay set at 0.50 ampere sensitivity.

Testing

BE1-87B acceptance testing may be performed by following the procedures of this chapter.

This retrofit version of the BE1-87B is not supplied with a relay case. A separate case must be obtained in order to perform acceptance testing.

Refer to the *Controls and Indicators* chapter for the locations and descriptions of the relay controls and indicators. Figure 13 illustrates a side view of the relay cradle assembly and identifies the individual circuit boards. Figure 14 illustrates the circuit board extender card used in these tests.

Caution

Observe all applicable electrostatic discharge (ESD) precautions when handling circuit boards/electronic assemblies.

The following equipment is required for BE1-87B acceptance testing:

- Variable voltage source, 0 to 200 Vac, with provision for automatic removal of test voltage upon sensing of contact closure
- Variable current test source, 0 to 3 Aac
- Timer
- Digital multimeter
- Circuit board extender card, Basler P/N 9112930101

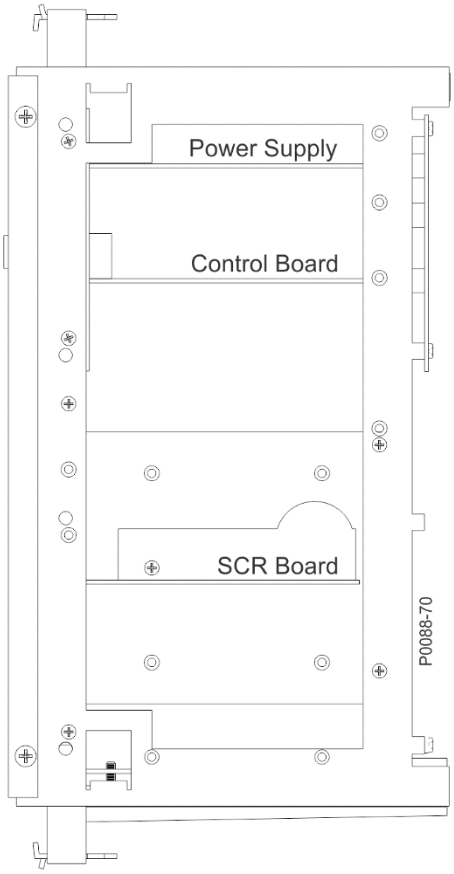


Figure 13. Side View of Cradle Assembly: Circuit Board Locations

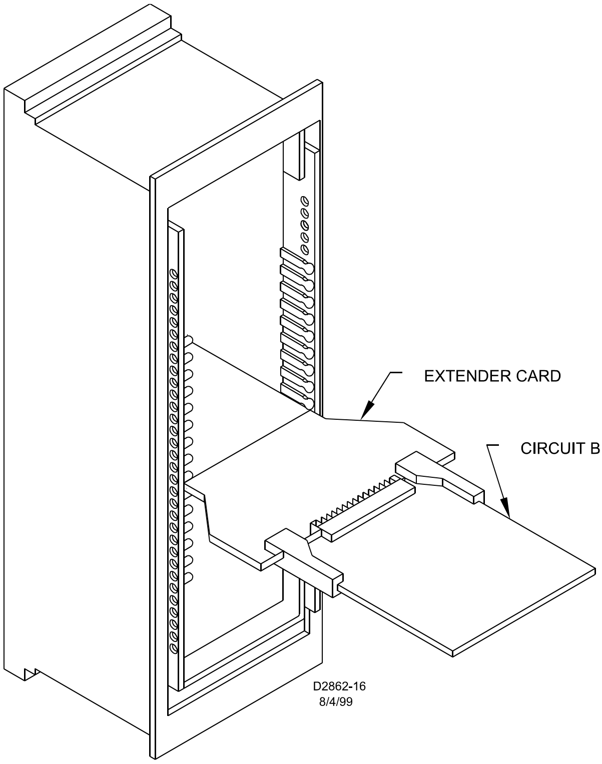


Figure 14. Circuit Board Extender Card

Power Supply Status Output Test

The power supply status output consists of a set of normally-closed contacts which are open when relay power is present and closed when relay power is absent.

1. With the relay de-energized, verify that there is continuity across relay terminals 9 and 10.
2. Apply nominal relay operating power at relay terminals 1 and 8. Verify that the relay power LED lights and there is no continuity across relay terminals 9 and 10.

Pickup Voltage Control Test

1. Ensure that no power is applied to the relay.
2. Remove the four screws from the relay front panel and remove the front panel.
3. Disconnect the ribbon cable that runs between the Control board and the SCR board, at the Control Board end.
4. Remove the Control board from the cradle assembly and install the circuit board extender card in its place. Insert the Control board into the card extender.
5. Connect a digital multimeter set for dc voltage between extender card pins 40 (+) and 43 (–).
6. Apply nominal relay operating power to terminals 1 and 8.
7. Set the Pickup Voltage control at each of the settings listed in Table 1 and observe that the corresponding voltage is observed at extender card pins 40 (+) and 43 (–).

Table 1. Pickup Voltage Control Test Parameters

Pickup Voltage Control Setting	Measured Voltage
50	1 Vdc
100	2 Vdc
150	3 Vdc
200	4 Vdc
250	5 Vdc
300	6 Vdc
350	7 Vdc
400	8 Vdc

8. Return the Pickup Voltage control to the 50 position (1 Vdc).
9. Remove the power supply voltage from terminals 1 and 8.
10. Remove the Control Board from the extender card and remove the extender card from the relay cradle assembly.
11. Return the Control Board to its original position in the cradle assembly.
12. Carefully reconnect the ribbon cable. Make sure the board pins are aligned with the ribbon socket.
13. Replace the front panel and secure it with the 4 screws removed in step 2.

Alarm Voltage Test

1. Set the BE1-87B Pickup Voltage control at 50 volts and set the Alarm Voltage control at 10%. This will yield an alarm voltage pickup threshold of 5 volts rms (0.1 x 50), +/-5%.
2. Connect the relay according to the test setup diagram of Figure 15. Configure the test set timer to start on application of test voltage and stop when the CT OV LED lights.

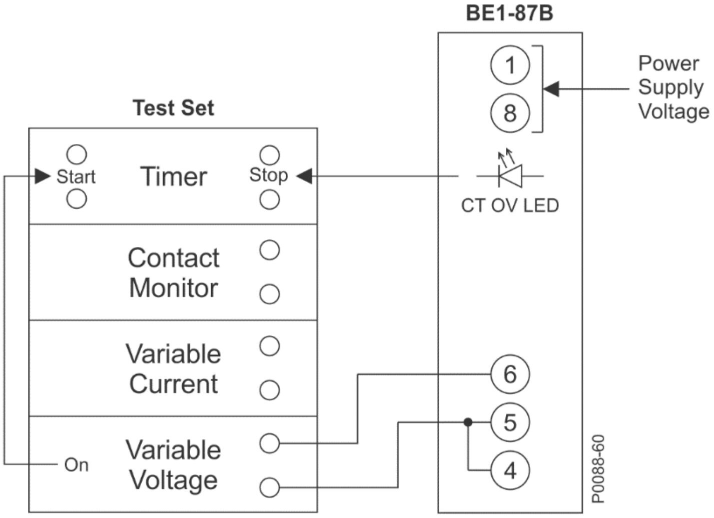


Figure 15. Alarm Voltage Test Setup

3. Apply nominal control power at relay terminals 1 (+) and 8 (–). Verify that the CT OV and Trip LEDs are reset.

4. Preset the test set voltage source at 90% (4.5 volts rms) of the alarm voltage pickup setting. Apply the voltage to the relay for a minimum of 10 seconds and verify that the CT OV LED does not light. Remove the test voltage.
5. Preset the test voltage source at 110% (5.5 volts rms) of the alarm voltage pickup setting. Apply the voltage to the relay and verify that the CT OV LED lights after several seconds. Remove the test voltage and confirm that the CT OV LED resets.
6. With the Pickup Voltage control set at 50 volts, repeat steps 4 and 5 for each of the remaining Alarm Voltage control settings listed in Table 2. Verify that the CT OV LED does not light when 90% of the alarm voltage threshold is applied. Verify that, after a delay of several seconds, the CT OV LED lights when 110% of the alarm voltage threshold is applied.

Table 2. Alarm Voltage Test Settings and Voltages

Alarm Voltage Control Setting (Pickup Threshold)	Applied Test Voltage	
	90% (CT OV LED Does Not Light)	**110% (CT OV LED Lights After Delay)**
20% (10 V)	9.0 Vrms	11 Vrms
30% (15 V)	13.5 Vrms	16.5 Vrms
40% (20 V)	18.0 Vrms	22.0 Vrms
50% (25 V)	22.5 Vrms	27.5 Vrms
60% (30 V)	27.0 Vrms	33.0 Vrms
70% (35 V)	31.5 Vrms	38.5 Vrms
80% (40 V)	36.0 Vrms	44.0 Vrms

Pickup Voltage Test

This test verifies the rms firing point of the BE1-87B SCRs. Upon firing, the SCRs seal through the primary winding of transformer T1, effectively placing a short circuit across the test source voltage. As a result, the pickup voltage test should be performed with a voltage source that will automatically turn off when the trip contact between terminals 1 and 2 closes.

The 100-volt and 200-volt test points used here verify that the voltage sensing -circuit and the pickup voltage setting (scaling) circuit are working together and will fire and seal the SCRs through transformer T1. There is no need to apply higher rms test voltages to the relay. The full pickup voltage range of the relay was tested previously under *Pickup Voltage Control Test.*

Note

Select R_{LOAD} that will cause the trip contacts to close (250 mA) or verify that the voltage channel used for this test can supply 250 mA and cause the trip contacts to close.

1. Set the BE1-87B Pickup Voltage control to 50 volts and set the Pickup Current control to 0.25 amperes. The BE1-87B test pickup voltage will be 100 volts rms symmetrical or twice the Pickup Voltage setting. (This is the rms test value equivalent to a fully offset waveform.)

2. Connect the relay according to the test diagram shown in Figure 16. Verify that the CT OV and Trip LEDs are reset.
3. Configure the test voltage source to automatically turn off when the trip contact closes. Preset the test pickup voltage to 95 volts rms. Apply the test voltage and note that the relay does not trip. Slowly increase the test voltage until the BE1-87B Trip output contacts close and the Trip LED lights (100 volts, ±5%). Note that the Trip LED remains lighted after the test voltage has been removed. Press the BE1-87B Reset pushbutton to turn off the Trip LED.

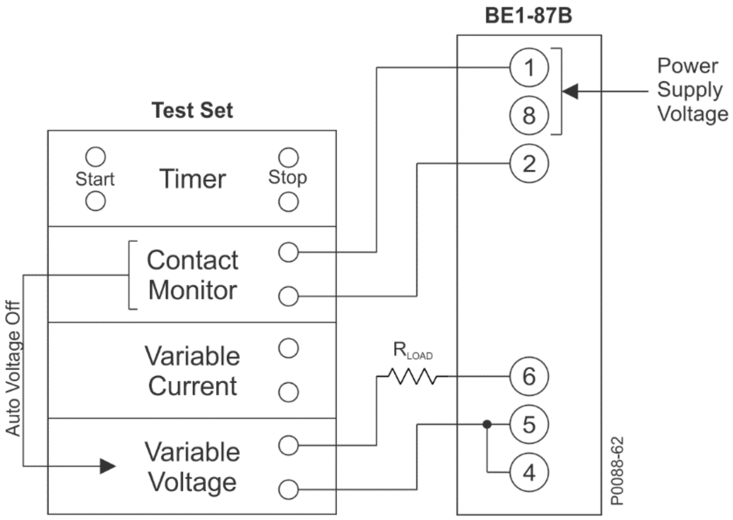


Figure 16. Pickup Voltage Test Setup

4. Set the Pickup Voltage control to 100 volts and the Pickup Current control to 0.25 amperes. As described above, the test pickup voltage will be twice the selector switch voltage or 200 volts rms symmetrical. The CT OV LED will light during this test as the alarm pickup voltage is exceeded. Verify that the CT OV and Trip LEDs are reset.
5. Configure the test voltage source to automatically turn off when the trip contact closes. Preset the test pickup voltage to 190 volts rms. Apply the test voltage and note that the relay does not trip. Slowly increase the test voltage until the BE1-87B Trip output contacts close and the Trip LED lights (200 volts, ±4%). Note that the Trip LED remains lighted after the test voltage has been removed. Press the BE1-87B Reset pushbutton to turn off the Trip LED. Return the Pickup Voltage selector switch to the 50-volt setting.

This completes the voltage tests for the BE1-87B. Set the Alarm Voltage and Pickup Voltage Controls to the values calculated for the user's specific application.

Pickup Current Test

1. Connect the test circuit as shown in Figure 17.
2. Set the BE1-87B Pickup Current control at 0.25 amperes. Apply the current test source and slowly increase the current until the BE1-87B Trip output contacts close and the Trip LED lights.
3. Remove the current test source and verify that the Trip LED remains lighted. Pickup should be 0.25 amperes, ±5%. Press the Reset button to turn off the Trip LED.
4. Repeat this test for each of the remaining Pickup Current settings. Pickup should be the value of the Pickup Current setting, ±5%.

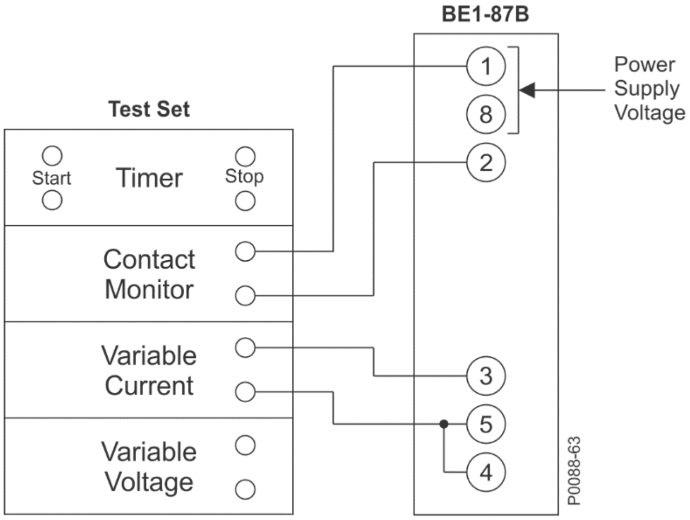


Figure 17. Pickup Current Test Setup

Trip LED, Loss of Power Test

1. Connect the test circuit as shown in Figure 17.
2. Set the Pickup Current Control to the 0.25 ampere position. Apply the current test source and increase current until the output contacts close and the Trip LED lights.
3. Remove the current test source and verify that the Trip LED remains lighted.
4. Remove the power supply voltage from terminals 1 and 8 for several minutes. Reapply the power supply voltage and verify that the Trip LED lights to indicate the previous trip condition.

Trip Time Test

1. Connect the test circuit as shown in Figure 18. The test set timer should be set to start on the application of current and stop on Trip contact (relay terminals 1 and 2) closure.

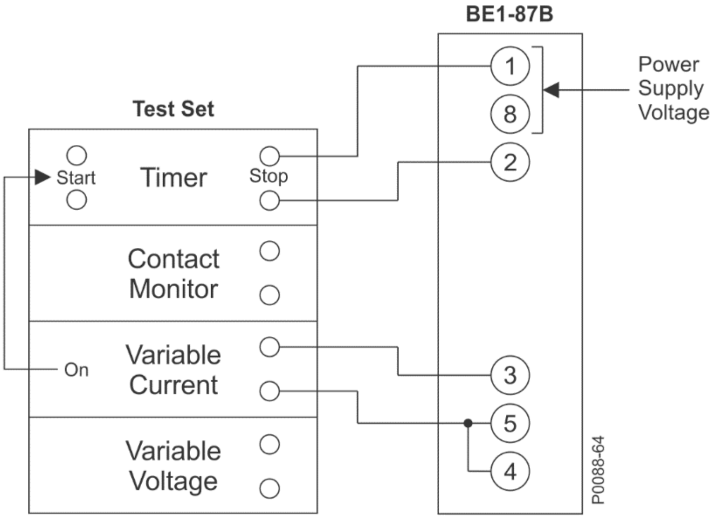


Figure 18. Trip Time Test Setup

2. With the Pickup Current control set for 0.25 amperes, apply 0.75 amperes or three times the selector switch setting. The trip contacts should close in approximately 4.5 milliseconds and the Trip LED should light. (For pickup timing performance, refer to the timing curve illustrated in the *Specifications* chapter.
3. Repeat the test several times to verify consistent trip times.

Trip Time Delay Test

This test is required only when an intentional trip time delay will be used.

1. Adjust Control circuit board jumper W1 for an intentional time delay by moving it from positions 1–2 to 2–3. Refer to the *Controls and Indicators* chapter for details about the Intentional Delay jumper.
2. Connect the test circuit as shown in Figure 18. Configure the test set timer to start on the application of current and stop on closure of the relay Trip contact.
3. Set the BE1-87B Pickup Current control at the 0.25 amperes setting.
4. Apply 0.75 amperes or three times the Pickup Current control setting. Observe that the Trip contacts close in approximately 6.4 milliseconds. (For pickup timing performance, refer to the timing curve illustrated in the *Specifications* chapter.)
5. Repeat the test several times to verify consistent trip times.

When the timing tests are complete, set the Current Pickup Control to the values calculated for the user's specific application. Verify that the Alarm Voltage and Pickup Voltage Controls have been set to their calculated positions.

Specifications

Operational Specifications

Current and Voltage Settings

Voltage Alarm Pickup............................10 to 80% in 10% increments
Voltage Pickup......................................50 to 400 V in 50 V increments
Current Pickup......................................0.25 to 2.5 A in 0.25 A increments

Table 3 describes input impedance while the SCRs are triggered (low impedance) and while the SCRs are not triggered (high impedance).

Table 3. Input Impedance While Triggered and Not Triggered

Impedance State	Input Impedance in Ohms	
	60 Hz Nominal	**50 Hz Nominal**
Low Impedance (SCRs Triggered, Current Circuit Active)	0.05	0.05
High Impedance (SCRs Not Triggered, Voltage Circuit Active)	4000 - j3300 5100 ∠ −40°	4500 - j3100 5500 ∠ −35°

Pickup Accuracy

±5% of the setting over the operating ranges for both current and voltage. Pickup accuracy over the ±5 Hz nominal frequency variation is within ±8% of the nominal frequency value.

Timing

A maximum of 7 milliseconds at 1.5 times the pickup setting.

A maximum of 5.5 milliseconds above six times the pickup setting.

Figure 19 illustrates typical response times.

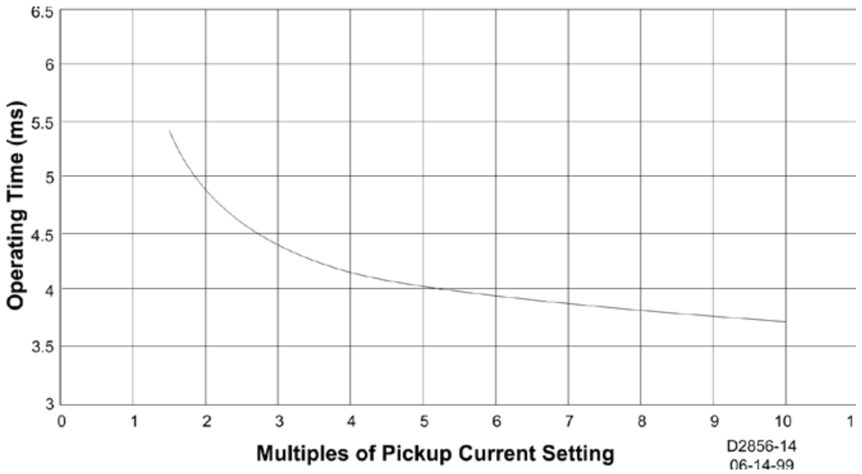


Figure 19. Typical Pickup Current Response Time without a Trip Delay

General Specifications

Power Supply

Nominal Input Voltage

DC:	48/125 Vdc
AC:	110 Vac

Input Voltage Range

DC:	24 to 150 Vdc
AC:	90 to 132 Vac

Burden at Nominal Input

DC:	7.5 W maximum
AC:	15.0 VA maximum

Frequency

Nominal 50 or 60 Hz, ± 5 Hz

Output Contacts

Output contacts are rated as follows.

Resistive

120/240 Vac	Make and carry 30 Adc for 0.2 s, carry 7 Adc continuously, break 7 Aac
125/250 Vdc	Make and carry 30 Adc for 0.2 s, carry 7 Adc continuously, break 0.3 Adc

Inductive

120 Vac, 240 Vac, 125 Vdc, 250 Vdc	Break 0.1 A (L/R = 0.04)

Current Rating

Continuous	10 A rms
1 second, symmetrical	160 A rms
5 cycles, symmetrical	480 A rms
2 cycles, fully offset	215 A

Voltage Rating

The nature of the BE1-87B relay’s application is that voltage is not applied continuously. For calibration and test purposes, it may be of value to apply input voltage for a longer duration than the few milliseconds that would typify an internal or external power system fault. For test and calibration purposes, the BE1-87B has been designed to withstand 300 Vac for a maximum duration of 60 minutes.

Targets

Front panel Trip LED is latched with an internal, mechanical latching relay. Reset is accomplished by pressing the Reset button on the front panel.

Isolation

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

All circuits to ground	2,000 Vac or 2,828 Vdc
Each circuit to all other circuits	2,000 Vac or 2,828 Vdc

Surge Withstand Capability (SWC)

Oscillatory and Fast Transient ....Qualified to IEEE C37.90.1-1989

Impulse Test

Qualified to IEC 255-5.

Radio Frequency Interference

Maintains proper operation when tested for interference in accordance with IEEE C37.90.2 1995.

Electrostatic Discharge (ESD)

In accordance with IEEE C37.90.3, contact discharges of 8 kilovolts and air discharges of 15 kilovolts were applied with no erroneous operation occurring.

Environment

Temperature

Operating Range.....................................–40°F to 158°F (–40°C to 70°C)
Storage Range..–40°F to 185°F (–40°C to 85°C)

Humidity

Qualified to IEC 68-2-38, First Edition 1974

Shock

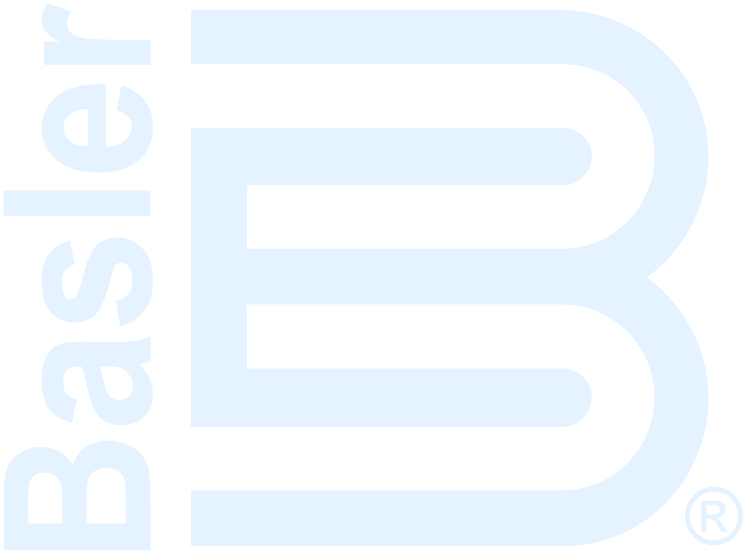
Qualified to IEC 255-21-2, Class 1.

Vibration

Qualified to IEC 255-21-1, Class 1.

Weight

Cradle Assembly.....................................2.4 kg (5.4 lb.)



Revision History

Table 4 provides a historical summary of the changes made to this instruction manual. Revisions are listed in chronological order.

Table 4. Instruction Manual Revision History

Manual Revision and Date	Change
—, 07/17	• Initial release

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