BE1-46N
Negative Sequence Protection

Washington State University
Hands-On Relay School
Sequence Currents

- **Positive-sequence** A-B-C
- **Negative-sequence** A-C-B
- **Zero-sequence**
Figure 1-1. Style Number Identification Chart

1. Target B is only available when Output is E or H.
2. All relays are supplied in an ST size case.
Input Ratings

5-A CT
- 5 A nominal; 10 A continuous; 250 A for 1 s
  Burden: < 2 VA
- Tap Adjust: 3.0 A to 5.0 A

1-A CT
- 1 A nominal; 2 A continuous; 50 A for 1 s
  Burden: < 2 VA
- Tap Adjust: 0.6 A to 1.0 A

Frequency, 50 Hz: 45–55 Hz
Frequency, 60 Hz: 55–65 Hz
• Pickup and Alarm
  › Range: 1–50%, increments of 1%
  › Accuracy: ±5% of I2
  › Dropout: Better than 98% of pickup
• Time Delay—factory set at 3.0 s
• K Set Timing Accuracy: ±5% of selected curve
• Minimum Trip Timer Accuracy
  › 200 ±25 ms
• Max Time (• 10 s)
  › Range: 10–990 s, increments of 10 s
  › Accuracy: ±5%
Contact-Outputs Ratings

- **Resistive Ratings**
  - 120 Vac: Make, break, and carry 7 Aac continuous
  - 250 Vdc: Make and carry 30 Adc for 0.2 s, carry 7 Adc continuous, and break 0.3 Adc
- **500 Vdc**
  - Make and carry 15 Adc for 0.2 s, carry 7 Adc continuously, and break 0.3 Adc

- **Inductive Ratings**
  - 120 Vac, 125 Vdc, 250 Vdc:
    - Break 0.3 A (L/R = 0.04)
      (L/R of 0.04 is about 15.1 X/R at 60-Hz, inductive)

- **Oscillograph-Start Output**: 0.5 A at 48 Vdc
Two Types of Targets

Internally operated or current operated targets

Internally operated—electronically latching
• Manual-reset targets indicate that a setpoint contact has energized.
• Select internally operated targets if the relay has normally closed output contacts.

Current-operated
• Require a minimum trip circuit current of 200 mA
  › Continuous rating of 3 amperes
  › Two-minute rating of 7 amperes
  › One-second rating of 30 amperes
# Power-Supply Options

Wide-range, isolated, low-burden, switching

Input power (source voltage) is NOT polarity sensitive

<table>
<thead>
<tr>
<th>Type</th>
<th>Nominal Voltage</th>
<th>Input Voltage Range</th>
<th>Burden (Nominal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K (midrange)</td>
<td>48 Vdc</td>
<td>24 to 150 Vdc</td>
<td>3.8 W</td>
</tr>
<tr>
<td>J (midrange)</td>
<td>125 Vdc</td>
<td>25 to 150 Vdc</td>
<td>4.0 W</td>
</tr>
<tr>
<td></td>
<td>120 Vac</td>
<td>90 to 132 Vac</td>
<td>17.1 VA</td>
</tr>
<tr>
<td>L (low range)</td>
<td>24 Vdc</td>
<td>12 to 32 Vdc*</td>
<td>3.9 W</td>
</tr>
<tr>
<td>Y (midrange)</td>
<td>48 Vdc</td>
<td>24 to 150 Vdc</td>
<td>3.8 W</td>
</tr>
<tr>
<td></td>
<td>125 Vdc</td>
<td>25 to 150 Vdc</td>
<td>4.0 W</td>
</tr>
<tr>
<td>Z (high range)</td>
<td>250 Vdc</td>
<td>68 to 280 Vdc</td>
<td>4.1 W</td>
</tr>
<tr>
<td></td>
<td>240 Vac</td>
<td>90 to 270 Vac</td>
<td>28.4 VA</td>
</tr>
</tbody>
</table>

*Type L begins operation at 14 Vdc; Once operating, voltage can be reduced to 12 Vdc
Figure 3-1. Function Block Diagram
With a generator FLC = 3.92A, and a 50% $I_2$ pickup:

Step 1. Set the TAP ADJUST switch to the next higher current value (4.0 A, position E for 5 A CT or 0.80 A, position E for 1 A CT) of the desired current value (3.92 A for 5 A CT or 0.784 A for 1 A CT).

**NOTE**
For the following step, any % value can be used. In this example, 50% has been chosen only for convenience.

Step 2. Set the % $I_2$ PICKUP thumbwheel switch to a value of 50 (0.5 pu).

Step 3. Using equation B, solve for $I_{\text{single-phase}}$.

> Single-phase test source

<table>
<thead>
<tr>
<th>CT Type</th>
<th>Equation B</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Amp CT</td>
<td>$I_{\text{single-phase}} = 3(I_{\text{nominal}})(0.5pu)$</td>
</tr>
<tr>
<td>1 Amp CT</td>
<td>$I_{\text{single-phase}} = 3(I_{\text{nominal}})(0.5pu)$</td>
</tr>
<tr>
<td></td>
<td>$I_{\text{single-phase}} = 3(3.92)(0.5)$</td>
</tr>
<tr>
<td></td>
<td>$I_{\text{single-phase}} = 3(0.784)(0.5)$</td>
</tr>
<tr>
<td></td>
<td>$I_{\text{single-phase}} = 5.88A$</td>
</tr>
<tr>
<td></td>
<td>$I_{\text{single-phase}} = 1.176A$</td>
</tr>
</tbody>
</table>

Step 4. Apply the calculated $I_{\text{single-phase}}$ to one of the phase inputs of the relay (example, phase A input, relay case terminals B, 9) and adjust the TAP CAL control from a fully clockwise until the front-panel PICKUP LED is ON.
With a generator FLC = 3.92A, and a 50% $I_2$ pickup:

Method 2, Three-Phase

If any two phases of a balanced three phase source are rotated, $I_{\text{input}} = I_2$ because a reverse phase quantity is being applied. The relay sees this as a 100% negative sequence condition.

To set the nominal current value (current being applied to the relay as derived in the calculation example):

Step 1. Set the TAP ADJUST switch to the next higher current value (4.0 amperes, position E for 5 A CT or 0.80 amperes, position E for 1 A CT) of the desired current value (3.92 amperes for 5 A CT or 0.784 amperes for 1 A CT).

Step 2. Set the % $I_2$ PICKUP thumbwheel switch to a value of 50 (0.5 pu).

Step 3. If applying A-C-B sequence,

<table>
<thead>
<tr>
<th>5 Amp CT</th>
<th>1 Amp CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_2 =</td>
<td>I_A</td>
</tr>
<tr>
<td>then, $0.5 \times</td>
<td>I_2</td>
</tr>
<tr>
<td>$0.5 \times 3.92 = 1.96A$</td>
<td>$0.5 \times 0.784 = 0.392A$</td>
</tr>
</tbody>
</table>

Step 4. Apply 1.96 amperes (for 5 A CT) or 0.392 amperes (for 1 A CT), and adjust the TAP CAL control from a fully clockwise position, counter-clockwise until the front-panel PICKUP LED is ON.
K factor specifies approximate delay at 100% $I_2$
Figure 4-9. Typical DC Connections
SECTION 5 • TESTING

Introduction
Although the BE1-46N is designed to monitor three-phase currents, verification of the relay pickup and dropout can be accomplished by using a single-phase source. To verify all three phases using a single-phase current source, repeat the operational test procedure for each of the three phases.
The test is divided into the following three functional areas:
• Pickup and Alarm
• Timing
• MAX Time

Operational Test
Pickup and Alarm
Additional testing to verify trip and alarm circuit pickup and dropout may be implemented by changing the PICKUP and ALARM thumbwheel settings. The procedures remain the same but the values differ.

Follow test routine in the instruction manual, at page 5-2
Your Lab Facilitator can help you do a 3-phase test
When testing with single-phase source, 
$I_2 = I_{\text{single\_phase}} / 3$

Solve for $I_{\text{single\_phase}}$:
Inject current into one of the phases and ramp up
The relay should pick up at $3 \times (\text{setting} \times \text{TAP})$

(Note—manufacturers are not agreed on whether the setting should be based on a single-phase quantity or a three-phase quantity)
Three-Phase Test

Inject current into all phases

Reverse phase sequence (ABC to ACB)

Ramp up

The relay should pick up at (setting • TAP)
Two-Phase Test

Inject current into two of the phases, 180 degrees apart

Ramp up

Relay should pick up at 173% • (setting • TAP)
Two-Phase Test, cont.

If you have a single-phase test set, you can jumper two phase inputs in series. Be sure polarity is reversed so the phases are 180 degrees apart.

Again, ramp to 173% • (setting • TAP)
Timing Tests

Alarm

Test 3.0-second alarm delay by injecting negative-sequence current above Alarm pickup setting and time LED light

You can also monitor terminals 11-12 for alarm output
Think of K SET setting as a time dial
Represents an inverse-time curve—the more negative-sequence current, the faster the relay responds
See graph from the IM—changing K SET moves curve up and down time axis
Similar to how time-dial setting moves an overcurrent curve up and down
K SET I2t Heating

Figure 3-2: Characteristic Curves
Timing Tests
K SET Setting

Test the K SET setting delay by injecting negative-sequence current above the Pickup setting and time the pickup LED light. You can also monitor terminals 1-10 for the trip output. The time is based on this formula from IM 5-3:

\[ t = \frac{K}{(I_{2pu})^2} \]

If \( K = 10 \) and \( PU = 0.5 \):

\[ t = \frac{10}{(0.5)^2} = 40 \text{ seconds} \quad (\pm 2 \text{ seconds}) \]
This is a setting for a small hydro generator. Set your relay with these settings and test the relay.

<table>
<thead>
<tr>
<th>G</th>
<th>Name</th>
<th>Setting</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Control Power</td>
<td>125VDC</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Tap</td>
<td>G (4.4)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Pickup</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Alarm</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>K Set</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Max Time</td>
<td>10</td>
<td>TIMES × 10</td>
</tr>
</tbody>
</table>
Next, do the following:

- Change TAP to 4.5
- K SET to 2
- Test again

Is there a difference between K SET time and MAX TIME (see IM pg 5-3)?

Try different settings for K SET and MAX TIME to get a sense of how these interact.
Questions?