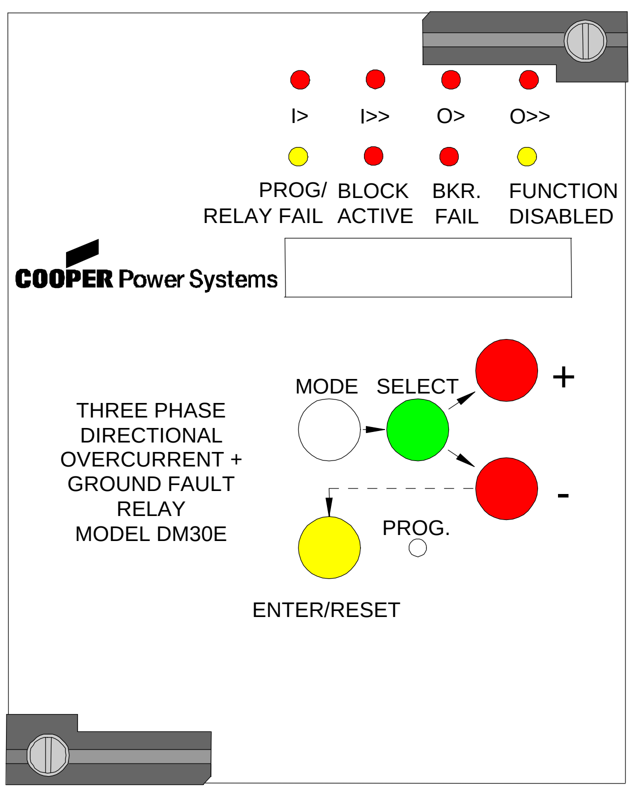
# MICROPROCESSOR DIRECTIONAL OVERCURRENT AND DIRECTIONAL GROUND FAULT PROTECTION RELAY

## TYPE

## DM30E

# OPERATIONS MANUAL



The Operations Manual is designed to familiarize the reader with how to install, program, and set up the relay for operation. For programming the relay via computer software, consult the appropriate manual. Contact your local Cooper Power Systems representative for ordering information.

## CONTENTS

# 1. INTRODUCTION

The DM30E relay provides all of the basic functions necessary for the protection of networked feeders and buses by providing directional three phase overcurrent and directional ground fault protection. The directional elements may be set to operate in either directional supervisory, true directional, or non-directional modes. True RMS values of the currents through the 9th harmonic are used, while the ground current and voltage inputs include 3rd harmonic filtering. Two digital inputs are provided to provide selective blocking of various functions. Five output relays are provided, of which four are programmable. All settings, measurements, and programming of the relay is possible through its front panel controls, or by means of a computer connected to the relay's RS485 communications port. The functions provided by the DM30E are:

- Directional time and instantaneous phase overcurrent (67/51, 67/50).
- Directional time and instantaneous ground overcurrent (67N/51N, 67N/50N).
- Breaker fail (62 BF).
- The DM30E offers two programmable inputs which can serve to block the operation of the phase or ground overcurrent elements.

The directional feature for any of the ground or phase elements can be disabled, making the element non-directional. It is also possible to disable the instantaneous time overcurrent elements. Separate pickup functions are provided which may be used to operate output relays.

# 2. HANDLING

As with any piece of electronic equipment, care should be taken when handling the relay, particularly in regards to electrostatic discharge as the damage may not be immediately obvious. All Edison relays are immune to electrostatic discharge when left in their protective case. However, when the relay is removed from its case, the following practices should be observed.

- Touch the case to ensure that your body and the relay are at the same potential.
- Whenever possible, handle the exposed relay by the front panel, the rear connector, or by the edges of the printed circuit boards. Avoid touching the individual electronic components or the embedded traces on the circuit boards.
- If you must handle the exposed (i.e., drawn-out) relay to another person, make sure you are both at the same electrical potential.
- When setting the drawn-out relay down, make sure the surface is either anti-static or is at the same electrical potential as your body.
- Relays should always be placed in storage in their protective case. If storage of the drawn-out relay outside of its protective case is required, then the exposed relay should be placed in a suitable anti static plastic or foam container.

# 3. INSTALLATION

Edison relays are shipped either in single or double width cabinets, or in standard 19" 3U rack mount enclosures capable of housing up to four Edison relays. Outline dimensions for the single relay housing is shown in Figure 1. For dimensions of other cabinets, see catalog section 150-05.

The double case mounting is similar to the single case, but requires a 113mm L x 142mm H panel opening. The 19" rack mount case is a standard 3U high 19" cabinet.

To remove the relay from its case, refer to Figure 2. The relay may be removed from its protective case by turning with a flat bladed screwdriver the locking screws ① and ② on the front panel latches ③ so that the slot on the screw is parallel to the ground. The latches may then be pulled from the inside edge to release the relay. Carefully pull on the latches to remove the relay from the housing.

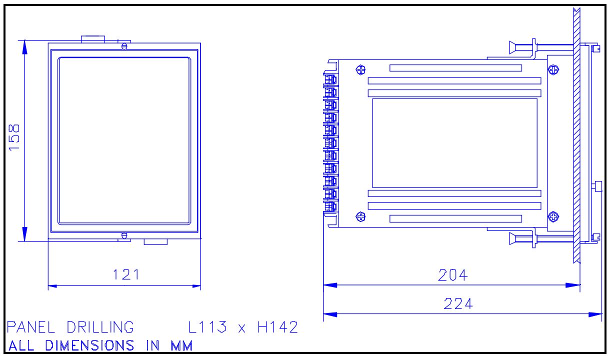



**FIGURE 1**: SINGLE MODULE ENCLOSURE MOUNTING

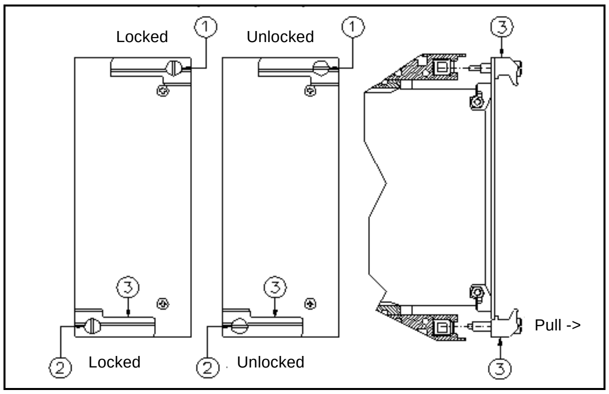



**FIGURE 2:** LATCH MECHANISM FOR REMOVAL OF RELAY FROM CASE

To re-install the relay in its case, align the printed circuit boards with the guides in the relay case and slide the relay in most of the way. For single and double cases, make sure the locking arm on the back of each of the latches ③ lines up with the locking pins in the case. Then push the latches in, seating the relay. Turn the screws on the latches until the slot is perpendicular to the ground.

# 4. ELECTRICAL CONNECTIONS

Power is supplied via terminals 12 and 13, with chassis ground at terminal 44. All Edison relays are available with one of two autoranging power supplies. Descriptions of the input voltage ranges are given in Table 1. The input supply voltage is noted on the relay case. In the event the relay is fitted with the incorrect power supply, the power supply boards are easily field replaceable. See Bulletin S150-99-1 for instructions and part numbers.

**TABLE 1:** POWER SUPPLY INPUT RANGES

| POWER SUPPLY | DC VOLTAGE RANGE | AC VOLTAGE RANGE |
|---|---|---|
| L | 24V (-20%) to 125V (+20%) | 24V (-20%) to 110V (+15%) 50/60 Hz |
| H | 90V (-20%) to 250V (+20%) | 80V (-20%) to 220V (+15%) 50/60 Hz |

All electrical connections, including the RS485 connections, are made on the back of the relay. See Figure 3. All the terminals will accept up to a No. 6 stud size spade connector (or any type of lug up to 0.25" (6.3mm) wide), 12 AWG wire (4 mm²), or FASTON connectors. Electrical connections must be made in accordance with the relay's wiring diagram found in Figure 4.

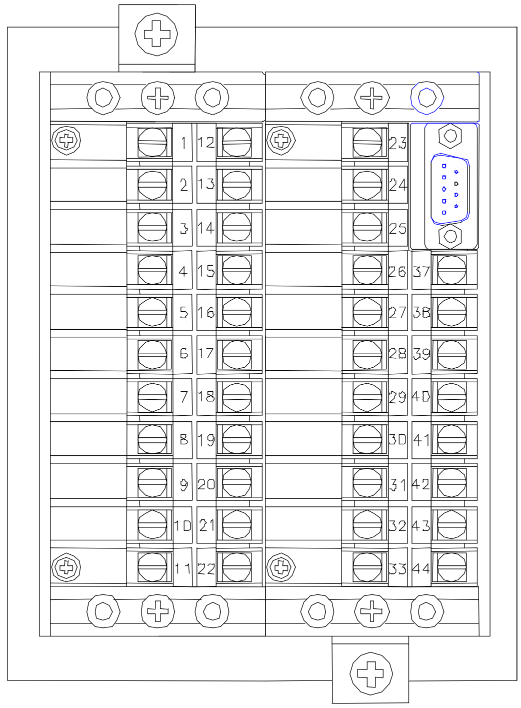



**FIGURE 3:** VIEW OF REAR TERMINAL CONNECTIONS

In Figure 4, the numbers next to the circles along the functional diagram of the relay indicate the terminal number on the back of the relay as shown in Figure 3. Note that two different input configurations are allowed. The connection shown furthest from the relay (the left connection) utilizes a window CT as the source of zero sequence current for the relay. This will provide the most accurate zero sequence input. If this connection is not practical, the connection shown on the right will provide the zero sequence current. The PT inputs must be in Y-Y form and in the phase rotation shown.

The relay is shipped with the CT inputs set for either 1A or 5A nominal inputs. The 6th and 7th characters of the relay's part number will either be "1A" or "5A" indicating the factory set input range. If the input range needs to be changed, for any of the CT inputs, this may be accomplished via jumpers on the relay's main circuit board. See the Edison Relay Technical Reference Manual for the location of these jumpers.

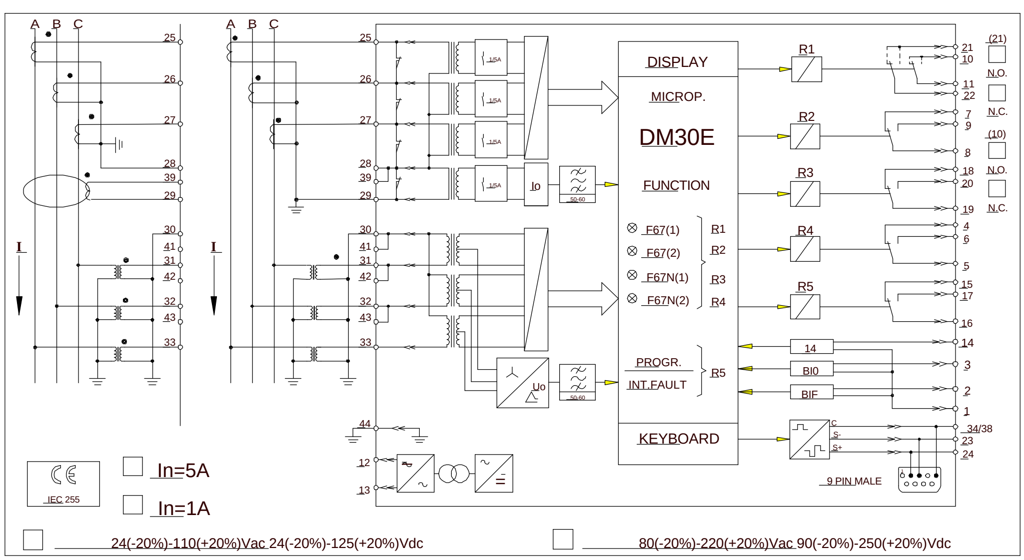



**FIGURE 4:** Wiring Diagram for the DM30E

# 5. OUTPUT RELAYS

Output relays 1 through 4 are user programmable to operate in conjunction with the tripping of any protective element or elements. Relay 1 consists of two isolated SPST terminals which may be selected as being either normally open or normally closed. The other three output relays, 2-4, are have form C (i.e., SPDT) contact arrangements.

Output relay 5 is normally energized (shown de-energized) and operates only upon power supply failure or on an internal relay fault.

# 6. BLOCKING INPUTS

The DM30E has two inputs which perform blocking functions. The open circuit voltage across the terminals of these inputs is 15 VDC. The internal resistance is 2.2 kΩ. When the external resistance across these terminals is less than 2.0kΩ, they are considered to be shorted. See Programming the Relay for more information on the function of these inputs.

# 7. TARGET DESCRIPTION

The front panel of the DM30E contains eight LEDs which act as the targets for the relay elements. See Figure 5 for identification of the targets. The top row of four targets correspond to the phase and ground overcurrent elements. As soon as the measured current level exceeds the trip level defined by the programming variables I>, I>>, $I_0$>, or $I_0$>>, the appropriate LED begins to flash. Once the time element associated with that element has expired (tI>, tI>>, $t_0$>, and $t_0$>>), the relay will have tripped and the LED goes to a constant ON state. Table 2 summarizes the target functions.

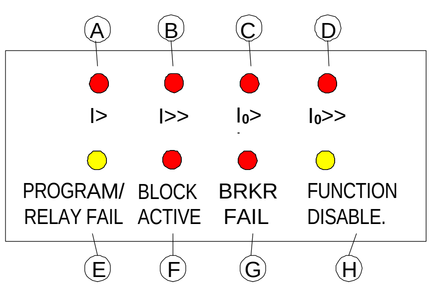



**FIGURE 5**: FRONT PANEL TARGETS ON THE DM30E

**TABLE 2**: TARGET DESCRIPTION

| TARGET ID | COLOR | LEGEND | DESCRIPTION |
|---|---|---|---|
| A | Red | I> | Flashing when measured current exceeds the low set phase overcurrent trip level [I>]. Illuminated on trip after expiration of the low-set trip time delay [tI>]. |
| B | Red | I>> | Same as above related to the high set phase overcurrent elements [I>>], [tI>>]. |
| C | Red | $I_0$> | Flashing when measured current exceeds the low set ground overcurrent trip level [$I_0$>]. Illuminated on trip after expiration of the low-set trip time delay [t$I_0$>]. |
| D | Red | $I_0$>> | Same as above related to the high-set ground overcurrent elements [$I_0$>>], [t$I_0$>>]. |
| E | Red | PROGRAM/ RELAY FAIL | Flashes when the relay is in programming mode. Constantly illuminated in case of an Internal Relay Fault. |
| F | Yellow | BLOCK ACTIVE | Flashes when either the phase or ground blocking inputs is active. |
| G | Red | BRKR FAIL | Illuminated when the breaker fail function operates. |
| H | Yellow | FUNCTION DISABLED | Illuminated when any internal function is set to “Disable” |

Reset of the LEDs takes place as follows:

- From flashing to off, automatically when the cause disappears.
- From ON to OFF, by "ENTER/RESET" push button only if the associated element is not picked up.

In case of an auxiliary power supply failure the status of the targets is recorded to non-volatile memory. The status of the targets is maintained when auxiliary power is restored.

# 8. KEYBOARD OPERATION

All measurements, programmed settings, and recorded data may be accessed through the front panel. The five buttons are color coded and their sequence of operation is indicated on the front panel by means of arrows directing the user to the next appropriate button to press. Figures 5 and 6 give an overview of the keyboard operation.

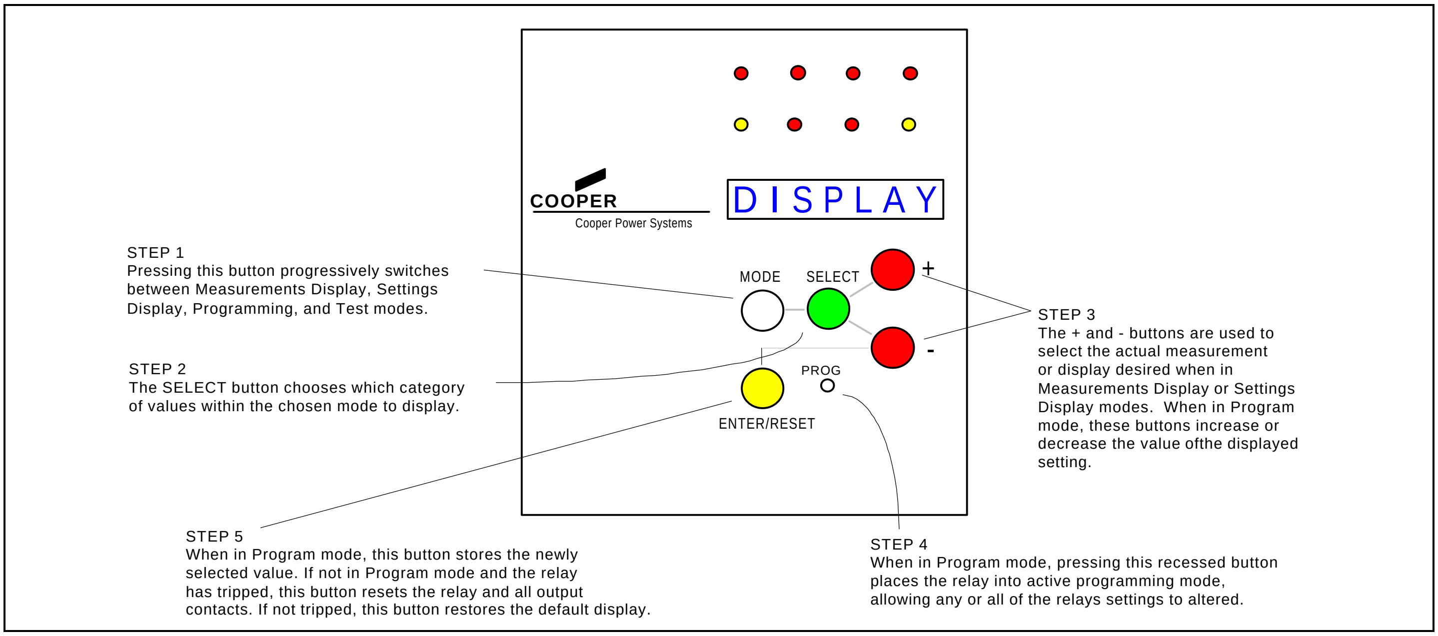



**FIGURE 6** - KEYBOARD OPERATION OVERVIEW

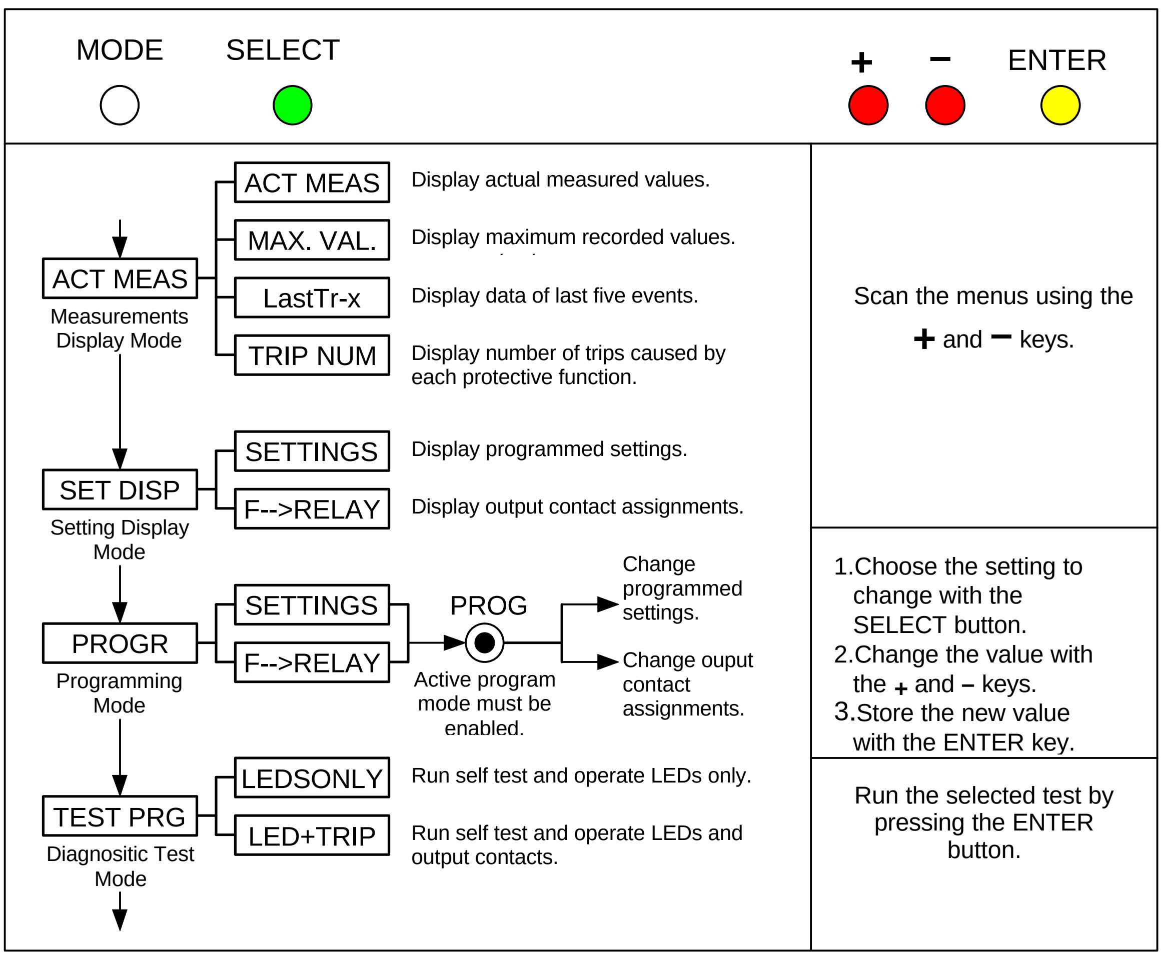



**FIGURE 7**: KEYBOARD MENU STRUCTURE

# 9. PROGRAMMING THE RELAY

Two programming modes are available. The first is the SETTINGS mode, where all of the input parameters (e.g., CT ratio, rated frequency) and settings (e.g., time dials, taps) are set. The second is the F➔Relay mode where the various output relays are assigned to the various protective elements. To enter the **PROGRAM** mode, follow these steps:

1. Make sure the input currents are all zero. As a security measure, the relay will not go into program mode when input quantities are not equal to zero. This prevents the settings from being altered while the relay is actively protecting the system.
2. Press the **MODE** button, to get into the **PROGRAM** mode.
3. Press the **SELECT** button to obtain either the **SETTINGS** or **F➔Relay** display.
4. Using a thin tool (e.g., a small screwdriver) press the recessed **PROG** button. The **PROGRAM** LED will now be flashing, indicating that **PROGRAM** mode has been successfully entered.

## 9.1 CHANGING A SETTING

Once in active PROGRAM SETTINGS mode, relay settings may be changed. For instruction on changing the output relay assignments see the section titled Changing Output Relay Assignments. Change the settings as follows:

1. Press the SELECT button to scroll through the various input parameters available for programming.
2. When the desired parameter to be changed is displayed, press the + and – buttons to change the displayed value. For numerical values where the range of settings is large, the display may be sped up by pressing the SELECT button at the same time the + or – is pressed.
3. When the desired value in displayed, press the ENTER/RESET button to store the new setting for that parameter.
4. Repeat steps 1 - 3 for each setting.

When finished, press the MODE button to leave programming mode and return the relay to normal operation.

## 9.2 DESCRIPTION OF RELAY SETTING VARIABLES

Table 3 describes each variable in the PROGRAM SETTINGS mode. The following conventions are used:

The name of the variable and any unit of measure displayed (Volts, Hz, etc.) is in bold face type. Some variables do not have a unit of measures displayed. An example of these are variables that define curve shapes.

The default value is shown in regular typeface.

For example:

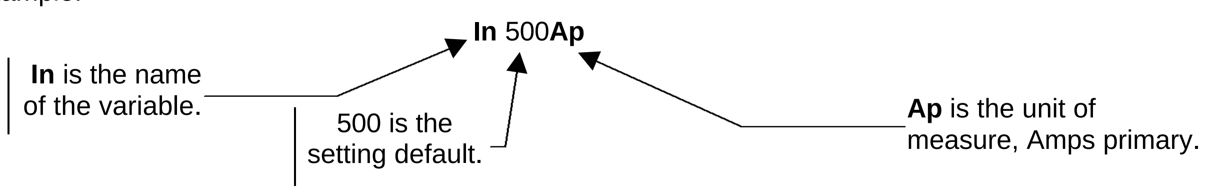


**TABLE 3 :** PROGRAM SETTING VARIABLES

| DISPLAY | DESCRIPTION | SETTING RANGE |
|---|---|---|
| **Fn** 50**Hz** | System frequency | 50 or 60 Hz |
| **In** 500**Ap** | Rated primary current of the phase CTs. | 1 to 9999 in 1A steps |
| **0n** 500**Ap** | Rated primary current of the CTs or the window CT used for supplying the zero sequence input current. | 1 to 9999 in 1A steps |
| **Fα=** Dir | Directional operation mode of the phase overcurrent elements. | Dir = True directional mode<br>Sup = Supervisory directional mode<br>Dis = Directional mode is Disabled. Phase elements behave as non-directional elements. |
| **α=** 90° | Maximum torque angle of the phase overcurrent elements. | 0°-359° in 1° steps. If **Fα** is set to Disable, this setting has no effect on the operation of the relay. |
| **F(I>)** D | Operating characteristic of the low set (time overcurrent) phase overcurrent element.<br>Note: IEC curves follow the standard curve definitions as given in IEC Standards 255-3 and 255-4.<br>The US curves follow the formula given in IEEE Draft Standard C37-118. This standard defines three curves, included here as curve names MI, VI and I. The other curves, SI and EI are based on the same formula and represent curve shapes in between the defined standard curves. | D Definite time delay<br>A IEC Inverse time (A curve)<br>B IEC Very Inverse time (B curve)<br>C IEC Extremely Inverse (C curve)<br>MI US Moderate Inverse<br>SI US Standard Inverse<br>VI US Very Inverse<br>I US Inverse<br>EI US Extremely Inverse |
| **I>** 1.0**In** | Tap (or pickup level) of the low set phase overcurrent element in per unit of the phase CT's rated current. | Dis, or 0.5 to 4.0 in 0.01 per unit steps |
| **tI>** 2.0**s** | *Definite time mode*: Trip time delay of the low-set phase overcurrent element<br>*Inverse time mode*: Time delay at 10 times pickup | 0.05 – 30.0 in 0.01 second steps |
| **I>>** 2**In** | Pickup level of the high set phase overcurrent element in per unit of the phase CT's rated current. | Dis, or 0.5 to 40 in 0.1 per unit steps |
| **tI>>** .1**s** | Time delay in seconds of the high set phase overcurrent element. | 0.05 to 3 seconds in 0.01 second steps |
| **Uo>** 25**V** | Enabling voltage threshold for the zero sequence polarizing element. This is the minimum value of the zero sequence voltage, in secondary volts, that is required in order to enable the operation of the directional element. | 2 to 25 V in 1V steps |
| **Fαo=** Dir | Directional operation mode of the ground overcurrent elements. | Dir = True directional mode<br>Sup = Supervisory directional mode<br>Dis = Directional mode is Disabled. The ground element behaves as a non-directional element. |
| **αo=** 90º | Maximum torque angle of the ground fault current element. | Dis, or 0º to 359º in 1º steps. |
| **F(0>)** D | Operating characteristic of the low set (time overcurrent) ground fault element. | Same curve selections as for F(I>). |
| **0>** .1**0n** | Tap (pickup level) of the low set ground overcurrent element in per unit of the zero sequence sensing CT's rated current. | Dis, or 0.02 to 0.4 per unit of 0n in 0.01 per unit steps |
| **t0>** 1.0**s** | *Definite time mode*: Trip time delay of the low-set | 0.05 - 30.00 in 0.01 second steps |

| DISPLAY | DESCRIPTION | SETTING RANGE |
|---|---|---|
| | ground overcurrent element<br>*Inverse time mode*: Time delay at 10 times pickup | |
| **0>>** .1**0n** | Tap (pickup level) of the high set ground element in per unit of the zero sequence sensing CT's rated current. | Dis, or 0.02 to 1.00 in 0.01 per unit steps |
| **t0>>** .1**s** | Time delay in seconds of the high set ground overcurrent element. | 0.05 to 3.0 seconds in 0.01 second steps |
| **tB0** .1s | Maximum reset time delay of the pick-up (start time) elements after tripping of the corresponding time delayed element in case the input value causing the trip does not drop below the set pick-up value. | 0.05 to 0.25 seconds in 0.01 second steps |
| **NodAd** 1 | Identification number of relay when connected on a serial communication bus. | 1 to 250 in steps of 1 |

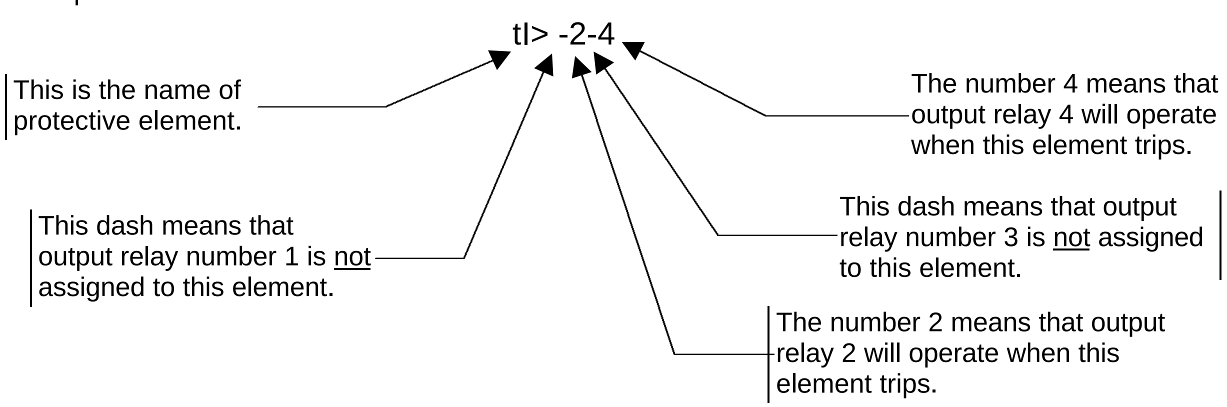
## 9.3 CHANGING OUTPUT RELAY ASSIGNMENTS

Output relays 1 through 4 may be assigned to any protective element, or any combination of elements. The only exception is that the relay cannot be assigned to both pick-up (start-time) elements, and time dependent protective elements.

1. First, enter the F➔Relay program mode.
2. Press the SELECT button to display the protective element for which the relay's assignments are to be made or changed.
3. Press the + key to select the output relay. Each press of the + key selects the next output relay. Once selected, the relay position blinks.
4. Press the - key to toggle whether the element is assigned to the output relay or not. If assigned, the output relay number appears. If not, only a hyphen (-) will be displayed.
5. Press the ENTER/RESET button to store the changes.
6. Repeat steps 1 through 5 for each protective element.

When finished, press the MODE button to leave programming mode and return the relay to normal operation.

For example:



## 9.4 DESCRIPTION OF OUTPUT RELAY VARIABLES

This section describes each variable in the PROGRAM, F➔Relay mode. The following conventions are used:

- The name of the variable is in bold face type.
- The default output relay settings are shown in regular typeface.

**TABLE 4 -** OUTPUT RELAY PROGRAMMING DISPLAY DEFINITIONS

| DISPLAY | DESCRIPTION |
|---|---|
| **I>** --3- | Pick-up (or start-time) element associated with the low set phase overcurrent element. |
| **tI>** 1--- | Time delayed element associated with the low set phase overcurrent element. |
| **I>>** --3- | Pick-up element associated with the high set phase overcurrent element. |
| **tI>>** 1--- | Time delayed element associated with the high set phase overcurrent element. |
| **0>** ---4 | Pick-up element associated with the low set ground overcurrent element. |
| **t0>** -2-- | Time delayed element associated with the low set ground overcurrent element. |
| **0>>** ---4 | Pick-up element associated with the high set ground overcurrent element. |
| **t0>>** -2-- | Time delayed element associated with the high set ground overcurrent element. |
| **tFRes:** A | Reset mode for time delay elements. If “A” then reset takes place automatically when the current drops below the pick-up value. When set to “M”, reset is only possible via the front panel ENTER/RESET key. |

## 9.5 PROGRAMMABLE BLOCKING VARIABLES

In addition to the output relay programming, the PROGRAM F➔Relay mode also provides access to setting four variables which determine which protective elements are affected by the various blocking inputs. Descriptions of these variable names, and their effects are found in Table 5.

**TABLE 5**: PROGRAMMING VARIABLES AFFECTING BLOCKING INPUT BEHAVIOR

| DISPLAY | DESCRIPTION |
|---|---|
| **Bf** I>>I> | The combination of phase overcurrent elements (I>> and I>) selected here, if any, will be blocked when input Bf is asserted. |
| **$B_0$** 0>> 0> | The combination of ground overcurrent elements ($I_0$>> and $I_0$>) selected here, if any, will be blocked when input B0 is asserted. |
| **tBf** 2tB0 | Operation mode of blocking input Bf:<br>Dis: Selected phase overcurrent elements are blocked as long as input Bf is asserted.<br>**2tB0: Blocking is removed after the set time delay of the element plus 2 times the tB0 setting** |
| **$tB_0$** 2tB0 | Operation mode of blocking input $B_0$: |

| DISPLAY | DESCRIPTION |
|---|---|
| | Dis: Selected ground overcurrent elements are blocked as long as input $B_0$ is asserted.<br>**2tB0: Blocking is removed after the set time delay of the element plus 2 times the tB0 setting** |

# 10. Overcurrent Element Characteristics

Both the phase and ground overcurrent elements in the DM30E consist of a traditional time overcurrent element and an instantaneous element. Figure 8 shows a typical composite relay curve. These are non-directional elements. In addition, the DM30E provides protective elements that operate upon pick-up of any of the above elements. These are referred to as the pick-up elements.

The time overcurrent elements, being sensitive to lower current levels, are more generically referred to as low set elements.

In Curve Mode the DM30E may be programmed to mimic one of eight predefined characteristics, including the three standard IEC curve shapes, the three standard IEEE curve shapes, and two other typical US characteristics. The curves are modeled based on the following formula per IEEE Draft Standard C37-118:

$$t(I) = \left( \frac{A}{M^P - 1} + B \right) \text{K } (T_s)$$

Where: A, B, and P are constants elected to provide the desired curve characteristics.

M is the ratio ($I_{input}/I_{pickup}$)

$T_s$ is the time setting of the relay and corresponds to either tI> or $t_0$> depending upon whether the phase or ground low set element is being set.

K is a constant, which allows for a very simple method of determining the time delay setting for the relay. See the section titled “Easy Set Curve Placement”.

Table 6 summarizes the values that the variables take for each characteristic.

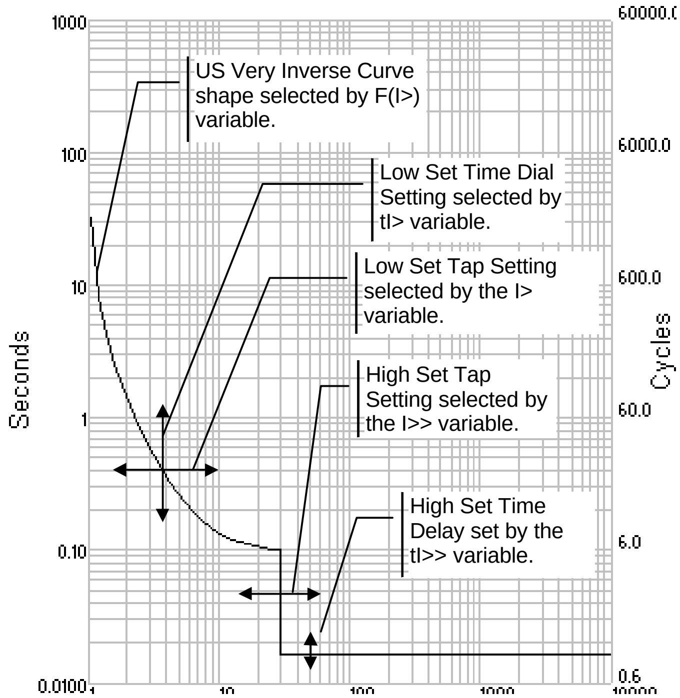



**FIGURE 8:** EXAMPLE OF COMPOSITE US VERY INVERSE CURVE WITH INSTANTANEOUS (HIGH SET) ELEMENT

**TABLE 6**: TIME OVERCURRENT VARIABLES

| Curve Name | Description | A | B | P | K |
|---|---|---|---|---|---|
| A | IEC Inverse | 0.14 | 0 | 0.02 | 0.3366 |
| B | IEC Very Inverse | 13.500 | 0 | 1 | 0.6667 |
| C | IEC Extremely Inverse | 80.000 | 0 | 2 | 1.2375 |
| MI | US Moderate Inverse | 0.0104 | 0.0226 | 0.02 | 4.1106 |
| SI | US Standard Inverse | 0.00342 | 0.00262 | 0.02 | 13.3001 |
| VI | US Very Inverse | 3.88 | 0.0963 | 2 | 7.3805 |
| I | US Inverse | 5.95 | 0.18 | 2 | 4.1649 |
| EI | US Extremely Inverse | 5.67 | 0.0352 | 2 | 10.814 |
| D | Definite Time | t = Ts | | | |

NOTE: Settings for the time dial (time delay) may be determined using either the time dial or Easy Set[SM] methods.

## 11. EASY SET℠ CURVE PLACEMENT METHOD

Instead of traditional time dial settings, the DM30E relay uses a time delay setting for moving the TCC curves vertically on the TCC graph. These time delay settings are tI> for the phase element, and $tI_0$> for the ground element. The traditional time dial setting may be calculated by multiplying the time setting by the constant K from Table 6 for the appropriate curve shape.

The Easy Set system allows multiple TCC curves to be drawn on a single TCC chart. Figures 10 and 11 show the IEEE and IEC curve families respectively. Note that all of the curves cross at the same point, pickup multiple of 10, and a time of 1x the set time delay.

Once the desired placement of the curve is determined, the time delay setting may be determined by noting the actual time delay in seconds at the pickup multiple of 10. That time delay is equal to the time delay setting (tI> or $tI_O$>) for the relay.

For example, the phase overcurrent element is set up to use the IEEE VI curve. The curve has been determined to be correctly located as shown in Figure 9. The TCC curve crosses the Pickup Multiple=10 line at 2.0 seconds. Therefore the tI> time delay setting is 2.0.

## 12. TIME DIAL METHOD

Figures 12 through 19 show a representative sample of the various curve shapes along with their Time Dial settings. The Time Dial settings are converted to the appropriate tI> or $tI_O$> settings by dividing the time dial by the value of K (see Table 6) for the appropriate curve shape.

To convert an existing time delay setting (either tI> or $tI_0$>) to a time dial value, multiply the time delay by the K factor in Table 6 for the appropriate curve.

Going back to the example shown in Figure 9, the time dial for the curve would be equal to 2.0 seconds multiplied by the constant K for the IEEE Very Inverse curve (7.381). Therefore, the time dial would equal 14.8.

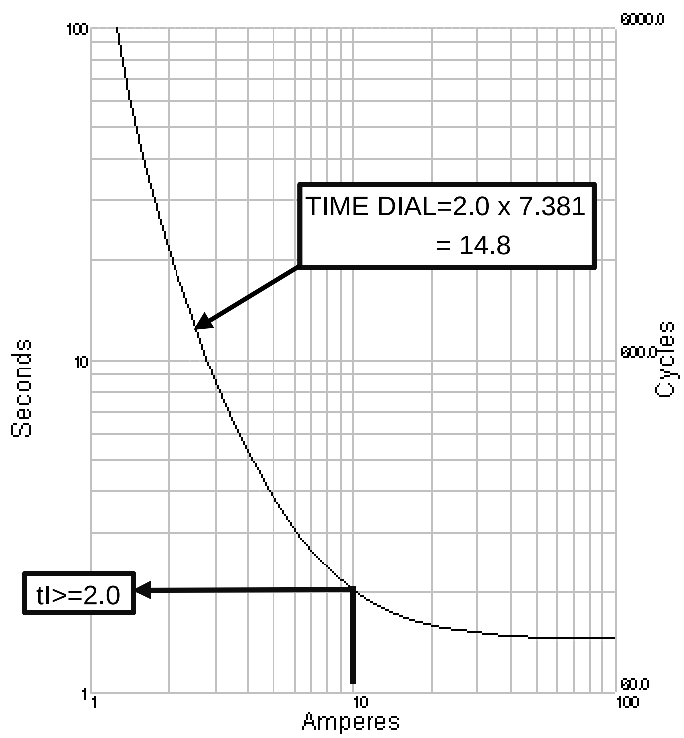



**FIGURE 9**: EXAMPLE OF IEEE VERY INVERSE CURVE TIME DELAY SETTING DETERMINATION

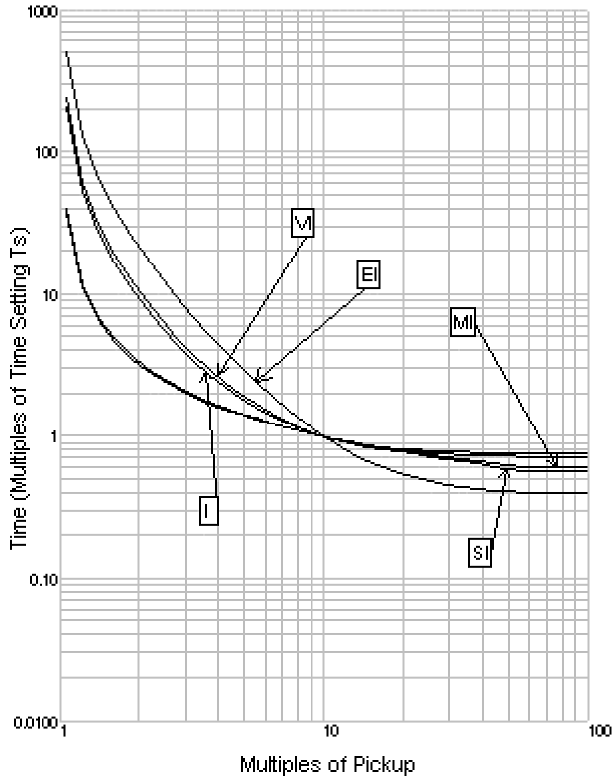



**FIGURE 10**: Easy Set Curve Set for IEEE TCC Curve Set

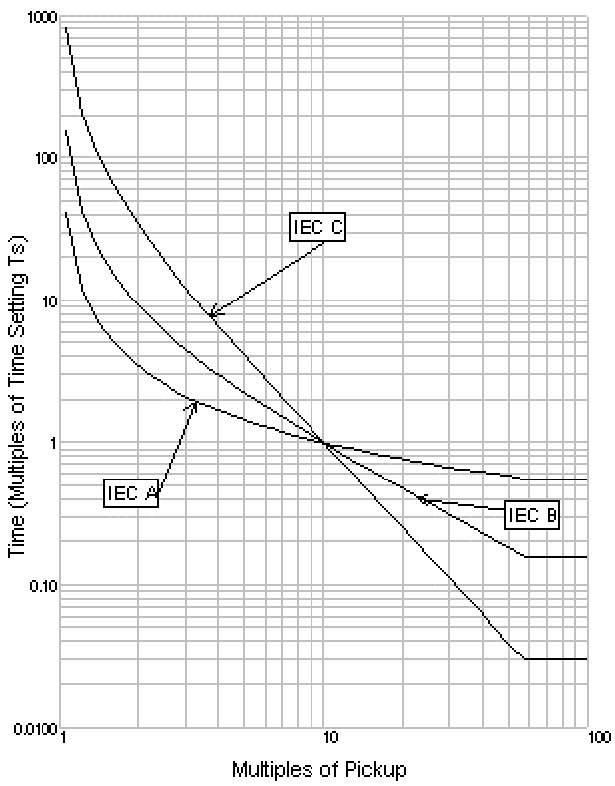



**FIGURE 11**: EASY SET CURVES FOR IEC CURVE SET

# 13. CURVE CHARACTERISTICS

The following figures show the curve shapes available and their setting ranges in terms of time dial settings. The time dial settings must be translated into time delay settings by dividing the time dial setting by the value of K shown on the figures. Note, time dial settings (and corresponding time delays) in between those indicated are possible.

Because of this characteristic, each of the curves have different absolute time dial ranges. However, the time dial range for any of the relays is much wider than typical, therefore it may be considered that all of the IEEE curves have a common time dial range from 0.7 to 123. All IEC curves have a common time dial range of 0.07 to 10. Table 7 summarizes the actual time dial limits.

Note: Actual time delays will be equal to the shown time delay plus output contact closing time and any algorithm processing time. This additional time delay (pickup time) ranges from 7 to 12 msec, with a mean of 9 msec.

**TABLE 7**: ABSOLUTE TIME DIAL RANGES FOR TCC CURVE TYPES

| CURVE NAME | CURVE CHARACTERISTIC | MINIMUM TIME DIAL | MAXIMUM TIME DIAL |
|---|---|---|---|
| A | IEC A - Normal Inverse | 0.017 | 10.099 |
| B | IEC B - Very Inverse | 0.033 | 20.000 |
| C | IEC C - Extremely Inverse | 0.062 | 37.125 |
| MI | IEEE Moderate Inverse | 0.21 | 123.3 |
| SI | IEEE Standard Inverse | 0.67 | 399.0 |
| VI | IEEE Very Inverse | 0.37 | 221.4 |
| I | IEEE Inverse | 0.21 | 124.9 |
| EI | IEEE Extremely Inverse | 0.54 | 324.4 |

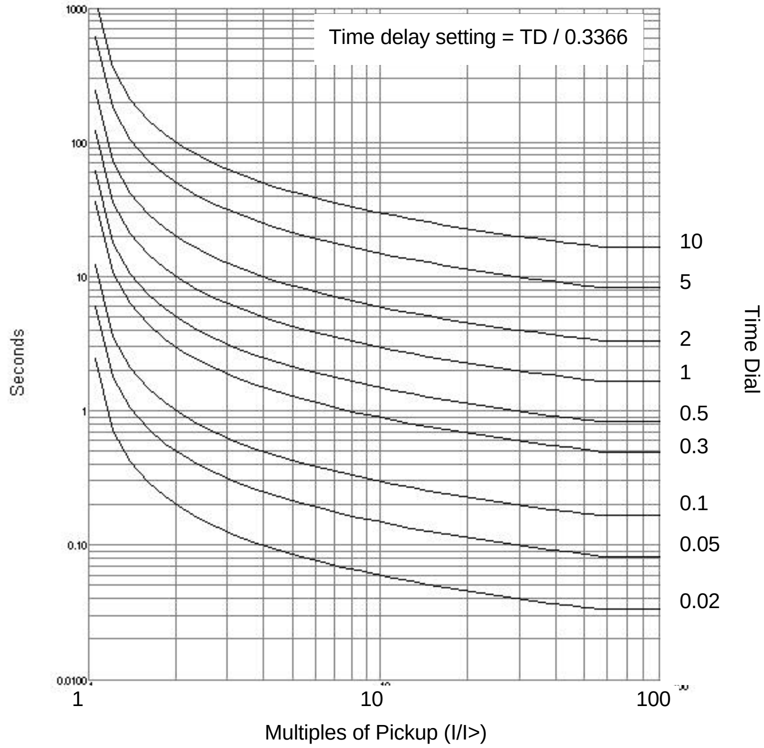



**FIGURE 12** - IEC INVERSE CURVE (A)

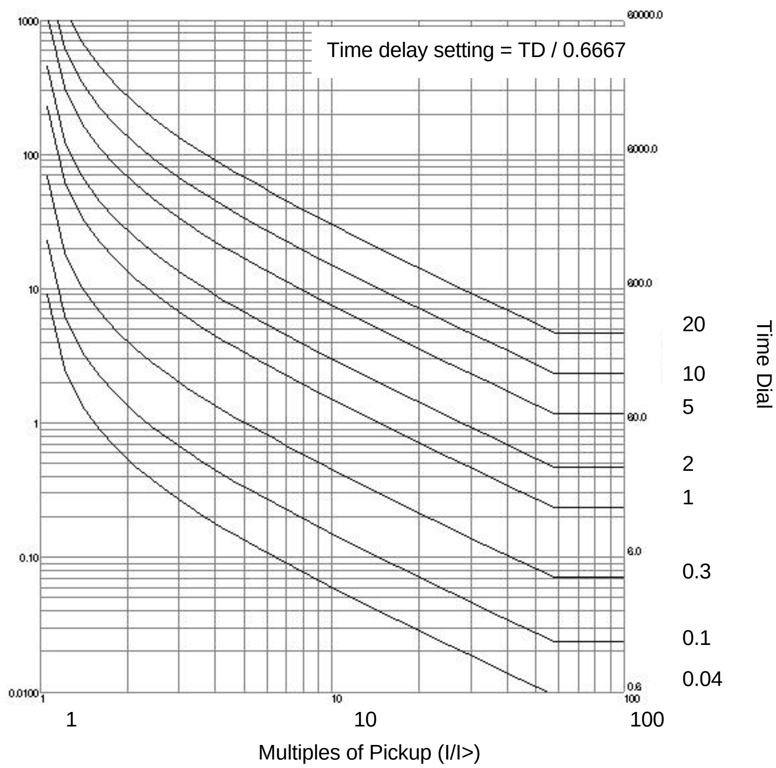



**FIGURE 13** - IEC VERY INVERSE (B) CURVE

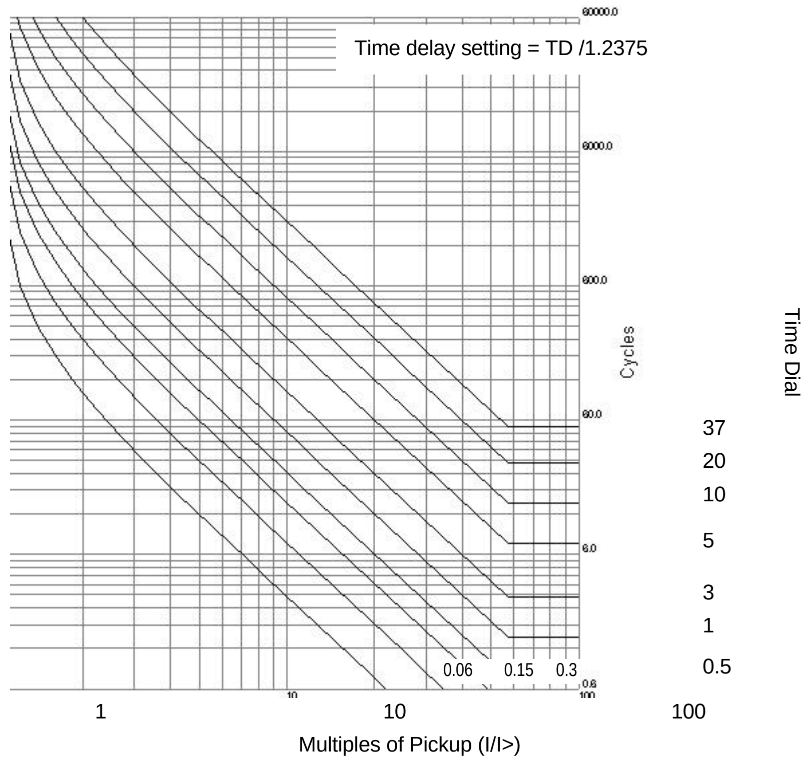



**Figure 14** - IEC Extremely Inverse (C) Curve

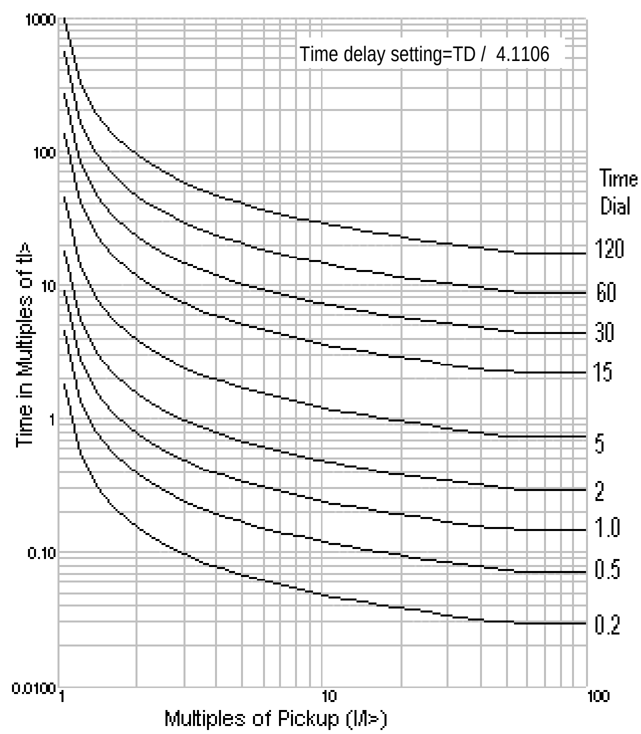



**FIGURE 15** - US MODERATELY INVERSE CURVE (MI)

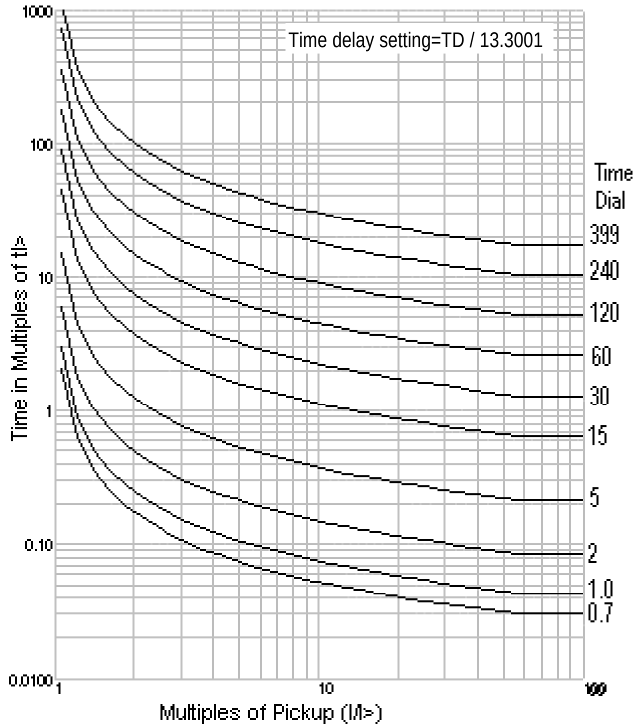



**FIGURE 16:** US STANDARD INVERSE CURVE (SI)

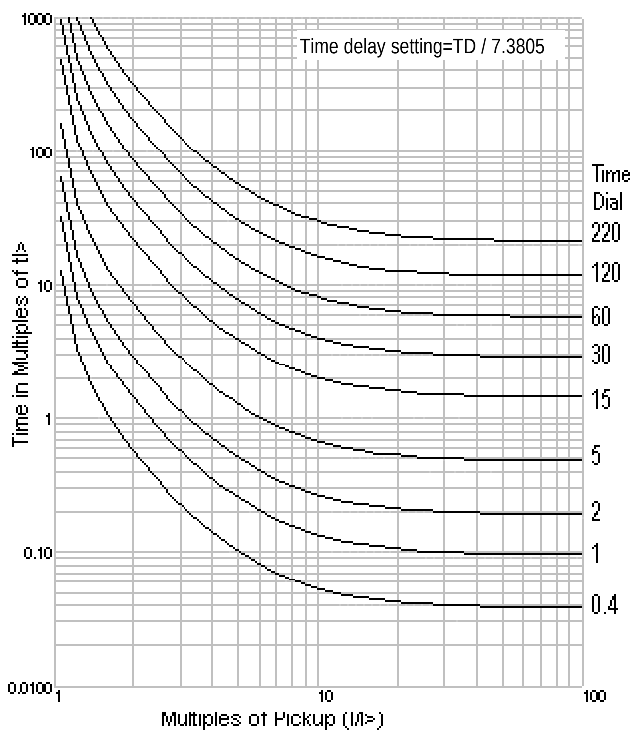



**FIGURE 17**: US VERY INVERSE CURVES (VI)

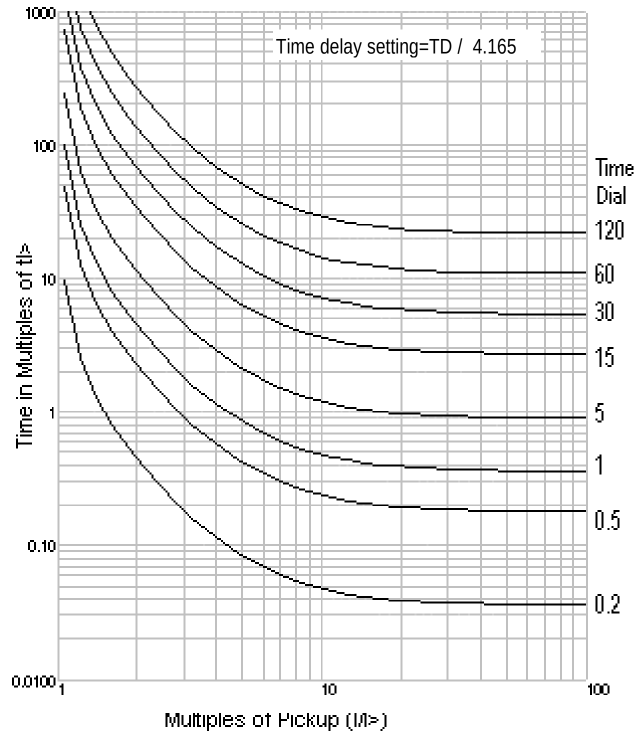



**FIGURE 18** - US INVERSE CURVES (I)

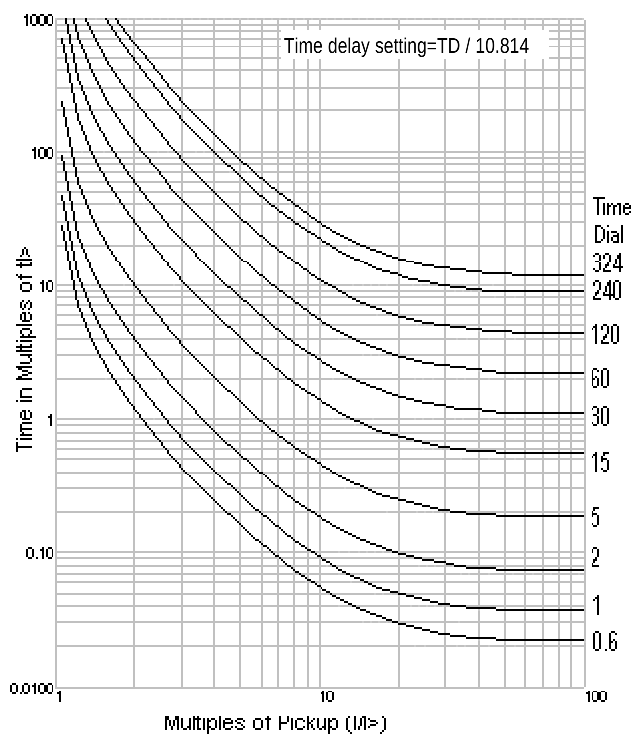



**FIGURE 19**: US EXTREMELY INVERSE CURVES (EI)

# 14. OPERATION OF THE DIRECTIONAL PHASE OVERCURRENT ELEMENTS

The operation of the phase overcurrent elements may be selected to operate in one of three modes, as set by the variable Fα.

- Non-directional (Fα=Dis): In this case the phase elements are simple 50/51 elements.
- Directional supervision (Fα=Sup): In this mode the phase elements will respond to a fault current only if the current is within +/- 90° of the set maximum torque angle.
- True directional mode (Fα=Dir): In this mode the phase elements respond only to the component of current in phase with the maximum torque angle.

## 14.1 NON-DIRECTIONAL MODE, Fα = DIS.

The element operates as a normal overcurrent element. See Figure 20.

The element operates if I ≥ [Is]

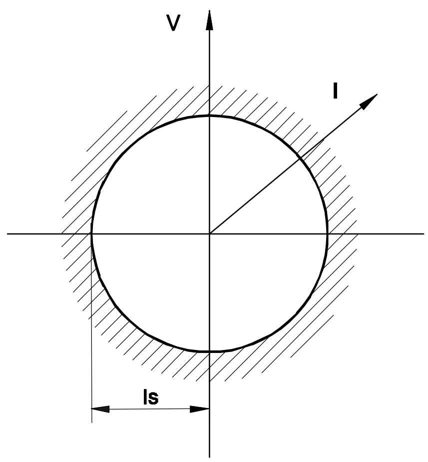



**FIGURE 20**: OPERATION IN NON-DIRECTIONAL PHASE OVERCURRENT MODE (Fα=DIS).

## 14.2 DIRECTIONAL SUPERVISION MODE, Fα = SUP.

This is the classic directional mode which permits operation of the overcurrent element if the fault current's characteristic angle is within +/- 90° of the set maximum torque angle. This is shown in Figure 21. The element operates if the following 3 conditions are present:

- The phase voltage exceeds 2% of the nominal phase voltage (required for polarization)
- The input phase current I exceeds the setting Is I ≥ [Is]
- The displacement angle φ of I from V is within ± 90° from the set maximum torque angle, α.

$$\alpha - 90 \leq \varphi \leq \alpha + 90$$

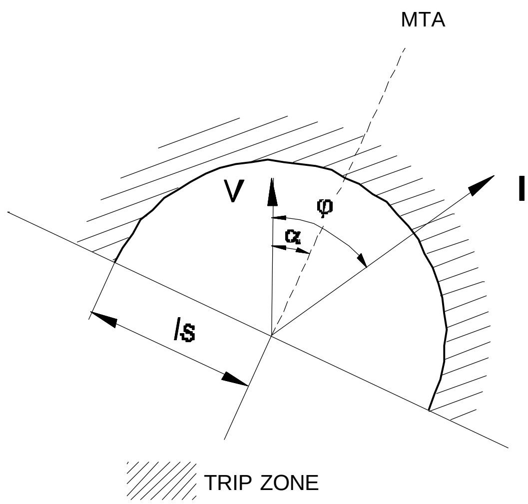



**FIGURE 21**: PHASOR RELATIONS FOR DIRECTIONAL SUPERVISION MODE

## 14.3 TRUE DIRECTIONAL MODE, Fα = DIR

The element performs a complete directional operation; element operates if the following conditions are present (see Figure 22):

- The phase voltage exceeds 2% of the nominal phase voltage (required for polarization)
- The component of the input current, I, in the direction of the maximum torque angle, α, exceeds the set level Is.

$$I \cos (\varphi_o - \alpha) \geq [I_s]$$

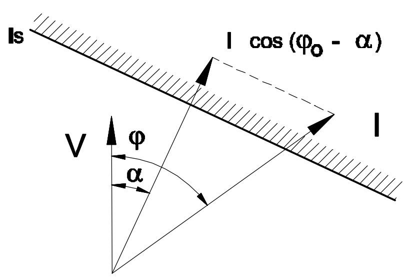



**FIGURE 22**: PHASOR RELATIONS FOR TRUE DIRECTIONAL CURRENT MODE

# 15. OPERATION OF THE DIRECTIONAL GROUND FAULT ELEMENT

Just as for the phase overcurrent elements, the ground overcurrent elements may be selected to operate in non-directional, directional supervision, or true directional modes. The directional earth fault element will operate according to the setting of the Fαo variable. The settings are the same as those described in Section 14.

## 15.1 NON-DIRECTIONAL MODE, Fα0 = DIS.

The element operates as a normal overcurrent element. See Figure 23.

The element operates if: 3I0 ≥ [Is]

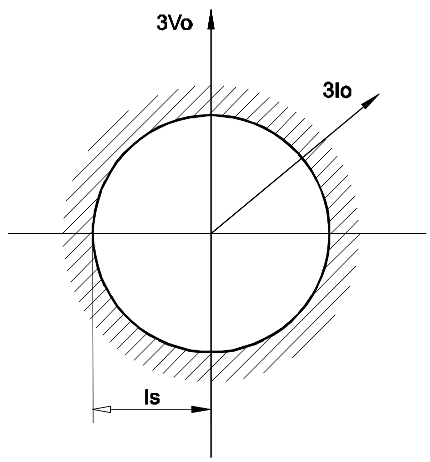



**FIGURE 23:** NON-DIRECTIONAL GROUND OVERCURRENT MODE.

## 15.2 DIRECTIONAL SUPERVISION MODE, Fα0 = SUP.

This is the classic directional mode, which permits operation of the overcurrent element if the fault current's characteristic angle is +/- 90° of the set maximum torque angle. The element operates if the following 3 conditions are present:

- The input residual voltage $3V_0$ exceeds the setting $U_0$ $3V_0 \geq [U_0]$
- The input residual current $3I_0$ exceeds the setting Is $3I_0 \geq [Is]$
- The displacement angle $\alpha_0$ of $I_0$ from $V_0$ is within ± 90° from the set maximum torque angle, α.

$$\alpha - 90 \leq \varphi_o \leq \alpha + 90$$

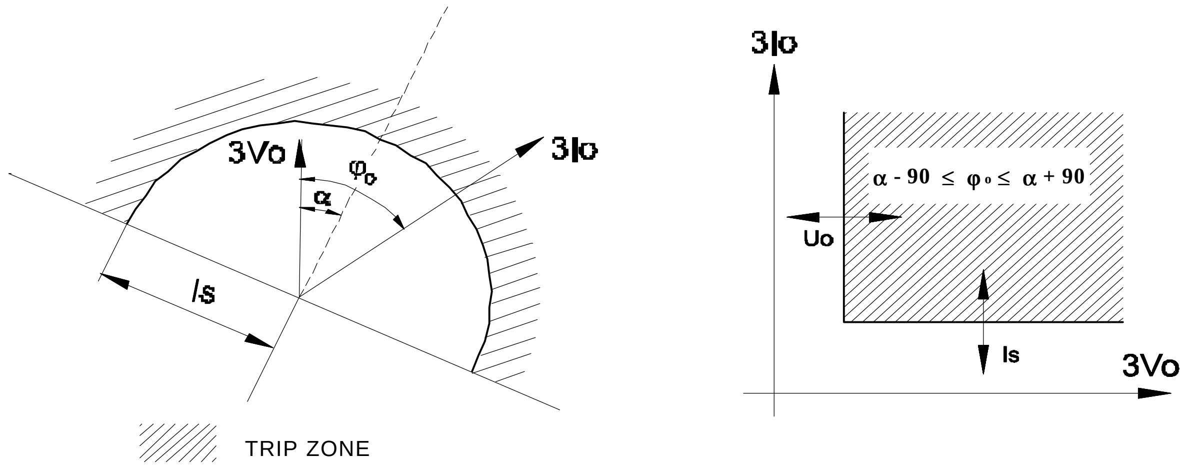



**FIGURE 24**: PHASOR RELATIONS FOR DIRECTIONAL SUPERVISION MODE

## 15.3 TRUE DIRECTIONAL MODE, Fα0 = DIR

The element performs a complete directional operation; pick-up takes place if the follow conditions ere present.

- The input residual voltage $3V_0$ exceeds the setting $U_0$ : $3V_0 \geq [U_0]$
- The component of the input residual current $3I_0$ in the direction α exceeds the setting level Is : $3I_0 \cos(\varphi_0 - \alpha) \geq [Is]$

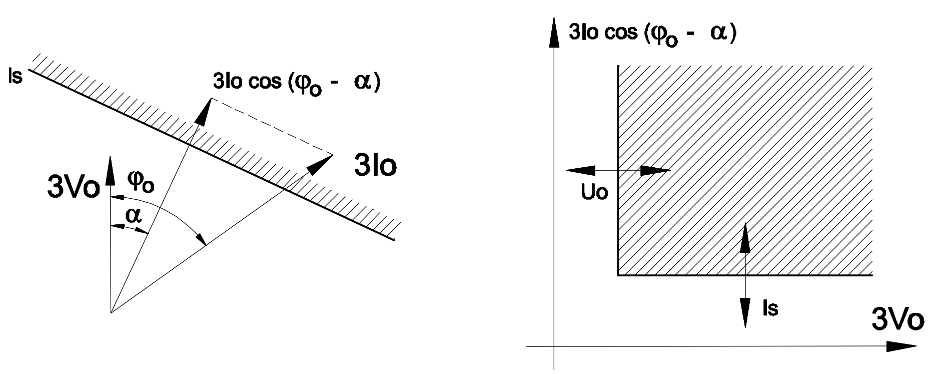



**FIGURE 25**: PHASOR RELATIONS FOR TRUE DIRECTIONAL CURRENT MODE

Because only the component of $I_0$ in the direction of $\alpha_0$ is used, if the actual direction of $I_0$, $\varphi$, is at an angle other than $\alpha$, then the sensitivity of the ground element will vary. The sensitivity is at its maximum when the angle of $I_0$ is equal to $\alpha_0$, and will approach zero as the angle approaches $\alpha \pm 90º$. See Figure 25.

The characteristic angle of the relay should be set according to the kind of grounding used in the power system; typical values would be:

- Ungrounded neutral $\alpha_0 = 90°$
- Neutral grounded via resistor $\alpha_0 = 0°$
- Solidly grounded neutral $\alpha_0 = 60°$

# 16. BREAKER FAIL (62BF) AND AUTOMATIC BACKUP

The IM30AE, IM30BE, IM30DE, and DM30E relays contain programmable blocking inputs which may be used to implement a very efficient bus fault and feeder backup mechanism without the need for a separate high impedance bus differential relaying system. The features used on these relays to implement this protection are:

- Programmable phase and ground blocking inputs, Bf, and $B_0$
- Phase and ground fault pick-up protective elements, I>, I>>, $I_0$>, and $I_0$>>
- Blocking request timers, TBf, and $TB_0$
- Breaker Fail timer, $tB_0$

Figure 26 indicates a typical application. It is assumed that all relays are set for both phase and ground overcurrent protection. In addition, it is assumed that both low and high set protective elements for both phase and ground elements are used. This document should be considered a guide as to the general methodology required to implement the described functions. It is incumbent upon the user to modify the described procedure as required for any given protective application.

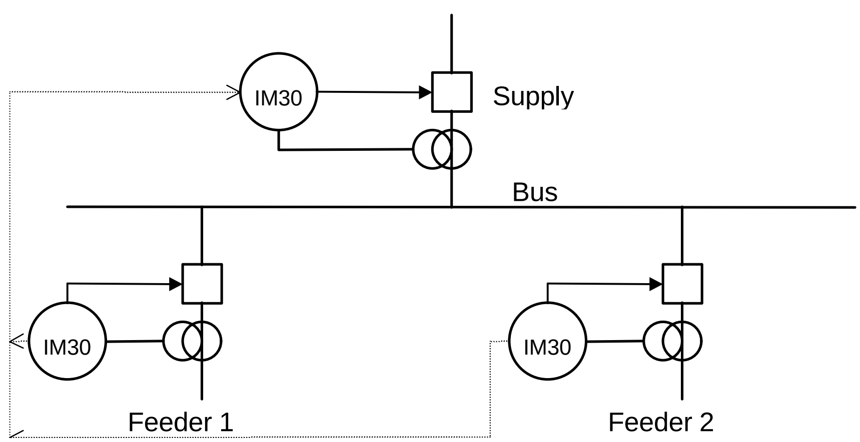



**FIGURE 26**

The Supply line and both feeders are protected by any combination of IM30AE, IM30BE, IM30DE, or DM30E relays. The Feeder relays are set so that the phase pick-up elements, I> and I>>, are programmed to operate output contact R3. The ground pick-up elements, $I_0$>, and $I_0$>>, are both assigned to operate contact R4. These contacts will close immediately when the operating quantity exceeds the pick-up value. These are sometimes referred to as start-time elements.

The output of the Feeder's phase pick-up contact, R3, is then connected to the phase blocking input, Bf (terminals 1 and 2) on the Supply relay. The phase blocking input variable Bf should be programmed to display "Bf I>> I>". This ensures that the Supply relay's low and high set phase elements will be prevented from operating as long as the phase block input is active. The ground overcurrent pick-up element contact R4 is similarly wired to the ground blocking input on terminals 1 and 3 of the Supply relay. The ground blocking input on the Supply relay is programmed to display "Bo O>> O>".

The blocking inputs on the Supply relay may be programmed to honor the blocking request for as long as the blocking input is active, or to ignore the blocking request after a certain period of time equal to twice the programming variable $tB_0$ (breaker fail timer). The blocking inputs should be set to honor the blocking request for only a fixed time period by setting the TBf and TB0 variables to "$2tB_0$". The variable $tB_0$ on each of the feeder relays should be set to a time delay equal to their breaker's expected operating time after receiving a trip signal.

The Supply relay should be set for very tight coordination with the Feeder relays to ensure rapid bus fault clearing.

With these connections and settings, the following will occur:

1. If a fault occurs on one of the feeders, the feeder relay will pick-up. The pick-up contact will block the operation of the upstream Supply relay, allowing the Feeder relay to clear the fault.
2. If a bus fault occurs, neither of the Feeder relays will pick-up, therefore the Supply relay will not be blocked and the Supply relay will trip, implementing bus fault protection.
3. If the Feeder relay experiences a breaker fail condition – meaning that the breaker has not cleared the fault after the time delay $tB_0$, then the pick-up element of the Feeder relay automatically drops out, removing the blocking signal from the Supply relay, allowing it to trip. This implements a breaker fail back-up function.
   Note that the blocking input blocks the pick-up of the time delayed functions on the Supply relay. Therefore the time delay for the Supply can be set for very fast operation, assuming a bus fault, allowing only enough time delay (10ms[1]) for the pick-up element of the Feeder relay to block the operation of the Supply relay in case of a feeder fault.
4. If the breaker fail function does not operate in the Feeder relay, or if the blocking circuit connection is shorted, then after twice the breaker operating time $tB_0$, as set in the Supply relay, the blocking request will be ignored, allowing the Supply relay to trip. This provides an additional level of back-up.

In a similar fashion, the Supply relay may be interconnected with an upstream breaker, effectively implementing fault discrimination and back-up functions for itself.

[1] The output contact of the feeder relay will close in 10 msec after it picks up. This is the inherent time delay of the output contact.

# 17. RUNNING THE TEST PROGRAMS

If desired, the start up diagnostic routines may be run at any time by accessing the TEST PRG mode. Two tests may be run, both of which are identical except for the effect on the output relays.

1. Press the Mode button until **TEST PRG** is displayed.
2. Select the test to run by pressing the **SELECT** button once to show **LEDSONLY**, or twice to display **LED+TRIP**.
    A. If the **LEDSONLY** test is selected, pressing the **ENTER/RESET** button will run the test. All the LEDs should illuminate during the duration of the test. If any error is found, an error code will be displayed and the **RELAY FAIL** light will remain illuminated. The test lasts approximately five seconds. No output relays will be operated or will change status.
    B. If the **LED+TRIP** test is selected, pressing the **ENTER/RESET** button will then display **TestRun?.** To run the test the **ENTER/RESET** button must be pressed again. At this point the test will run and all of the output relays will also be operated. The test lasts approximately five seconds.

**⚠ CAUTION**

Running the **LED+TRIP** test will operate all of the output relays. Care must be taken to ensure that no unexpected or harmful equipment operations will occur as a result of running this test. It is generally recommended that this test be run only when all dangerous output connections are removed.

# 18. DM30E SETTING SHEET

**PAGE 1 OF 3**

| Variable | Factory default | Units | Description | Range | Step | Setting |
|---|---|---|---|---|---|---|
| **Fn** | 50 | Hz | System frequency | 50 or 60 Hz | --- | |
| **In** | 500 | Primary Amps | Rated primary current of the phase CTs. | 1 to 9999 in 1A steps | 1.0 | |
| **0n** | 500 | Primary Amps | Rated primary current of the CTs or the window CT used for supplying the zero sequence input current. | 1 to 9999 | 1.0 | |
| **Fα** | Dir | None | Directional operation mode of the phase overcurrent elements. | Dir, Sup, Dis | --- | |
| **α** | 90° | Degrees | Maximum torque angle of the phase overcurrent elements. | 0°-359° | 1° | |
| **F(I>)** | D | None | Operating characteristic of the low set (time overcurrent) phase overcurrent element. | D, A, B, C, MI, SI, VI, I, EI | --- | |
| **I>** 1.0 | 1.0 | Per unit | Tap (or pickup level) of the low set phase overcurrent element in per unit of the phase CT's rated current. | Dis, or 0.5 to 4.0 | 0.01 | |
| **tI>** 2.0**s** | 2.0 | Seconds | Definite time mode:<br>Trip time delay of the low-set phase overcurrent element<br><br>Inverse time mode:<br>Time delay at 10 times pickup | 0.05 – 30.0 | 0.01 | |
| **I>>** | 2.0 | Per unit | Pickup level of the high set phase overcurrent element in per unit of the phase CT's rated current. | Dis, or 0.5 to 40 | 0.1 | |
| **tI>>** | 0.1 | seconds | Time delay in seconds of the high set phase overcurrent element. | 0.05 to 3 | 0.01 | |
| **Uo>** | 25 | Volts | Enabling voltage threshold for the zero sequence polarizing element. | 2 to 25 V | 1.0 | |
| **Fαo** | Dir | None | Directional operation mode of the ground overcurrent elements. | Dir, Sup, Dis | --- | |
| **αo** | 90º | Degrees | Maximum torque angle of the ground overcurrent current elements. | Dis, or 0º to 359º | 1.0 | |
| **F(0>)** | D | --- | Operating characteristic of the low set (time overcurrent) ground overcurrent element. | Same curve selections as for F(I>). | | |

### DM30E SETTING SHEET PAGE 2 OF 3

| Variable | Factory default | Units | Description | Range | Step | Setting |
|---|---|---|---|---|---|---|
| **0>** | 0.1 | Per unit | Tap (pickup level) of the low set ground overcurrent element in per unit of the zero sequence sensing CT's rated current. | Dis, or 0.02 to 0.4 | 0.01 | |
| **t0**> 1.0**s** | 1.0 | Seconds | Definite time mode:<br>Trip time delay of the low-set ground overcurrent element<br><br>Inverse time mode:<br>Time delay at 10 times pickup | 0.05 - 30.00 | 0.01 | |
| **0>>** | 0.1 | Per unit | Tap (pickup level) of the high set ground element in per unit of the zero sequence sensing CT's rated current. | Dis, or 0.02 to 1.00 | 0.01 | |
| **t0>>** | 0.1 | Seconds | Time delay in seconds of the high set ground overcurrent element. | 0.05 to 3.0 | 0.01 | |
| **tBO** | 0.10 | Seconds | Maximum reset time delay of the pick-up (start time) elements. | 0.05 to 0.25 | 0.01 | |
| **NodAd** 1 | 1 | | Modbus communication Address. | 1 to 250 | 1 | |

**DM30E SETTING SHEET PAGE 3 OF 3**

| OUTPUT RELAY PROGRAMMING ASSIGNMENTS (ACCESSIBLE VIA THE F→Relay PROGRAM MODE.) | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Factory default** | **Units** | **Description** | **Range** | **Setting** |
| **I>** | - - 3 - | Outputs | Pick-up (or start-time) element associated with the low set phase overcurrent element. | 1 2 3 4 | |
| **tI>** | 1 - - - | Outputs | Time delayed element associated with the low set phase overcurrent element. | 1 2 3 4 | |
| **I>>** | - - 3 - | Outputs | Pick-up element associated with the high set phase overcurrent element. | 1 2 3 4 | |
| **tI>>** | 1 - - - | Outputs | Time delayed element associated with the high set phase overcurrent element. | 1 2 3 4 | |
| **0>** | - - - 4 | Outputs | Pick-up element associated with the low set ground overcurrent element. | 1 2 3 4 | |
| **t0>** | - 2 - - | Outputs | Time delayed element associated with the low set ground overcurrent element. | 1 2 3 4 | |
| **0>>** | - - - 4 | Outputs | Pick-up element associated with the high set ground overcurrent element. | 1 2 3 4 | |
| **t0>>** | - 2 - - | Outputs | Time delayed element associated with the high set ground overcurrent element. | 1 2 3 4 | |
| **tFRes** | A | --- | Reset mode for time delay elements. If “A” then reset takes place automatically when the current drops below the pick-up value. When set to “M”, reset is only possible via the front panel ENTER/RESET key. | A, M | |
| **Bf** | I>>I> | --- | The combination of phase overcurrent elements (I>> and I>) selected here, if any, will be blocked when input Bf is asserted. | I>, I>> | |
| **B0** | 0>> 0> | --- | The combination of ground overcurrent elements (I0>> and I0>) selected here, if any, will be blocked when input B0 is asserted. | 0>>, 0> | |
| **tBf** | 2tB0 | --- | Operation mode of blocking input Bf:<br>Dis: Selected phase overcurrent elements are blocked as long as input Bf is asserted.<br>2tB0: Blocking is removed after the set time delay of the element plus 2 times the tB0 setting | Dis, 2tB0 | |
| **tB0** | 2tB0 | --- | Operation mode of blocking input B0:<br>Dis: Selected ground overcurrent elements are blocked as long as input B0 is asserted.<br>2tB0: Blocking is removed after the set time delay of the element plus 2 times the tB0 setting | Dis, 2tB0 | |

**MANUAL REVISION HISTORY**

July 1999 Version Supercedes April 1999 Version: (1) Corrected the values in Table 6.



COOPER Power Systems
P.O. Box 1640, Waukesha, WI 53187
http://www.cooperpower.com/