COOPER Power Systems

Electrical Apparatus

MM30 Motor Protection Relay

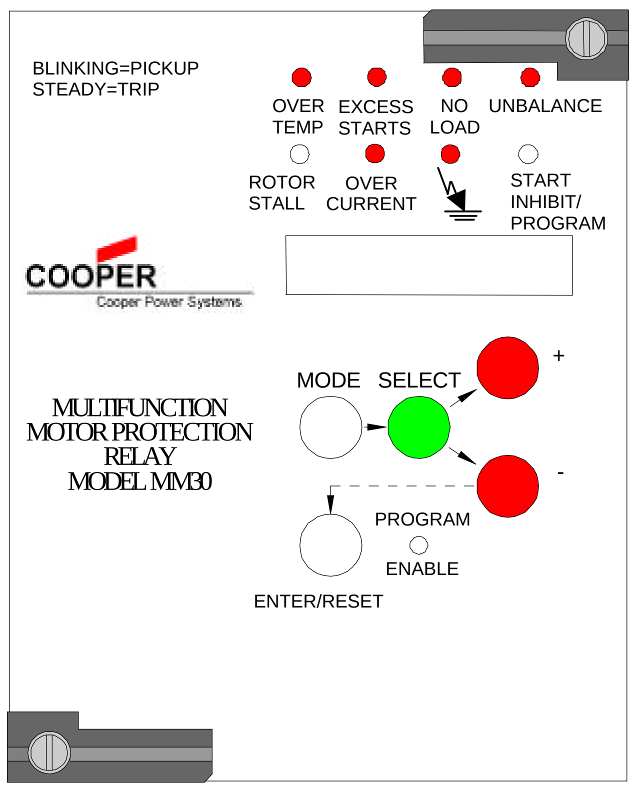
S150-45-1

MICROPROCESSOR MOTOR PROTECTION

TYPE

MM30

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.

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1. INTRODUCTION

The MM30 relay provides many of the basic protective functions necessary for the protection of small, medium, and large size motors. Five output relays are provided, of which four are programmable. All settings, measurements, and programming of the relay are 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 MM30 relay are:

- Thermal pre-alarm element (49)
- Thermal overload element (49)
- Locked rotor element (50S)
- Current unbalance element (46)
- Undercurrent (Loss of Load) element (37)
- Instantaneous overcurrent element (50)
- Time delayed high set overcurrent element (50D Definite Time)
- Ground overcurrent element (50G)
- Time delayed ground overcurrent element (51N)
- Too many sequential attempted starts element (66)
- Incomplete starting sequence element (48).

There are three optional inputs available on request as shown in Figure 4. The first is a remote trip (R.T.) input, which is activated by an external contact closure. The second is a speed switch (S.C.) input, which is activated when the motor fails to reach running conditions in the set start time. The last is a remote thermal device (RTD) which provides a contact closure to the MM30 relay.

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 hand the exposed (i.e., drawn-out) relay to another person, make sure both of you are 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 stored in their protective cases. If storage of a 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 that are 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 ℵ and ℑ on the front panel latches ℜ 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.

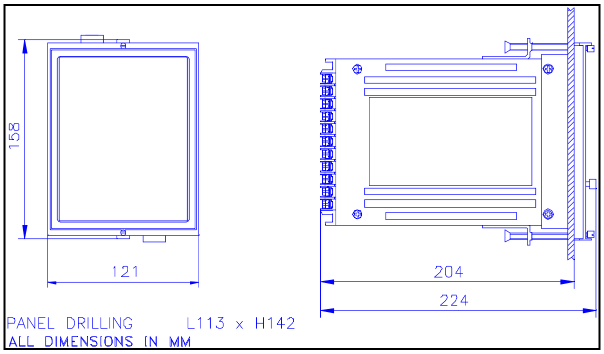


FIGURE 1: SINGLE MODULE ENCLOSURE MOUNTING

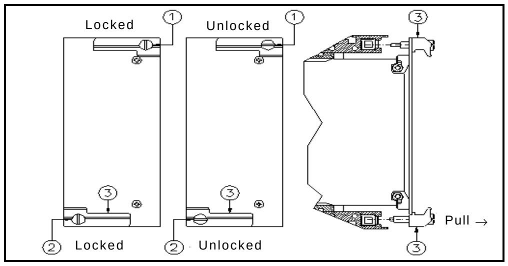


FIGURE 2: LATCH MECHANISM FOR REMOVAL OF RELAY FROM CASE

To re-install the relay into 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 ℜ 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

Input quantities are supplied to three Current Transformers (two measuring phase currents - one measuring the ground fault zero-sequence current). Rated current inputs can be either 1 or 5A. Make electric connections in conformity with the diagram reported on the relay's enclosure. Check that the input currents are the same as reported on the diagram and on the test certificate.

Auxiliary power is supplied via terminals 12 and 13, with a chassis ground at terminal 44. All Edison relays are available with one of two interchangeable auto-ranging power supplies. Descriptions of the input voltage ranges are given in Table 1. The input supply voltage is noted on the relay case. If 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 of the relay's 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 one of the relay's wiring connection diagrams shown in Figure 4.

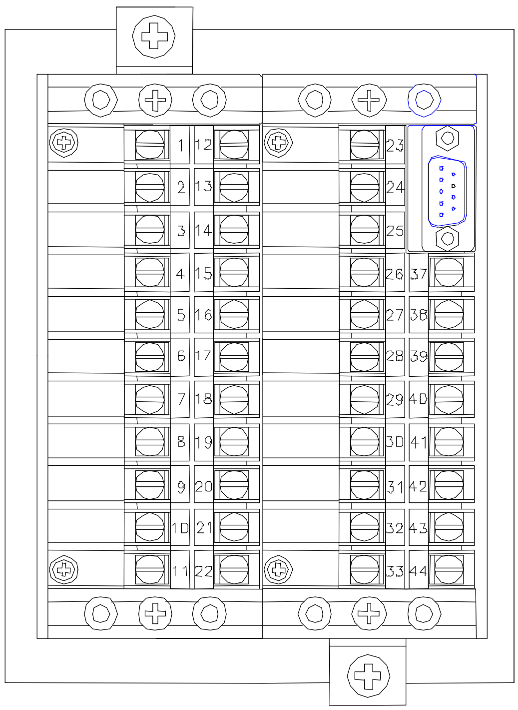


FIGURE 3: REAR VIEW OF TERMINAL CONNECTIONS

In Figure 4, the numbers next to the circles along the functional diagram of the relay indicate the terminal numbers on the back of the relay as shown in Figure 3. Note that two different input configurations are possible. The left-most connection shown in Figure 4 uses a window CT as the source of zero sequence current for the relay. This will provide the most accurate zero sequence current input. If this connection is not practical, then the connection shown to the right will provide the zero sequence current.

The relay is shipped with the CT inputs set for either 1A or 5A nominal inputs. The 9th character of the relay's part number (PRMM30JH5S) will either be "1" or "5" 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 Figure 6).

5. CONNECTION DIAGRAM

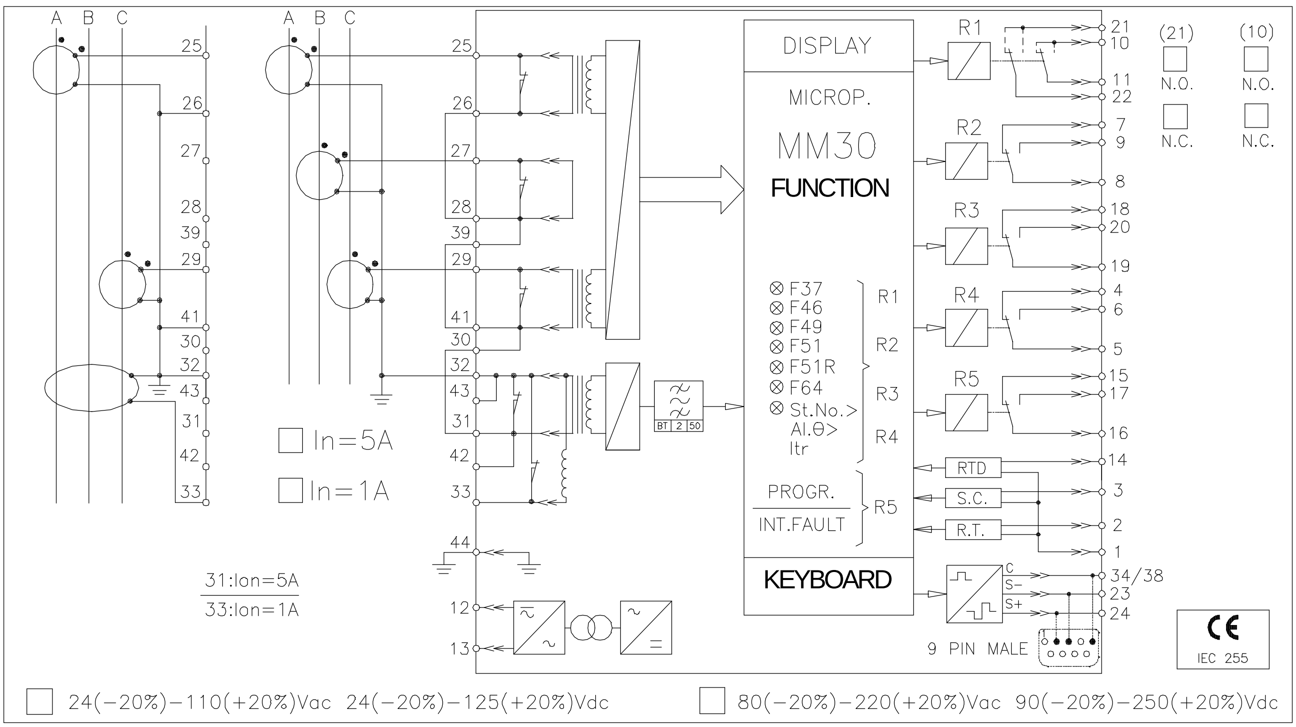


Figure 4: MM30 Wiring Diagram

6. WIRING THE SERIAL COMMUNICATION BUS

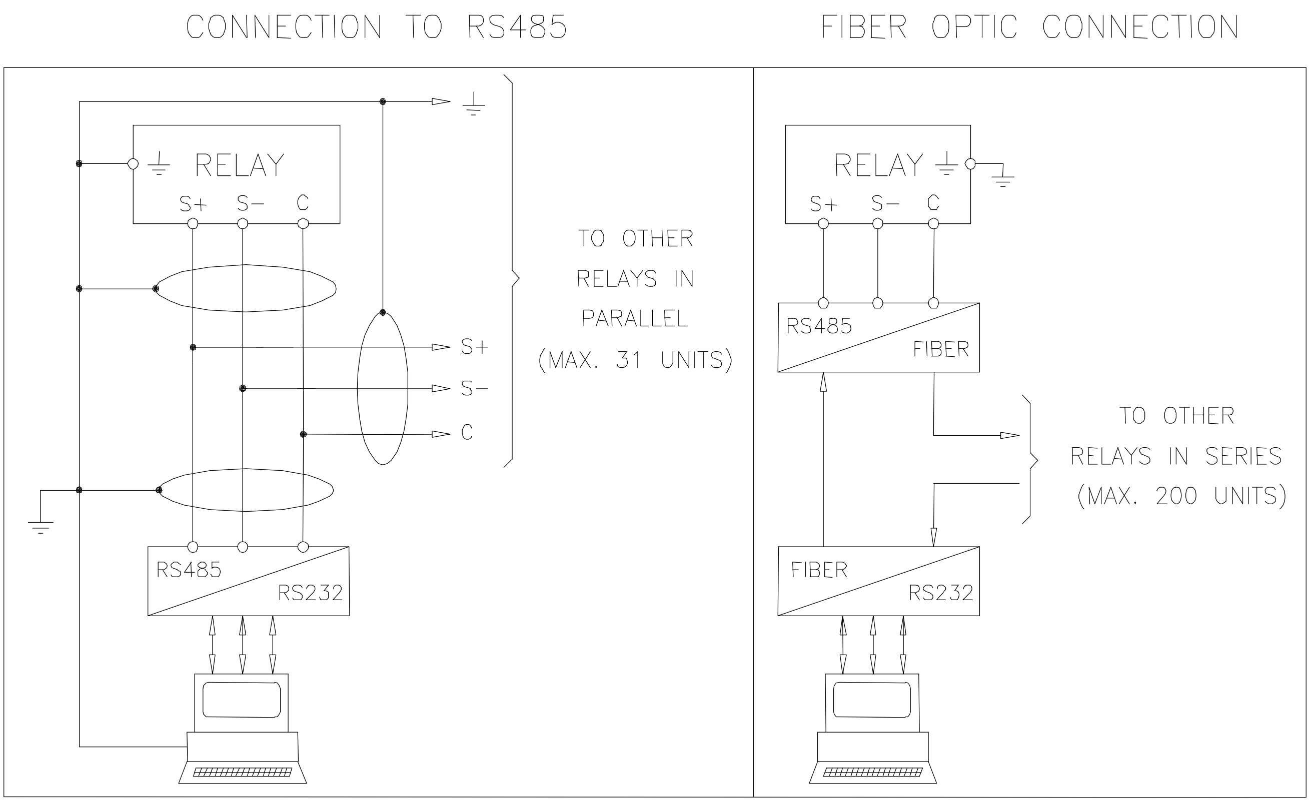


FIGURE 5: Wiring the Serial Communication Bus

7. CHANGE THE CT SECONDARY RATED INPUT, 1 OR 5A

The two possible selections to specify the rated secondary input currents are 1 or 5 Amperes. The jumper placement establishes what the secondary rated current values will be. The 5 Amperes rating is selected by either joining the bottom two pins (vertical) or the two leftmost pins (horizontal). The 1 Ampere rating is selected by either joining the top two pins (vertical) or the two rightmost pins (horizontal).

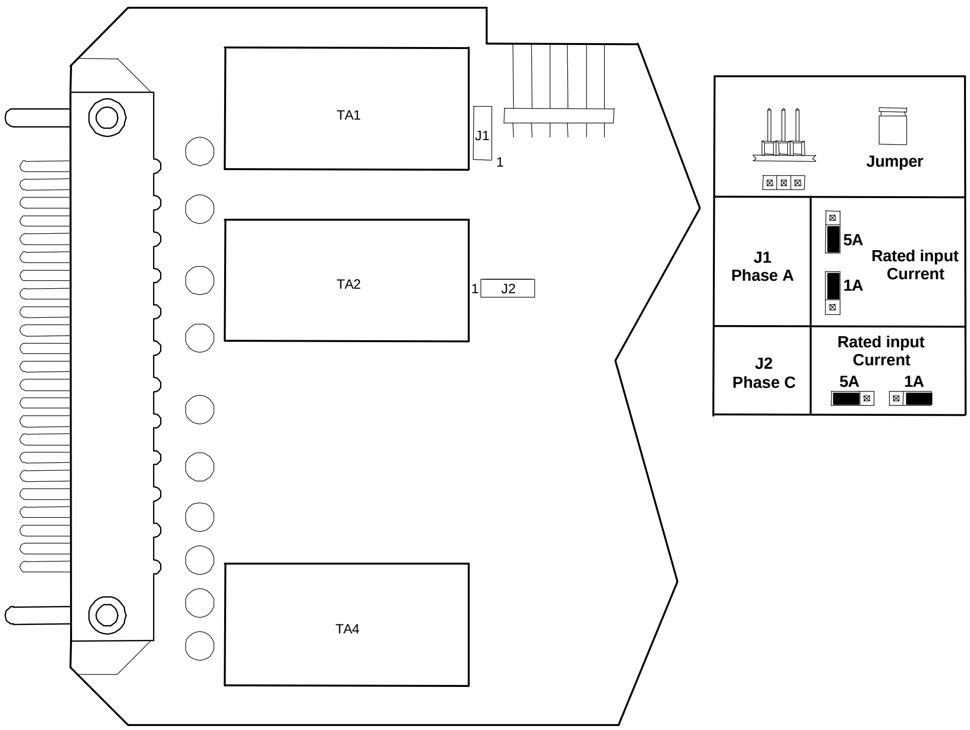


FIGURE 6: Selection of the Rated Secondary Input Currents

8. OUTPUT RELAYS

Five output relays are available (R1, R2, R3, R4, R5).

a) - The output relays **R1,R2,R3,R4** are normally de-energized (energized on trip). These output relays are user programmable and any of them can be associated to any of the MM30's functions. 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, have form C (i.e., SPDT) contact arrangements.

Reset of the output relays associated with the time delayed trip functions takes place automatically when the tripping cause is cleared. One relay associated to the instantaneous element of the function 51 or 51N, after pick-up normally drops-out as soon as the tripping cause is cleared (current below the set trip level). If the current remains above the trip level longer than the time delay programmed for the same function, the drop-out of the instantaneous relay is then forced after an adjustable waiting time [tBO] (Breaker failure protection control).

b) - The output relay **R5** is normally energized, is not programmable and it is de-energized for:

- internal fault
- power supply failure
- during programming of the relay
- reached the maximum number of consecutive motor starting attempts
- restart Lock-out activated.

9. DIGITAL INPUTS

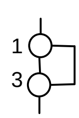
Upon a customer's request, three digital inputs can be activated when the relevant terminals are shorted.

- **R.T.** (terminals 1-2) Remote trip control. (Optional)

- **S.C.** (terminals 1-3) Speed switch.

The Speed Control input is connected to a N/O contact which closes as soon as the motor is running. If the contact does not close within the set start time (tst) from the moment the motor is energized, the Locked Rotor function is tripped. The relay element ILR is energized, the recording on the last trip will show cause: S.C. and trip number LR will be increased by one.

If the Speed Control function is not used, terminals 1-3 must be permanently shorted.



- **RTD** (terminals 1-14) Remote Thermal Device.(Optional)

One of the output relays R1, R2, R3 or R4 has to be programmed for being controlled by the tripping of RTD function. The RTD is a remote thermal device which provides a contact closure to the MM30 Relay. When terminals 1 and 14 are shorted, the RTD function is activated. Activation of the RTD function produces the following operations:

The Yellow LED (second row first LED from the left, located on the faceplate of the relay), will be Flashing.

The Relay Output associated to RT is energized.

The Trip Number counter of the function T> is increased by one.

The Last Trip shows: Cause RTD.

10. TARGET DESCRIPTION

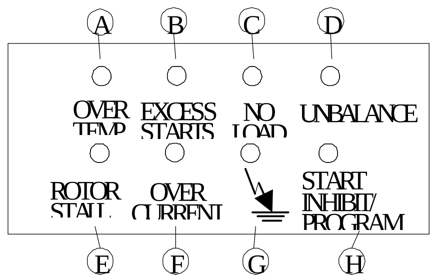


FIGURE 7: FRONT PANEL TARGETS ON THE MM30

The front panel of the MM30 relay contains of eight LEDs that are normally OFF and which act as the targets for the relay elements. See Figure 7 for identification of the targets. The top row of four targets from left to right corresponds respectively to: Over Temperature, Excessive Starts, No Load and Unbalance. The second row of four targets from left to right corresponds respectively to: Rotor Stall, Overcurrent, Ground Current and High motor temperature/set wait time/Programming mode.

Table 2 summarizes the target functions.

FIGURE 7: FRONT PANEL TARGETS ON THE MM30

TABLE 2: TARGET DESCRIPTION

TARGET ID	COLOR	LEGEND	DESCRIPTION
A	Red	OVER TEMP	Flashing when the motor heating exceeds the set alarm level of [Ta]. Illuminated on over temperature trip.
B	Red	EXCESS STARTS	Illuminated on tripping of the element for limitation of the number of consecutive attempted motor starts.
C	Red	NO LOAD	Flashing as soon as the motor current drops below the set level [I<]. Illuminated at the end of the trip time delay of 3 seconds.
D	Red	UNBALANCE	Flashing as soon as the motor unbalance current exceeds the set level of [Is>]. Illuminated on trip by the time delayed element [tIs>].
E	Yellow	ROTOR STALL	Flashing when the motor current exceeds the set level [ILR] after twice the normal starting time. Illuminated on trip after an additional 1 second time delay.
F	Red	OVER CURRENT	Flashing when the motor current exceeds the set level of [I>]. Illuminated on trip by the time delayed element [tI>].
G	Red		Flashes when the ground fault current exceeds the set level of [O>]. Illuminated on trip by the time delayed element [tO>].

TARGET ID	COLOR	LEGEND	DESCRIPTION
H	Yellow	START INHIBIT/ PROGRAM	Flashing when the motor temperature exceeds the set restart level of [Ts] or after StNo trip during the set waiting time [tBst]. Illuminated when in PROGRAM MODE or when a relay internal fault is detected.

Reset of the LEDs takes place as follows:

- From flashing to OFF, automatically when the tripping cause disappears.
- From ON to OFF, by "ENTER/RESET" push button only if the associated tripping 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.

11. 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 8 and 9 give an overview of the keyboard operation.

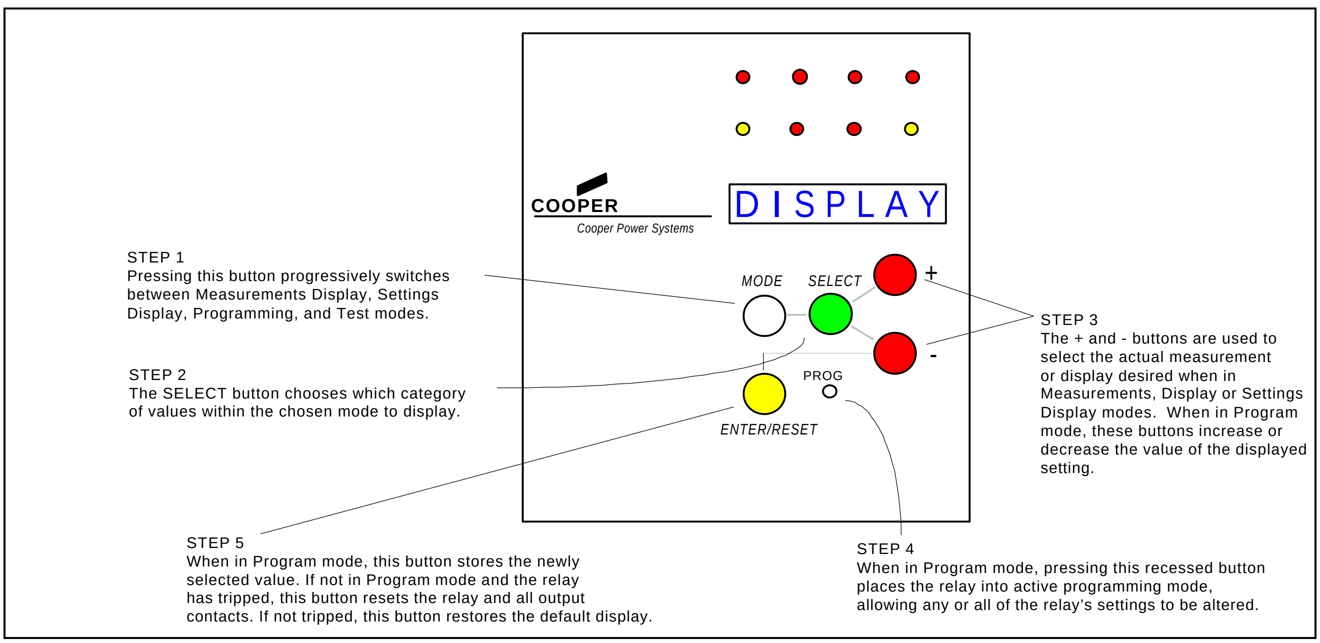


FIGURE 8: Keyboard Operation Overview

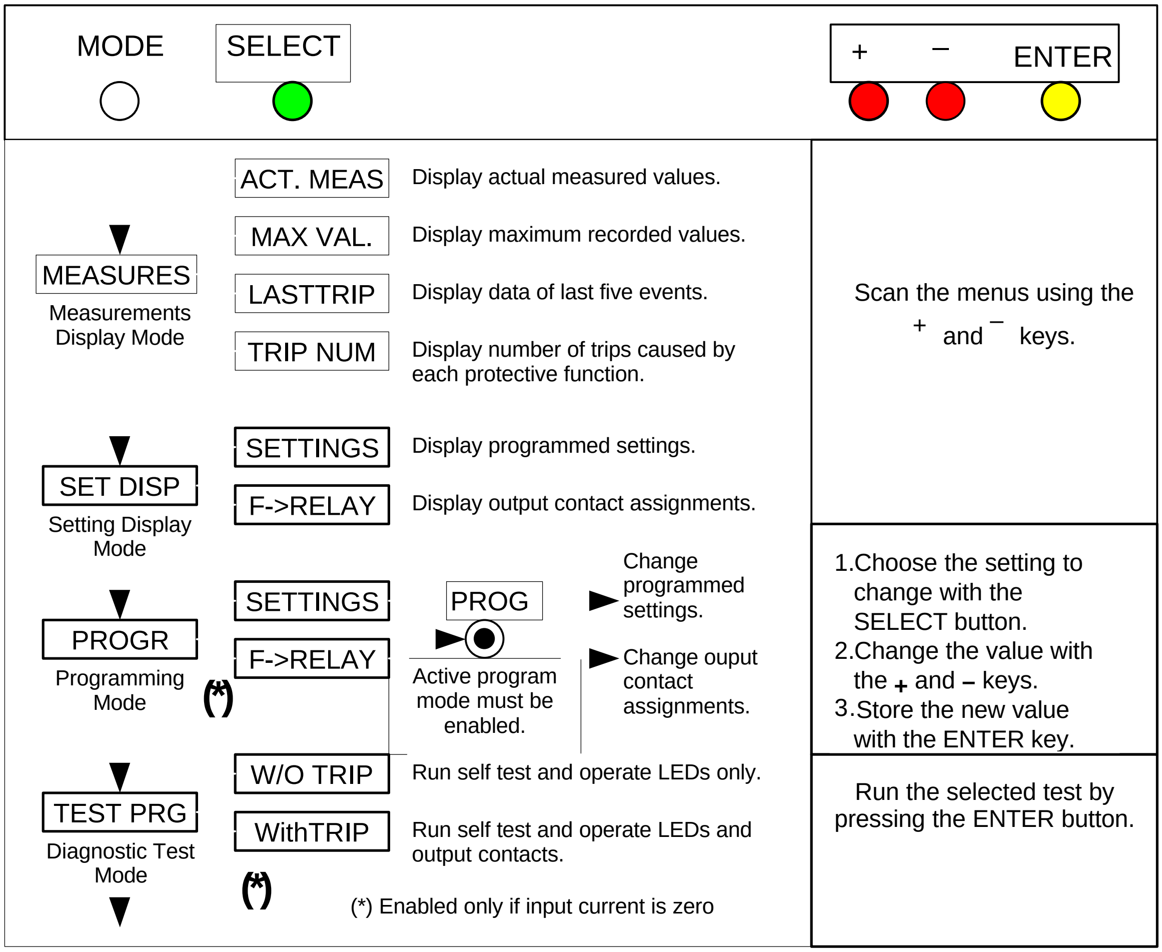


FIGURE 9: KEYBOARD MENU STRUCTURE

12. 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. If it is necessary to make setting changes while the relay is in service, the use of the optional EdisonCom software is required.
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 the **PROGRAM** mode has been successfully entered.

12.1 CHANGING A SETTING

Once you have enter the 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 (12.3). 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 – button is pressed.
3. When the desired value in displayed, press the ENTER/RESET button to store the new setting for that parameter. Press the ENTER/RESET button to store each setting change. If the ENTER/RESET button is pressed only at the end of all of the setting change, then only the last setting change will actually be changed.
4. Repeat steps 1 - 3 for each setting.

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

12.2 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. Examples of these are variables that define curve shapes.

The default value is shown in regular typeface.

For example:

In 500**Ap**

In is the name of the variable.

500 is the default setting.

Ap is the unit of measure, Amps primary.

TABLE 3: PROGRAM SETTING VARIABLES

DISPLAY	DESCRIPTION	SETTING RANGE
NodAd 1	Identification number of relay when connected on a serial communication bus.	1 to 250 in steps of 1
Fn 50 **Hz**	System frequency	50 or 60 Hz
In 500**Ap**	Rated primary current of the phase CTs	1 to 9999 Amps in 1 Amp steps
On 500**Ap**	Rated primary current of either the phase CTs or of the ground sensing CT	1 to 9999 Amps in 1 Amp steps
Im 1.0**In**	Motor full-load rated current in per unit of the phase CTs rated current (**In**)	0.1 to 1.5 pu of **In** in 0.01 steps
Ist 6**Im**	Motor starting current in per unit of the motor full-load rated current (**Im**)	0.5 to 10 pu of **Im** in 0.1 steps
tst 5**s**	Motor starting time	1 to 60 seconds in 1 second steps
ITr.5**Ist**	Motor starter switch-over current in per unit of the motor starting current (**Ist**)	0.1 to 1 pu of **Ist** in 0.1 steps, or Disable
tTr 6**s**	Maximum starting switch-over time	0.5 to 50 seconds in 0.1 second steps
Autoset?	Autoset? of all the following parameters computed on the basis of the previous settings. See **note** at end of Table. This Autoset? function is activated by pressing the **Enter** key.	
tm 34**min**	Running motor thermal time constant	1 to 60 minutes in 1 minute steps
to/tm 3	Steady motor thermal time constant in per unit of the running motor thermal time constant	1 to 10 pu of **tm** in steps of 1
Ta/n 90**%**	Pre-alarm motor heating level in percent of the full load motor temperature rise	50 to 110% of **Tn** in 1% steps
Ts/n100**%**	Motor restart heating level in percent of the full load motor temperature rise	40 to 100% of **Tn** in 1% steps
StNo 6	Maximum number of allowable consecutive motor starting attempts within the time **tStNo**	1 to 60 starts in 1 start steps, or Disable
tStNo60**m**	Time during which **StNo** is counted	1 to 60 minutes in 1minute steps
tBSt 12**m**	Attempted restarting inhibition time once **StNo** has picked up. Rm: starting is inhibited until manually reset.	1 to 60 minutes in 1minute steps, or Rm (manually reset)
ILR 2**Im**	Pick-up level of locked rotor function in per unit of the motor full-load current (**Im**). This element includes a timer (**tLR**) with a fixed setting of 1.0 second.	1 to 5 pu of **Im** in 0.1 steps, or Disable
Is> .3**Im**	Pick-up level of the inverse time current unbalance element	0.1 to 0.8 pu of **Im** in 0.1 steps, or Disable
tIs> 4**s**	Pick-up time delay of inverse time current unbalance protection element	1 to 8 seconds in 1 second steps

DISPLAY	DESCRIPTION	SETTING RANGE
I< 0.2**Im**	Pick-up level of undercurrent (loss of load) element in per unit of the motor full-load current (**Im**). This element includes a timer (**tI<**) with a fixed setting of 3.0 seconds.	0.15 to 1 pu of **Im** in 0.01 steps, or Disable
I> 2**Ist**	Pick-up level of overcurrent element in per unit of the motor starting current (**Ist**)	1 to 5 pu of **Ist** in 0.1 steps, or Disable
tI> .1**s**	Pick-up time delay of overcurrent element	0.05 to 1 second in 0.01 second steps
O> .1**On**	Pick-up level of ground fault element in per unit of the phase CTs or of the ground sensing CT rated current (**On**)	0.02 to 2 pu of **On** in 0.01 steps, or Disable
tO> .2**s**	Pick-up time delay of ground fault element	0.05 to 5 seconds in 0.01 second steps
tBO .15**s**	Output relay reset time delay - Output relays associated with time delayed functions will be forced to drop-out after this time delay, even if the pick-up cause is still present (Breaker Failure)	0.05 to 0.5 second in 0.01 second steps

NOTE: If the user wishes to use the Automatic setting feature, this can be accomplished by pressing the ENTER key for the setting **Autoset?** when programming the relay. . When the setting **Autoset?** has been selected, the relay will determine the value of **tm** and then automatically assign these values for the following elements: **to** = 3 **tm** (**to/tm** = 3), **Ta/n** = 90%, **Ts/n** = 100%, **StNo** = 6, **tStNo** = 2x**tm** = 60 (60 max.), **tBSt** = 0.33x**tm** = 12, **ILR** = 2, **Is>** = 0.3x**Im**, **tIs>** = 4 seconds, **I<** = 0.2 **Im**, **I>>** = 2 **Ist**, **tI>>** = 0.1 second, **O>** = 0.1 **On**, **tO>** = 0.2 second and **tBO** = 0.15 second. Even if the user chooses to use the **Autoset?** setting, the values for **NodAd**, **Fn**, **In**, **On**, **Im**, **Ist**, **tst**, **ITr** and **tTr** must still be determined by the customer. The **Autoset?** feature is explained more fully in Section 15.3 (Pages 31-32).

12.3 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 each setting change. If the ENTER/RESET button is pressed only at the end of all of the setting change, then only the last setting change will actually be changed.
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:

tI> -2-4

This is the name of protective element.

This dash means that output relay number 1 is not assigned to this element.

The number 4 means that output relay 4 will operate when this element trips.

This dash means that output relay number 3 is not assigned to this element.

The number 2 means that output relay 2 will operate when this element trips.

12.4 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
T> 1---	Pick-up of thermal overload element
Ta -2--	Pick-up of thermal pre-alarm element
ITr ----	Pick-up of starting sequence element
StNo ----	Pick-up of too many consecutive starting attempts element
ILR 1---	Pick-up of locked rotor element (time delay = 1 second)
tIs> 1---	Pick-up of current unbalance element
I< ---4	Pick-up of undercurrent (loss of load) element (time delay = 3 seconds)
I> ----	Pick-up of instantaneous overcurrent element
tI> 1---	Pick-up of time delayed overcurrent element
O> ----	Pick-up of ground fault overcurrent element
tO> 1---	Pick-up of time delayed ground fault overcurrent element

12.5 READING OF MEASUREMENTS AND RECORDED PARAMETERS

Enter the MODE “MEASURE”, SELECT the menus “ACT.MEAS”-“MAX VAL”-“LASTTRIP”-“TRIP NUM”, scroll the available information by using the “+” or “-” key.

12.5.1 ACT.MEAS

Actual values as measured during the normal operation. The values displayed are continuously refreshed.

TABLE 5: ACTUAL MEASUREMENTS DISPLAY

DISPLAY	DESCRIPTION
T/Tnxx0**%**	Motor temperature rise displayed as a % of the motor full load temperature rise
IAxxxx0**A**	RMS value of the primary Phase A current
IBxxxx0**B**	RMS value of the primary Phase B current
ICxxxx0**C**	RMS value of the primary Phase C current
Ioxxxx0**A**	RMS value of the primary Ground current
Id/mxx0**%**	Positive sequence component of the motor current displayed as a % of the motor full load rated current.
Is/mxx0**%**	Negative sequence component of the motor current displayed as a % of the motor full load rated current.

12.5.2 MAX VAL

Highest values recorded starting from 100ms after closing of main Circuit Breaker plus inrush values recorded within the first 100ms from Breaker closing, (refreshed any time the breaker closes).

TABLE 6: MAXIMUM VALUES DISPLAY

DISPLAY	DESCRIPTION
T/Tnxx0**%**	Highest Motor temperature recorded after starting
IAxxxx0**A**	Highest Phase A current after starting time
IBxxxx0**A**	Highest Phase B current after starting time
ICxxxx0**A**	Highest Phase C current after starting time
Ioxxxx0**A**	Highest Ground current after starting time
Id/mxx0**%**	Highest Positive sequence component of motor full load rated current after starting time
Is/mxx0**%**	Highest Negative sequence component of motor full load rated current after starting time
SAxxxx0**A**	Highest Phase A current during starting
SBxxxx0**A**	Highest Phase B current during starting
SCxxxx0**A**	Highest Phase C current during starting
SOxxxx0**A**	Highest Ground current during starting
Sd/mxx0**%**	Highest Positive sequence component of motor current during starting
Ss/mxx0**%**	Highest Negative sequence component of motor current during starting
tStxx.0**s**	Longest Starting time

12.5.3 EVENT RECORDING (LASTTRIP)

This function displays the cause of the last trip of the relay and the values of the parameters at the moment of the tripping. The memory buffer is refreshed each time the relay is tripped.

TABLE 7: Last Trip Display

DISPLAY	DESCRIPTION
Causexxx	"xxx" is the element which caused the last trip operation as follows: T> Motor overload element Is> Unbalanced current element I> Inst. overcurrent element O> Ground overcurrent element I< Undercurrent element LR Locked rotor element StN Too many starts element ITr Starting sequence element
IAxxxx0**A**	Phase A current at time of trip
IBxxxx0**A**	Phase B current at time of trip
ICxxxx0**A**	Phase C current at time of trip
Ioxxxx0**A**	Ground current at time of trip
Id/mxx0**%**	Positive sequence component of motor current at time of trip
Is/mxx0**%**	Negative sequence component of motor current at time of trip
T/Tnxx0**%**	Motor temperature rise at time of trip

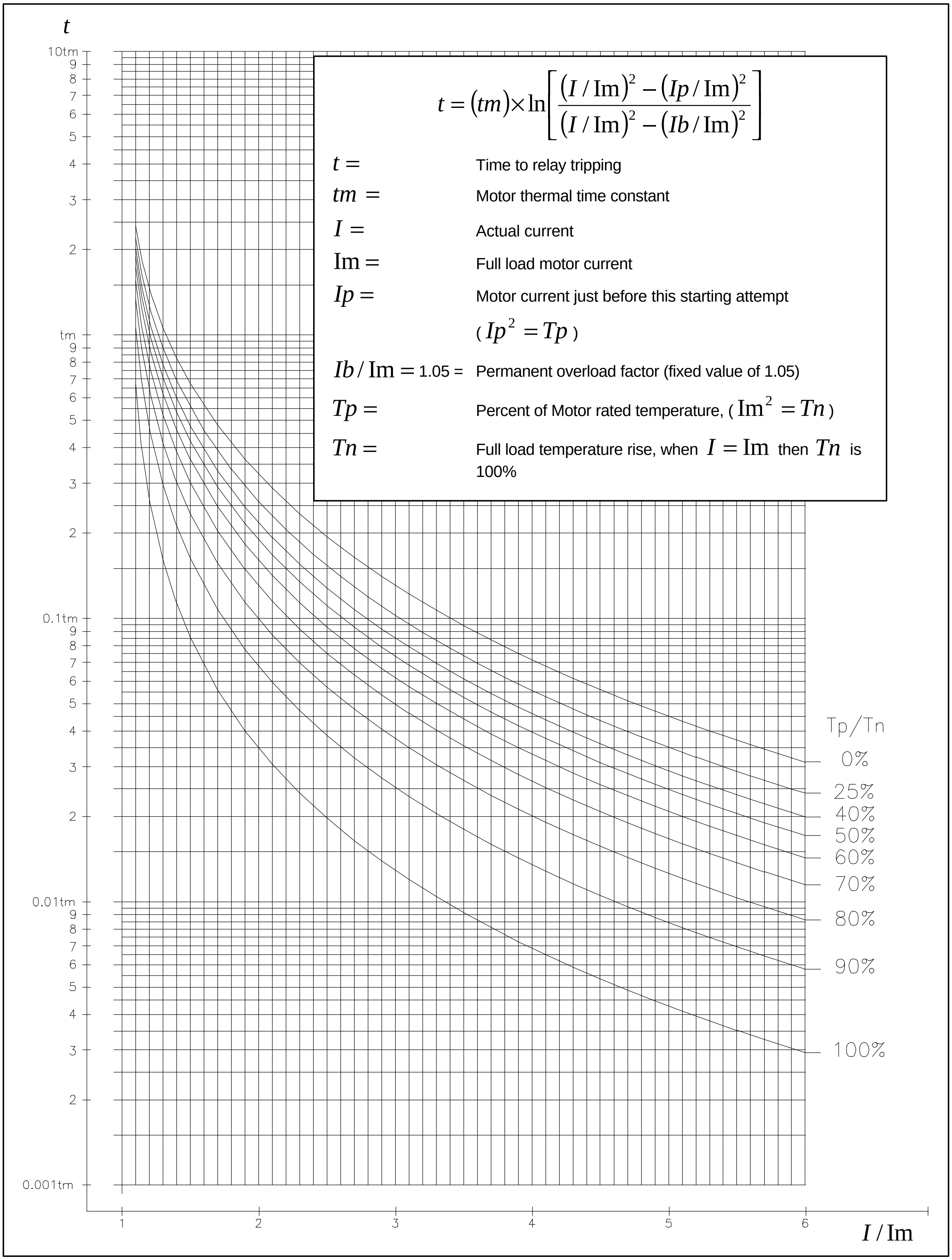
12.5.4 TRIP NUM

Counters of the number of operations for each of the relay functions.

TABLE 8: Trip Number Display

DISPLAY	DESCRIPTION
T>xxxxx0	Motor overload element
Is>xxxx0	Unbalanced current element
I>xxxxx0	Instantaneous overcurrent element
O>xxxxx0	Ground overcurrent element
I<xxxxx0	Undercurrent (loss of load) element
LRxxxxx0	Locked rotor element
StN>xxx0	Number of consecutive motor starting attempts
Itrxxxx0	Number of too long motor starting attempts.

13. THERMAL IMAGE CURVES



$$t = (tm) \times \ln\left[\frac{(I/\mathrm{Im})^2 - (Ip/\mathrm{Im})^2}{(I/\mathrm{Im})^2 - (Ib/\mathrm{Im})^2}\right]$$

$t =$ Time to relay tripping

$tm =$ Motor thermal time constant

$I =$ Actual current

$\mathrm{Im} =$ Full load motor current

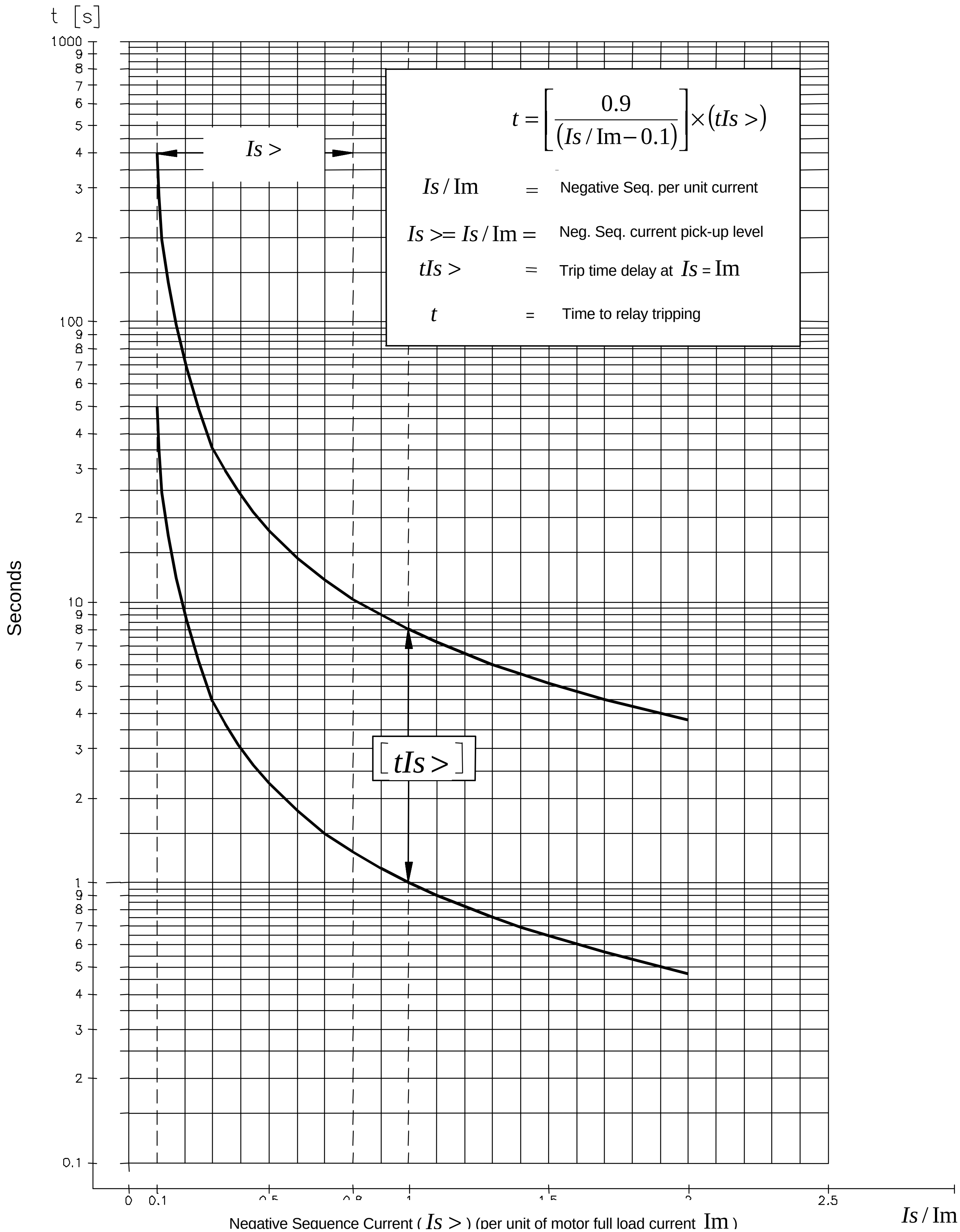
$Ip =$ Motor current just before this starting attempt ($Ip^2 = Tp$)

$Ib/\mathrm{Im} =$ 1.05 = Permanent overload factor (fixed value of 1.05)

$Tp =$ Percent of Motor rated temperature, ($\mathrm{Im}^2 = Tn$)

$Tn =$ Full load temperature rise, when $I = \mathrm{Im}$ then Tn is 100%

14. INVERSE TIME UNBALANCE PROTECTION ELEMENT



15. SETTING EXAMPLE

15.1 INTRODUCTION

The following setting example is but one procedure of how the MM30 relay element settings could be determined. This example will provide you with the basic steps required to determine settings for the MM30 relay. The motor is considered to be started across the line.

Please Note:

*The values derived in this example **should not** be used in your actual application. These values are derived to provide a general setting example. The values are determined for a specific motor which is operating under known system operating voltage levels. These settings were not derived based upon any particular setting philosophy. Your specific relay settings should be based upon your company's setting philosophy and the motor data information provided by the motor manufacturer for your specific application.*

15.2 EXAMPLE 1: DETERMINING SETTINGS WITHOUT USING (AUTOSET?)

In preparation for determining the relay's settings, you should first obtain the motor data sheets if possible. These data sheets, which contain the specifications of the motor, will be necessary to properly determine the settings.

15.2.1 STEP 1: TYPICAL DATA VALUES FROM NAMEPLATES AND DATA SHEETS

The system bus voltage values used during the motor starting condition must be determined by the customer based upon the system operating conditions which exist when the motor is started. These parameters can vary from additional loads on the motor bus; system generation, transmission and substation operating conditions; starting the largest or smallest motor on the bus and bus-tie operating conditions, etc. The following data examples are the various values from the motor nameplates/motor data sheets and some applicable general system values.

SYSTEM DATA

System bus voltage:	2.4kV
System bus voltage during starting:	2.064kV (86% of 2.4kV, 90% of 2.3kV)
CTR:	150/5

Across the line starting conditions

NAMEPLATES AND DATA SHEETS VALUES

Rated Horsepower:	600
Rated Voltage:	2300
Rated Full Load Amps:	128
Rated Locked Rotor Amps:	844
Rated Frequency:	60Hz
Phases:	3
Safe Stall Time Hot at 100% Voltage:	10 seconds
Safe Stall Time Hot at 80% Voltage:	12 seconds
Safe Stall Time Cold at 100% Voltage:	25 seconds
Safe Stall Time Cold at 80% Voltage:	29 seconds
Acceleration Time at 100% Voltage:	3.8 seconds
Acceleration Time at 90% Voltage:	5.2 seconds

Starting Limitations:

Number of starts, coasting to rest between starts:

Two starts with motor initially at ambient temperature (cold)

One start with motor at service factor operating temperature (hot)

Cooling period, after either of above and before making an additional start:

30 minutes, motor running at service factor load

20 minutes, motor running, equipment unloaded

60 minutes, motor de-energized, coasted to rest and left idle.

15.2.2 STEP 2: SYSTEM, NAMEPLATE/DATA SHEET AND GENERAL SETTINGS

The following would be the element function settings that could be determined thus far based upon the given data.

NodAd = 1 [Relay address assignment]

Fn = 60 [This is the System Frequency which should be found on the motor nameplate.]

In = 150 [Rated primary current of the phase CTs]

On = 150 [Rated primary current of the phase CTs or of the ground sensing CT] In this example the CT's are residually connected.

tst = 5 seconds [Motor starting time at 90% voltage, rounded down. This should be found on the motor data sheets provided by the manufacturer.]

Autoset? = "ENTER" key not pressed, (so will not have automatically set values) [autoset of several functions, See Section 15.3].

to/tm = 3 [This is the ratio of the cooling time of the motor. A setting of 3 is chosen to increase the cooling time when the motor is standing idle compared to when it is serving load. A ratio factor of 3 is a very common selected value for this ratio.]

Ta/n = 90 [Motor pre-alarm heating level, 90% of motor running load is a very common general alarm level, if desired.]

Ts/n = 100 [Motor restart heating level, this allows us to start the motor if the motor was just previously running at full load.]

StNo = 1 [Allows us to start the motor if the motor was just previously running at full load. This information is found on the motor nameplates or on the motor data sheets.]

tStNo = 60 [Motor cooling period after failed restart attempt. This information is found on the motor nameplates or on the motor data sheets.]

tBSt = 30 [This is the time period for which the number of attempted starts (**StNo**) is allowed. This information is found on the motor nameplates or on the motor data sheets.]

ILR = 2.0 [This element will trip the motor if the fault current exceeds the motor's locked rotor current by this multiplie. The timer **tLR** is fixed at 1.0 second.]

I< = Dis. (Undercurrent, loss of load) [This motor is not critical for serving a specific level of load.]

I> = 2 [This is the high set phase overcurrent pick-up setting, which trips at two times the actual locked rotor current **Ist**.]

tI> = 0.05 [This is the associated time delay for the **I>** function.]

O> = 0.1 [This is the pick up setting of the ground overcurrent element. A setting of 10% of **In** or 15 amps primary, 0.5 amps secondary, is a common setting.]

tO> = 0.05 [This is the associated time delay for the **O>** function.]

tBO = 0.15 [This gives 9 cycles as the breaker failure timer for this motor.].

15.2.3 STEP 3: DETERMINING THE MOTOR FULL LOAD CURRENT AND LOCKED ROTOR CURRENT

When this 600 HP motor is started on the customer's 2.4kV system, the motor bus voltage drops from 2.4kV to 2.064kV which is approximately 86% of the system's 2.4kV voltage and approximately 90% of the motor's rated voltage of 2.3kV. The actual starting voltage for each motor must be determined from the customer's system studies. The normal system voltage when this motor is running at full load will be maintained at 2.4kV. Therefore, the motor's operating parameters under these operating conditions are:

Full load current = 128 amps$\times\left(2.3kV/2.4kV\right)$=122.7$\approx$123 amps, **Im** =123/150 = 0.82

Starting current (locked rotor current) = 844 amps $\times\left(0.9\right)$=759.6$\approx$760 amps, **Ist** =(760/150)/0.82$\approx$6.2

Im = 0.82 [This is the motor's adjusted full load current. The motor's rated full load current is found on the motor nameplates or on the motor data sheets.]

Ist = 6.2 [This is the motor's adjusted locked rotor current. The motor's rated locked rotor current is found on the motor nameplates or on the motor data sheets.].

15.2.4 **STEP 4**: SELECTING THE METHOD TO BE USED TO ESTABLISH THE SETTING FOR tm

There are three different methods that could be used to determining the setting value for **tm**:

- Calculation of the Thermal Image Setting **tm** (15.2.4.1)
- Graphical Determination of the Thermal Image Setting **tm** (15.2.4.2)
- Conversions of the Thermal Image Equation to an Approximate Equivalent Singular Point of a Phase Time Overcurrent Characteristic (15.2.4.3).

The following three subsections show different methods which could be selected by the user to determine his preference for the value of **tm**. There are two different suggested setting points that could be used in this third method of determining the value of **tm**. Subsections 15.2.4.1 and 15.2.4.2 will give the user approximately equal settings as those determined by the relay if the **AUTOSET?** function were used. Subsection 15.2.4.1 details the solving of the thermal image formula to determine a value for **tm**, which has a 20% time margin above the expected starting time of the motor. Subsection 15.2.4.2 demonstrates how to interpret the thermal image curves to select a setting for **tm**, which also has a 20% time margin above the expected starting time of the motor. Subsection 15.2.4.3 details two ways to solve the thermal image formula to derive an exact setting for the value of **tm** which allows the customer to decide the amount of time margin to be above the expected starting time of the motor. These two calculations can only be done for a singular point consideration and only if there is no applicable level of negative sequence current.

15.2.4.1 **METHOD #1**: CALCULATION OF THE THERMAL IMAGE SETTING tm

The Thermal Image replication curve used to protect the motor can be set using the formula for the Thermal Image Curves shown on Page 20. The Thermal Image Curve is defined by the formula:

$$t=(tm)\times\ln\left[\frac{(I/\mathrm{Im})^2-(Ip/\mathrm{Im})^2}{(I/\mathrm{Im})^2-(Ib/\mathrm{Im})^2}\right]$$

t = the time in minutes to start the motor

I = the motor current, $I=\sqrt{\left(I_d^2+3I_s^2\right)}$

Im = the motor full load current, Im^2 is proportional to Tn

Ip = the value of current that was flowing in the motor just before this motor starting attempt, Ip^2 is proportional to Tp

Ib/Im = the fixed service factor value of 1.05.

Note that the current (I) which is used in the computation of the thermal status is not just the RMS value of the motor current but is a conventional composition of its positive (I_d) and negative sequence (I_s) current components. The following equation that defines I , takes into account the additional heating due to the negative sequence current, I_s . The current (I) is defined by the equation:

$$I=\sqrt{\left(I_d^2+3I_s^2\right)}.$$

If there is no negative sequence current, then I is equal to the positive sequence current which is either the motor load current or starting current. This is because Is = 0.0 and therefore,

$$I = \sqrt{\left(I_d^2 + 3(0)^2\right)} = \sqrt{I_d^2} = I_d .$$

Now, the motor has been running at full load before being tripped off line. When this 600 HP motor is then subsequently started on the customer's 2.4kV system, the motor bus voltage drops from 2.4kV to 2.064kV which is approximately 86% of the system's 2.4kV voltage and approximately 90% of the motor's rated voltage of 2.3kV. The normal system voltage when the motor is running at full load will be maintained at 2.4kV. Therefore, the motor's operating parameters under these operating conditions are:

Full load current = 128 amps$\times\left(2.3kV/2.4kV\right)$=122.7$\approx$123 amps

Starting current (locked rotor current) = 844 amps $\times(0.9)$=759.6$\approx$760 amps

Motor starting time at 86% of system 2.4kV voltage (90% of motor rated voltage) = 5.2 seconds.

Therefore, substituting these adjusted motor operating values into the Thermal Image Formula based upon these system operating conditions yields:

$$\frac{5.2}{60} = (tm)\times\ln\left[\frac{(760/123)^2 - (123/123)^2}{(760/123)^2 - (1.05)^2}\right]$$ which simplifies to:

0.087 minutes = **tm**$\times(0.00276)$ and thus:

tm = 0.087/0.00276 = 31.52 minutes.

Now a safety factor of 20% applied to the answer, yields a setting of **tm** = $1.2\times31.5\approx$ 37.8 or approximately 38 minutes.

The per unit values of currents (I = 760/150 $\approx$ 5.07, $\mathrm{Im} = Ip \approx$ 123/150 = 0.82) could have been substituted into the Thermal Image Formula which would have yielded the same result:

$$\frac{5.2}{60} = (tm)\times\ln\left[\frac{(5.07/0.82)^2 - (0.82/0.82)^2}{(5.07/0.82)^2 - (1.05)^2}\right]$$ which simplifies to:

0.087 minutes = **tm**$\times(0.00276)$ and thus:

tm = 0.087/0.00276 = 31.52 minutes.

Now a safety factor of 20% applied to the answer, yields a setting of **tm** = $1.2\times31.5\approx$ 37.8 or approximately 38 minutes.

tm = 38 minutes [Motor thermal time constant].

15.2.4.2 **METHOD #2: GRAPHICAL DETERMINATION OF THE THERMAL IMAGE SETTING tm**

The value determined for **tm** from this graphical method should be very similar to the value of **tm** that was just derived from the Thermal Image Formula. If the user wishes to use the Thermal Image Curves found on Page 20 rather than the formula for the Thermal Image Curves, the following would be the procedure to derive a setting for **tm**.

Step A: Referring to the Thermal Image Curves found on Page 20, we are trying to define the thermal image curve setting to protect the motor if it is started immediately after running at a rated full load condition. Since the motor was operating at rated full load, the motor is assumed to be at the rated operating temperature. Therefore, **Tp** (prior motor operating temperature, proportional to the percent of prior motor full load current-squared, **Tp**= Ip^2) is equal to **Tn** (motor rated operating temperature, proportional to the percent of motor full load current-squared, **Tp**= Im^2) and **Tp/Tn** is equal to 100%. So the 100% **Tp/Tn** curve should be used.

Step B: When the motor is restarted with no negative sequence current, the current value I will be equal to the motor's locked rotor current for a bus voltage that is 90% of the motor's rated voltage. Therefore in this example, the motor's locked rotor current is 90% of the nameplate locked rotor current of 844 amps. Thus, I (actual overcurrent value) is equal to 0.9 × 844 ≈ 760 amps. Along the X-axis of the graph on Page 20, the value of I/Im in this case is 760/123 ≈ 6.18.

Step C: Now the intersection of the **Tp/Tn** 100% curve with a value of 6.18 for I/Im on the Y-axis gives an approximate value for **t** (starting time at 90% rated motor voltage) equal to slightly less than 0.03×**tm** or approximately 0.0028×**tm**.

Step D: We know from the manufacturer's performance motor starting curves that this 600 HP motor will start in 5.2 seconds at 90% rated motor voltage. Now **t** = 0.0028×**tm**, with **t** at 90% rated voltage equal to 5.2 seconds. Therefore, **tm** = $\frac{5.2/60}{0.0028} \approx \frac{0.087}{0.0028} \approx$ 31.1.

Step E: Now a safety factor of 20% applied to the answer, yields a setting of **tm** = $1.2 \times 31.1 \approx$ 37.3 or 37 minutes.

Therefore, if the user desires an exacting value for **tm**, then the Thermal Image Formula will give a very exacting answer. The quicker method of determining the value of **tm** from the Thermal Image Curve yields just about the equivalent value for **tm**.

15.2.4.3 METHOD #3: CONVERSIONS OF THE THERMAL IMAGE EQUATION TO AN APPROXIMATE EQUIVALENT SINGULAR POINT OF A PHASE TIME OVERCURRENT CHARACTERISTIC

Under certain conditions, it is possible to approximate one point on an equivalent phase time overcurrent characteristic with the thermal image function. When we are attempting to restart the motor, given the fact that the motor has just been running at full load, then one point on the thermal image curve can be converted to an equivalent single point of a phase time-overcurrent characteristic. This specific current and corresponding time delay represents probably the most adverse starting condition. The thermal image curve can now be set to fall between the motor's starting time and the motor's safe stall hot time at the corresponding available motor terminal voltage present during starting conditions.

We recall that the current (I) which is used in the computation of the thermal status is not just the RMS value of the motor current but is a conventional composition of its positive (I_d) and negative sequence (I_s) current components and that the current (I) is defined by the equation:

$$I = \sqrt{\left(I_d^2 + 3I_s^2\right)}.$$

Now the terms in the thermal image formula can be simplified if the formula is applied for a hot motor restarting attempt. If we can assume that there is no negative sequence current flowing of any applicable degree, then the motor current I is equal to the motor's starting current that corresponds with 90% motor rated voltage. The current Ip is equal to the motor's full load current of 123 amps (as shown on Page 24).

15.2.4.3.1 TIME MARGIN SETTINGS FOR tm THAT ARE DIFFERENT THAN A 20% TIME SAFETY FACTOR

We recall that the thermal image formula is defined as:

$$t = (tm) \times \ln\left[\frac{(I/\mathrm{Im})^2 - (Ip/\mathrm{Im})^2}{(I/\mathrm{Im})^2 - (Ib/\mathrm{Im})^2}\right]$$, it simplifies to:

$$t = (38) \times \ln\left[\frac{(760/123)^2 - (123/123)^2}{(760/123)^2 - (1.05)^2}\right]$$, which yields:

$$t = (38) \times \ln\left[\frac{(760/123)^2 - (1)^2}{(760/123)^2 - (1.05)^2}\right]$$, resulting in:

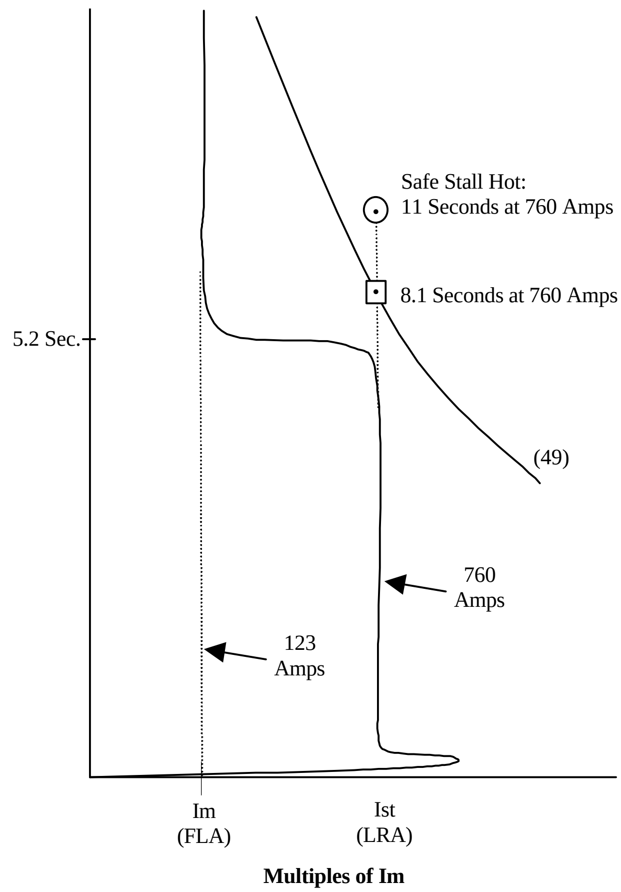
$t = 38 \times (0.00276) =$ 0.1049 minutes or approximately 6.3 seconds.

With tm = 38, this time value of 6.3 seconds indicates that the thermal image characteristic will produce a relay trip signal when 760 amps of motor starting current have existed for 6.3 seconds.

The system studies (which most be performed by the customer) have determined that the voltage on the motor bus will be 4.064kV, which is 86% of the system's 2.4kV voltage and 90% of the motor's 2.3kV voltage rating. From the motor data sheets, the starting time of this 600 HP motor with 90% motor rated voltage is 5.2 seconds. Now 760 amps for 6.3 seconds falls between 760 amps for 5.2 seconds (starting time at 90% motor voltage) and 760 amps for 11 seconds (motor safe stall time hot at 90% motor voltage). If additional starting time at any particular point is desired by the customer, then the desired motor starting time at 90% motor rated voltage (in this example) can be determined by substituting into the thermal image formula the value of t that is desired and subsequently solving for the value of tm .

15.2.4.3.2 SETTING tm TO BE HALFWAY BETWEEN THE MOTOR'S STARTING TIME AND THE MOTOR'S SAFE STALL HOT TIME

Alternately, it is also a very common practice to set the phase time overcurrent function in such a manner that the timing point of this element splits the time differential between the motor's starting time and the motor's safe stall hot time.



Motor Starting Coordination Example at one point

Setting the phase time overcurrent function between these two timing limits can be generally accomplished, provided that there is at least four (4.0) seconds time separation between these two timing limits. These two timing limits correlate directly to the motor's percent rated voltage, which is applied to the motor at the time of the motor's starting. Note that in our example, the starting time at 90% motor rated voltage is 5.2 seconds and that the motor's safe stall hot times at 100% rated voltage is 10 seconds and at 80% rated voltage is 12 seconds. It is probably safe to approximate the motor's safe stall hot time at 90% motor rated voltage to be approximately 11 seconds. Therefore, if we split the time differential between 5.2 seconds and 11 seconds, we get a result of 8.1 seconds. This would give margins of 2.9 seconds either side of starting this hot motor and before damaging the motor if it stalled during this starting attempt. Recall that this motor is being started from a prior hot or full load operating condition. Now, if one were to determine the equivalent thermal image curve setting at 8.1 seconds for a hot motor starting condition, merely substitute the same adjusted motor operating rated values into the thermal image formula. As was first shown on Page 24 in Subsection 15.2.4.1, the thermal image formula is defined by the formula:

$$t = (tm) \times \ln\left[\frac{(I/\mathrm{Im})^2 - (Ip/\mathrm{Im})^2}{(I/\mathrm{Im})^2 - (Ib/\mathrm{Im})^2}\right]$$

t = the time in minutes to start the motor

I = the motor current, $I = \sqrt{\left(I_d^2 + 3I_s^2\right)}$

Im = the motor full load current, Im^2 is proportional to Tn

Ip = the value of current that was flowing in the motor just before this motor starting attempt, Ip^2 is proportional to Tp

Ib/Im = the fixed service factor value of 1.05.

Similar to the conditions as was stated in Section 15.2.4.1 above, the motor's operating parameters under these operating conditions are:

Full load current = 128 amps$\times(2.3kV/2.4kV)$=122.7$\approx$123 amps

Starting current (locked rotor current) = 844 amps $\times(0.9)$=759.6$\approx$760 amps

Motor starting time at 86% of system 2.4kV voltage (90% of motor rated voltage) = 5.2 seconds.

However, in this calculation, we would like to set the thermal image curve to produce a trip indication by its thermal image curve at 8.1 seconds for 760 amps of current. Substituting these adjusted motor operating values into the Thermal Image Formula yields:

$$\frac{8.1}{60} = (tm) \times \ln\left[\frac{(760/123)^2 - (122.7/123)^2}{(760/123)^2 - (1.05)^2}\right].$$

Now solving for tm yields:

$$tm = \frac{8.1/60}{\ln\left[\frac{(760/123)^2 - (123/123)^2}{(760/123)^2 - (1.05)^2}\right]} \approx = \frac{0.135}{0.00276} \approx 48.9$$

and therefore, tm should be set for 49. With tm = 49, this time value of 8.1 seconds indicates that the thermal image characteristic will produce a relay trip signal when 760 amps of motor starting current have existed for 8.1 seconds.

15.2.5 <u>STEP 5</u>: DETERMINING THE NEGATIVE SEQUENCE ELEMENT SETTINGS (IS>, tIS>)

The graph on Page 21 shows the setting range for the Negative Sequence Current Time Overcurrent Element **Is>**. As is shown by the time overcurrent characteristic of the **Is>** element , the pick-up setting of the **Is>** element is the negative sequence current in percent of motor full load current for which the Negative Sequence Overcurrent Element will first begin to operate. The pick-up range of **Is>** is from 0.1 to 0.8, which is again the per unit amount of the motor's full load current **Im**. The time delay setting **tIs>** of the **Is>** element is defined as the time delay that the **Is>** element will operate at when the negative sequence current **Is>** is equal to the full load motor current **Im**. The time delay setting range of the **tIs>** element is defined to be from 1 to 8 seconds when **Is>** = **Im**. Changing the **tIs>** setting effectively shifts the response curve up or down. This then defines the negative sequence overcurrent characteristic shape given by the **Is**> and **tIs>** elements. Therefore, if **Im** = 0.82 (0.82 x **In**), **Is>** is set equal to 0.1 (0.1 x **Im**) and **tIs>** is set equal to 1 second, and if the motor experiences negative sequence current values of 1.1 x **In**, (110% of full load current), then the relay will give a trip indication at 0.9 seconds with negative sequence current equal to 110% of **In** current. Or in this example, (with **In** = 150, **Im** = 0.82 x 150 = 123 amps, **Is>** = 1.1 x 122.7 amps or approximately 135 amps and **tIs>** = 1 second), when 135 amps of negative sequence current is detected for at least 0.9 seconds duration then a negative sequence trip output signal will be produced by the MM30 relay.

The same can be accomplished by substituting these same values into the formula on Page 21 for the **I**nverse Time Unbalance Protection Element.

According to this Negative Sequence Current formula:

$$t = \left[\frac{0.9}{Is/\mathrm{Im} - 0.1} \right] \times (tIs >)$$

t = Trip time delay

tIs> = 1.0

Is = 135 amps

Im = 123 amps.

Therefore, substituting these values into this equation yields:

$$t = \left[\frac{0.9}{135/123 - 0.1} \right] \times 1.0 = \left[\frac{0.9}{1.0} \right] \times 1.0$$, results in:

$t = 0.9$ seconds.

The following would be the additional element function settings that have been derived for the MM30 relay for this example:

Is> = 0.1 (typically set between 10-20% of motor full load current)

tIs> = 1.

15.2.6 <u>STEP 6</u>: REDUCED VOLTAGE START CONSIDERATIONS

If the user will be utilizing one of the three common methods of reduced voltage motor starting, through the use of either an autotransformer, an inductor or a resistor, then the settings for the elements **ITr** and **tTr** would be defined according to the user's choice of reduced voltage starting, the voltage reduction amount and starting switch-over time. These values must be defined by the user, according to the reduced voltage starting time of the motor and the customer's pre-defined philosophy of switching this motor over to the normal operating system configuration that will be used to serve the motor during its normal running condition (serving load).

ITr = Dis. (Disabled)

tTr = 6 (default value, ITr is disabled so this does not matter).

15.2.7 STEP 7: FINALIZED SETTINGS

The following settings are the final compilations of all the final settings established in sections 15.2.1 through 15.2.6, but only for this example. The settings would be programmed into the MM30 relay in this exact order with their respective settings based upon the preceding setting example.

NodAd = 1

Fn = 60

In = 150

On = 150 (Residually connected ground overcurrent element)

Im = 122.7/150 = 0.82

Ist = 760/122.7 = 6.2

tst = 5 seconds (rounded down)

ITr = Dis. (Disabled)

tTr = 6 (default value, ITr is disabled so this does not matted)

Autoset? = “ENTER” key not pressed, (so will not have automatically set values).

tm = 38 (method #1), or 37 (method #2) or 49 (method #3)

to/tm = 3

Ta/n = 90 (90% of motor running load is a very common general alarm level, if desired)

Ts/n = 100 (this allows us to start the motor if the motor was just previously running at full load)

StNo = 1 (allows us to start the motor if the motor was just previously running at full load)

tStNo = 60

tBSt = 30 (given on motor nameplate/data sheets)

ILR = 2.0 (the timer **tLR** is fixed at 1.0 second)

Is> = 0.1 (typically set at 10% of motor full load current)

tIs> = 1

I< = Dis. (this motor is not critical for serving a specific level of motor load, the timer **tI<** is fixed at 1.0 second)

I> = 2 (this gives tripping at two times the actual locked rotor current Ist)

tI> = 0.05 (associated time delay for the I> function)

O> = 0.1 (picks up the ground overcurrent element at 10% of In or 15 amps primary, 0.5 amps secondary)

tO> = 0.05 (associated time delay for the O> function)

tBO = 0.15 (allows 9 cycles as the breaker failure timer for this motor).

15.3 EXAMPLE 2: DETERMINING SETTINGS USING (AUTOSET?)

If the user wishes to use the Automatic setting feature, this can be accomplished by pressing the ENTER key for the setting **Autoset?** when programming the relay. When the setting **Autoset?** has been selected, the relay will automatically determine the value of **tm** (**tm**=34 in this case). The value of **tm** is calculated to allow for a hot motor starting condition, the motor previous operating at its rated full load running condition. Therefore, $Ip = \mathrm{Im}$, so $Tp/Tn = (Ip/\mathrm{Im})^2 = 100\%$. In this case, referring to the thermal image formula as first described in Subsection 15.2.4.1 on Page 24:

$$t = (tm) \times \ln\left[\frac{(I/\mathrm{Im})^2 - (Ip/\mathrm{Im})^2}{(I/\mathrm{Im})^2 - (Ib/\mathrm{Im})^2}\right]$$

t = the time in minutes to start the motor

I = the motor current, $I = \sqrt{\left(I_d^2 + 3I_s^2\right)}$

Im = the motor full load current, Im^2 is proportional to Tn

Ip = the value of current that was flowing in the motor just before this motor starting attempt, Ip^2 is proportional to Tp

Ib/Im = the fixed service factor value of 1.05.

However, the relay will be using the starting time **tst** of 5 seconds (5.2 seconds rounded down), and the locked rotor to full load current ratio **Ist** is rounded down to the nearest half integer value ($I/\mathrm{Im} =$ **Ist** $= 6.2$ rounded down to 6.0). The values of **Ist** from 6.0 to 6.4 are rounded to 6.0, and the values of **Ist** from 6.5 to 6.9 are rounded to 6.5. Substituting these values into the formula yields:

$$\frac{5}{60} = (tm) \times \ln\left[\frac{(6.0)^2 - (1)^2}{(6.0)^2 - (1.05)^2}\right]$$ which simplifies to:

0.083 minutes = **tm**$\times(0.00293)$ and thus:

tm = 0.083/0.00293 = 28.3 minutes.

Now a safety factor of 20% applied to the answer, yields a setting of **tm** = $1.2 \times 28.4 \approx$ 33.96 or approximately 34 minutes.

tm = 34 minutes [Motor thermal time constant]

Even if the user chooses to use the **Autoset?** setting, the values for **NodAd**, **Fn**, **In**, **On**, **Im**, **Ist**, **tst**, **ITr** and **tTr** must still be determined by the customer. The other settings are then automatic determined based upon the value calculated for **tm** and then applied to the following elements: **to** = 3 **tm** (**to/tm** = 3), **Ta/n** = 90%, **Ts/n** = 100%, **StNo** = 6, **tStNo** = 2x**tm** = 60 (60 max.), **tBSt** = 0.33x**tm** = 12 (60 max.), **ILR** = 2, **Is>** = 0.3x**Im**, **tIs>** = 4 seconds, **I<** = 0.2 **Im**, **I>>** = 2 **Ist**, **tI>>** = 0.1 second, **O>** = 0.1 **On**, **tO>** = 0.2 second and **tBO** = 0.15 second. Therefore, if the **Autoset?** feature was used in this example, the final settings would be:

NodAd = 1

Fn = 60

In = 150

On = 150

Im = 122.7/150 = 0.82

Ist = 760/122.7 = 6.2

tst = 5 seconds (rounded down)

ITr = Dis. (Disabled)

tTr = 6 (default value, ITr is disabled so this does not matted)

Autoset? = “ENTER” key pressed, (so will have automatically set values).

tm = 34

to/tm = 3

Ta/n = 90

Ts/n = 100

StNo = 6

tStNo = 60

tBSt = 12

ILR = 2.0 (the timer **tLR** is fixed at 1.0 second)

Is> = 0.3

tIs> = 4

I< = 0.2 (the timer **tI<** is fixed at 3.0 seconds)

I> = 2

tI> = 0.1

O> = 0.1

tO> = 0.2

tBO = 0.15 (allows 9 cycles as the breaker failure timer for this motor).

16. SERIAL COMMUNICATION

The relay which is fitted with the serial communication option can be connected via a cable bus or (with proper adapters) a fiber optic bus for interfacing with a Personal Computer (type IBM or compatible).

All the operations that can be performed locally (for example reading of measured data and changing of relay’s settings) are also possible via the serial communication interface. Furthermore, the serial port allows the user to read the oscillographic recording data. The unit has a RS485 interface that can be connected either directly to a P.C. via a dedicated cable or to a RS485 serial bus. Therefore, many relays can exchange data with a single master P.C. using the same physical serial line. An optional RS485/232 converter is available.

The communication protocol is MODBUS RTU, but only functions 3, 4 and 16 are implemented. Each relay is identified by its programmable address code (NodAd) and can be called from the P.C. Dedicated communication software EdisonCom for Windows 3.11 and Windows 95 is available. Please refer to the EdisonCom instruction manual for more information. A separate Modbus communication reference manual is available. Request reference bulletin R150-05-3.

17. TEST

Besides the normal "WATCHDOG" and "POWERFAIL" functions, a comprehensive program of self-test and self-diagnostic provides:

Diagnostic and functional test: This checks the program routines and the memory content. This runs every time the auxiliary power is switched-on. The display shows the relay type and its version Number.

Dynamic functional test: This runs during the normal operation of the relay every 15 minutes. The relay is disabled for less than 10 ms. If an internal fault is detected, the display shows a fault message, the LED "**PROG/IRF**" illuminates and the relay R5 is de-energized.

Complete test: This may be activated by the keyboard or via the communication bus either with or without tripping of the output relays. The output relay assigned to reclosing is not energized during this test.

18. RUNNING THE TEST PROGRAMS

18.1 MODE "TESTPROG" SUBPROGRAM "W/O TRIP"

Operation of the yellow key activates a complete test of the electronics and the process routines.

All the LEDs are lit and the display shows (TEST RUN).

If the test routine is successfully completed, the display switches-over to the default reading (T/Tnxxx%).

If an internal fault is detected, the display shows the fault identification code and the relay R5 is de-energized. This test can be carried-out even during the operation of the relay without affecting the relay tripping in the event that a fault occurs during the test itself.

18.2 MODE "TESTPROG" SUBPROGRAM "WITHTRIP"

Access to this program is enabled only if the current detected is zero (breaker open).

After pressing the yellow key, the display shows "TEST RUN?". A second operation of the yellow key starts a complete test, which includes the activation of all of the output relays.

The display shows (TEST RUN) with the same procedure as for the test with W/O TRIP.

Every 15 minutes during the normal operation, the relay automatically initiates an auto test procedure (duration ≤ 10ms). If an internal fault is detected during the auto test, the relay R5 is de-energized, and the relevant LED is activated with the applicable fault code displayed.

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.

19. SPECIFICATIONS

Operating Temperature Range	-20 to +60°C at 95% humidity
Storage Temperature	-30 to +80°C
Rated input Current	In=1 or 5A, On=1 or 5A
Rated Input Voltage	125V
Current Overload	200A for 1 sec; 10A continuous
Voltage Circuits Overload	2.0 pu rated voltage, Continuous
Burden on current inputs	Phase: 0.01 VA at In=1A; 0.2 VA at In=5A
Burden on Voltage Inputs	0.08 VA at rated voltage
Dielectric test Voltage	2000V, 50/60Hz, 1 minute
Impulse Test Voltage	5 kV common mode, 1 kV differential mode, 1.2 x 50 µsec.
Immunity to high frequency burst	1 kV common mode, 0.5 kV differential mode at 100 kHz,
	2.5 kV common mode, 1 kV differential mode at 1 MHz
Immunity to electrostatic discharge	15 kV
Immunity to sinusoidal wave burst	100V over 10 - 1000kHz range
Immunity to radiated electromagnetic field	10V/m over 20 - 1000MHz range
Immunity to high energy burst	4 kV common mode, 2kV differential mode
Immunity to pulse magnetic field	1000 A/m, 8 x 20 seconds
Immunity to magnetic burst	100 A/m over 100 - 1000kHz range
Resistance to vibration	1g from 10 -500 Hz
Rear Connection Terminals	Up to 12AWG (4mm²) stranded wire
	Lugs up to 0.25 inch (6.5mm) wide
Output Contacts	rated current 5 A
	rated voltage 380 V
	nominal switching power with AC resistive load 1100W(380V max.)
	breaking capacity at 110 VDC: 0.3A with L/R=40ms for 100,000 operations
	make and carry capacity for 0.5 sec = 30 A (peak)
	mechanical life over 2,000,000 (2×10^6) operations
PC Board Connectors	Gold plated, 10A continuous, 200A 1 sec.
Power Supply Input Voltage Range:	Two Available at 24 - 110 V AC-DC ± 20%
	or 90 – 220 V AC-DC; ± Ave 20%
Average Power Supply consumption	8.5 VA
Weight (in single relay case)	2.3kg (5.0lbs)

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Variable	Factory default	Units	Description	Range	Step	Setting
NodAd	1	None	Modbus Communication Address	1 to 250	1	
Fn	50	Hz	System frequency	50 or 60 Hz		
In	500	amps	Rated primary current of the phase CTs	1 to 9999 Amps	1	
On	500	amps	Rated primary current of the phase CTs or of the ground sensing CT	1 to 9999 Amps	1	
Im	1	p.u.- amps	Motor full-load current in per unit of the phase CTs rated current (**In**)	0.1 to 1.5 pu of In	0.01	
Ist	6	p.u.- amps	Motor starting current in per unit of the motor full-load current (**Im**)	0.5 to 10 pu of Im	0.1	
tst	5	seconds	Motor starting time	1 to 60 seconds	1	
ITr	0.5	p.u.- amps	Motor starter switch-over current in per unit of the motor starting amps (**Ist**)	0.1 to 1 pu of Ist	0.1	
tTr	6	seconds	Maximum starting switch-over time	0.5 to 50 seconds	0.1	
			Autoset of all the following parameters computed based upon the above settings.	Autoset? + Enter		
tm	34	minutes	Running motor thermal time constant	1 to 60 minutes	1	
to/tm	3	None	Steady motor thermal time constant in per unit of the running motor thermal time constant	1 to 10 pu of tm	1	
Ta/n	90	%	Pre-alarm motor heating level in percent of the full load motor temperature rise	50 to 110% of Tn	1%	
Ts/n	100	%	Motor restart heating level in percent of the full load motor temperature rise	40 to 100% of Tn	1%	
StNo	6	None	Maximum # of starts allowed in time **tStN**	1 to 60 starts, or Dis.	1	
tStNo	60	minutes	Time during which **StNo** is counted	1 to 60 minutes	1	
tBSt	12	minutes	Restart inhibition time after Pick-up of **StNo**	1 to 60 minutes, or RM (manual reset)	1	
ILR	2	p.u.- amps	Pick-up level of locked rotor function in per unit of the motor full-load current (**Im**)	1 to 5 pu of Im , or Dis.	0.1	
Is>	0.3	p.u.- amps	Pick-up level of inverse time current unbalance protection element in per unit of the motor full-load current (**Im**)	0.1 to 0.8 pu of Im, or Dis.	0.1	
tIs>	4	seconds	Pick-up time delay of inverse time current unbalance protection element	1 to 8 seconds	1	
I<	0.2	p.u.- amps	Pick-up level of undercurrent (loss of load) element in per unit of the motor full-load current (**Im**)	0.15 to 1 pu of Im, or Dis.	0.01	
I>	2	p.u.- amps	Pick-up level of overcurrent element in per unit of the motor starting current (**Ist**)	1 to 5 pu of Ist, or Dis.	0.1	
tI>	0.1	seconds	Pick-up time delay of overcurrent element	0.05 to 1 second	0.01	

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Variable	Factory default	Units	Description	Range	Step	Setting
O>	0.1	p.u.- amps	Pick-up level of ground fault element in per unit of the phase CTs or of the ground sensing CT rated current (**On**)	0.02 to 2 pu of On, or Dis.	0.01	
tO>	0.2	seconds	Pick-up time delay of ground fault element	0.05 to 5 seconds	0.01	
tBO	0.15	seconds	Output relay reset time delay - Output relays associated with time delayed functions will be forced to drop-out after this time delay, even if the pick-up cause is still present (Breaker Failure)	0.05 to 5 seconds	0.01	

OUTPUT RELAY PROGRAMMING ASSIGNMENTS (ACCESSIBLE VIA THE F→Relay PROGRAM MODE.)

Variable	Factory default	Units	Description	Range	Setting
T>	1---	Outputs	Pick-up of thermal overload element	1 2 3 4	
Ta	-2--	Outputs	Pick-up of thermal pre-alarm element	1 2 3 4	
ITr	----	Outputs	Pick-up of incomplete starting sequence element	1 2 3 4	
StNo	----	Outputs	Pick-up of too many attempted consecutive starts element	1 2 3 4	
ILR	1---	Outputs	Pick-up of locked rotor element	1 2 3 4	
tIs>	1---	Outputs	Pick-up of time delayed current unbalance element	1 2 3 4	
tI<	---4	Outputs	Pick-up of time delayed undercurrent (loss of load) element	1 2 3 4	
I>	----	Outputs	Pick-up of instantaneous overcurrent element	1 2 3 4	
tI>	1---	Outputs	Pick-up of time delayed overcurrent element	1 2 3 4	
O>	----	Outputs	Pick-up of ground fault overcurrent element	1 2 3 4	
tO>	1---	Outputs	Pick-up of time delayed ground fault overcurrent element	1 2 3 4	

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