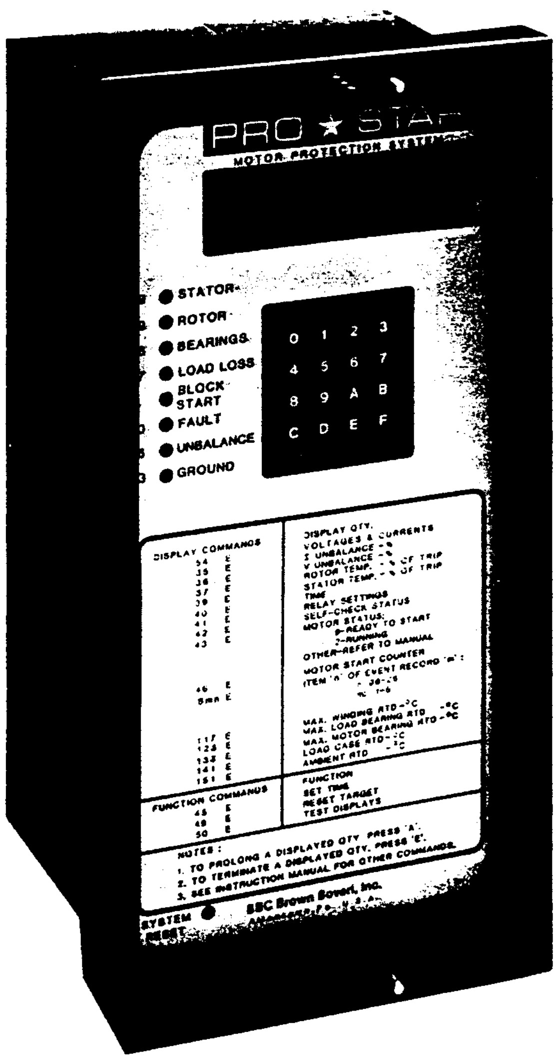
IB-7.11.1.7-3
Issue A

INSTRUCTIONS

PRO*STAR Motor Protection System

Pro*Star(TM) Motor Protection System



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INTRODUCTION

These instructions contain the information required to properly install, operate, and test the PRO-STAR Microprocessor Based Motor Protection System. The unit provides twelve motor protection functions in one integrated package. Various metering and recording functions give the user a picture of the operating history of the motor that is unvavailable with conventional protective relays.

The unit is packaged in a metal case suitable for conventional semi-flush mounting on a panel. All connections to the unit are made at terminals located on the rear of the case which are clearly identified. A standard connector is provided for an RS-232-C communications link.

Various displays may be called up for observation by operating personnel by means of the keypad on the front of the unit; however, a password is required to change settings. Access may also be gained via the communications link from a terminal. Information transmitted to the terminal is more "user friendly" than can be provided on the built-in display.

PRECAUTIONS

The following precautions should be taken when applying this unit:

1. Incorrect wiring may result in damage. Be sure wiring agrees with connection diagram before energizing.

2. Apply only the rated control voltage marked on the front panel.

3. High voltage insulation tests are not recommended. If a control wiring insulation test is required, connect all terminals together before applying test voltage.

4. Follow test instructions to verify proper operation. CAUTION: Since troubleshooting entails working with energized equipment, caution should be taken to avoid personal shock. Only competent technicians familiar with good safety practices should service these devices.

5. This relay is voltage and current phase rotation sensitive and polarity sensitive. Incorrect wiring will result in improper relay operation.

6. In the event the self-checking function detects a system failure, the protective functions are disabled and the alarm contacts are actuated. Replacement of the unit should be made as soon as possible.

7. The correct passwords are required to make changes in the relay settings and to remotely stop and start the motor. Once the user chooses his own passwords and enters them into the system, access will be prohibited if the passwords are forgotten. In this event, contact the factory.

APPLICATION DATA

The Microprocessor-based Motor Protection System is designed for the protection of one induction motor. The unit operates from standard 5 ampere secondary CT's, 120 VAC secondary VT's and resistance temperature devices. The unit takes advantage of the power of the microprocessor to provide in one integrated package the following protection, control, and monitoring functions:

- Stator Overtemperature Protection: RTD's & Stator Thermal Model
- Rotor Overtemperature Protection: Rotor Thermal Model
- Block Start Protection: Rotor Overtemperature & Phase Reversal
- Ground Overcurrent Protection: Definite Time
- Load Jam (Overcurrent) Protection: Definite Time
- Instantaneous Overcurrent Protection
- Load Loss (Undercurrent) Protection: Definite Time
- Phase Current Unbalance Protection: Definite Time
- Instantaneous Phase Reversal Protection
- Load Bearing Overtemperature Protection: RTD's
- Motor Bearing Overtemperature Protection: RTD's
- Load Case Overtemperature Protection: RTD's
- Ammeter: Phase Currents
- Voltmeter: Line to Line Voltages
- Event Recording
- Continuous Self-checking
- RS-232-C Communications Port for Remote Terminal Connection

STATOR OVERTEMPERATURE PROTECTION (49)

The user has the choice of using from one (1) to six (6) stator winding RTD's. The stator winding RTD's can be 10 ohm copper, 100 ohm platinum, 100 ohm nickel, or 120 ohm nickel (reference setting number 24). All three terminals (+, -, G) of any unused RTD inputs MUST be shorted together.

Tripping will occur when the measured temperature exceeds the trip temperature setting. The trip temperature setting is adjustable from 10 to 200 degrees C. An alarm will occur when the measured temperature exceeds the alarm temperature setting. The alarm temperature setting is adjustable from 2 to 20 degrees C below the trip setting (reference setting numbers 29 and 30).

An alarm will actuate the RTD ALARM output contacts and the front panel display will flash "30" and the measured temperature. A trip will set the STATOR (49) target and will actuate the MOTOR STOP output contacts.

The stator thermal model is shown in Figure 1. Settings associated with the parameters of the stator model are:

- 00 Motor Current in Per Unit at Stator Thermal Limit Times
- 01 Stator Thermal Limit Time in Seconds When Motor Starts from Operating Temperature
- 02 Stator Thermal Limit Time in Seconds When Motor Starts from Ambient Temperature
- 03 Stator Thermal Limit in Degrees C.
- 04 Winding RTD Time Constant in Seconds
- 14 Full Load Motor Current in CT Secondary Amperes

During motor starting, stator heating is considered adiabatic. When the motor is running, stator heat is dissipated to the ambient and the winding RTD measurements are used to correct the temperature estimated by the thermal model. Tripping will occur during the starting or running condition when the estimated stator conductor temperature exceeds the stator starting trip threshold or the stator running trip threshold, respectively. The trip thresholds are set as a per unit value of the stator thermal limit (reference setting numbers 11 and 12). Tripping on the above functions sets the STATOR (49) target and actuates the MOTOR STOP contacts. NOTE: <u>After a motor start, the stator starting trip threshold is used until the estimated stator temperature drops below 90% of the stator running trip threshold</u>.

ROTOR OVERTEMPERATURE PROTECTION (49)

The rotor thermal model is shown in Figure 2. Settings associated with the parameters of the rotor thermal model are:

05 Motor Current in Per Unit at Rotor Thermal Limit Times
06 Rotor Thermal Limit Time in Seconds When Motor Starts from Operating Temperature
07 Rotor Thermal Limit Time in Seconds When Motor Starts From Ambient Temperature
08 Rated Slip in Per Unit (Running Rotor Resistance)
09 Locked Rotor Resistance in Per Unit (At Slip = 1)

The motor current and terminal voltage are used to determine the slip dependent rotor resistance. The rotor thermal model takes into account the slip dependent heat source, including the effects of both positive and negative sequence currents, and the heating of prior operations. The thermal model produces an estimated rotor temperature which is valid for the entire operating cycle. Tripping will occur when the estimated rotor temperature exceeds the rotor trip threshold. The trip threshold is set as a per unit value of the rotor thermal limit (reference setting number 10). Tripping sets the ROTOR (49) target and the BLOCK START (5) target, and actuates the MOTOR STOP contacts. The Motor Stop contacts will remain actuated and the Block Start target will remain lit until the estimated rotor temperature falls below the block start threshold which is also set as a per unit value of the rotor thermal limit (reference setting number 13).

GROUND OVERCURRENT PROTECTION (50G)

A definite-time ground-overcurrent function is provided to detect a ground fault condition. The ground current sensor (400:1 ratio) is connected to terminals 7 and 8. The ground current pickup setting is in primary amperes and is adjustable from 5 to 50 amperes in steps of 1. The definite-time delay is adjustable from 0.04 to 1.00 seconds in steps of 0.01 (reference setting numbers 15 and 16). Tripping by this function sets the GROUND (50G) target and actuates the MOTOR STOP contacts.

LOAD JAM (OVERCURRENT) PROTECTION (48)

A second definite-time overcurrent function is provided to detect a load jam condition. This function is instituted only after the motor has started. The load jam pickup current setting is in MULTIPLES of the motor's full load current. The pickup adjustment range is 1 to 10X in steps of 1 and the definite-time delay is adjustable from 0.5 to 10.0 seconds in steps of 0.1 (reference setting numbers 17 and 18). Tripping by this function sets the ROTOR (49) target and actuates the MOTOR STOP contacts.

INSTANTANEOUS OVERCURRENT PROTECTION (50)

Instantaneous overcurrent protection is provided to detect phase fault conditions. The instantaneous overcurrent pickup setting is in MULTIPLES of the motor's full load current. The pickup adjustment range is 1 to 10X in steps of 1 (reference setting number 19). Tripping by this function sets the FAULT (50) target and actuates the MOTOR STOP contacts.

LOAD LOSS (UNDERCURRENT) PROTECTION (37)

A definite-time undercurrent function is provided to detect a loss of load condition. The load loss pickup current setting is in MULTIPLES of the motor's full load current. The pickup adjustment range is 0.00 to 1.00X in steps of 0.01 and the definite time delay is adjustable from 1.0 to 20.0 seconds in steps of 0.1 (reference setting numbers 20 and 21). Tripping by this function sets the LOAD LOSS (37) target and actuates the MOTOR STOP contacts.

PHASE CURRENT UNBALANCE PROTECTION (46)

A definite-time negative sequence overcurrent function is provided to detect an unbalanced current condition. The negative sequence current pickup setting is in MULTIPLES of the motor's full load current. The pickup adjustment range is 0.10 to 0.50X in steps of 0.01 and the definite-time delay is adjustable from 0.05 to 5.00 seconds in steps of 0.01 (reference setting numbers 22 and 23). Tripping by this function sets the UNBALANCE target (46) and actuates the MOTOR STOP contacts.

INSTANTANEOUS PHASE REVERSAL PROTECTION

An instantaneous negative sequence overvoltage function is provided to detect a reverse phase condition. Tripping on this function occurs when the negative sequence voltage (V2) is greater than the positive sequence voltage (V1). No settings are required. Operation is instantaneous and self-resetting. Tripping sets the UNBALANCE (46) and the BLOCK START (5) targets and actuates the MOTOR STOP contacts. The Motor Stop contacts will remain actuated and the Block Start target will remain lit until the proper phase sequence is established.

LOAD BEARING OVERTEMPERATURE PROTECTION (38)

There are two (2) load bearing RTD inputs. The RTD's can be one of four different types (reference setting number 25). Tripping occurs when the measured temperature exceeds the trip temperature setting. The trip temperature setting is adjustable from 10 to 200 degrees C. An alarm will occur when the measured temperature exceeds the alarm temperature setting. The alarm temperature setting is adjustable from 2 to 20 degrees C below the trip setting (reference setting numbers 31 and 32). An alarm will actuate the RTD ALARM contacts and the front panel display will flash "32" and the measured temperature. A trip will set the BEARING (38) target and will actuate the MOTOR STOP contacts.

MOTOR BEARING OVERTEMPERATURE PROTECTON (38)

There are two (2) motor bearing RTD inputs. The RTD's can be one of four different types (reference setting number 26). Tripping occurs when the measured temperature exceeds the trip temperature setting. The trip temperature setting is adjustable from 10 to 200 degrees C. An alarm will occur when the measured temperature exceeds the alarm temperature setting. The alarm temperature setting is adjustable from 2 to 20 degrees C below the trip setting (reference setting numbers 33 and 34). An alarm will actuate the RTD ALARM contacts and the front panel display will flash "34" and the measured temperature. A trip will set the BEARING (38) target and will actuate the MOTOR STOP contacts.

LOAD CASE OVERTEMPERATURE PROTECTION (38)

There is one (1) load case RTD input. The RTD's can be one of four different types (reference setting number 27). Tripping occurs when the measured temperature exceeds the trip temperature setting. The trip temperature setting is adjustable from 10 to 200 degrees C. An alarm will occur when the measured temperature exceeds the alarm temperature setting. The alarm temperature setting is adjustable from 2 to 20 degrees C below the trip setting (reference setting numbers 35 and 36). An alarm will actuate the RTD ALARM contacts and the front panel display will flash "36" and the measured temperature. A trip will set the BEARING (38) target and will actuate the MOTOR STOP contacts.

AMMETER AND VOLTMETER FUNCTIONS

These functions allow the user to display the phase currents (IA, IB, IC) in primary amperes and the line to line voltages (VAB, VBC) in primary volts. For these functions to be active, the user MUST enter the CT Ratio, VT Ratio and the Input Voltage (KV) (reference setting numbers 37, 38 and 39). Note: If the CT ratio, VT ratio or input voltage is not entered into the settings, then all current and voltage metering functions and event recording will show incorrect values.

EVENT RECORDING AND REPORTING

Reference the COMMAND Table for the form of the trip event record. Five trip events are retained, with the oldest deleted as new trips occur. An internal clock is provided to tag the trip events as they occur. The user must set the clock when the system is placed in service. Also, if control power is interrupted, the clock is lost and must be reset. The clock reads in days (1-365 or 366 for leap year), hours (0-23), minutes (0-59), and seconds (0-59).

A motor start event record is also available. This record contains information for the most recent motor start. This information includes the motor speed, estimated rotor temperature as a percent of the trip threshold, and the estimated stator temperature in degrees C and as a percent of the trip threshold. These values are given at 0.5 second intervals until the motor current has decreased to less than two (2) per unit. The motor start record is stored in a RAM , is updated with each motor start, and is lost when external control power is removed.

SELF-CHECKING FUNCTION

The system provides continuous self-checking of its internal power supply voltages, memory elements, A/D converter, and the microprocessor. In the event of a system failure, the protective functions are disabled and the self-check alarm contacts are actuated. Except in the case of a "processor stalled" condition, you can interrogate the unit to determine which self-check problem has occurred. The self-check Status Command is "42".

TARGET INDICATORS

Light-emitting diode (LED) target indicators are provided to indicate the type of fault that caused a trip. The target displayed represents the last tripping event, except in the case of the BLOCK START condition. When the BLOCK START condition resets, the target display will revert to the last trip event. Previous trips may be viewed by interrogating the trip event record. A target may be cleared by entering the target reset command "49".

SYSTEM RESET

A button labeled SYSTEM RESET is located on the lower left side of the front panel. This is NOT a target reset function. SYSTEM RESET resets the microprocessor to the start of its program. System reset can be attempted should the processor enter a stall condition. The relay settings, baud rate selection and passwords are not affected; however, the most recent trip event record, estimated rotor and stator temperatures, and motor start count may be lost upon actuation.

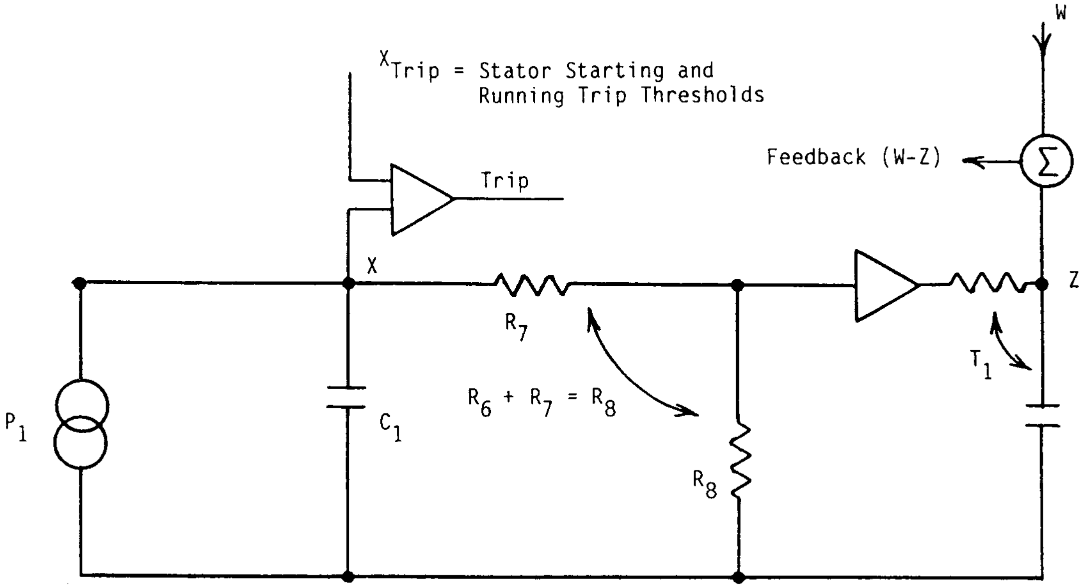
NON-VOLATILE MEMORY

A non-volatile memory retains vital information upon loss of control power. This information includes the relay settings, trip event record, passwords, baud rate, estimated rotor and stator temperatures, and the number of motor starts.

RATINGS AND TOLERANCES

Phase Current Input Circuits	
Rating	16A Continuous and 450A for 1 Second
Burden	0.043VA @ 5A (0.0017 ohm resistance)
Frequency	Models available for 50 Hz and 60 Hz nominal
Input Voltage Circuits:	
Rating	160 VAC Continuous
Burden	0.075 VA @ 120 VAC
Ground Current Input Circuit:	
Ground Sensor	Type GS (400:1 Ratio)
Current Range	5-50A primary
Control Power (Models Available For):	
	125 VDC @ 0.15A maximum (range 100 - 140 VDC); 120 VAC @ 0.17A maxixum (range 90 - 140 VAC)
	48 VDC @ 0.35A maximum (range 38 - 56 VDC)
Operating Temperature Range:	-20 to +70 degrees C
Tolerances (For 60 Hz Models at 60 Hz, Over Temperature Range -20 to +55 degrees C):	
Clock	Less than +/- one (1) minute per month over the operating temperature range of -20 to +70 degrees C.
Ammeter Function	+/-3% of full load current for FLC setting greater than or equal to 2 amperes and CT ratio greater than 50.
Voltmeter Function	+/-2% of VT primary voltage.
Phase Angle	+/-2 degrees.
Output Contacts:	@ 125 VDC 30A tripping 5A continuous 1A break resistive .3A break inductive
Dielectric:	1500 VAC, 1 minute test, all circuits to ground.
Electromagnetic Environment:	10V/M, 27 MHz to 1000 MHz (ANSI C37.90.2).
Transient Immunity:	3000V, 1 MHz bursts at 60 Hz repetition rate, (ANSI C37.90a SWC).

FIGURE 1: STATOR THERMAL MODEL



$I_S^2t =_{AS}$ Stator Thermal Limit

t_{AS} = Thermal Limit Time from Ambient Temperature

t_{OS} = Thermal Limit Time from Operating Temperature

I_S = Stator Current at t_{AS} and t_{OS}

$R_6 = I_S^2\,(t_{AS} - t_{OS})$ = Operating Temperature (Thermal Resistance to Ambient)

$C_1 = 1$ = Conductor Thermal Capacitance

$P_1 = I_1^2 + I_2^2$ = Heat Loss

I_1 = Stator Positive Sequence Current

I_2 = Stator Negative Sequence Current

$X = (1 - T/R_6C_1)X_0 + (T/C_1)P$ = Estimated Stator Temperature

$X_0 = X + K_1(W - Z)$ = Stator Initial Temperature

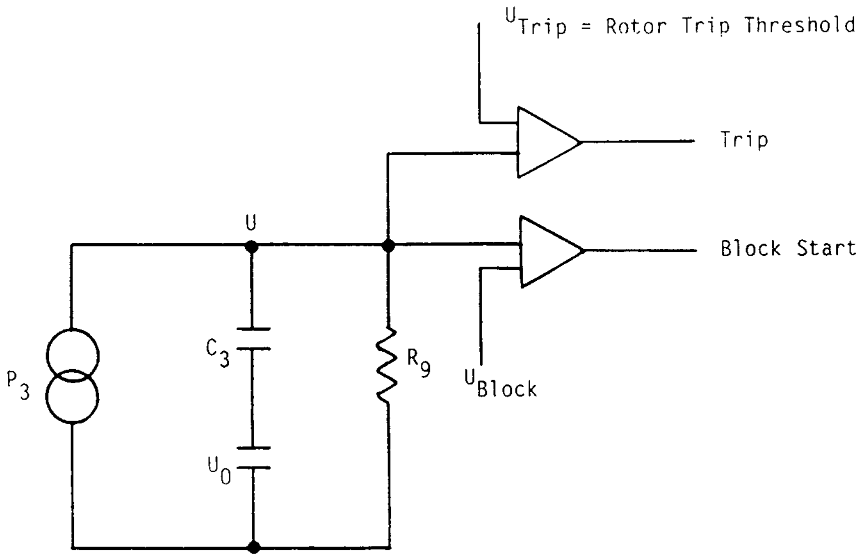
W = Measured RTD Temperature

Z = Estimated RTD Temperature

T_1 = RTD Time Constant

T = Sampling Interval (0.1 seconds)

FIGURE 2: ROTOR THERMAL MODEL



$I_R^2\, t_{AR}$ = Rotor Thermal Limit

t_{AR} = Thermal Limit Time from Ambient Temperature

t_{OR} = Thermal Limit Time from Operating Temperature

I_R = Locked Rotor Current at $t_{AR} + t_{OR}$

$R_9 = I_R^2(t_{AR} - t_{OR})$ = Operating Temperature (Thermal Resistance to Ambient)

$C_3 = R_1/R_0$ = Conductor Thermal Capacitance

$P_3 = I_4^2(R_4/R_0) + I_5^2(R_5/R_0)$ = Heat Loss

$I_4 = I_1/A$ = Rotor Positive Sequence Current

$I_5 = I_2/A$ = Rotor Negative Sequence Current

R_0 = Rated Slip

R_1 = Rotor Resistance at Slip Equals 1

$R_4 = (R_1 - R_0)S + R_0$ = Rotor Positive Sequence Resistance

$R_5 = (R_1 - R_0)(2 - S) + R_0$ = Rotor Negative Sequence Resistance

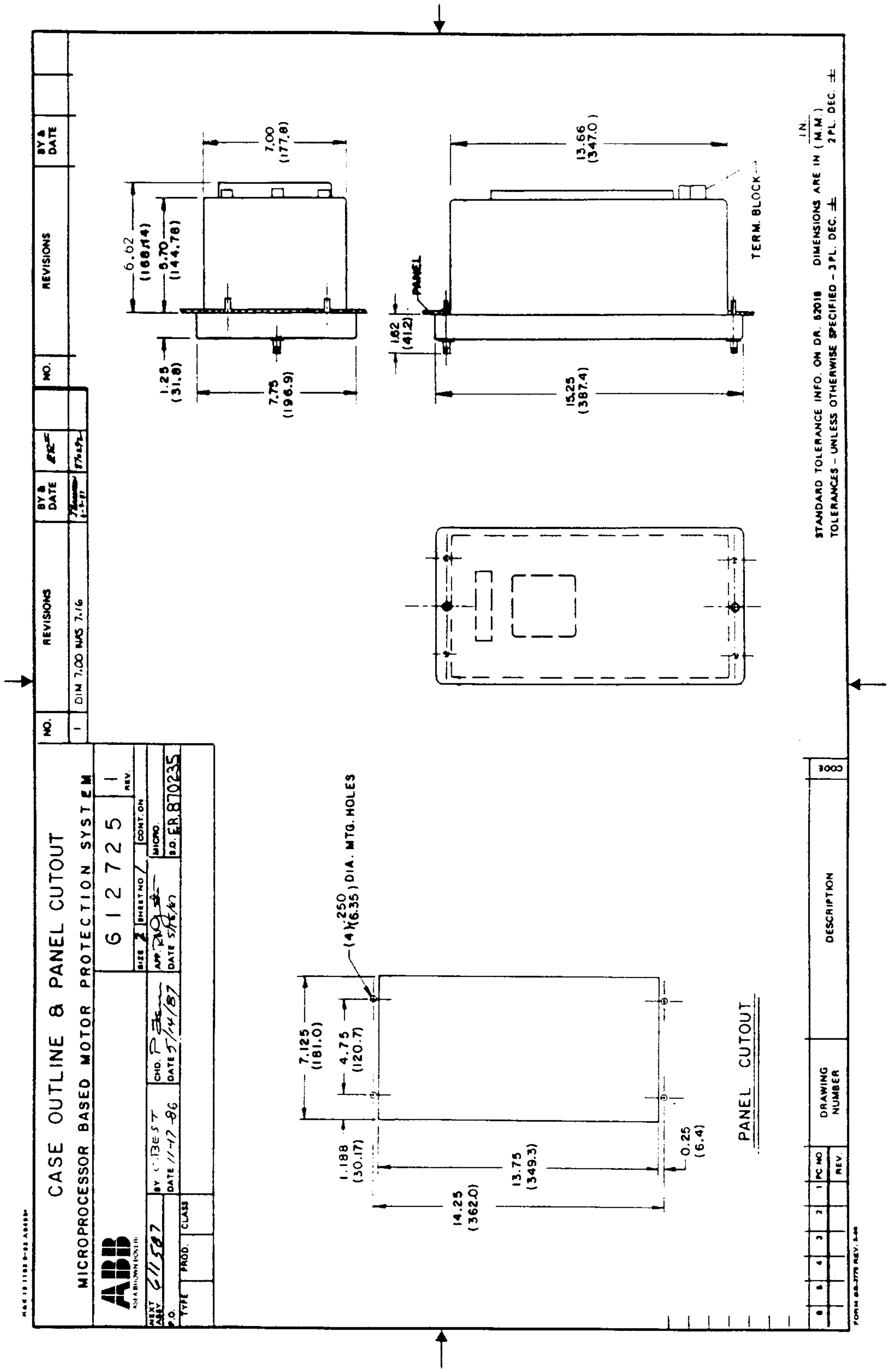
S = Motor Slip

$U = (1 - T/R_9C_3)U_0 + (T/C_3)\, P_3$ = Estimated Rotor Temperature

U_0 = Rotor Initial Temperature

T = Sampling Interval (0.1 seconds)

FIGURE 3


CASE OUTLINE & PANEL CUTOUT
MICROPROCESSOR BASED MOTOR PROTECTION SYSTEM
612725
REVISIONS
DIM 7.00 WAS 7.16
7.00 (177.8)
6.62 (168.14)
5.70 (144.78)
1.25 (31.8)
7.75 (196.9)
13.66 (347.0)
1.62 (41.2)
15.25 (387.4)
PANEL
TERM. BLOCK
(4) .250 (6.35) DIA. MTG. HOLES
7.125 (181.0)
4.75 (120.7)
1.188 (30.17)
13.75 (349.3)
14.25 (362.0)
0.25 (6.4)
PANEL CUTOUT
STANDARD TOLERANCE INFO. ON DR. 52018 DIMENSIONS ARE IN IN. (M.M.)
TOLERANCES - UNLESS OTHERWISE SPECIFIED - 3 PL. DEC. ± 2 PL. DEC. ±
DRAWING NUMBER
DESCRIPTION

PLACING THE SYSTEM INTO SERVICE

1. RECEIVING, HANDLING, STORAGE

Upon receipt of the system (when not included as part of a switchboard) examine for shipping damage. If damage or loss is evident, file a claim at once and promptly notify the nearest BBC Brown Boveri sales office. Keep the unit clean and dry and use normal care in handling to avoid mechanical damage.

2. INSTALLATION

Mounting: The outline dimensions and panel drilling and cutout information is given in Figure 3.

3. CONNECTIONS

Apply only the rated control voltage marked on the front of the unit. The system is enclosed in a metal case. A ground stud is provided on the rear of the case. This ground stud must be wired directly to the equipment ground bus with at least a #10 AWG wire less than 5 feet long.

Typical connections are shown in Figure 4. Current transformer and voltage transformer polarities and phase rotation must be observed for proper relay operation. These connections are the minimum necessary for a functioning system.

Phase Current Inputs	IA: Terminals 1 and 2. IB: Terminals 3 and 4. IC: Terminals 5 and 6. Accepts current inputs from standard 5A secondary CT's
Ground Current Input	IO: Terminals 7 and 8. Accepts a current input from a BBC type GS ground sensor (400:1 ratio)
Line to Line Voltage Inputs	VAB: Terminals 9 and 10, respectively. VBC: Terminals 10 and 11, respectively. Accepts voltage inputs from standard 120 VAC secondary VT's
Motor Stop Output Contacts	Two (2) Form C: Terminals 49, 50, 51, 52, 53, and 54. The motor stop contacts are actuated from the protective functions. The contacts are actuated until the Motor Stops or until the Block Start condition is corrected. The motor stop contacts will also actuate on command through the serial port. A password, separate from that used to make settings, is required.
Self-Check Alarm	One (1) Form C: Terminals 64, 65, and 66. These output contacts change state on a loss of DC control power or on a failure status of a specific self-test. A contact should be connected to a local annunciator light or; if available, to a remote terminal unit.

OPTIONAL CONNECTIONS

RTD INPUTS - Terminals 13 through 48. Six (6) for stator winding RTD's; two (2) for load bearing RTD's; two (2) for motor bearing RTD's; one (1) for load case RTD's, and one (1) for ambient temperature RTD. The unit accepts 10 ohm copper, 100 ohm platinum, 100 ohm nickel and 120 ohm nickel RTD's. All three terminals (+, -, G) of any unused RTD inputs MUST be shorted together.

RTD ALARM OUTPUT CONTACTS - One (1) Form C: Terminals 58, 59, and 60.
The RTD alarm contacts are actuated when a measured temperature exceeds the alarm temperature setting. The RTD alarm contacts self-reset when the measured temperature falls approximately 2 degrees C below the alarm temperature setting. NOTE: An open RTD also actuates the RTD alarm output contacts.

FIGURE 4

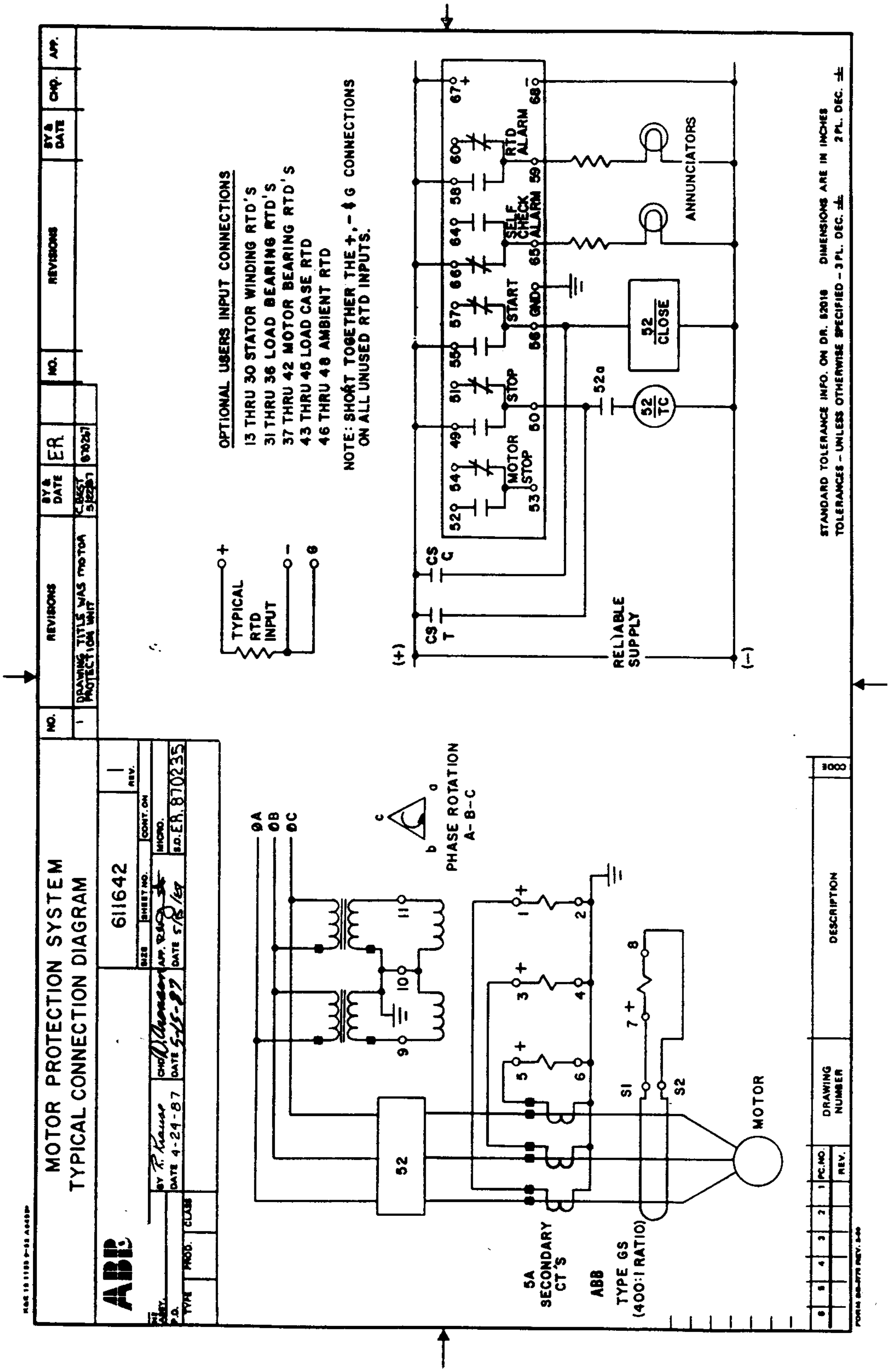
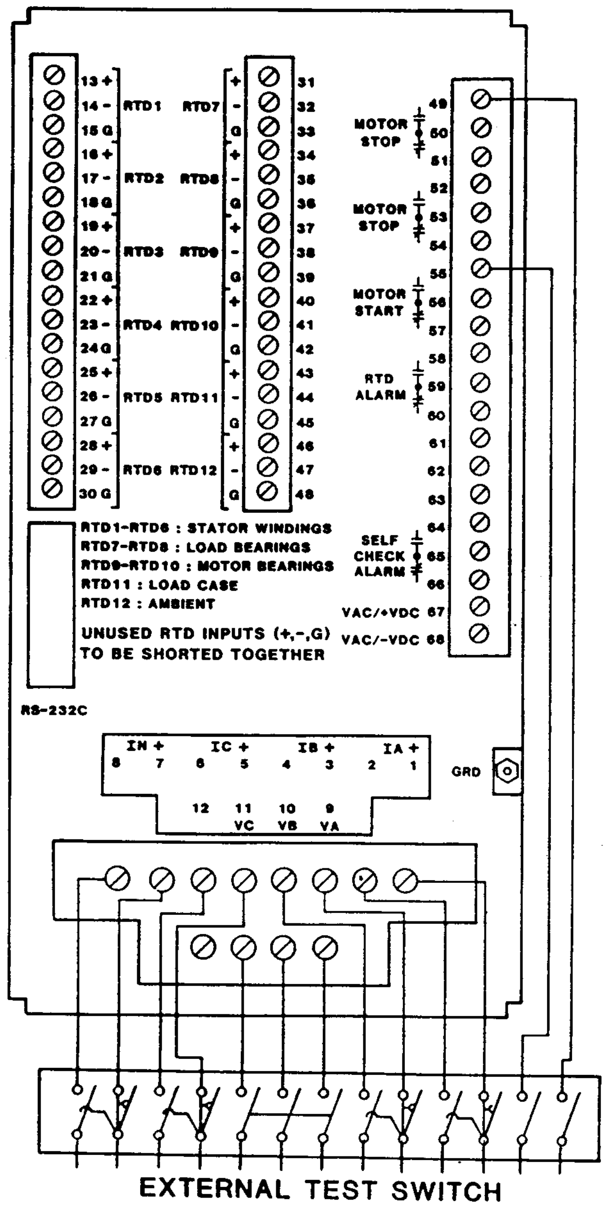

MOTOR PROTECTION SYSTEM
TYPICAL CONNECTION DIAGRAM
611642
OPTIONAL USERS INPUT CONNECTIONS
13 THRU 30 STATOR WINDING RTD'S
31 THRU 36 LOAD BEARING RTD'S
37 THRU 42 MOTOR BEARING RTD'S
43 THRU 45 LOAD CASE RTD
46 THRU 48 AMBIENT RTD
NOTE: SHORT TOGETHER THE +, - & G CONNECTIONS ON ALL UNUSED RTD INPUTS.
TYPICAL RTD INPUT
MOTOR STOP
STOP
START
SELF CHECK ALARM
RTD ALARM
ANNUNCIATORS
52 CLOSE
52 TC
RELIABLE SUPPLY
PHASE ROTATION A-B-C
5A SECONDARY CT'S
ABB TYPE GS (400:1 RATIO)
MOTOR
STANDARD TOLERANCE INFO. ON DR. 82016 DIMENSIONS ARE IN INCHES
TOLERANCES - UNLESS OTHERWISE SPECIFIED - 3 PL. DEC. ± 2 PL. DEC. ±

FIGURE 5


13 +
14 -
15 G
16 +
17 -
18 G
19 +
20 -
21 G
22 +
23 -
24 G
25 +
26 -
27 G
28 +
29 -
30 G
RTD1
RTD2
RTD3
RTD4
RTD5
RTD6
RTD7
RTD8
RTD9
RTD10
RTD11
RTD12
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
MOTOR STOP
MOTOR STOP
MOTOR START
RTD ALARM
SELF CHECK ALARM
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
VAC/+VDC 67
VAC/-VDC 68
RTD1-RTD6 : STATOR WINDINGS
RTD7-RTD8 : LOAD BEARINGS
RTD9-RTD10 : MOTOR BEARINGS
RTD11 : LOAD CASE
RTD12 : AMBIENT
UNUSED RTD INPUTS (+,-,G) TO BE SHORTED TOGETHER
RS-232C
IN +
IC +
IB +
IA +
8 7 6 5 4 3 2 1
12 11 10 9
VC VB VA
GRD
EXTERNAL TEST SWITCH

MOTOR START OUTPUT CONTACTS - One (1) Form C: Terminals 55, 56, 57.
The motor start contacts will actuate on command through the serial port and remain closed for one (1) second. A password, separate from that used to make settings, is required.

TEST SWITCHES - We recommend that an external test switch of the user's preference such as the Multi-Amp/States type MTS or the Westinghouse FT-1 be included on the panel to provide isolation means for the input current circuits, the motor stop and start output contacts, and the input voltage circuits.

4. RELAY COMMANDS, SETTINGS AND DISPLAYS

Two modes of communication are possible:

1. Local mode via the 16-key hexadecimal keypad on the relay front panel.
2. Remote mode via the RS-232-C serial interface provided on the rear.

In the local mode the keypad is used to display or edit the different relay settings and also to execute other commands related to the various functions of the relay. The seven segment display on the front panel will continuously show the phase A, B or C line current in primary amperes. Other quantities selected for display through the proper commands will appear for approximately 10 seconds. The display then reverts to the phase current previously selected.

All the keypad commands can also be executed via the serial interface. In this case however, the relay responds on the terminal connected to the interface. Since an external terminal would incorporate a very elaborate keyboard, a more user-friendly set of commands is available for the serial port. The relay also transmits messages through the serial port, during its normal operation. These messages correspond to the various events detected by the relay, e.g., a fault trip or a manual trip causing the motor to stop. The relay identification ("ID") which can consist of up to 10 alphanumeric characters is also transmitted at the beginning of these messages.

COMMAND ENTRY VIA KEYPAD

A list of all the keypad commands is given in Table 1.

The keypad commands consist of hexadecimal characters. When the keys corresponding to a command are entered, the characters are echoed back on the readout. If more than four keys are entered, the first four entries are blanked and the fifth entry becomes the first entry for the command. This is because the relay does not expect more than four characters per command from the keypad.

A command entry is executed by the key "E". If the entered command is invalid, the relay responds with an "Error" message. This error message is displayed for a short time before the display blanks out. A command entry can be cleared completely in the middle of the entering process by the key "C". If the command entered is valid, the relay executes the command and responds accordingly. Refer to Table 1 for the special function keys, e.g., "E", "C", etc.

COMMAND ENTRY VIA SERIAL PORT

A list of all the serial port commands is given in Table 1.

The keypad commands can also be executed from the serial port. In addition, a different set of commands, more oriented towards the English language, is provided for the serial port.

Table 1 also shows that, unlike from the keypad, the relay can accept more than four characters for a command from the serial port. Corrections to a command entry can be made using the "BACK SPACE" key on the terminal keypad. The relay responds to an invalid command with an error message worded "INVALID COMMAND" on the terminal. All command entries must be terminated by entering the "CARRIAGE RETURN" or the "RETURN" key on the terminal keypad. All entries from the serial port are echoed back on the terminal connected to the serial port.

It is not possible to interrogate the relay from the keypad and the serial port simultaneously. For example, if command execution from the serial port is in progress, the relay will not accept any commands from the keypad. However, if command execution from the keypad is in progress, the relay WILL accept commands from the serial port. These commands will be echoed back on the terminal, but will not be executed until the keypad execution is complete.

TABLE 1: RELAY COMMANDS

COMMAND FUNCTION	Relay Command KEYPAD	SERIAL PORT
Display/Edit Time Clock	45 <E>	CLOCK <CR>
Display/Edit Relay Settings	44 <E>	EDIT <CR>
Display/Edit Baud Rate	47 <E>	BAUD <CR>
Display/Edit Number of Motor Starts	46 <E>	STARTCTR <CR>
Change Password for Editing Relay Settings	48 <E>	PASSWORD <CR>
Change STOP/START and SETID Password		
Display/Edit Relay Identification (Ten Characters Maximum)	-----	SETID <CR>
Display Relay Identification	-----	ID <CR>
Display Self-Test Status	42 <E>	SELFTEST <CR>
Display Relay Settings	41 <E>	SHOW <CR>
Display All Currents and Voltages	54 <E>	PHASORS <CR>
Display Current IA	30 <E>	IA <CR>
Display Current IB	31 <E>	IB <CR>
Display Current IC	32 <E>	IC <CR>
Display Line to Line Voltage VAB	33 <E>	VAB <CR>
Display Line to Line Voltage VBC	34 <E>	VBC <CR>
Display % Current Unbalance	35 <E>	IUNB <CR>
Display % Voltage Unbalance	36 <E>	VUNB <CR>
Display Estimated Rotor Temperature in % of Trip Threshold	37 <E>	ROTORPC <CR>
Display Estimated Stator Temperature in Degrees C	38 <E>	STATORC <CR>
Display Estimated Stator Temperature in % of Trip Threshold	39 <E>	STATORPC <CR>
Display Time	40 <E>	TIME <CR>
Display Status of Motor	43 <E>	MTRSTAT <CR>
Reset Front Panel Targets	49 <E>	TGTRST <CR>
Test Target Lights	50 <E>	-----
Display Phase A Current Continuously	51 <E>	-----
Display Phase B Current Continuously	52 <E>	-----
Display Phase C Current Continuously	53 <E>	-----
Motor Stop: Manual	-----	STOP <CR>
MOTOR START: MANUAL	-----	START <CR>
Display Motor Start Event Record	-----	START-RCD <CR>
Reset Estimated Rotor and Stator Temperatures	F1 <E>	CLRTMP <CR>
Display Event #1	-----	EVENT1 <CR>
Display Event #2	-----	EVENT2 <CR>
Display Event #3	-----	EVENT3 <CR>
Display Event #4	-----	EVENT4 <CR>
Display Event #5	-----	EVENT5 <CR>

NOTE: X = 1 to 5 = EVENT1 to EVENT5

COMMAND FUNCTION	KEYPAD	SERIAL PORT
Event #X, Day of the Year	BX00 <E>	-----
Event #X, Time of the Day	BX01 <E>	-----
Event #X, Ground Current	BX02 <E>	-----
Event #X, VAB Magnitude	BX03 <E>	-----
Event #X, VAB Phase Angle	BX04 <E>	-----
Event #X, VBC Magnitude	BX05 <E>	-----
Event #X, VBC Phase Angle	BX06 <E>	-----
Event #X, IA Magnitude	BX07 <E>	-----
Event #X, IA Phase Angle	BX08 <E>	-----
Event #X, IB Magnitude	BX09 <E>	-----
Event #X, IB Phase Angle	BX10 <E>	-----
Event #X, IC Magnitude	BX11 <E>	-----
Event #X, IC Phase Angle	BX12 <E>	-----
Event #X, % Voltage Unbalance	BX13 <E>	-----
Event #X, % Current Unbalance	BX14 <E>	-----
Event #X, Estimated Rotor Temperature in % of Trip Threshold	BX15 <E>	-----
Event #X, Estimated Stator Temperature in Degrees C	BX16 <E>	-----
Event #X, Estimated Stator Temperature in % of Trip Threshold	BX17 <E>	-----
Event #X, Maximum Winding RTD Temperature in Degrees C	BX18 <E>	-----
Event #X, Maximum of Load Bearing RTD Temperature in Degrees C	BX19 <E>	-----
Event #X, Maximum Motor Bearing RTD Temperature in Degrees C	BX20 <E>	-----

Event #X, Load Case RTD Temperature in Degrees C	BX21 <E>	-----
Display Winding RTD #1 Temperature in Degrees C	111 <E>	111 <CR>
Display Winding RTD #2 Temperature in Degrees C	112 <E>	112 <CR>
Display Winding RTD #3 Temperature in Degrees C	113 <E>	113 <CR>
Display Winding RTD #4 Temperature in Degrees C	114 <E>	114 <CR>
Display Winding RTD #5 Temperature in Degrees C	115 <E>	115 <CR>
Display Winding RTD #6 Temperature in Degrees C	116 <E>	116 <CR>
Display Maximum Winding Temperature in Degrees C	117 <E>	117 <CR>
Display Load Bearing #1 Temperature in Degrees C	121 <E>	121 <CR>
Display Load Bearing #2 Temperature in Degrees C	122 <E>	122 <CR>
Display Maximum Load Bearing Temperature in Degrees C	123 <E>	123 <CR>
Display Motor Bearing #1 Temperature in Degrees C	131 <E>	131 <CR>
Display Motor Bearing #2 Temperature in Degrees C	132 <E>	132 <CR>
Display Maximum Motor Bearing Temperature in Degrees C	133 <E>	133 <CR>
Display Load Case Temperature in Degrees C	141 <E>	141 <CR>
Display Ambient Temperature in Degrees C	151 <E>	151 <CR>
Display Winding #1 Temperature in % of Trip Setting	211 <E>	211 <CR>
Display Winding #2 Temperature in % of Trip Setting	212 <E>	212 <CR>
Display Winding #3 Temperature in % of Trip Setting	213 <E>	213 <CR>
Display Winding #4 Temperature in % of Trip Setting	214 <E>	214 <CR>
Display Winding #5 Temperature in % of Trip Setting	215 <E>	215 <CR>
Display Winding #6 Temperature in % of Trip Setting	216 <E>	216 <CR>
Display Maximum Winding Temperature in % of Trip Setting	217 <E>	217 <CR>
Display Load Bearing #1 Temperature in % of Trip Setting	221 <E>	221 <CR>
Display Load Bearing #2 Temperature in % of Trip Setting	222 <E>	222 <CR>
Display Maximum Load Bearing Temperature in % of Trip Setting	223 <E>	223 <CR>
Display Motor Bearing #1 Temperature in % of Trip Setting	231 <E>	231 <CR>
Display Motor Bearing #2 Temperature in % of Trip Setting	232 <E>	232 <CR>
Display Maximum Motor Bearing Temperature in% of Trip Setting	233 <E>	233 <CR>
Display Load Case Temperature in % of Trip Setting	241 <E>	241 <CR>

Special Keys for Keypad

"A"	Used to terminate a 'relay editing' session or to prolong a 'display'.
"B"	Used to reverse the relay editing sequence.
"C"	Used to clear a keypad entry.
"D"	Used for the 'decimal point' where applicable.
"E"	Used to execute a 'keypad command' or 'data entry'.

Special Keys for Serial Port

"A"	Used to terminate a 'relay editing' session.
"B"	Used to reverse the relay editing sequence.
"CR"	The carriage return is used to execute a serial port command or 'data entry'.

SETTINGS AND DISPLAYS

A listing of the display (Command "41") and edit (Command "44") sequence for the relay settings is given in Table 5. A password is required to change the settings. The relay is shipped with "0000" as the initial password. It is recommended that this be changed as soon as the relay is installed in service. The valid characters for the password are numbers "0" through "9" and the hexadecimal characters "A", "B", "D" and "F". The password MUST be four characters long. Settings can be displayed without the password. When the password is entered via the serial port, it is not echoed back on the terminal for security purposes.

Each setting has an associated setting number. A method for easy access to a particular setting number is provided at the beginning of the edit sequence. The edit sequence can also be reversed by entering a "B". The relay operates on the "old" settings until the editing session is terminated by entering an "A". Upon entering an "A", the old settings are replaced in the non-volatile memory with the new settings. While editing the settings, values outside the range or step size are not accepted. The relay treats such entries as invalid and responds with a blinking display which indicates the correct range of values and the correct step size.

The codes for the selection of the resistance temperature devices (RTD's) for settings 24 through 28 are:

TABLE 2

CODE	RTD TYPE
0	10 Ohm Copper
1	100 Ohm Platinum
2	100 Ohm Nickel
3	120 Ohm Nickel

The display order for the self-check status (Command "42") is listed below. The eight digit display is read from left to right with a "zero" indicating a normal status and a "one" indicating a failure.

TABLE 3

DISPLAY DIGIT	SELF-TEST
1	ROM
2	RAM
3	+5 VDC, +/-15 VDC
4	A/D Converter
5	Failure to Stop Detected

The display codes for the motor status (Command "43") are:

TABLE 4

CODE	MOTOR STATUS
0	Ready to Start State
1	Starting State
2	Running State
3	Stopped or Blocked Start State
4	Stop Relay Energized State
5	Possible Stop Failure State
6	Delayed Stop State
7	Inverse Inst. Picked Up State
8	Start Relay Energized State
9	Failure Detected in Self Test

TABLE 5: DISPLAY AND EDIT SEQUENCE FOR RELAY SETTINGS

Setting No.	Description	Range	Step Size	Units
00	Motor current at stator thermal limit times	3.0-6.0	0.1	per unit
01	Stator 'thermal limit time' when motor starts from operating temperature	2.0-100.0	0.1	seconds
02	Stator 'thermal limit time' when motor starts from ambient temperature	2.5-200.0	0.1	seconds
03	Stator Thermal Limit	60-200	1.0	degree C
04	Winding RTD time constant	1.0-20.0	0.1	seconds
05	Motor current at rotor thermal limit times	3.0-6.0	0.1	per unit
06	Rotor 'thermal limit time' when motor starts from operating temperature	2.0-100.0	0.1	seconds
07	Rotor 'thermal limit time' when motor starts from ambient temperature	2.5-200.0	0.1	seconds
08	Rated Slip (Running rotor resistance)	0.003-0.030	0.001	per unit
09	Locked rotor resistance	0.012-0.120	0.001	per unit
10	Rotor trip threshold	0.50-1.00	0.01	X Rotor thermal limit
11	Stator starting trip threshold	0.00-1.50	0.01	X Stator thermal limit
12	Stator running trip threshold	0.00-1.50	0.01	X Stator thermal limit
13	Block start threshold	0.10-1.00	0.01	X Rotor thermal limit
14	Motor Full load current	1.0-6.0	0.1	CT Sec. Amps
15	Ground tap	5-50	1	Primary Amps
16	Ground fault trip delay	0.04-1.00	0.01	seconds
17	Load jam tap	1-10	1	X FLC
18	Load jam trip delay	0.5-10	0.1	seconds
19	Inverse instantaneous tap	1-10	1	X FLC
20	Load loss trip	0.00-1.00	0.01	X FLC
21	Load loss trip delay	1.0-20.0	0.1	seconds
22	Unbalance trip	0.10-0.50	0.01	X FLC
23	Unbalance trip delay	0.05-5.00	0.01	seconds

24	Type of winding RTD	0-3	1	See Table 2
25	Type of load bearing RTD	0-3	1	See Table 2
26	Type of motor bearing RTD	0-3	1	See Table 2
27	Type of load case RTD	0-3	1	See Table 2
28	Type of ambient RTD	0-3	1	See Table 2
29	Winding RTD trip	10-200	1	degree C
30	Winding RTD alarm	2-20	1	degree C below trip
31	Load bearing RTD trip	10-200	1	degree C
32	Load bearing RTD alarm	2-20	1	degree C below trip
33	Motor bearing RTD trip	10-200	1	degree C
34	Motor bearing RTD alarm	2-20	1	degree C below trip
35	Load case RTD trip	10-200	1	degree C
36	Load case RTD alarm	2-20	1	degree C below trip
37	CT ratio	0-5000	1	#
38	VT ratio	20.0-200.0	0.1	#
39	VT rated primary voltage	2.40-15.00	0.01	KV

5. SERIAL COMMUNICATIONS LINK

The serial communications link consists of the industry standard RS-232-C interface. The serial port connector (25-pin D-subminiature) is located at the rear of the relay. This port can be used to interface the relay with a CRT terminal, a printer, or other such devices having communications capability via an RS-232-C link.

The serial port is configured as a data terminal equipment. The designations and descriptions of the serial port pins/signals are:

Pin #1 - frame ground: This pin is internally tied to the relay chassis.

Pin #2 - transmit data: The relay transmits data through this output.

Pin #3 - receive data: The relay receives data through this input.

Pin #4 - request to send: The relay permanently asserts this output signal, thus indicating to the serial port device that it is ready to receive data. This pin is internally connected to the data terminal ready output pin (pin #20).

Pin #5 - clear to send: The relay monitors this input constantly, and transmits data to the serial port device only if this input pin is asserted.

Pin #7 - signal ground: This pin is also internally tied to the chassis.

Pin #8 - data carrier detect: This signal must be asserted by both the relay and the serial port device at all times for any communications to take place. The relay asserts this signal internally.

Pin #20 - data terminal ready: Same as 'request to send'.

For the communication link to be established between the relay and the serial port device, the transmit and receive speed must be the same for the relay and the serial port device. This is achieved by selecting the same baud rate for the relay, as the external device. Also the data format must be the same for the two units.

BAUD RATE SELECTION

The baud rate selection can be done only from the front panel keypad. The baud rate setting command is "47" and the range is 50 to 9600. Most serial port devices allow different baud rate selections. Set the baud rate on the serial port device first, and then select the same baud rate for the relay.

DATA FORMAT

The relay uses a data format consisting of eight data bits, two stop bits and no parity. The same data format must be selected for the serial port device when connected to the relay.

DATA TRANSMIT / RECEIVE PROTOCOL

All commands from the serial port device to the relay must be terminated by a <CR> ("CARRIAGE RETURN" or "RETURN"). The relay responds by transmitting the requested data to the terminal. An invalid command invokes a message "INVALID COMMAND". The transmitted data consists of a series of ASCII characters. Each character is of the format described above. In addition, the relay transmits messages to the terminal, indicating the different events seen by the relay.

All data transmission from the relay to the serial port is terminated by a <LF> ("LINE FEED") and a <CR> ("CARRIAGE RETURN" or "RETURN"). Note that the data format mentioned earlier is strictly followed while transmitting each of the above characters.

SERIAL PORT CABLE CONNECTION

As mentioned earlier, the serial port is configured as a data terminal equipment. This means that the port can be connected to a MODEM, which is a data communications equipment, by a straight through cable. If a modem is used, the baud rate of the relay and data terminal must be compatible with the modem's capabilities. If the relay is to be connected to other data terminal equipment, like a line printer or a CRT terminal, the cable connection required is shown in Figure 6.

TESTING

1. MAINTENANCE AND RENEWAL PARTS

No routine maintenance is required on this system. Continuous self-testing insures maximum availability of the unit. Testing by conventional methods can be conducted by following the procedures given below to verify proper operation. We recommend that an inoperative unit be returned to the factory for repair.

2. HIGH POTENTIAL TESTS

High potential insulation tests are not recommended. If a control wiring insulation test is required, bond all terminals together before applying test voltage.

3. In order to properly exercise the system, it must be connected in a test circuit that simulates motor starting and running conditions. Protective relay test sets that can be accurately preset without actually applying current to the unit are preferred for this testing. Reference figures 4 and 5 for three phase voltage and current connections to the relay.

   A. Apply proper control power to the unit, execute command F1 and enter the correct settings on the unit by means of the keypad or an external terminal. With control power applied and the system operating properly, the self-check alarm contact (65-66) should be open and the digital display should show 0's when the self-test status command "42" is executed. Interrupt the control power to the unit and verify the closure of the self-check alarm contact (65-66). After 10 seconds, apply control power and interrogate the unit to verify that all settings were properly retained.

   B. Motor Running Test: Set the input quantities on the test source as follows:

INPUT	MAGNITUDE	PHASE ANGLE
VAB	120 V	0 degrees
VCB	120 V	60 degrees
IA	1.5A	-40 degrees
IB	1.5A	-160 degrees
IC	1.5A	80 degrees

Enter the following settings:

SETTING #	VALUE	SETTING #	VALUE
00	5.0	21	20.0
01	20.0	22	0.5
02	30.0	23	5.0
03	180.0	24	0
04	5.0	25	0
05	5.0	26	0
06	15.0	27	0
07	25.0	28	0
08	0.008	29	165.0
09	0.024	30	20.0
10	1.0	31	165.0
11	1.0	32	20.0
12	1.0	33	165.0
13	1.0	34	20.0
14	2.0	35	165.0
15	25.0	36	20.0
16	0.5	37	100.0
17	10.0	38	115.0
18	10.0	39	13.8
19	7.0		
20	0.0		

Verify that the relay is in the "Ready to Start" state by executing command "43" (Code 0). If it is not in this state, execute command F1. Turn on the test source, reset the relay and then execute the relay command "43" to verify that the relay is in the "Motor Running" state (code 2). Record the ammeter and voltmeter readings using commands "30" through "34". Note, the relay has to be reset after the test current is applied because an actual motor start condition (FLA greater than 2 per unit) is not being simulated.

C. Locked Rotor Test: Set the current source to provide a continuous 3 phase output equal to the locked rotor current (Reference settings 05 and 14). Verify that the relay is in the "Ready to Start" state (code 0) by executing command "43". Execute the relay command "F1" to clear residual temperature values in the RAM. Verify that the stator thermal limit (settings 00 and 02) is greater than the rotor thermal limit (settings 05 and 07). Apply the test source voltage and "simultaneously" activate the three test source currents and the timer. Record the locked rotor trip time. The locked rotor trip time should be within +/-7 percent of the expected value (setting 07 times setting 10). Interrogate the START-RCD to verify a valid locked rotor condition. NOTE: The currents must be removed within 0.3 seconds after the trip signal is given, otherwise the relay will detect a "Possible Stop Failure" state or "Delayed Stop" state.

D. Instantaneous Pickup Test: Set a fairly low instantaneous pickup (setting 14 times setting 19). Execute command "43" and verify that the relay is in the "Ready to Start" state (code 0). Starting at about 85 percent of the set value, increase the current in steps until an instantaneous trip (50) is indicated on the front panel. Be sure to wait sufficient time between shots to reduce thermal stress due to high test currents. Instantaneous pickup should be within +/-10 percent of the set value.

E. Ground Fault Timing Test: Set the current source to provide a ground current of 0.125 amperes to terminals 7 and 8. Execute the relay command "43" and make sure the relay is in the "Motor Running" state (code 2). Simultaneously activate the test source and the timer. The ground fault tripping time should be +/-5 percent of the expected value (setting 16). Check event record #1 for the magnitude of the ground fault current in primary amperes.

F. RTD Alarm and Trip Test: Connect a 15 ohm resistor across RTD Input Number 1 (Terminals 13, 14, and 15). Note that all unused RTD inputs (+, -, G) must be shorted together. Execute the relay command "43" and verify that the relay is in the "Motor Running" state (code 2). With settings given in Test B above, the RTD alarm output contact will be closed and the front panel display will flash "30" and a measured temperature. Edit the relay settings and change setting number 29 to 145. This setting will result in a trip output condition. Repeat the RTD alarm test for the other RTD inputs.

4. DISASSEMBLING THE UNIT

Although field repair of a unit is not recommended, the Pro-Star Motor Protection System can be easily disassembled for replacement of the power supply unit, the microprocessor board (PCB100) or the A/D converter board (PCB200). The following sequence is followed when disassembling the unit:

A. Disconnect all control power to the unit.

B. Remove the front plexiglass cover.

C. Remove the two hex-spacers and the metal face plate containing the instructional information.

D. Remove the three screws from the ground bracket located in the upper righthand corner.

E. Withdraw the inner chassis far enough to disconnect the five flexible cable connectors from the input and output board (PCB300) and the current input board (PCB500).

F. Remove the three screws holding the ground bracket to the power supply unit.

Removal of the microprocessor board (PCB100) from the inner chassis can be accomplished by disconnecting the three flexible cable connectors on the right and withdrawing it from the inner chassis. Removal of the A/D converter board (PCB200) from the inner chassis can be accomplished by disconnecting a rear cable connector, removing two screws located on the top and bottom righthand side and withdrawing it from the inner chassis. The power supply unit is permanently connected to the inner chassis. The input and output board (PCB300) and the current input board (PCB500) are permanently connected to the rear of the enclosure.

Reassembly is accomplished by following the sequence mentioned above in the reverse order. The cables must be reconnected in accordance with Figure 7.

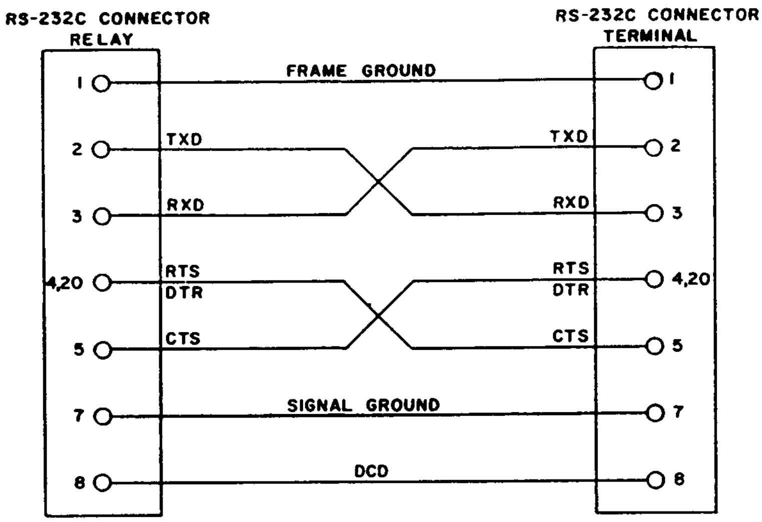


FIGURE 6 : SERIAL PORT CABLE CONNECTION TO A TERMINAL (DATA TERMINAL EQUIPMENT)

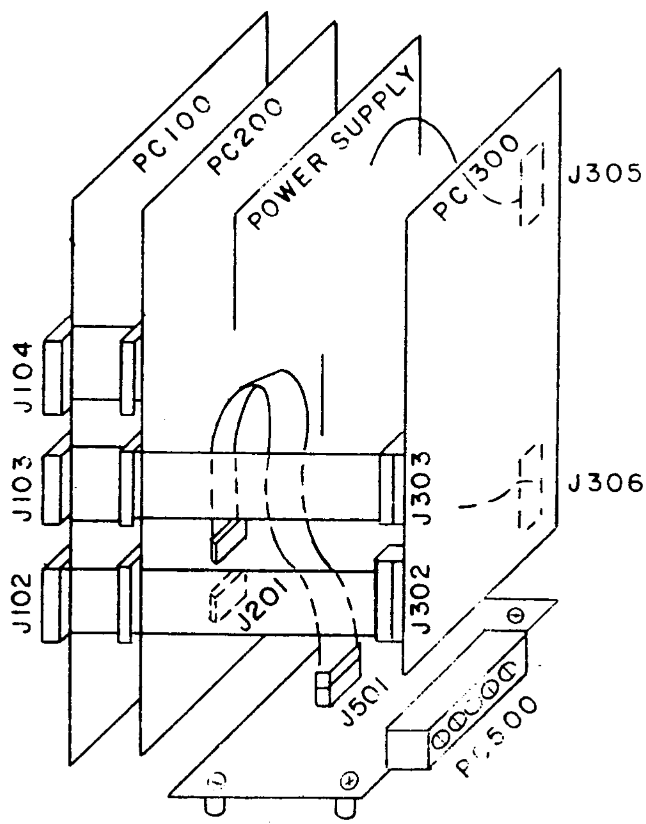


FIGURE 7

INSTRUCTIONS

PRO*STAR Motor Protection System

Connections:

Referring to "Connections", paragraph 3 on page 11: the connections to the RTD's in the machine should be made with shielded cable. The shield should be grounded at one point only.

Firmware Version V1.3 and higher:

For units such as wound rotor motors where external resistance is inserted in series with the rotor to limit starting current and to modify the torque characteristic, the unit will recognize a transition from a stopped condition to a running condition for line current in the range of 0.5-2 times the full load current (setting # 14). A start record will not be made for this type of start.

Firmware Version V1.6:

The following changes are incorporated in V1.6:

a) The start record (page 5, last paragraph) displays positive-sequence current and positive-sequence voltage. For motor speeds close to zero, an asterisk (*) is shown rather than a speed value.

b) The RTD alarming range (page 3, function 49) is extended to allow adjustment from 2 to 99 degrees below the trip setting.

c) When a trip is issued by the relay, the front display will indicate "STOP" after the breaker or contactor opens. In previous versions the display indicated "TRIP".

d) A new setting command has been added: "60" (keypad or serial port) or "STARTIME" (serial port). The range for this setting is 5 to 99 and corresponds to 0.5 - 9.9 seconds. This sets the delay from when the motor is started to when a slip reference factor is calculated. This delay is needed due to the unsettled line conditions that exist when the motor is first energized. The default value of this setting is 5 which corresponds to 0.5 second. This value is usually suitable for motors with starting times below 10 seconds. For large high-inertia motors a setting of 3 seconds appears to work well in practice. Proper selection is indicated by less than 3 seconds of asterisks in the start record occuring <u>after</u> the set delay period expires, for a normal machine start. During the delay period, for the purposes of the rotor thermal model calculations the motor is assumed to be in a locked rotor condition, which is slightly conservative.

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