Section 3

FUNCTIONAL THEORY

3.0 General — This section describes how the IQ-1000 II's hardware and software function together to control, monitor, and protect the motor.

The explanations are divided into the following areas:

- Sensing inputs (Par. 3.1)
- Protective functions (Par. 3.2)
- Metering functions (Par. 3.3)

3.1 Sensing Inputs — The IQ-1000 II receives motor current sensing derived from 3 separate current transformers, each of which monitors one phase of an AC line to the motor (see Figure 3-1). If an optional zero sequence ground fault transformer is used, the IQ-1000 II monitors ground fault current levels and compares them to a user-selected setpoint. If optional RTDs are used, the IQ-1000 II gathers winding temperature data from six RTDs embedded in the stator windings of the motor. Four RTDs associated with the motor bearings and load bearings can also be monitored for temperature levels. Additionally, one auxiliary RTD, such as motor case temperature, can be monitored.

3.2 Protective Functions — Protective functions monitor motor operating conditions (such as current and temperature) in an ongoing manner. When these exceed user-selected levels, an alarm condition is initiated, and then, if necessary, a trip condition occurs. These two conditions have the following functions:

- An alarm condition energizes the IQ-1000 II's internal Alarm Relay.
- A trip condition — other than AC line loss — removes power from the motor by either energizing or de-energizing the Trip Relay. This relay is used for protective control and reporting purposes within the application.
- An auxiliary trip condition — other than AC line loss — either energizes or de-energizes the Auxiliary Trip Relay. An auxiliary trip condition, programmed by the user, occurs on one of the following trip conditions:

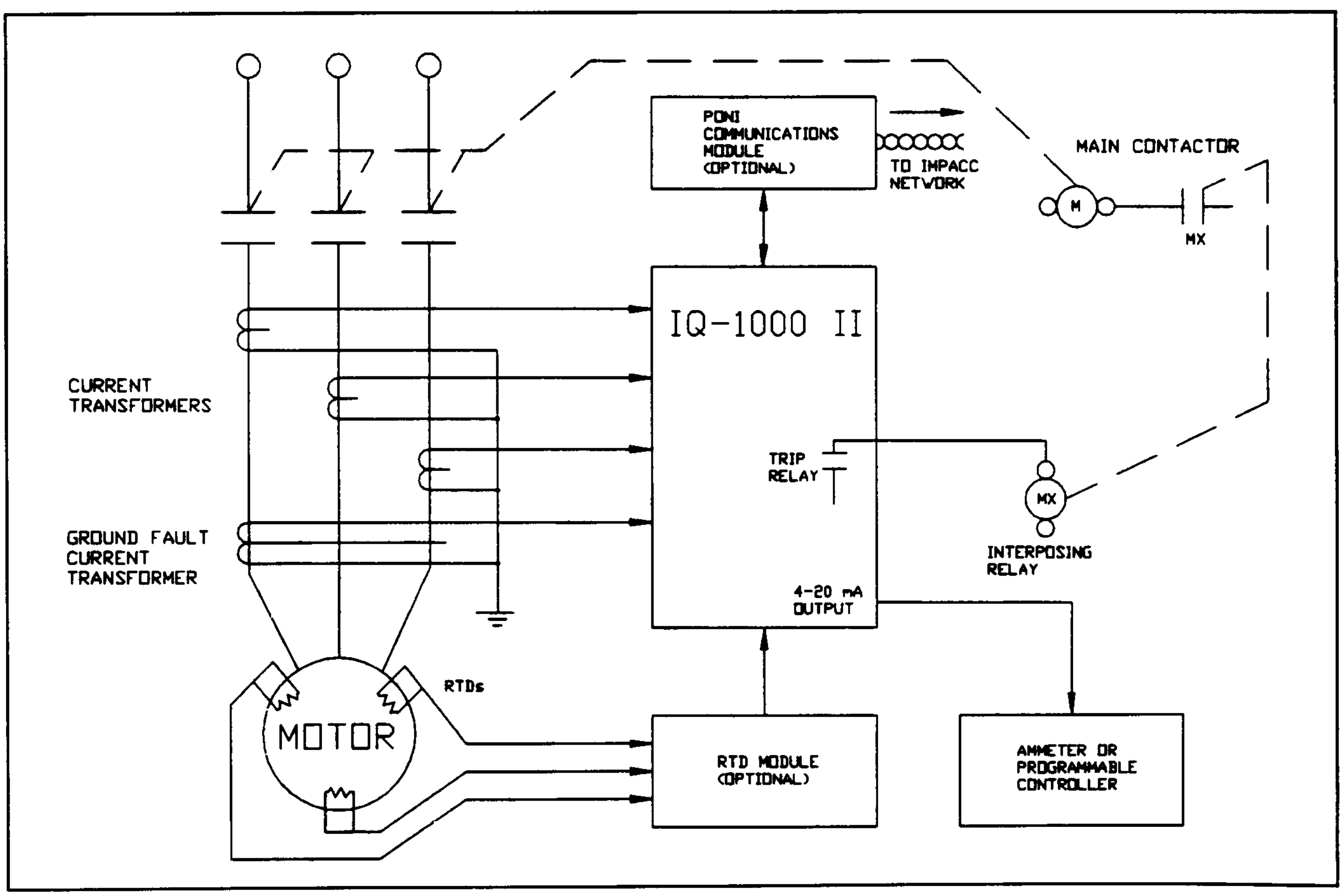


Figure 3.1 — System Overview (Simplified)

- Any trip condition
- Instantaneous overcurrent
- I^2T
- Ground fault
- Jam
- Underload
- Motor bearing temperature
- Load bearing temperature
- Winding temperature
- Phase reversal

The Auxiliary Trip Relay can be wired to perform either trip (removing power from the motor) or trip indication features.

- When a trip condition occurs, the IQ-1000 II stores metering functions such as motor current levels, temperatures, etc. This "picture" is maintained for use by maintenance personnel and is stored until a Reset is performed.

The IQ-1000 II maintains the metering data stored just prior to a trip condition indefinitely, provided that a reset from the Reset pushbutton, remote input or IMPACC is not received.

The IQ-1000 II's fault monitoring can be divided into the following types:

- Load-associated protection (Par. 3.2.1)
- Rotor temperature protection (Par. 3.2.2)

3.2.1 Load-Associated Protection — The monitored level of actual motor current is used to determine when the instantaneous overcurrent trip, jam trip, and underload trip setpoints have been reached. Actual temperature feedback from the load bearing RTDs are compared with the load bearing temperature setpoint. If necessary, alarm and/or trip conditions are initiated. (Refer to Table 8.B for a complete listing of these functions.)

3.2.2 Rotor Temperature Protection — Each design of motor has a specific damage curve. Usually it is called the I^2T curve (current squared multiplied by time). In AC motors, the current balance between phases is of major concern due to the additional heating associated with an unbalanced phase condition. Current unbalance is mainly caused by voltage unbalance, the result of single-phase loads on a 3-phase system, and/or motor winding unbalance.

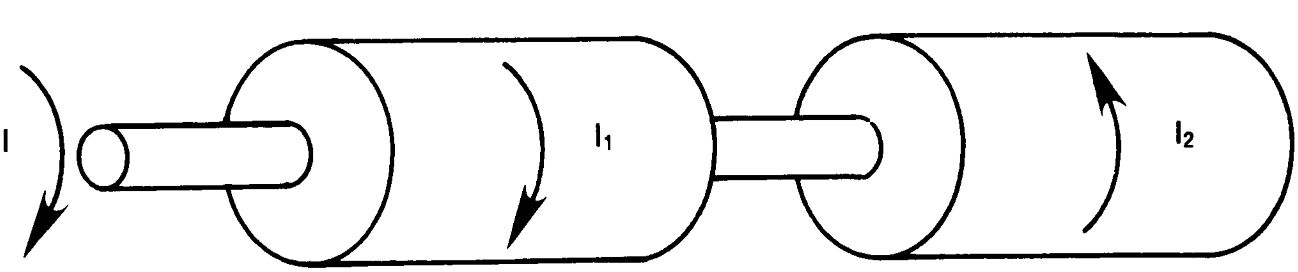
With larger horsepower motors, the design is usually rotor-limited. It therefore becomes important to determine the total heating effect on the rotor. For analysis, the motor can be considered to have two rotors (see Figure 3.2). One is the effect resulting from balanced current. The other is the effect of unbalanced current. If perfect current balance existed in each phase of the motor current, then I_1 would be the line current squared with no error in the heating projected from this current. This positive component of current generates the motor output torque or work.

The second component of the current is the negative sequence, represented as I_2. It is a 3-phase current with a reverse phase rotation from that of the AC source. This current generates countertorque to the motor output torque, or negative work. Because the torque generated by I_2 does not leave the rotor, it is absorbed as heat and therefore has a more significant effect on the rotor heating than the I_1. Any 3 phase AC current can be represented by the addition of I_1 plus I_2. Using vector analysis to determine the positive sequence, one rotates phase B in the positive direction 120 degrees and phase C in the positive direction 240 degrees. (Refer to Figures 3.3 and 3.4.) The formula for I_1 is:

$$I_1 = \frac{I_A + (I_B + 120) + (I_C + 240)}{3}$$

The negative sequence is determined by rotating phase B in the opposite, or negative, direction for 120 degrees and phase C rotated in the negative direction for 240 degrees. (Refer to Figure 3.5.) The formula for I_2 becomes:

$$I_2 = \frac{I_A + (I_B - 120) + (I_C - 240)}{3}$$



$$I^2 = I_1^2 + KI_2^2$$

Figure 3.2 — Positive and Negative Sequence Current Components

Prior to the use of a microprocessor in a motor protection system, there was no practical way of determining the total heating effect of the positive and negative sequence on a continuous basis. Therefore, less than adequate assumptions had to be made. This resulted in nuisance tripping and actual, or near-actual, motor burnouts. The IQ-1000 II microprocessor uses a unique, patented system for determining these values.

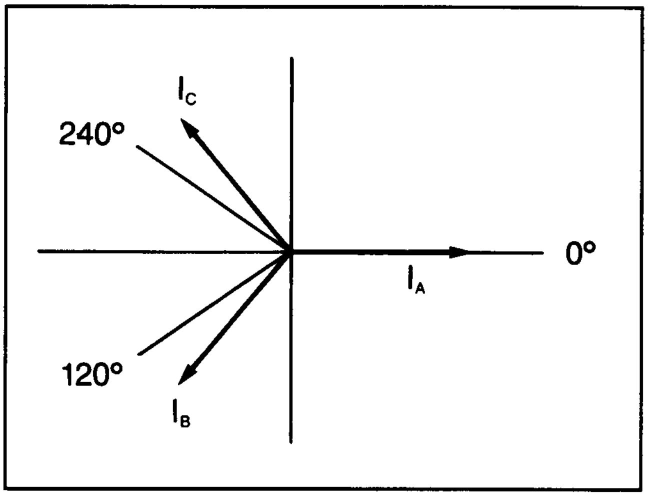


Figure 3.3 — Symmetrical Components

The current squared, as used in the calculation for rotor heat, is:

$$I^2 = I_1^2 + KI_2^2$$

Here I_2^2 is weighted by K because of the disproportional heating caused by the negative sequence.

With the use of a microprocessor, the effects of both the positive and negative sequence currents are accurately taken into account. Their **combined** effect is incorporated into a "rotor protection algorithm." The algorithm effectively keeps track of the temperature of the rotor.

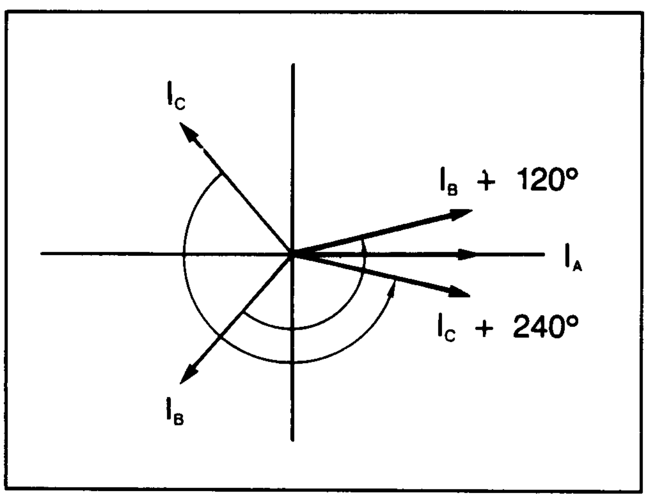


Figure 3.4 — Positive Sequence Currents

It is not necessary to pick an arbitrary phase unbalance set point to trip the motor. As long as the combined effect of the positive and negative sequence currents does not approach the motor damage curve, the IQ-1000 II will allow the motor to operate.

3.3 Metering Functions — The IQ-1000 II calculates and displays the accumulated values obtained by monitoring characteristics such as motor current level, RTD temperature levels, etc. (Section 8 describes the monitoring capabilities of the IQ-1000 II in detail.)

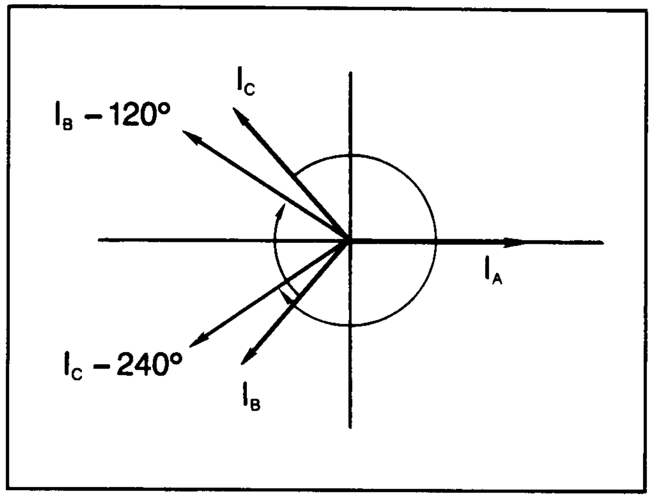


Figure 3.5 — Negative Sequence Currents

Section 4

OPERATOR PANEL

4.0 Introduction — This section describes the IQ-1000 II's Operator Panel and details its major components. Each component's function is described and the procedures for setpoint entry, modification and examining monitored motor parameters is detailed. The section is divided into the following areas:

- General description
- Component descriptions
- Entering setpoint values
- Reviewing IQ-1000 II setpoints
- Monitoring metered values

4.1 General Description — The IQ-1000 II's faceplate is a plastic and polyester material designed to withstand a variety of harsh industrial environments. All indicators, displays and pushbuttons are located on the faceplate (see Figure 4.1). White colored lettering relates to the Protection mode and blue colored lettering relates to the Program mode. A keyswitch, which switches the IQ-1000 II between the Program and

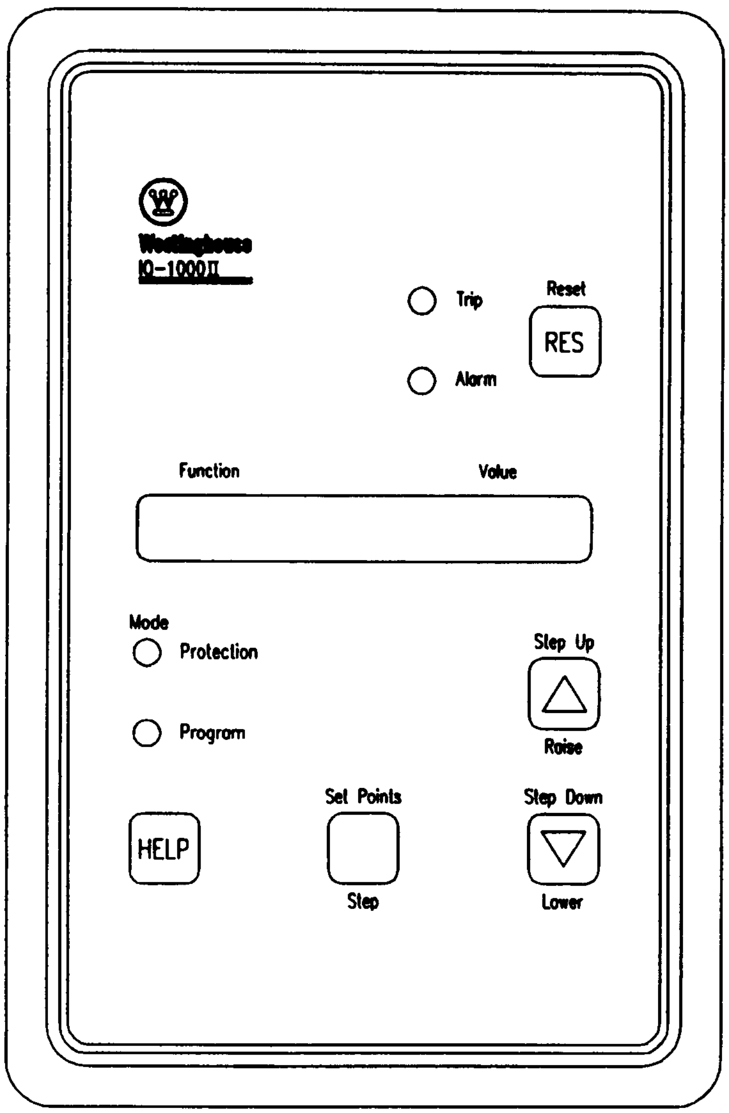


Figure 4.1 — IQ-1000 II Operator Panel

Protection modes, is located on the right side of the unit's chassis as it is viewed from the rear (see Figure 4.2).

4.2 Component Descriptions — This paragraph and its subparagraphs provide a description of the IQ-1000 II's display window, keyswitch, pushbuttons and LED indicators.

4.2.1 Display Window — The display window consists of eight alphanumeric illuminated characters which indicate the following information and data:

- Setpoints and values
- Metered data from the monitored motor or equipment
- Alarm condition information
- Pre-trip data
- Trip conditon data
- Scrolling "Help" messages.

The display window shows the Function name or abbreviation on the left side of the display, with the Value information on the right side.

4.2.2 Keyswitch — The Program/Protection keyswitch allows the user to select either the Program mode or the Protection operating mode for the IQ-1000 II. The key for the keyswitch is removable, providing security against unauthorized modification of setpoints.

NOTE

The key can be removed only when the switch is in the Protection mode.

4.2.2.1 Program Mode — When the keyswitch is in the Program position, the controlled motor cannot be started if setpoint 51 is set to STOP PGM (all units are shipped from the factory with setpoint 51 set to the default, STOP PGM). With setpoint 51 set to STOP PGM, the controlled motor must first be stopped in order to enter the Program mode. Placing the keyswitch to the Program position will not initiate the Program mode if the motor is running.

When the keyswitch is in the Program position, the motor can be started and/or run if setpoint 51 is set to RUN PGM. This allows the IQ-1000 II user to program the unit without interrupting a manufacturing process.

CAUTION

If setpoint 51 is set to RUN PGM and the motor is running while setpoints are being entered, all IQ-1000 II motor protection features are disabled and the motor is unprotected until the unit's keyswitch is returned to the Protection position.

4.2.2.2 Protection Mode — When the keyswitch is in the Protection position, the controlled motor can be started or stopped and is allowed to run normally, as defined by the setpoint values programmed into the IQ-1000 II. In the Protection mode, the IQ-1000 II monitors motor parameters and provides protective functions for the controlled motor.

Individual setpoints may be examined in the Protection mode, but they may not be modified.

4.2.3 Set Points/Step Pushbutton — The Set Points (white lettering)/Step (blue lettering) pushbutton function varies according to the IQ-1000 II's operating mode (determined by the position of the keyswitch).

In the Program mode, pressing the Step (blue lettering) pushbutton repeatedly will cycle through the Program menu in the forward direction. To cycle through the Program menu in the reverse direction, press and hold the Step pushbutton while repeatedly pressing the Lower (down arrow) pushbutton. While in the Program mode, the Program LED is continuously lit.

In the Protection mode, pressing the Set Points (white lettering) pushbutton causes the display window to display the software version installed in the IQ-1000 II. If the user desires to review the programmed setpoint values, pressing either the up or down arrow key causes the setpoints to be displayed sequentially.

If the Set Points pushbutton is pressed again, the display window will show the message PRE-TRIP. Pre-trip refers to

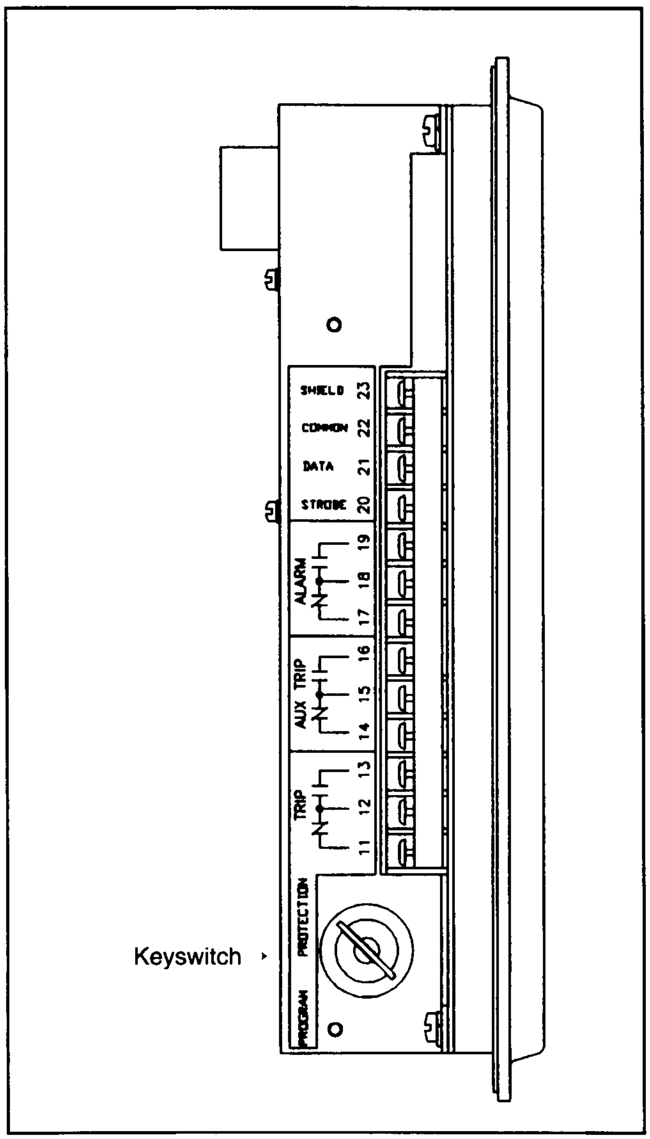


Figure 4.2 — Side View Showing Keyswitch

the monitored motor parameters that were present the instant before the last trip condition occurred. The pre-trip values are displayed by pressing either the up or down arrow keys. While the pre-trip information is displayed, the Protection LED remains lit and the Trip LED blinks as a reminder that the information being displayed pertains to a pre-trip state.

Pressing the Set Points pushbutton again will return the display to the system READY/RUN message that is first displayed upon entering the Protection mode.

4.2.4 Step Up/Raise, Step Down/Lower Pushbuttons — The Step Up/Raise and the Step Down/Lower each have two separate functions corresponding to their lettering color. An explanation of their functions follows.

In the Protection mode with the system READY/RUN message displayed, the Step Up and Step Down pushbuttons (white lettering) scroll through run-monitor data. This data contains information such as phase current, operations count, trip counts, etc. (see Table 9.B for a complete listing of run-monitor data).

If the software version message is displayed, the Step Up and Step Down pushbuttons scroll through the setpoint values programmed in the IQ-1000 II.

In the Program mode, the Raise and Lower pushbuttons (blue lettering) respectively increment and decrement a selected setpoint value.

4.2.5 Help Pushbutton — Pressing the Help pushbutton provides a scrolling description of the displayed message, including units of measure, for any of the IQ-1000 II's messages. The Help message may be terminated by pressing the Reset pushbutton while the Help message is displayed.

4.2.6 Reset Pushbutton — The Reset pushbutton is primarily used to reset the IQ-1000 II after a trip condition has occurred, assuming that the cause of the trip has been corrected.

In the Program mode, pressing the Reset pushbutton will display the first item in the program menu.

In the Protection mode, pressing the Reset pushbutton will clear a trip condition if the underlying cause of the trip condition has been corrected. If the Reset pushbutton is pressed and there is no trip condition present, the display window will display the status of the motor (first item of the run-monitor table, Table 9.B).

4.2.7 Protection, Program, Alarm and Trip LEDs — The IQ-1000 II has four status indicator LEDs–Protection, Program, Alarm and Trip.

The Protection LED is lit when the keyswitch is in the Protection position.

The Program LED is lit when the keyswitch is in the Program position. Additionally, the Program LED blinks continuously when the keyswitch is in the Protection position and the Set Points/Step pushbuttons are pressed to review programmed setpoints (see Par. 4.2.3). The blinking Program LED indicates that the program menu, not protection-monitor data, is being displayed.

The Alarm LED is lit when an alarm setpoint value has been equalled or exceeded.

The Trip LED is lit when a trip condition has occurred. Additionally, the Trip LED blinks continuously when the keyswitch is in the Protection position and the Set Points/Step pushbuttons are pressed to review pre-trip data (see Par. 4.3.2). The blinking Trip LED indicates that pre-trip data is being displayed and that a trip condition is not present.

4.3 Entering Setpoint Values — Setpoint values may be entered or modified only when the IQ-1000 II is in the Program mode. The following procedure details how to enter or modify setpoints, assuming that actual setpoints for a specific application are available on the Set Point Record Sheet (see Par. 8.0 and Table 8.B).

Step 1 — If the associated motor is running and the keyswitch is in the Protection position, press the Set Points pushbutton until the software version message is displayed. Press the Step Down pushbutton twice. The display window will display either STOP PGM or RUN PGM. If STOP PGM is displayed, the associated motor must be stopped before attempting to enter or modify setpoint values. If RUN PGM is displayed, setpoint values may be entered or modified while the motor is running.

CAUTION

If setpoint 51 is set to RUN PGM and the motor is running while setpoints are being entered, all IQ-1000 II motor protection features are DISABLED and the motor is unprotected until the unit's keyswitch is returned to the Protection position.

Step 2 — Place the Program/Protection keyswitch to the Program position. The display window will display the software version message and the Program LED will be continuously lit. The Protection LED will extinguish if the unit is in the STOP PGM mode. If the unit is in the RUN PGM mode, the Protection LED will blink continuously.

Step 3 — Press the Step pushbutton to display menu item 1 or the setpoint to be modified. The display window will display the setpoint name and some value (represented by an X in the Set Point Record Sheet, Table 8.B). Increase or decrease the setpoint value by pressing the Raise or Lower pushbuttons. Values change at the approximate rate of 2 increments per second. After the Raise or Lower pushbuttons has been held continuously for a count of 10 changes, the rate of change increases to 20 increments per second. Setpoint values wrap from maximum to minimum or vice versa to prevent the user from going out of the usable range.

Step 4 — When the setpoint value is correctly set, press the Step pushbutton to move to the next setpoint.

Step 5 — Once all setpoints have been entered correctly according to the Set Point Record Sheet, turn the keyswitch to the Protection position. The Protection LED will light and the Program LED will extinguish. The IQ-1000 II is now fully functional and ready to monitor and protect its associated motor.

4.4 Reviewing IQ-1000 II Setpoints — Once all setpoints have been entered, they may be verified while the unit is in the Protection mode. To review programmed setpoints, ensure the keyswitch is in the Protection position and press the Set

Points pushbutton until the software version message is displayed. Programmed setpoints may be reviewed by stepping up or down through the setpoints by using the Step Up or Step Down pushbuttons. If the setpoint messages are not clear, press the Help pushbutton for an unabbreviated explanation of the setpoint name and unit of measurement.

4.5 Monitoring Metered Values — The IQ-1000 II allows the user to monitor the actual operating values of various metered functions (see Table 4.A).

Step 1 — Place the keyswitch in the Protection position (the motor can be either running or stopped). If system message READY/RUN is not displayed, press the Set Points pushbutton until one or the other message is displayed.

Step 2 — Press either the Step Up or Step Down pushbutton to display individual metered values.

Values appear in an abbreviated format.

Table 4.A

PROTECTION-MONITOR MENU

Item No.	Display		Complete "Help" Description	Resolution
0	(Status of Motor) READY--X/START/RUN		READY TO START MOTOR – READY -- 1 FOR SINGLE PHASE MODE – READY -- 3 FOR THREE PHASE MODE/ATTEMPTING TO START MOTOR/MOTOR IS RUNNING	–
1	I_A	XXX	PHASE A CURRENT IN AMPS	1 amp
2	I_B	XXX	PHASE B CURRENT IN AMPS	1 amp
3	I_C	XXX	PHASE C CURRENT IN AMPS	1 amp
4	I_G	XX	GROUND FAULT CURRENT IN AMPS	1 amp
5	% I_A	XXX	PERCENT FULL LOAD CURRENT PHASE A	1%
6	% I_B	XXX	PERCENT FULL LOAD CURRENT PHASE B	1%
7	% I_C	XXX	PERCENT FULL LOAD CURRENT PHASE C	1%
8	**WT1**	**XXX**	**WINDING TEMP 1 IN DEGREES**	**1° C**
9	**WT2**	**XXX**	**WINDING TEMP 2 IN DEGREES**	**1° C**
10	**WT3**	**XXX**	**WINDING TEMP 3 IN DEGREES**	**1° C**
11	**WT4**	**XXX**	**WINDING TEMP 4 IN DEGREES**	**1° C**
12	**WT5**	**XXX**	**WINDING TEMP 5 IN DEGREES**	**1° C**
13	**WT6**	**XXX**	**WINDING TEMP 6 IN DEGREES**	**1° C**
14	**MBT1**	**XXX**	**MOTOR BEARING TEMP 1 IN DEGREES**	**1° C**
15	**MBT2**	**XXX**	**MOTOR BEARING TEMP 2 IN DEGREES**	**1° C**
16	**LBT1**	**XXX**	**LOAD BEARING TEMP 1 IN DEGREES**	**1° C**
17	**LBT2**	**XXX**	**LOAD BEARING TEMP 2 IN DEGREES**	**1° C**
18	**AUXT**	**XXX**	**AUXILIARY TEMP IN DEGREES**	**1° C**
19	OCNT	XX	OPERATION COUNT	1 count
20	RT	X	RUN TIME IN HOURS	1 hr.
21	RMST	XX	REMAINING STARTS	1 start
22	OST	XXX	TIME LEFT ON OLDEST START IN MINUTES	1 min.
23	IMX	XXXX	HIGHEST PHASE CURRENT SINCE LAST RESET	1 amp
24	WTMX	XXX	HIGHEST WINDING TEMP SINCE LAST RESET	1° C
25	I^2T	XX	NUMBER OF I^2T TRIPS SINCE LAST RESET	1 trip
26	IOC	XX	NUMBER OF IOC TRIPS SINCE LAST RESET	1 trip
27	UL	XX	NUMBER OF UL TRIPS SINCE LAST RESET	1 trip
28	JAM	XX	NUMBER OF JAM TRIPS SINCE LAST RESET	1 trip
29	GF	XX	NUMBER OF GF TRIPS SINCE LAST RESET	1 trip
30	RTD	XX	NUMBER OF RTD TRIPS SINCE LAST RESET	1 trip
31	ICM	XXX	ADDRESS ON THE IMPACC NETWORK	1 (hex)
32	%I^2T	XXX	PERCENT OF I^2T TRIP LEVEL	1%

▪ Not displayed if RTD Module is not connected