POWER CONTROLLER
MODEL 664F, 664G AND 664K
USER'S MANUAL

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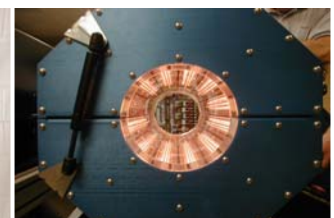
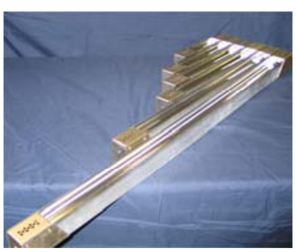
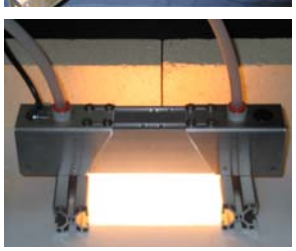
The photos below show some of the products that we have provided:

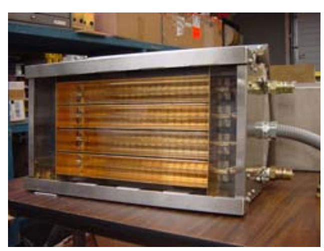
← 6 Meter long, Adjustable Height, 4 Zone IR Oven & Controls. Uses PCS designed water-cooled strip heaters, Allen-Bradley PLC and Operator Interface. ←

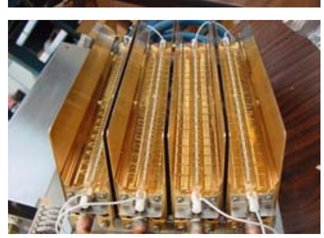
Multi-Zone Clamshell style → heater using short wave IR emitters and multiple heaters lengths. Available with controls and adjustable height cart or heater only. →

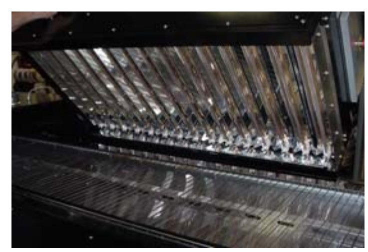












↑↑ Water Cooled Line & Strip heaters using short-wave ↑↑ IR emitters. Utilizes a highly polished custom aluminum extrusion, easy access covers for wiring and lamp access, quick-push-connect water fittings, easy mount t-slots and optional quartz window and multi-axis mounting brackets. Available in 5, 10, 16, 25, 38" lighted lengths.

↑↑ Custom Gold plated Water and Air cooled Heater assembly & enclosure. High Intensity, Short-wave IR lamps, 250W/Inch. Full Quartz window and anti-vibration mounting

↑↑ 120" long, 28" wide, multi-zone heating, conveyorized drying oven & controls. Adjustable speed & temperature settings with pyrometer feedback

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SECTION 1.

INTRODUCTION

1.1 GENERAL DESCRIPTION

Model 664F, 664G, and 664K power controllers (figure 1–1) are compact, versatile, and highly reliable SCR-type phase-angle power controllers. *Models 664F and 664G are suitable for use with resistive, inductive, and transformer coupled loads. Model 664K is suitable for use with resistive loads only.*

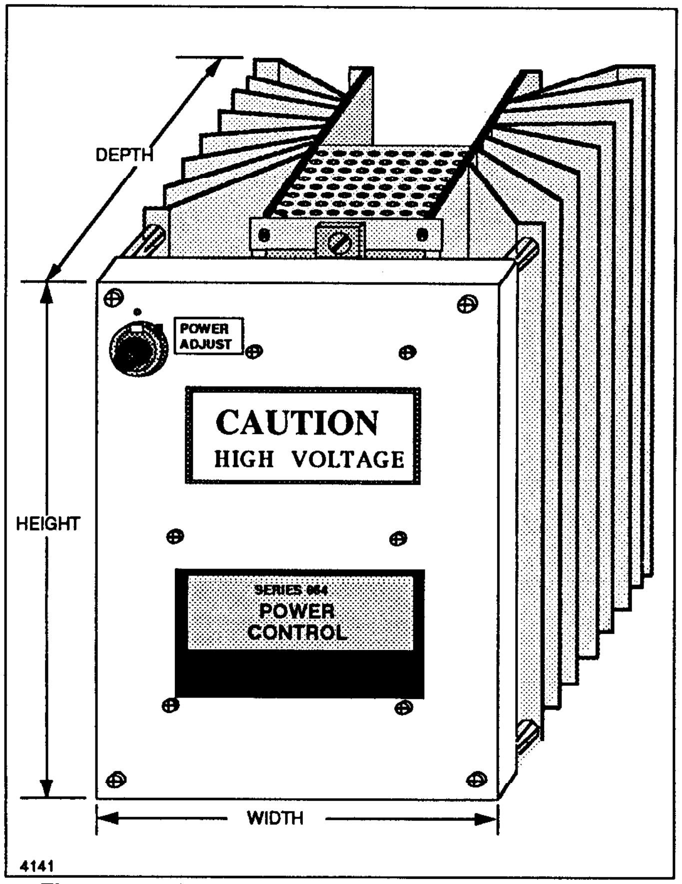

Figure 1–1. Typical model 664 SCR power controller.

The 664F is a single-phase controller and operates on 120- through 480-VAC power. The 664G and 664K are three-phase controllers and operate on 208- to 600-VAC, 47- to 63-Hz power. Controller current capacity ranges from 35 amperes through 300 amperes, depending on the version.

Standard model 664 controllers are controlled automatically by means of a 4–20 mA signal. If the optional input module is used, they can be controlled manually with a potentiometer, or automatically by a 0–5 VDC or 0–20 mA signal.

1.2 STANDARD FEATURES

Each standard model 664F, 664G, or 664K controller includes:

1. One or three pairs of SCRs the conduction of which controls the load power.
2. Either a phase angle firing circuit module (664F) or a phase angle control module and associated SCR driver module (664G and 664K), which control(s) the conduction of the SCRs.
3. A dv/dt circuit connected across each SCR module to prevent the firing circuit from being activated by voltage transients on the AC line.
4. A metal oxide varister (MOV) connected across each SCR module to protect the SCRs from being damaged by high-voltage AC line transients.
5. Jumpers for using different line voltages to power the controller.
6. A cooling fan (on 175 A, 250 A, and 300 A versions only).
7. A thermostat (standard on all 175 A, 250 A, and 300 A versions and optional on all others).
8. On/off control of the controller from a remote location.
9. A 0–100 microampere drive signal for a remote load-voltage meter.
10. Firing circuit fuses to protect critical portions of the phase angle firing circuit module or phase angle control module in case an SCR fails or does not fire properly.

1.3 OPTIONAL FEATURES

SCR Alarm

Operates a set of form C relay contacts if an SCR short circuits (the most common way an SCR fails).

Input Module

Permits the 664F, 664G, and 664K to be controlled manually with a 1000 ohm potentiometer, or automatically by either a 0–5 VDC or 0–20 mA signal.

Subcycle Fuses

Protect the SCRs from current overloads (available for 70–300 A controllers only).

Current module

1. Permits the use of load conditioning (to match the controller's response time to the nature of the load).
2. Permits the use of instantaneous current trip (an alternative to subcycle fuses).
3. Permits use of either ***current feedback*** or ***current limiting***:
   A. Current feedback:
      (1) Linearizes the relationship between the control signal and the controller's average output current.
      (2) Provides current regulation to maintain the selected output level despite variations in line voltage and load impedance.
   B. Current limiting can be used to limit the average load circuit to a user-adjustable maximum value from 25 to 125 percent of the controller's rated current capacity.
4. Provides a 0–100 microampere drive signal for a remote load-current meter.

1.4 MODEL NUMBER INTERPRETATION

Table 1–1 shows how to interpret a model 664 controller's model number (located on the top panel of the controller). Table 1–1 also lists all options available for the 664F, 664G, and 664K controllers.

1.5 DIMENSIONS AND WEIGHT

See tables 1–2 and 1–3.

1.6 SPECIFICATIONS

NOTE

Unless stated otherwise each specification presented applies to the 664F, 664G, and 664K controller's.

1.6.1 Power Control Action

NOTE

The following specifications are applicable when standard average load voltage feedback is used.

Type

Phase angle power control with line and load voltage regulation.

Output Linearity

Average load voltage varies linearly with control signal, within ±2 percent.

Line Regulation

RMS load voltage is stable within ±3 percent for rms line voltage variations of –15 percent to +10 percent.

Table 1–2. Dimensions and Weight*—664F

CURRENT RATING	MOUNTED HEIGHT	WIDTH	DEPTH	WEIGHT	
				LBS	KG.
35–125 A	7.50 (190.5)	6.25 (158.8)	10.20 (259.1)	6	2.8
175 A	11.37 (288.8)	6.25 (158.8)	10.20 (259.1)	10	4.6
250–300 A	21.87 (555.5)	6.25 (158.8)	10.20 (259.1)	18	8.3

*Dimensions in inches (millimeters)

Table 1–3. Dimensions and Weight*—664G/K

CURRENT RATING	MOUNTED HEIGHT	WIDTH	DEPTH	WEIGHT	
				LBS	KG.
35–70 A	18.00 (457.2)	6.25 (158.8)	10.20 (259.1)	6	2.8
90–125 A	27.00 (685.8)	6.25 (158.8)	10.20 (259.1)	15	6.9
175 A	30.87 (784.1)	6.25 (158.8)	10.20 (259.1)	16	7.4
250–300 A	30.87 (784.1)	6.25 (158.8)	10.20 (259.1)	20	9.2

*Dimensions in inches (millimeters)

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Table 1–1. Model 664 Power Controller Model Number Interpretation

MODEL	
664	POWER CONTROLLER

CODE	CONTROL TYPE
B	Single Phase Time Proportioned Zero Cross (TPZC)
C	Three Phase 2 Leg Time Proportioned Zero Cross (TPZC)
D	Single Phase Distributed Zero Cross (DZC)
E	Three Phase 2 Leg Distributed Zero Cross (DZC)
F	Single Phase, Phase Angle (PA)
G	Three Phase (Hybrid) Phase Angle (PA) – Inductive Loads Only
K	Three Phase (Hybrid) Phase Angle (PA) – Resistive Loads Only
L	Single Phase Peak Fire Zero Cross (PFZC)
M	Three Phase 2 Leg Peak Fire Zero Cross (PFZC)

CODE	VOLTAGE
1	120 V (664F only)
2	208V
3	240V
4	277V
5	380V
6	415V
7	480V
8	600V

CODE	CURRENT
1	35A
2	50A
3	70A
4	90A
5	125A
6	175A
7	250A
8	300A

CODE	CIRCUIT OPTION #1
0	None
1	Input Module
2	Input Module w/1 Turn Pot (pot mounted on Power Cont. Top Plate)
3	Input Module w/10 Turn Pot & Dial (pot mounted on Pwr Cont Top Plate)

CODE	CIRCUIT OPTION #2
0	None
2	ICT
3	ICT w/Current Limiting (phase angle controllers only)
4	ICT w/Current Feedback (phase angle controllers only)

CODE	COVER OPTION
0	No Cover
1	Cover

CODE	OPTIONS
00	None
11	Thermostat
22	Failed SCR Detector
XX	Custom Feature

664 F – 4 4 – 3 2 1 – 11 – 22 ◄—TYPICAL MODEL NUMBER

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Load Regulation

Average load voltage is stable within ±1 percent for load impedance variations up to the current capacity limitation of the AC line source.

Temperature Stability

Average load voltage varies by less than 0.2 VAC per degree C change in ambient temperature.

Controllable Range

On standard controllers, when the control signal activates the SCRs, the controller's load voltage is controllable from zero to 97 percent of the controller's input line voltage.

1.6.2 SCR/Load Configuration

664F

Single-phase power control (one SCR pair) suitable for resistive and inductive loads.

664G

Three-phase, three-leg hybrid power control (three SCR/diode pairs) suitable for resistive, inductive, and transformer-coupled loads in 3-wire closed delta or 3-wire wye configurations. "D-guard" circuit permits 664G to handle load unbalances of 25 percent.

664K

Three-phase, three-leg hybrid power control (three SCR/diode pairs) suitable for resistive loads in 3-wire closed delta or 3-wire wye configurations.

1.6.3 Control Signal

4 mA (–0, +0.5 mA) to 20 mA (–0.5 , +0 mA). Minimum control signal compliance: 12 VDC. Input impedance equivalent to 600 ohms for interconnection purposes (impedance varies inversely with control signal level). Span is affected by **SPAN** potentiometer adjustment (see section 2.14).

1.6.4 Feedback Input

Either the internal feedback circuit (average load voltage feedback) or an external, isolated feedback signal (typically 0–4 VDC) can be selected. Input impedance for external feedback signal is 400K ohms.

1.6.5 Load Conditioning

Three types of jumper-selected load conditioning are available to match output response time (the time required for the controller output to reach 90 percent of its final value) to load requirements. Available output response times are:

Fast

Suitable for resistive loads. Provides 30–60 millisecond response time.

Ramp

Suitable for inductive loads. Provides 250–350 millisecond response time.

Lamp

Suitable for high-inrush loads such as incandescent lamps. For more information on load conditioning, see section 2.7.

1.6.6 Span Adjustment

User-adjustable, 20-turn potentiometer that adjusts the gain of the firing circuit's internal feedback circuit (average load voltage feedback). Matches the gain of the internal feedback circuit to the line voltage being used. When internal feedback is selected, the firing circuit **SPAN** potentiometer varies the control signal input span by changing the control signal value that produces full output over a range of at least ±25 percent (15–20 mA). Adjusting the **SPAN** potentiometer also adjusts the span of the firing circuit 0–100 microampere load-voltage meter drive signal.

1.6.7 Line Voltage

664F

120 to 600 VAC, +10% –15% (line voltage configuration required only for fan-cooled units).

664G/K

208 to 600 VAC, +10% –15% (line voltage configuration required only for fan-cooled units).

1.6.8 Line Frequency

47 to 63 Hz (K version requires two jumper cuts for 50 Hz).

1.6.9 SCR V_{RRM} Rating

1200 V.

1.6.10 DV/DT

Circuit

RC network across each SCR pair.

DV/DT Rating

200 V/microsecond.

1.6.11 Current Capacity

See table 1-4.

1.6.12 Cooling

35 to 125 A units: Convection cooled.
175 to 300 A units: Fan cooled.

1.6.13 Line Transient Protection

MOV across each SCR/diode pair.
Clamping voltage: 820 V peak at 1 mA.
Peak surge current: 1000 A.

Table 1–4. Model 664F and 664G/K Current Capacities

Continuous Current Rating	Maximum Current (Amperes) 10 Cycle Surge*	1/2 Cycle Surge	I^2T	Maximum Power (KW) @ 600 VAC	Maximum Power (3 Phase) @ 600 VAC
35	130	280	390	21.0	36.33
50	185	400	800	30.0	51.90
70	400	850	3,600	42.0	72.66
90	585	1250	8,000	54.0	93.42
125	820	1750	15,000	75.0	129.75
175**	820	1750	15,000	105.0	181.65
250	1500	3400	58,000	150.0	259.50
300	1995	4250	90,000	180.0	311.40

*Typical current surge duration for start-up of incandescent loads.
**Continuous current derated to 135 A for loads with high current draw when cold, e.g., tungsten heaters and tungsten lamps.

1.6.14 Firing Circuit Fuse

0.25 A fuse. Fuse opens if an SCR fails to fire when activated.

1.6.15 Isolation

Control Signal to AC Line and Load

1500 VAC.

Heatsink to AC Line and Load

1500 VAC.

1.6.16 Environmental Limits

Operating

32°F to 122°F (0°C to 50°C) at up to 90 percent relative humidity (non-condensing).

Storage

–40°F to 158°F (–40°C to 70°C) at up to 90 percent relative humidity (non-condensing).

1.6.17 Thermostat

Non-latching, normally closed switch connected to firing circuit **ENABLE** terminals. Automatically shuts down power controller in case of overtemperature. Recloses to restart power controller when normal operating temperature is restored.

Switch Action	Degrees F	Degrees C
Opens at:	180 ± 5	82 ± 3
Recloses at:	140 ± 20	60 ± 11

1.6.18 Electrical Connections

Control Signal

Firing circuit + and – push-on terminals.*

Enable Switching

Two pairs of push-on terminals* on this firing circuit module are used for thermostat option, for customer-supplied enable/disable switch, and for optional instantaneous current trip (ICT), an electronic alternative to subcycle fusing.*

Line

Two compression screw terminals.**

Load

Two compression screw terminals.**

Ground

Compression screw terminal.**

*The terminal lugs supplied with unit accept 22 to 18 ga. wire.
**Maximum wire capacities:

Continuous Current Rating	Maximum Wire Gauge Line, Load	Ground	Subcycle Fuses
35-175 A	1/0 ga.	1/0 ga.	1/0 ga.
250-300 A	250 mcm	1/0 ga.	4/0 ga.

NOTES

SECTION 2.

INSTALLATION, SETUP, AND CONFIGURATION

2.1 INTRODUCTION

This section describes how to install and wire the Model 664 SCR power controller.

The features and options mentioned here are identified in the model number found on the plate attached to the top cover of the controller. See table 1–1 for the interpretation of the model number.

WARNING

1. Hazardous voltages are present at the controller's LINE and LOAD terminals and within the controller's chassis. Disabling firing circuit operation or setting the control signal to minimum does not eliminate these hazardous voltages.

2. Always remove AC line voltage from the controller before making contact with internal assemblies, line or load wiring, or any other areas where hazardous voltages may be present. Also remove AC line voltage from the controller before making connections, equipment changes, or resistance measurements.

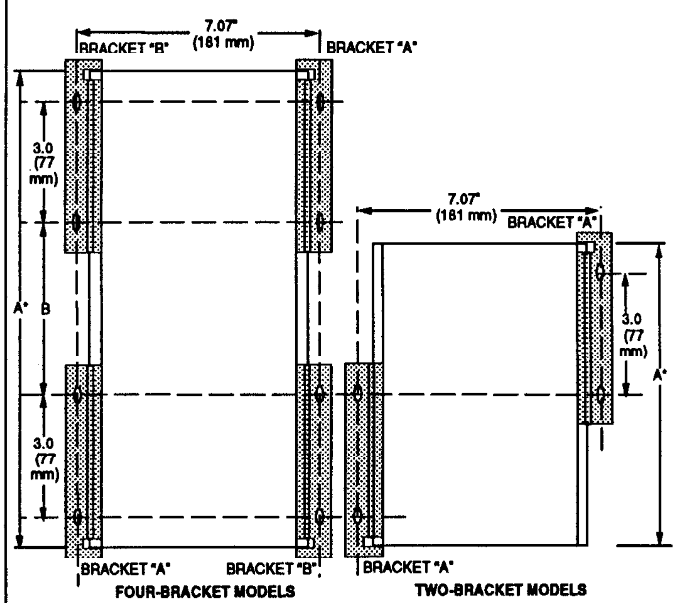

Figure 2–1. Mounting orientation for large (four-bracket) and small (two-bracket) Model 664 SCR controllers.

2.2 MOUNTING THE CONTROLLER

You can mount all models of the model 664 controller on a bench, but the preferred method is to mount them vertically on a bulkhead using two or four brackets (supplied) depending on the size of the controller. Figure 2–1 and table 2–1 give mounting dimensions for each model.

All model 664 controllers may be mounted either vertically or horizontally. If mounted vertically, fan-cooled units should be oriented so that the air flow is upward, not downward. If mounted horizontally, the controller's capacity must be derated 25 percent.

Allow at least 2 inches (50.8 mm) of space at the ends of the chassis for ventilation. If necessary, allow additional clearance if required by the wire gauge and routing methods used.

At least 0.75 inch (19.05 mm) clearance is required at each side for access to the mounting brackets.

Table 2–1. Mounting Bracket Dimensions for Figure 2–1. Dimensions in Inches (mm).

Controller Current Rating	664F	664G/K
35–70 A	A = 7.50 (192 mm) B = 0.00 (Uses two brackets only)	A = 18.00 (457.2 mm) B = 10.50 (267 mm)
90–175 A	A = 7.50 (192 mm) B = 0.00 (Uses two brackets only)	A = 27.00 (686 mm) B = 19.50 (495.3 mm)
250–300 A	A = 18.00 (462 mm) B = 10.50 (269 mm)	A = 27.00 (686 mm) B = 19.50 (495.3 mm)

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If subcycle fuses are mounted on the heatsink, be sure to allow space for the fuse at the side of the power controller. If the subcycle fuse is not mounted on the heatsink, allow sufficient space for both the fuse and its associated wiring (see section 2.4).

To mount the controller on a bulkhead or bench:

1. Determine the location in which you wish to mount the controller.
2. Using figure 2–1 and table 2–1 as guides, mark the locations of the holes that must be drilled.
3. Drill holes for #10 screws.
4. Attach the lower mounting bracket(s) (one or two, depending on the size of the controller) to the mounting surface using #10 screws (not supplied). Orient the bracket as shown in figure 2–1. Do *not* tighten the screws yet.
5. Slide the bottom fins of the heat sink into the lower bracket(s) and have an assistant hold the controller in place, with the bottom edge of each fin resting against the lip of the bracket.
6. Tighten the screws for the top bracket(s) loosely. Do *not* tighten them yet.
7. Tighten the screws for the lower bracket(s), adjusting the screws in their holes so that they are equidistant from each end of the hole.
8. Slide the top bracket(s) down securely against the lip(s) of the fin(s) and tighten the screws for both the top and bottom brackets. Mounting is now complete.

2.3 POWER WIRING CONNECTIONS

After you have mounted the controller, wire the instrument to the load and power lines using the following procedure:

1. Loosen the protective side cover if the controller has one.
   A. Remove the screws that hold the side cover to the top cover.
   B. If conduit is connected to the protective side cover, you may wish to leave the cover in place after removing the screws.
2. Remove the top cover.
   A. Note the positions of the slotted holes in the long side of the top cover (see figure 2–2).
   B. Remove the screws that hold the chassis cover to the standoffs.
   C. Lift the cover from its position as far as the wiring harness will permit.
   D. Replace the screws in the standoffs on the same side as the slotted holes in the cover, turning the screws until they are halfway into the standoffs.
   E. Position the top cover with the slotted holes aligned over the heads of the screws just replaced (figure 5–16). The top cover will now remain in place, "on edge," rotated 90 degrees from its original position. This provides complete access to all wiring connections and all internal components.

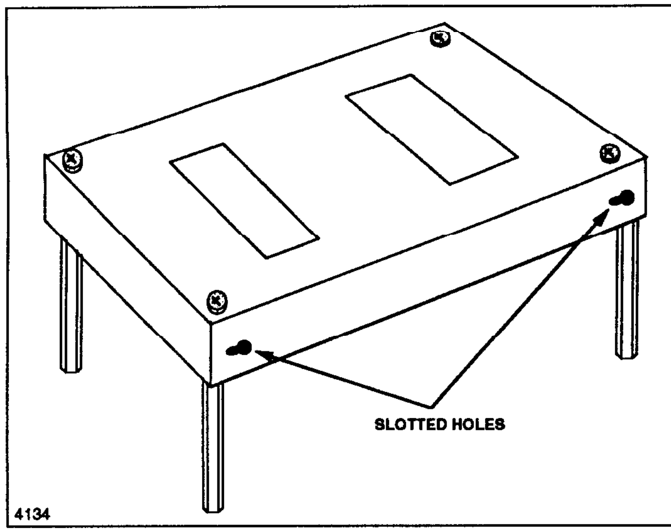


Figure 2–2. Slotted holes in controller cover.

3. Attach the ground wire to the screw compression connector mounted at the end of the heat sink (figures 2–3 and 2–4).
   A. Attach the external power lines to the **LINE** connectors on the printed circuit board(s) (see figure 2–3 for the 664F or figure 2–4 for the 664G/K). On a model 664G/K controller, connect the phase A power line to the **LINE 1** connector, the phase B power line to the **LINE 2** connec-tor, and the phase C power line to the **LINE 3** connector.

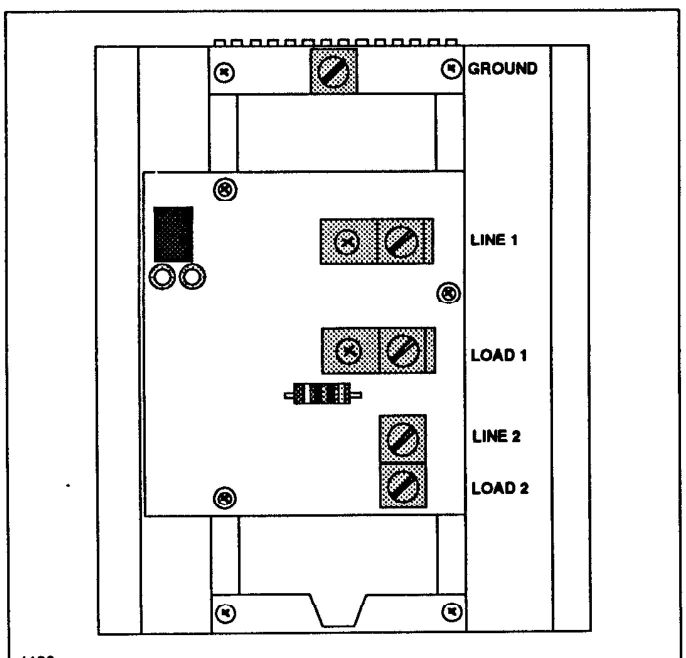


Figure 2–3. Typical model 664F LINE and LOAD connector locations.

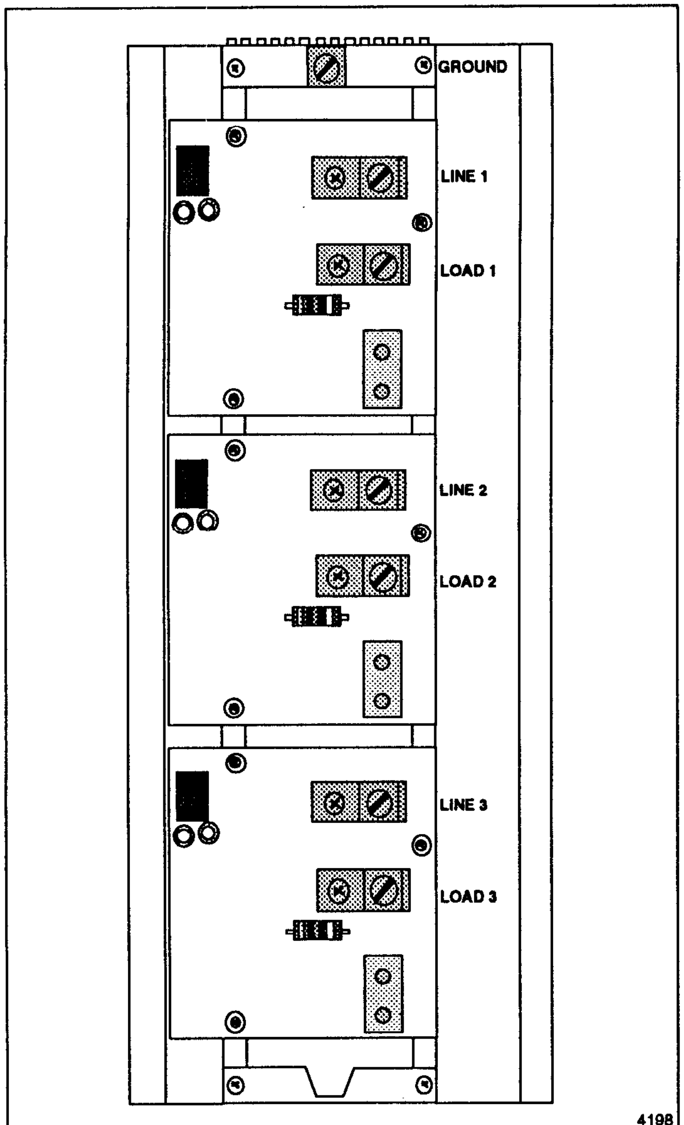


Figure 2–4. Typical model 664G/K LINE and LOAD connector locations.

B. If the controller is a model 664G/K and its output level jumps suddenly as the level of the control signal is increased, the AC line connections may be out of sequence.
   1) Remove line voltage from the controller.
   2) Reverse any two connections to the **LINE** terminals.
   3) Reapply line voltage.
   4) If proper power control is achieved, retain the new connections. Otherwise, restore the connections as they were previously and continue with this checkout procedure.

4. Replace the chassis cover and tighten all cover mounting screws.

2.4 OPTIONAL SUBCYCLE FUSE MOUNTING

Subcycle fuses (figure 2–5) for 70 A through 175 A controllers may be mounted on the side of the controller's heat sink, as shown in figures 2–5 and 2–6, or externally on a nearby bulkhead or bench. Subcycle fuses for 250 A and 300 A controllers must be mounted externally and should be located as close as possible to the controller.

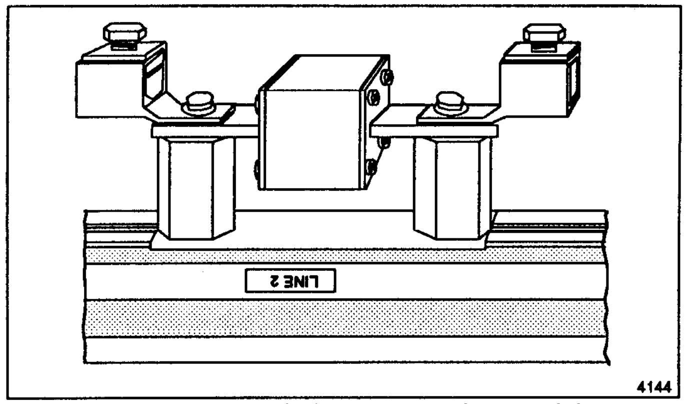


Figure 2–5. Subcycle fuse mounted on model 664 heatsink fins.

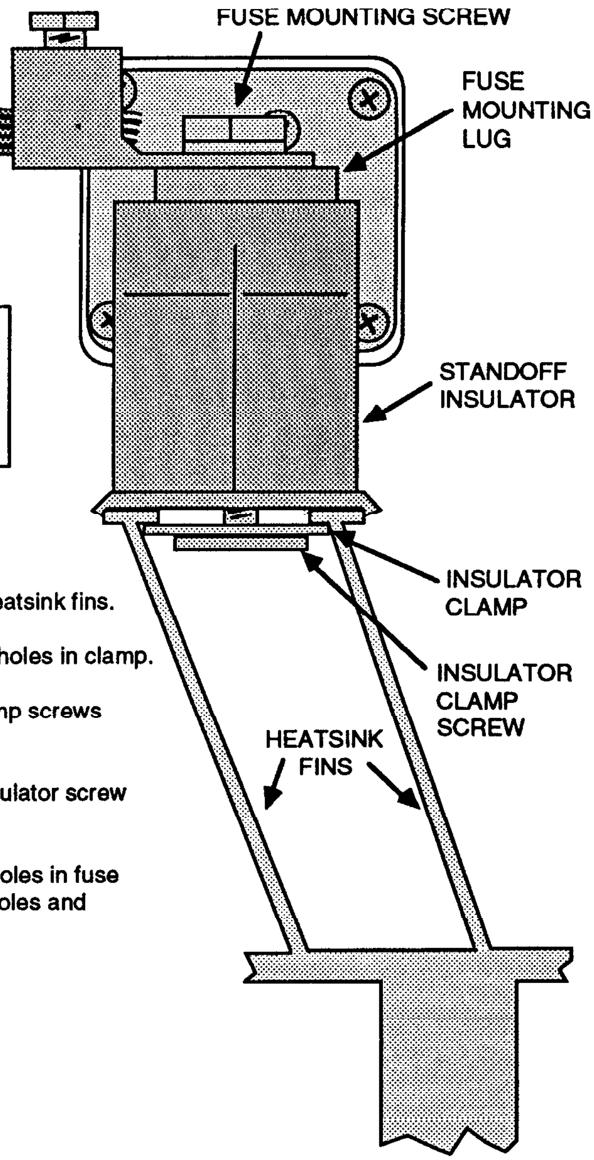
Even if ordered with a controller, subcycle fuses are not mounted to the controller at the factory. The fuses and all mounting hardware are furnished in the form of a kit, which includes insulated standoffs and mounting hardware. The kit for 70 A through 175 A controllers also includes brackets for mounting the fuses on the side of the controller's chassis.

To install and connect the single subcycle fuse required for a model 664F controller:

1. Connect AC line 1 to one fuse terminal and connect the other fuse terminal to the **LINE 1** connector on the printed circuit board.
2. Connect the other AC line to the **LINE 2** connector on the printed circuit board.
3. Connect the load wires to the **LOAD 1** and **LOAD 2** connectors on the printed circuit board.

To install and connect the three subcycle fuses required for a model 664G/K controller:

1. Connect the phase A power line to one fuse terminal and connect the other fuse terminal to the **LINE 1** connector on the printed circuit board.
2. Connect the phase B power line to the second subcycle fuse and connect that fuse's other terminal to the **LINE 2** connector on the printed circuit board.
3. Connect the phase C power line to the third subcycle fuse and connect that fuse's other terminal to the **LINE 3** connector on the printed circuit board.
4. Connect the load wires to the **LOAD 1, LOAD 2,** and **LOAD 3** connectors on the printed circuit board.



CAUTION
MAKE SURE AC POWER IS DISCONNECTED FROM THE MODEL 664 CONTROLLER BEFORE BEGINNING THIS PROCEDURE.

Fuse Mounting Procedure

1. Place clamp under insulators below lips of heatsink fins.
2. Insert insulator clamp screws through screw holes in clamp.
3. Thread standoff insulators onto insulator clamp screws and tighten securely.
4. Position fuse mounting lugs over standoff insulator screw holes.
5. Insert fuse mounting screws through screw holes in fuse mounting lugs into standoff insulator screw holes and tighten securely.

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Figure 2–6. Subcycle fuse mounting details.

CAUTION

1. Any control transformer used to monitor the power controller's output should have a rating sufficient to prevent damage to the transformer from saturation.

2. AC power connections should be made by a qualified electrician to ensure that all wiring is in accordance with National Electrical Code standard (within the United States) or equivalent standards (outside the United States).

2.5 SIGNAL WIRE CONNECTIONS

The standard 664 controller without options will accept only a 4–20 mA control signal with a 12-volt minimum compliance. The optional input module (if installed) allows you to use a 1000 ohm potentiometer, a 0–5 volt DC signal, or a 0–20 mA signal as a control input.

The accessory package supplied with the 664 controller contains push-on lugs for attachment to 18- to 22-gauge control signal wiring.

The phase angle firing circuit module is standard on all 664F controllers The phase angle control module is standard on all 664G and 664K controllers. The current module and input module are factory-installed options.

Connect the control signal wires as follows:

1. If the controller does not have an input module or current module, connect the 4–20 mA control-signal wires to the **INPUT +** and **–** terminals on the phase angle firing circuit module (664F) or phase angle control module (664G/K). See figures 3–10 and 3–12 for the 664F or figures 3–11 and 3–13 for the 664G/K.
2. If the controller has a current module but does not have an input module, connect the 4–20 mA control-signal wires to the **4–20 IN** terminals of the current module (figure 3–16). See figure 3–17 for the 664F or figure 3–18 for the 664G/K.
3. If the controller has an input module, regardless of whether it also has a current module (see figures 3–20 and 3–22 for the 664F or figures 3–21 and 3–23 for the 664G/K):
   A. If a 0–5 VDC control signal is being used (see figure 2–15):
      (1) Connect the positive control-signal wire to the **0–5 V** terminal of the input module.
      (2) Connect the negative control-signal wire to one of the **COM** terminals of the input module.
   B. If a 0–20 mA control signal is being used (see figure 2–15):
      (1) Connect the positive control-signal wire to the **0–20 MA** terminal of the input module.
      (2) Connect the negative control-signal wire to one of the **COM** terminals of the input module.
4. If the controller has an input module and an installed 1000 ohm potentiometer, all wiring has been factory-installed on the input module.
5. If a remote 1000 ohm potentiometer is to be used:
   A. Connect its wiper to the **0–5V** lug on the phase angle firing circuit module (for the 664F) or phase angle control module (for the 664G/K).
   B. Connect its **CW** end to the module's **POT** terminal.
   C. Connect its **CCW** end to one of the module's **COM** terminals.

NOTE

The potentiometer cannot normally be used concurrently with another control signal. The potentiometer wiper must be disconnected from the input module if a 0–5 VDC, 0–20 mA, or 4–20 mA input signal is to be used.

2.6 ENABLE/DISABLE SWITCH OR RELAY

The controller can be enabled and disabled by means of an "enable/disable" switch (not supplied) the user installs and connects to the **ENABLE 3** and **4** terminals on the model 664F phase angle firing circuit module (figure 3–12) or model 664G/K phase angle control module (figure 3–13).

We recommend that you use a maintained-position, SPST switch for enable/disable switching. To avoid noise pickup, separate the switch wiring from all AC power wiring. If the wiring to the switch is long or if it passes through an electrically noisy environment, it may be necessary to use a local relay in conjunction with the enable/disable switch. In that case, install the relay as close as possible to the power controller. The switch then activates or deactivates the local relay, the contacts of which are connected to the **ENABLE 3** and **4** terminals on the firing circuit module.

To install and connect an enable/disable switch (see figure 2–7):

1. Move the thermostat connection on the phase angle firing circuit module or phase angle control module from the **ENABLE 3** terminal (as it is in figure 2–7A) to the **ENABLE 1** terminal.
2. Install the enable/disable switch in a location of your choice. Route the switch or relay wiring through one of the two access holes in the top cover of the controller.
3. Crimp a push-on lug (supplied) on each switch or relay-contact wire.
4. Connect the lugs to the **ENABLE 3** and **4** terminals on the firing circuit module as shown in figure 2–7B. There is no wiring polarity for these connections.

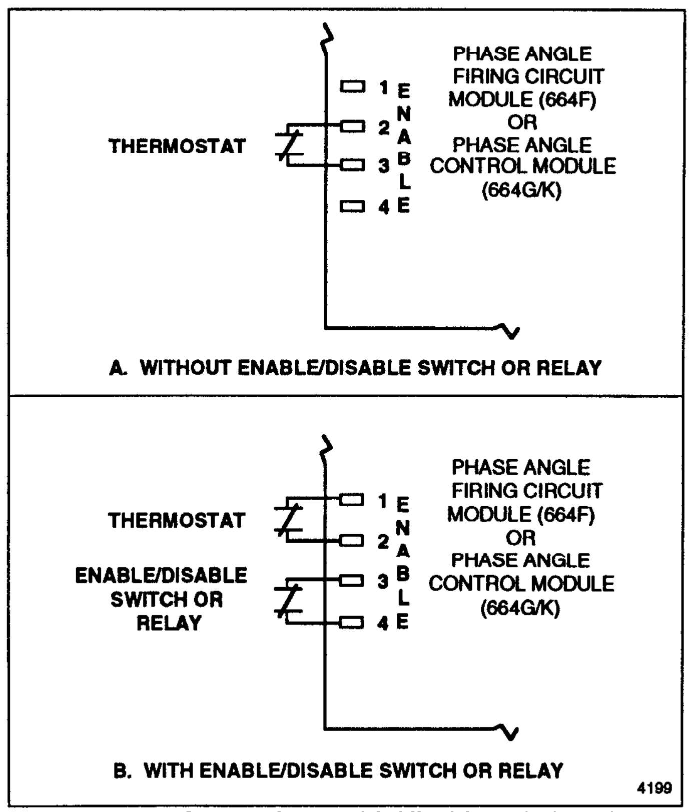

Figure 2–7. Connecting enable/disable switch to the phase angle firing circuit module or the phase angle control module.

2.7 LOAD CONDITIONING CONFIGURATION

2.7.1 General Description

The model 664F phase angle firing circuit module and the model 664G/K phase angle control modules include jumper-selectable load conditioning as a standard feature. The load conditioning circuit allows the user to match the power controller response time (the time required for the controller output to reach 90 percent of its final value) to the load requirements. Three load conditioning selections are available:

1. Fast.
2. Ramp.
3. Lamp.

Fast load conditioning is suitable for resistive loads and provides a 30- to 60-millisecond response time.

Ramp load conditioning is suitable for inductive loads and provides a 250- to 350-millisecond response time.

Lamp load conditioning is suitable for high-inrush loads such as incandescent lamps. Lamp load conditioning provides fast response time (30 to 60 milliseconds) for step decreases in the control signal but slow response time (up to 2.5 to 3.5 seconds) for increases in the control signal.

If the control signal is reduced and then increased again, the response time varies according to the duration of the reduced control signal level. The longer the control signal remains at the reduced level, the slower the response time for a control signal increase. After ten seconds at the reduced control signal level, the response time for an increase reaches its maximum value (2.5 to 3.5 seconds). Also, response time is increased by several seconds when starting from the control signal minimum (4 mA).

2.7.2 Connections

The load conditioning circuit is factory-configured for fast response. To change the load conditioning, connect a jumper to the terminals on the 664F phase angle firing circuit module or 664G/K phase angle control module as follows (see figure 2–8):

1. For ***fast*** load conditioning, connect the **RAMP** terminal to the **LAMP** terminal.
2. For ***ramp*** load conditioning, connect the **RAMP** terminal to the **LD COND** terminal.
3. For ***lamp*** load conditioning, connect the **LAMP** terminal to the **LD COND** terminal.

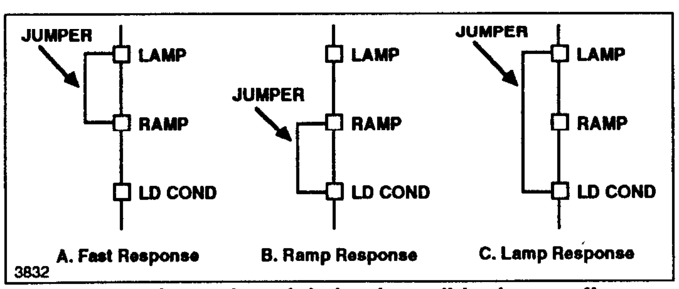

Figure 2–8. Control module load conditioning configuration connections on model 664F phase angle firing circuit module and model 664G/K phase angle control module.

NOTE

Push-on lugs (part number KB067741-001) for the module terminals are included with the controller. The lugs are suitable for use with 18- to 22-gauge wire.

2.8 LOAD VOLTAGE METER DRIVE SIGNAL

The 664F phase angle firing circuit module and the 664G/K phase angle control module generate a 0-100 microampere signal the level of which is proportional to the average load voltage at the output of the controller. This signal may be used to drive an external meter.

Zero microamperes represents zero load voltage; 100 microamperes corresponds to the *line* voltage for which the controller is configured when the **SPAN** potentiometer is adjusted as described in section 2.14. Terminal locations are shown in figure 3–12 for the 664F or figure 3–13 for the 664G/K.

To utilize the load voltage meter drive signal:

1. Crimp a push-on lug to each meter wire.

NOTE

Push-on lugs (part number KB067741-001) for the module terminals are included with the controller. The lugs are suitable for use with 18- to 22-gauge wire.

2. Connect the + terminal of the external meter to the module's **METER** terminal.
3. Connect the – terminal of the external meter to the module's **COM** terminal.

2.9 LOAD CURRENT METER DRIVE SIGNAL

On the 664F, 664G, and 664K controllers, when either current feedback or current limiting is selected as described in section 2.10, the current module provides a 0–100 microampere meter drive signal the level of which is proportional to the average load current at the output of the controller. This signal may be used to drive an external meter.

When current feedback is selected, a zero meter-drive signal corresponds to zero controller load current, and a 100 microampere meter-drive signal corresponds to full rated current capacity. See section 2.10.2.3 for the effects of current feedback calibration.

When current limiting is selected, the operating range of the meter drive signal is determined by the current limiting setting. A zero meter-drive signal corresponds to zero controller load current, but a 100 microampere meter drive signal corresponds to *89 percent* of the current limit set in section 2.10.3.

To utilize the load current meter drive signal:

1. Crimp a push-on lug to each meter wire.

NOTE

Push-on lugs (part number KB067741-001) for the module terminals are included with the controller. The lugs are suitable for use with 18- to 22-gauge wire.

2. Connect the + terminal of the external meter to the current module's **MTR** terminal. Terminal locations are shown in figure 3–16.
3. Connect the – terminal of the external meter to one of the module's **COM** terminals.

2.10 LOAD CURRENT FEEDBACK AND CURRENT LIMITING

2.10.1 Introduction

If the 664F, 664G, or 664K controller is equipped with a current module, either load current feedback or load current limiting—but not both—can be used.

Current feedback or current limiting is selected by adding a connection between the current module and either the phase angle firing circuit (664F) or the phase angle control module (664G/K). If neither current feedback nor current limiting is desired, this connection is deleted or not made. When the controller is shipped, the connection (or lack thereof) is configured to match the customer order.

2.10.2 Load Current Feedback

2.10.2.1 General Description

Load current feedback linearizes the relationship between the control signal and the power controller's average total load current (for all three phases in the 664G/K). Current feedback also provides current regulation to maintain the selected load current level despite variations in line voltage and load impedance. When selected, current feedback replaces the power controller's standard average load-*voltage* feedback circuit.

The 664F phase angle firing circuit module and 664G/K phase angle control modules require an isolated load feedback signal (0–4 VDC nominal) suitable for operating into 400K ohms. That signal can be supplied by the optional current module (if installed) or from some other source.

2.10.2.2 Connections

If the controller is not equipped with a current module, or if the controller is factory equipped with a current module but the purchaser does not select current feedback at the time the controller is ordered, the 664F phase angle firing circuit or 664G/K phase angle control module is factory configured to use internal feedback (average load voltage feedback). Internal feedback is selected by connecting a jumper wire between the **FB INPUT** and **INT FB** terminals of the 664F phase angle firing circuit module or 664G/K phase angle control module (see figure 2–9A).

To change from internal feedback to external current feedback from a source other than the model 664 current module (see figure 2–9B):

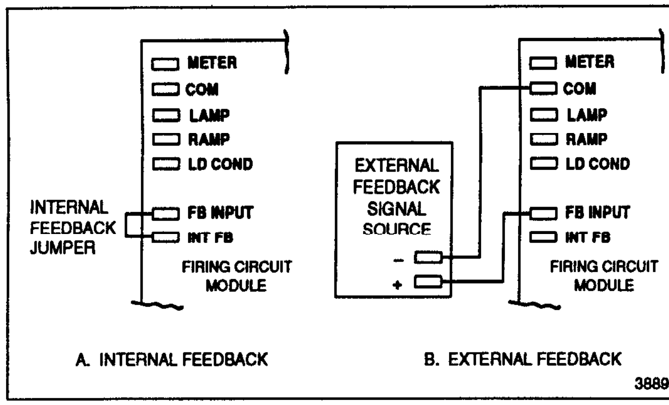

Figure 2–9. Feedback configuration connections.

1. Disconnect the jumper connected between the **FB INPUT** and **INT FB** terminals of the 664F phase angle firing circuit module or the 664G/K phase angle control module.
2. Connect the positive external feedback wire to the module's **FB INPUT** terminal.
3. Connect the negative external feedback wire to one of the module's **COM** terminals.

To change from internal feedback to external current feedback from the model 664 current module (see figure 2–10):

1. On the current module, disconnect the **CLA** end of the jumper that is connected between the **IFB** terminal and the **CLA** terminal and leave it loose. Leave the other end of the jumper connected to the **IFB** terminal.
2. On the phase angle firing circuit module or phase angle control module:
   A. Remove the jumper connected between the **IFB** and **FB INPUT** terminals.
   B. Connect to the **FB INPUT** terminal the loose end of the jumper that is connected to the current module's **IFB** terminal.

To change from external current feedback that is being furnished by the current module to internal feedback:

1. On the current module, disconnect the **IFB/CLA** wire from the **IFB** terminal.
2. On the 664F phase angle firing circuit module or the 664G/K phase angle control module:
   A. Disconnect the current-module **IFB/CLA** wire from the **FB INPUT** terminal.
   B. Connect a jumper between the **INT FB** and **FB INPUT** terminals.

To change to internal feedback from external current feedback that is being received from a source other than the model 664 current module, make the following connection changes on the 664F phase angle firing circuit module or the 664G/K phase angle control module:

1. Disconnect the external feedback wires from the module's **FB INPUT** and **COM** terminals.
2. Connect a jumper wire between the **FB INPUT** and **INT FB** terminals.

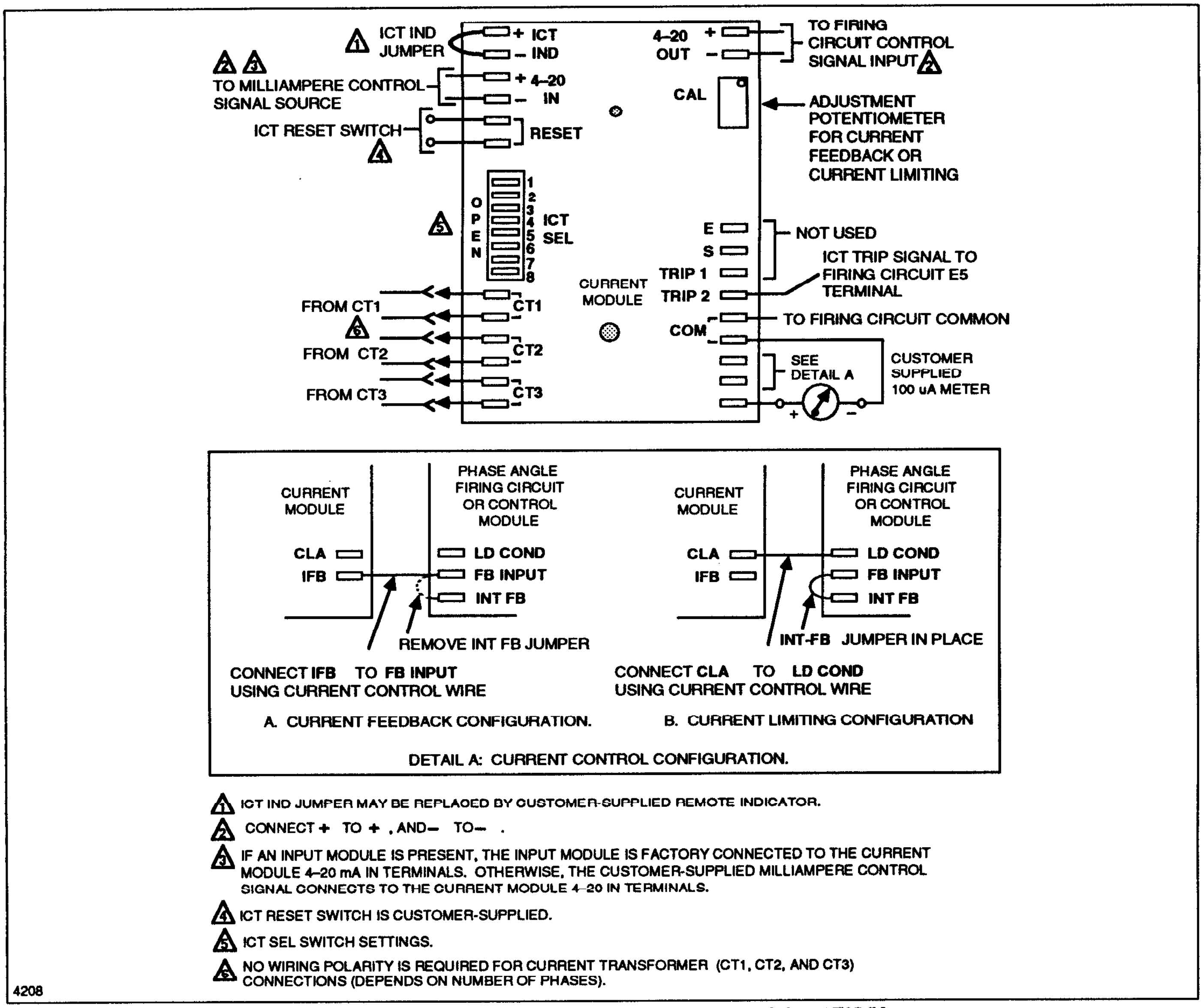

Figure 2–10. Current module connections, model 664F/G/K.

2.10.2.3 Calibration

WARNING

Hazardous voltage is present when performing the current module calibration procedures. These adjustments should be made only by qualified service personnel. Before performing these adjustments, the controller should be completely mounted, configured, and connected as specified in this manual. Be sure to remove all power from all associated electrical equipment before making or breaking any electrical connections.

If current feedback is selected, the current module's **CAL** potentiometer adjusts the control signal input span. The **CAL** potentiometer should be set so that when the control signal is at the maximum value to be used, the load current is at the desired maximum value. For most applications, the desired maximum load current is approximately 100 percent of the controller's rated current capacity. The nominal control signal maximum value is 20 mA. See section 2.14 for additional input span adjustment information.

The required control signal value for rated maximum load current can be varied from 15 mA to 20 mA. In addition, the **CAL** potentiometer can be used to restrict the maximum load current to a value less than the controller's rated maximum load current. To provide such load current restriction, simply set the **CAL** potentiometer so that the maximum control signal value to be used produces less than rated maximum controller load current. For a 4–20 mA control signal, the maximum load current can be varied from 100 percent to 80 percent of the controller's rated maximum

The **CAL** potentiometer determines the relationship between the controller's load current and the current module's meter drive signal. When current feedback is selected, the meter drive signal reaches 100 microamperes when the average load current reaches nominal maximum. Nominal maximum load current is the average load current when the control signal is 20 mA.

To adjust the current module's **CAL** potentiometer when current feedback is selected:

1. Connect an AC ammeter to monitor the controller's load current (figure 2–11A (for 664F) or figure 2–11B (for 664G/K).

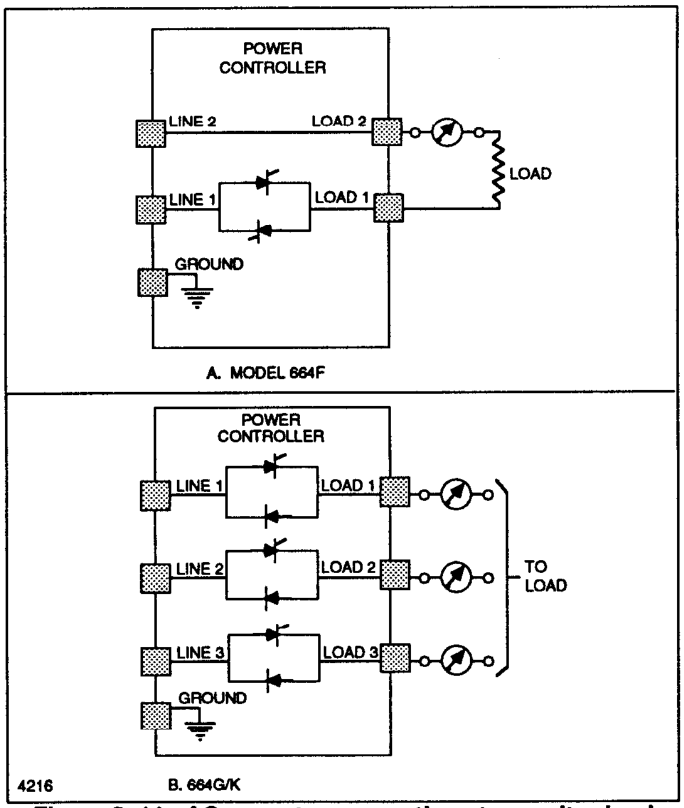

Figure 2–11. AC ammeter connections to monitor load current.

2. Connect a milliammeter as shown in figure 2–12.
3. Perform the start-up procedure as described in section 4.1.
4. Set the control signal to the maximum value to be used.
5. While watching the AC ammeter, using a small screwdriver adjust the current module's **CAL** potentiometer until the load current equals the desired value. Turning the **CAL** potentiometer clockwise increases the load current.
6. Remove the connections installed in steps 1 and 2.
7. Calibration is complete.

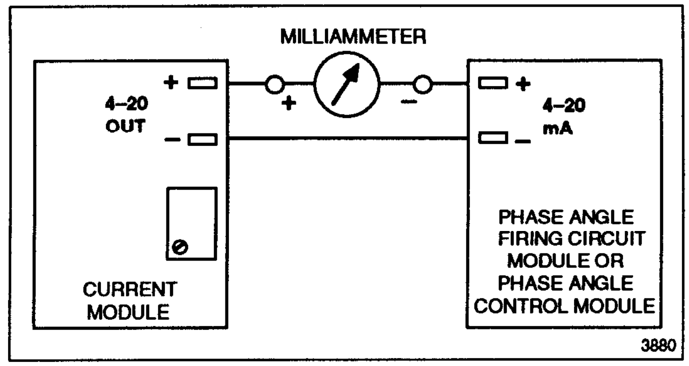

Figure 2–12. Milliammeter connections to monitor firing circuitry control signal.

2.10.3 Load Current Limiting

2.10.3.1 General Description

Current limiting limits the controller's average total load current (for all three phases in the 664G/K) to a user-adjustable maximum value between 50 and 125 percent of the controller's total rated current capacity. Current limiting is especially useful for limiting inrush current to loads that have inrush periods longer than several seconds.

If current limiting is selected, the current module **CAL** potentiometer sets the load current value at which current limiting occurs and also determines the operating range for the current meter drive signal.

2.10.3.2 Connections

To utilize current limiting:

1. On the current module, connect the **IFB/CLA** wire to terminal **CLA**.
2. On the 664F phase angle firing circuit module or the 664G/K phase angle control module, connect the current control wire to the **LD COND** terminal. A push-on tab adaptor is mounted on the **LD COND** terminal to allow connection of both the current control wire and the load conditioning jumper to the **LD COND** terminal.

2.10.3.3 Calibration

WARNING

Hazardous voltage is present when performing the current module calibration procedures. These adjustments should be made only by qualified service personnel. Before performing these adjustments, the controller should be completely mounted, configured, and connected as specified in this manual. Be sure to remove all power from all associated electrical equipment before making or breaking any electrical connections.

To adjust the current module **CAL** potentiometer when current limiting is selected:

1. Connect an AC ammeter to monitor the controller's load current (figure 2–11).
2. Connect a milliammeter as shown in figure 2–12.
3. Set the current module's **CAL** potentiometer fully counterclockwise. This setting limits the controller's load current to approximately 50 percent of rated capacity.
4. Perform the controller startup procedure described in section 4.1.
5. Set the control signal to the maximum value to be used.
6. Slowly turn the current module's **CAL** potentiometer clockwise until the load current reaches the desired maximum load current.
7. Remove the connections installed in steps 1 and 2.
8. Calibration is complete.

2.11 OPTIONAL SCR ALARM CIRCUIT

The optional SCR alarm circuit, if installed, monitors SCR operations and operates a set of form C relay contacts if an SCR short circuits (a short circuit is the most common type of SCR failure).

Connect external indicators or devices that operate on contact *closures* between the **C** (common) terminal and the **NC** (normally closed) terminal (see figure 2–13). Connect external indicators or devices that operate on contact *openings* between the **C** (common) terminal and the **NO** (normally open) terminal (see figure 2–14 for wire-connection procedure).

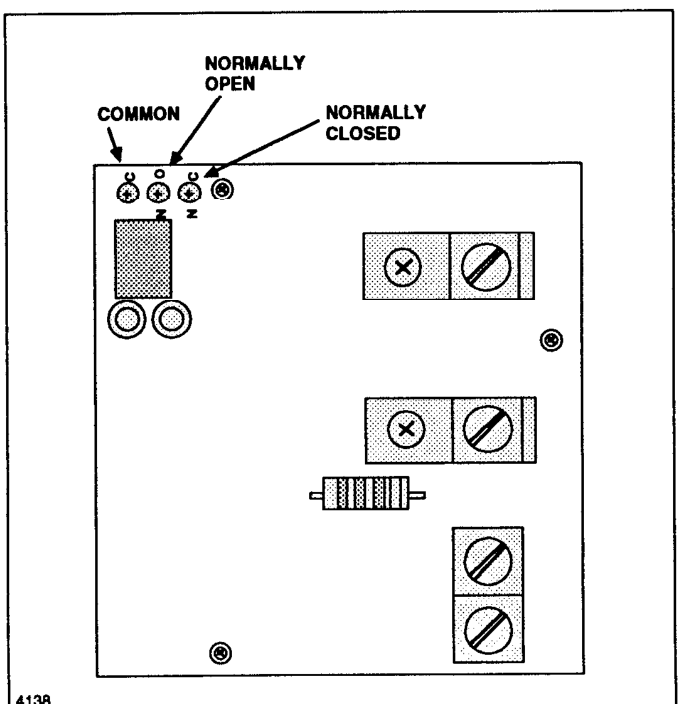

Figure 2–13. SCR alarm circuit terminal locations.

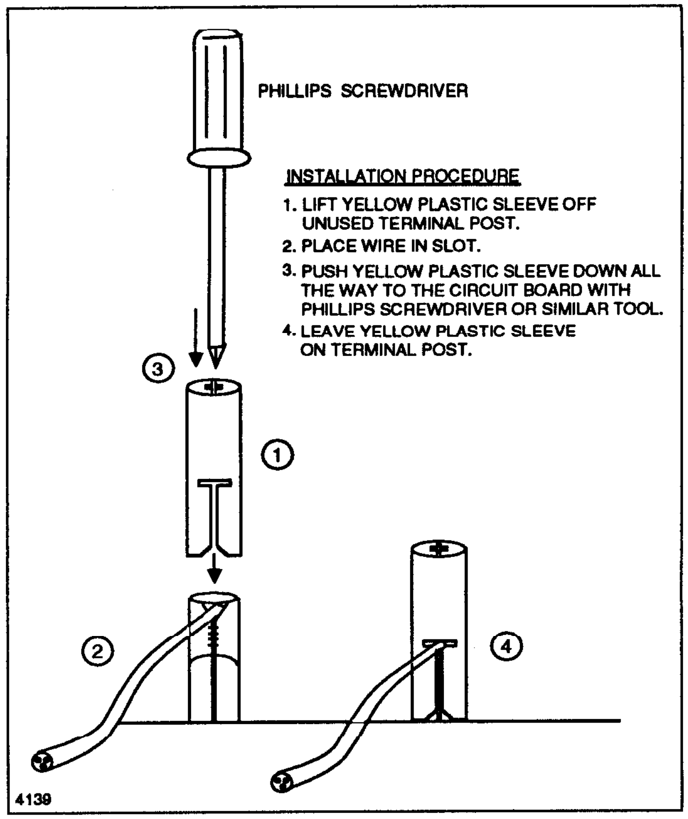

Figure 2–14. Wire connection procedure for insulation displacing terminals.

2.12 ICT FUNCTION

2.12.1 ICT Reset Switch Wiring

Instantaneous current trip (ICT) is a function provided by the optional current module, if installed (see figure 3–16), which sends a "trip"signal to the controller's firing circuit that disables controller operation within one AC cycle if the controller's output current exceeds a preset level. Once "tripped," the ICT circuit remains tripped until it is reset.

There are two ways to reset the ICT circuit:

1. Connect a customer-supplied single pole, normally *open*, momentary contact push-button switch between the two **RESET** terminals on the current module (see figure 3–17 for the 664F or figure 3–18 for the 664G/K). Pressing the switch closes the switch contacts, which resets the ICT circuit.
2. Connect a customer-supplied single pole, normally *closed*, push-button switch in series with one of the control-signal wires that are connected to the **4–20 IN +** and – terminals of the current module. Pressing the switch opens the switch contacts, which resets the ICT circuit.

The current module (if supplied) is mounted under the controller's cover plate (see figure 5–16). Push-on lugs (part number KB067427-001) suitable for 18- to 22-gauge wire, are supplied with the power controller.

If installing a reset switch, crimp a push-on lug to each switch wire and install the lugs on the **RESET** terminals. There is no polarity to observe.

If installing a switch to interrupt the **4–20 IN +** or **–** signal, installation details will depend on where the switch is to be inserted in the signal wire.

2.12.2 Current Rating Configuration

The **ICT SEL** switches determine the sensitivity of the current module, and are factory set to correspond to the controller's 100 percent current rating. The ICT trip level is internally fixed at four times (400 percent) rated current selected by the switches. The switches can be set to a current value lower than the controller's actual rating, but should never be set to a higher value.

Normally, the settings of the **ICT SEL** switches need not be checked or changed unless the current module is replaced.

The switch settings versus rated current are shown in table 2–2 (for the 664F) and table 2–3 (for the 664G/K).

Table 2–2. ICT SEL Switch Settings, Model 664F

	Switch Number							
Amps	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
35 and 50	0	C	0	0	0	0	0	0
70 and 90	0	0	C	0	0	0	0	0
125	0	C	C	0	0	0	0	0
175	C	0	0	C	0	0	0	0
250	C	0	C	C	0	0	0	0
300	C	C	C	C	0	0	0	0

Note: C = Closed
0 = Open

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Table 2–3. ICT SEL Switch Settings, Model 664G/K

	Switch Number							
Amps	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
35 and 50	0	0	C	0	0	0	0	0
70 and 90	C	0	0	C	0	0	0	0
125	C	0	C	C	0	0	0	0
175	C	C	C	C	0	0	0	0
250	C	C	C	C	C	C	0	0
300	C	C	C	C	C	C	C	0

Note: C = Closed
0 = Open

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2.12.3 ICT Indicator Wiring

A jumper wire is factory installed across the **ICT IND** terminals of the current module (see figure 5–6). If desired, this jumper can be removed and the **ICT IND** signal can be used to operate a remote indicator.

When the ICT circuit is tripped, the **ICT IND** terminals supply a DC current, ranging from approximately 4 to 20 mA, that is derived from the control signal received at the ICT module's **4–20 IN** terminals. This current may be used to drive an LED or operate a solid-state relay.

Push-on lugs (part number KB067427-001) suitable for 18- to 22-gauge wire are supplied with the power controller. Crimp a push-on lug to each indicator or relay wire and install the lugs on the **ICT IND** terminals in place of the **ICT IND** jumper. Be sure to observe the indicated signal polarity.

<u>**CAUTION**</u>

The ICT IND – terminal is not at common potential. The ICT IND signal must be connected to an isolated input or device.

Any LED or solid state relay that will operate on 4 mA of current may be connected to the **ICT IND** terminals. Some typical solid-state relays suitable for use in this application are listed in table 2–4.

Table 2–4. Typical Solid State Relays Suitable for Use with ICT IND Signal

Solid State Relay	Relay Application
OPTO 22 Model OAC5	12 to 140 VAC at up to 3A
OPTO 22 Model OAC5P	12 to 280 VAC at up to 3A

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2.13 LINE VOLTAGE CONFIGURATION

2.13.1 Input Module

The optional input module, if installed, uses AC power from the controller's **LINE** terminals and therefore must be configured to match the line voltage supplied to the controller.

The input module is configured for the line voltage specified at the time of purchase. If the controller is to be operated on a different line voltage, the input module must be reconfigured for the new voltage.

<u>**CAUTION**</u>

The input module may be damaged or may not operate correctly if it is not properly configured for the line voltage to which it is connected.

Voltage configuration consists of connecting one or two jumpers or a capacitor between the proper terminals on the input module. The terminals to which the jumper(s) or capacitor are connected depend on the line voltage in use. See table 2–5 and figure 2–15 for connection instructions.

Terminal lugs (part number KB067427-001) for making jumpers or for attaching to capacitor leads are supplied with the power controller.

Table 2–5. Input Module Line Voltage Configuration Connections

AC SUPPLY VOLTAGE	WHAT TO CONNECT	CONNECT BETWEEN THESE INPUT MODULE TERMINALS
120*	Jumper Jumper	1 and 2 3 and 4
208-277	Jumper	1 and 2
380-480	Jumper	2 and 3
600	Capacitor**	2 and 3

*664F only
**Part Number 062864-002. Order from Research, Inc. Field Service Department.

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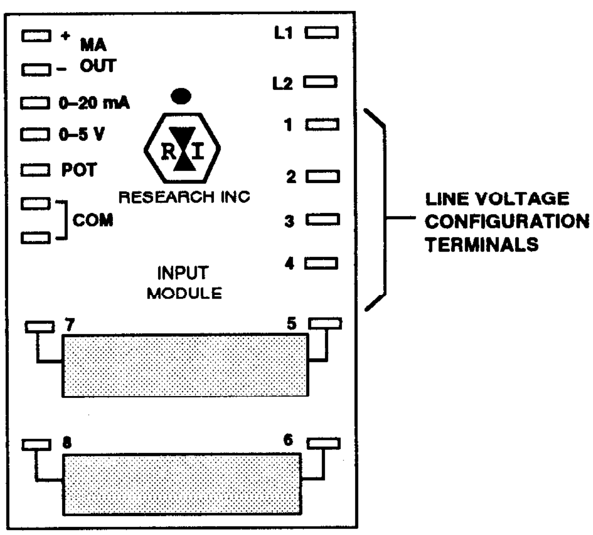

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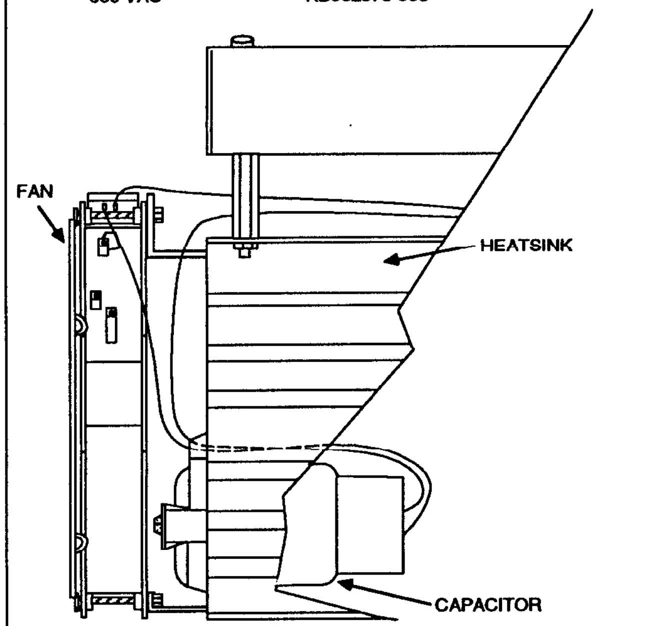
Figure 2–15. Input module line-voltage configuration terminals.

2.13.2 Fan Assembly

The cooling fan (installed only on 175 A, 250 A, and 300 A controllers) is factory-configured for the line voltage specified at the time of purchase by installation of a capacitor. If the controller is to be operated on a different voltage, you must change the voltage-configuration capacitor. See figure 2–16 for the capacitor's location and the part number of the capacitor that must be used for each line voltage.

Line Voltage	Capacitor Part Number
120 VAC	None
208 VAC	KB062877-002
240 VAC	KB062877-001 and KB062865-001 *
277 VAC	KB062877-001
380 VAC	KB062878-002
415 or 480 VAC	KB062878-001
600 VAC	KB062878-003



* For 240 VAC operation, a second capacitor assembly (P/N KB062865-001) connects in parallel with the larger capacitor (P/N KB062877-001) by means of push-on connectors.

The second capacitor assembly consists of a capacitor (P/N KB062864-001), two push-on lugs (P/N KB055016-021), and lead sleeving (P/N KB055016-021).

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Figure 2–16. Fan assembly voltage configuration capacitor.

If you change the capacitor, check the voltage across the fan leads after the capacitor has been changed. It should be approximately 120 VAC if the proper capacitor is installed.

2.14 CONTROL SIGNAL INPUT SPAN ADJUSTMENT

2.14.1 Introduction

WARNING

1. Hazardous voltage is present when performing the span adjustment. This adjustment should be made only by qualified service personnel.

2. Before performing the span adjustment, the controller must be completely mounted, configured, and connected as described in the preceding parts of section 2 of this manual.

A 20-turn **SPAN** potentiometer is located along the left side of the 664F phase angle firing circuit module (see figure 3–12) or 664G/K phase angle control module (see figure 3–13). The **SPAN** potentiometer is factory set so that a 20 mA control signal produces full rated power output when the controller is connected to the line voltage specified in the customer order.

For most applications, no adjustment of the **SPAN** potentiometer is required. However, the user may wish to change the **SPAN** potentiometer's setting when changing the load current feedback configuration (described in section 2.10.2) or in order to:

1. Adjust the firing circuit module for a line voltage different from the value specified in the customer order.
2. Accommodate a control signal maximum value other than 20 mA.
3. Provide output limiting by adjusting the **SPAN** potentiometer's setting so the controller can deliver only the desired maximum output in response to the maximum control-signal value to be used.
4. Verify correct **SPAN** potentiometer adjustment.

2.14.2 Adjustment Procedure

2.14.2.1 If Internal Feedback is Selected

The **SPAN** potentiometer adjustment procedure is as follows:

WARNING
Remove AC power from all affected equipment while making or breaking electrical connections.

1. Connect an AC voltmeter across the controller's **LOAD 1** and **LOAD 2** terminals.
2. Connect a milliammeter as shown in figure 5–5.
3. Perform the general startup procedure described in section 4.1.
4. Watching the milliammeter, set the control signal to the maximum value that will be used.
5. Adjust the **SPAN** potentiometer until the controller's output reaches the level desired for the control signal set in step 4. Turning the **SPAN** potentiometer *counter-clockwise* increases the controller's output.
   A. For most applications, the desired maximum controller output level is 100 percent of the line voltage. The required control signal value for 100 percent output can be varied from 15 mA to 20 mA.
   B. To provide output limiting, set the **SPAN** potentiometer so the maximum control signal value produces less than 100 percent controller output—whatever output level is desired. When a 4–20 mA control signal is used, the controller's maximum output level can be varied from 100 percent to 80 percent.
6. Remove the milliammeter and AC voltmeter connections installed in steps 1 and 2.

2.14.2.2 If External Feedback is Selected

If external feedback is selected, the control module **SPAN** potentiometer setting affects only the span of the load voltage meter drive signal (see section 2.8).

To adjust the span potentiometer:

1. Connect an average-reading AC voltmeter across the controller's **LOAD 1** and **LOAD 2** terminals.
2. Connect a 100 microampere meter between the **METER** and **COM** terminals of the 664F phase angle firing circuit module or the 664G/K phase angle control module.
3. If necessary, connect a milliammeter as shown in figure 5–5 to monitor the controller's control signal.
4. Perform the initial startup procedure presented in section 4.1.
5. Adjust the **SPAN** potentiometer so the 100 microampere meter reading matches the AC voltmeter reading according to the scale installed on the 100 microampere meter (this could be average load voltage, output percentage, etc.).

2.15 FINAL CHECKOUT

When the model 664F or 664G/K has been completely installed, set up, and configured, perform the checkout procedure described in section 5.3 to verify correct operation.

NOTES

SECTION 3.

THEORY OF OPERATION

3.1 PRINCIPLES OF SCR POWER CONTROL

SCR type power controllers control power by controlling when silicon controlled rectifiers (SCRs) conduct AC line current to the load.

An SCR is a solid-state, electronic switching device that turns on (fires) very quickly when a low-level "gating" signal is applied to its gate electrode. The timing of the gating signal, and therefore the length of time the SCRs conduct, is determined by the controller's firing circuitry in response to a control signal. The greater the percentage of time the SCRs are on, the greater the average power they allow to pass through them to the load.

During the positive half-cycle of the AC line voltage the SCR's anode is positive with respect to its cathode, so during that half-cycle the SCR will begin to conduct whenever a gating signal is applied to its gate electrode (see figure 3–1). Once turned on, an SCR will continue to conduct until its anode-to-cathode voltage drops to zero, so the SCR continues to conduct until the end of the half-cycle.

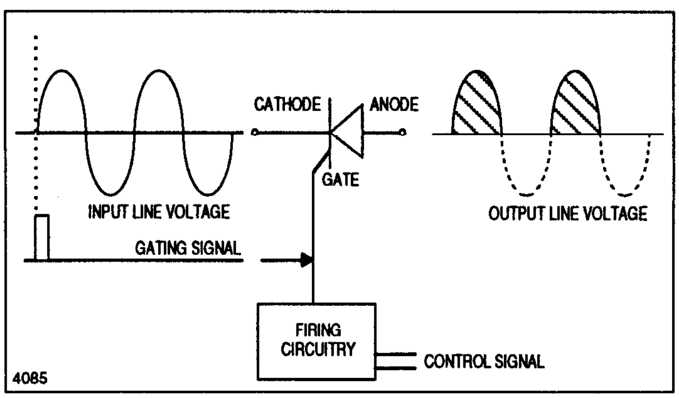

Figure 3–1. Conduction of one SCR when turned on at the beginning of a half-cycle.

Because an SCR is a type of diode, it can conduct only during every other half-cycle of the applied voltage. Therefore, SCRs used to control AC power are usually installed in pairs, connected in reverse-parallel, as shown in figure 3–2. One of the SCRs then can be fired during the positive half-cycle and the other can be fired during the negative half-cycle.

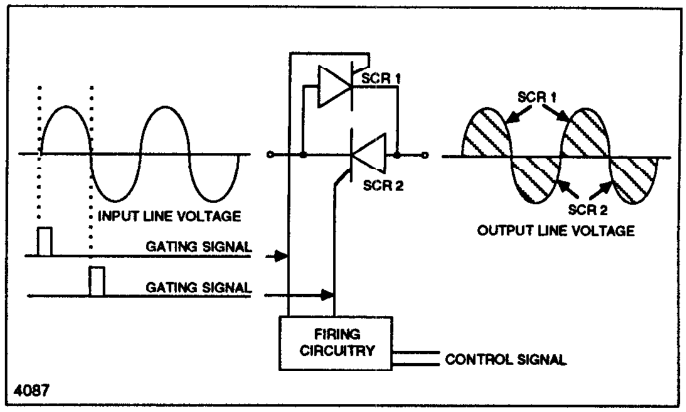

Figure 3–2. Conduction of two SCRs connected in reverse parallel when turned on at the beginning of half-cycles.

3.2 PRINCIPLES OF PHASE ANGLE CONTROL

In phase angle controllers, the SCRs conduct during all or part of every half-cycle. When delivering full power, the SCRs start conducting at the beginnings of the AC half-cycles. When delivering less than maximum power, the gating signal is delayed so the SCRs start conducting some time later than the beginnings of the half-cycles. Operation of a phase angle controller at partial output is depicted in figure 3–3.

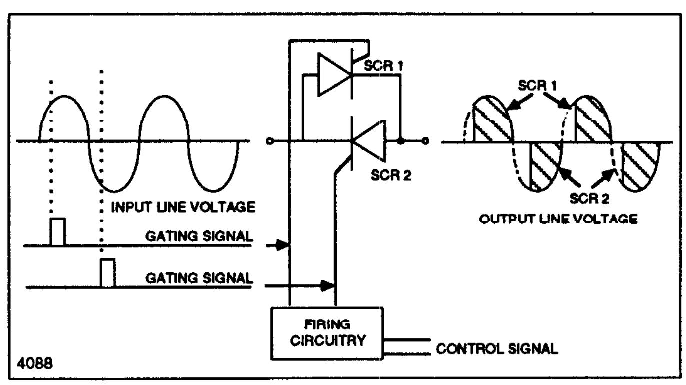

Figure 3–3. Conduction of two SCRs connected in reverse parallel when turned on after the beginning of the half-cycles.

The average power a phase angle controller delivers to its load is determined by the number of electrical degrees by which the gating signal that turns on the SCRs is delayed past the beginnings of the half-cycles. The later in each half-cycle the SCRs fire, the less the time the SCRs conduct during each half-cycle and, therefore, the less power is delivered to the load (see figure 3–4). The 4–20 mA control signal received by the phase angle firing-circuit (664F) or phase-angle control module (664G/K) determines the amount by which the gating signal is delayed.

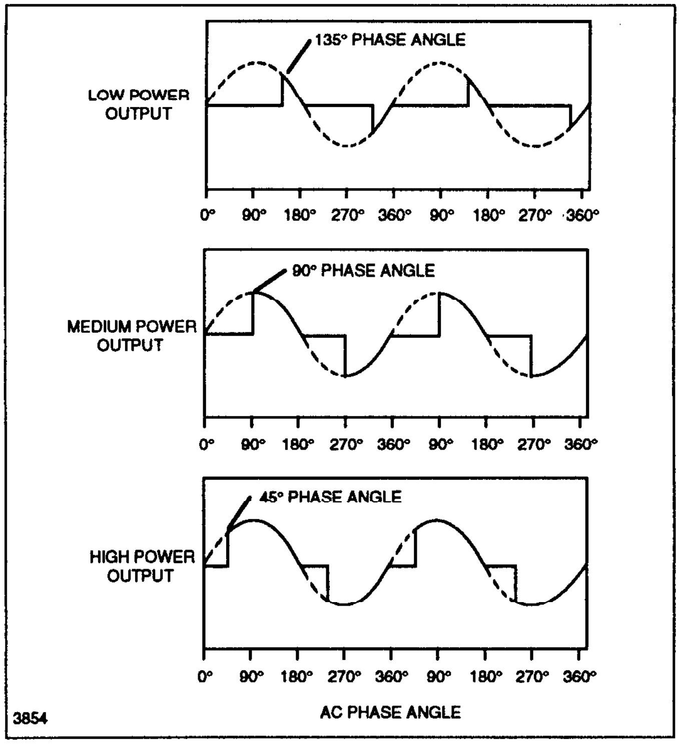

Figure 3–4. Phase angle power control.

The output power of a phase angle controller does not change linearly with respect to the number of degrees the SCR conduction phase angle changes. Therefore, the standard 664F, 664G, and 664K controllers have a built-in load feedback circuit to linearize the relationship between the control signal and the power output. The feedback circuit also adjusts the power controller output to compensate for changes in line voltage and load impedance (this is called "line and load regulation"). Figure 3–5 illustrates the relationship between the control signal and the power controller output when the internal (built-in) feedback circuit is used (the internal feedback circuit provides average load voltage feedback). Model 664F, 664G, and 664K controllers also can use an external load-current feedback circuit that can be provided by the optional current module (see section 3.5.12.3).

Phase angle power control offers a number of attractive features. Because the power controller output level is adjusted by varying the SCR on time within each AC half-cycle, the

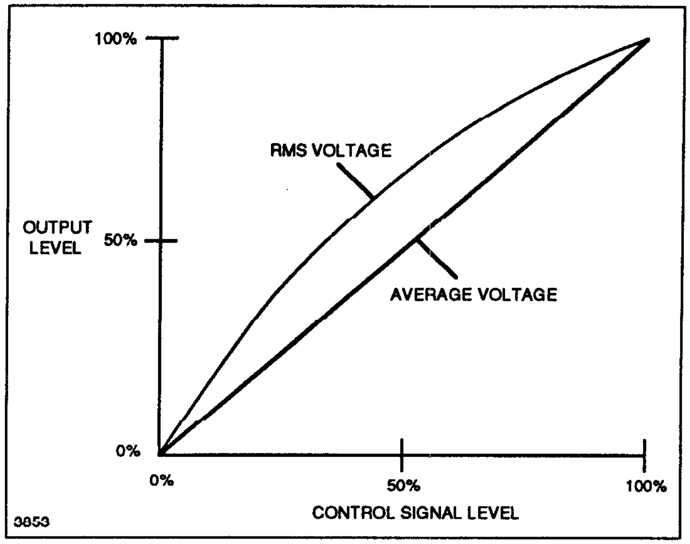

Figure 3–5. Controller output versus control signal input level.

controller's output is quite constant, rather than being divided into multiple-cycle periods of on time and off time. In addition, a variety of feedback and output indication (metering) circuits can easily be incorporated into the controller.

Phase angle controllers can be used with virtually any type of load—resistive, inductive, or high-inrush (e.g., lamp). However, when a phase-angle controller is connected to inductive and high-inrush loads, a load conditioning circuit must also be added to the controller to regulate the rate at which the power controller output level can change. Model 664F, 664G, and 664K controllers include user-selectable load conditioning.

Because the SCRs in phase angle power controllers turn on *during* the AC half-cycles, they generate electromagnetic and radio-frequency interference, which can be a problem in some applications. Use of a zero crossover power controller minimizes such interference problems.

3.3 CONTROLLER BASIC ELEMENTS

As shown in figure 3–6, the basic elements of a standard 664F consist of:

1. One SCR module containing SCRs, the conduction angles of which are varied to control output power.
2. A firing circuit module, which generates the gating signals that control the SCRs' conduction angle. The timing of the gating signals is controlled by the level of the 4–20 mA control signal applied to the firing circuit module.

The basic elements of a standard 664G or 664K controller (see figure 3–7) consist of:

1. Three SCR modules, each containing a diode and an SCR the conduction angles of which are varied to control output power.
2. A phase angle control module, which generates low-level gating signals that, after amplification by the SCR driver

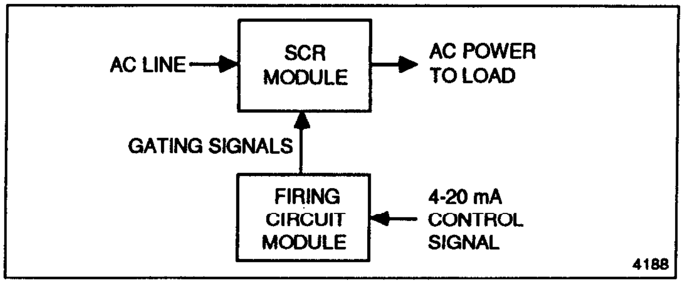

Figure 3–6. Basic elements of standard model 664F SCR controller. Firing circuit accepts only 4–20 mA control signals.

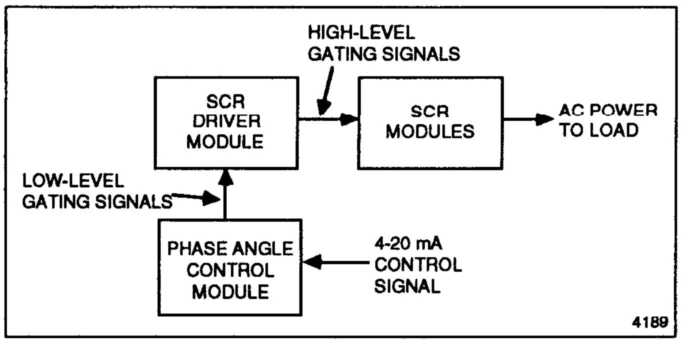

Figure 3–7. Basic elements of standard model 664G or 664K SCR controller. Phase angle control module accepts only 4–20 mA control signals.

module, control the SCRs' conduction angles. The timing of the gating signals is controlled by the level of the 4–20 mA control signal applied to the firing circuit module.

3. An SCR driver module, which amplifies the low-level gating signals generated by the phase angle control module and feeds them to the SCRs.

Some model 664F, 664G, and 664K controllers have an optional current module (see figure 3–8), which permits use of instantaneous current trip (an alternative to subcycle fuses), current feedback, and current limiting.

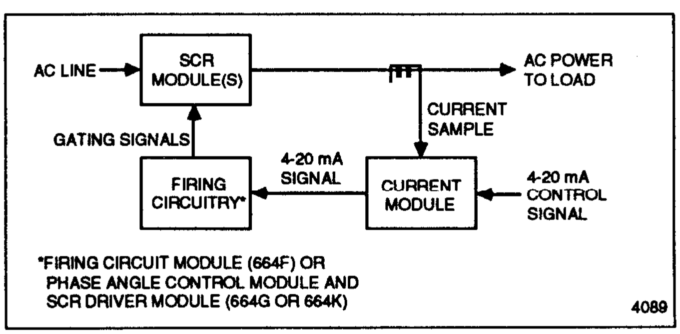

Figure 3–8. Use of current module permits use of instantaneous current trip and either current feedback or current limiting. Current module accepts only 4–20 mA controls signals.

The standard firing circuit module, standard phase angle control module, and optional current module accept only 4–20 mA control signals. Therefore, some model 664F, 664G, and 664K controllers have an optional input module (see figure 3–9), which permits manual control by means of a potentiometer, or automatic control by either a 0–20 mA or 0–5 VDC control signal.

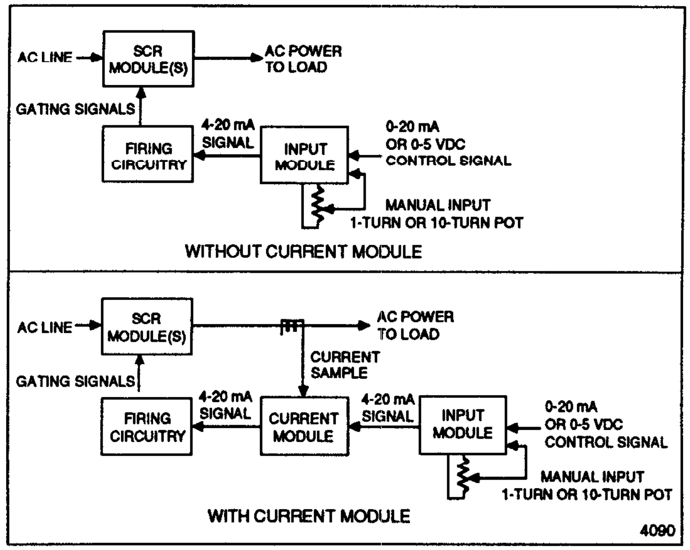

Figure 3–9. Input module permits use of manual control input from potentiometer and 0–20 mA or 0–5 VDC control signals.

3.4 DIFFERENCE BETWEEN 664G AND 664K CONTROLLERS

Model 664G and 664K controllers are identical except the phase angle control module for the model 664G includes "D-guard" circuitry, which minimizes DC current buildup in the primary winding of the load transformer, whereas the phase angle control module for the model 664K does not have D-guard circuitry.

3.5 CONTROLLER FUNCTIONAL DESCRIPTIONS

3.5.1 SCR Modules

As shown in figures 3–10 and 3–11, the 664F has one SCR module containing two SCRs. The 664G and 664K have three SCR modules, each of which contains one SCR and one diode (two SCRs per AC phase are not required in hybrid phase-angle controllers such as the 664G and 664K).

3.5.2 DV/DT Networks

A dv/dt network is connected across each SCR module to keep the firing circuit module or SCR driver module from being activated by voltage transients on the AC lines.

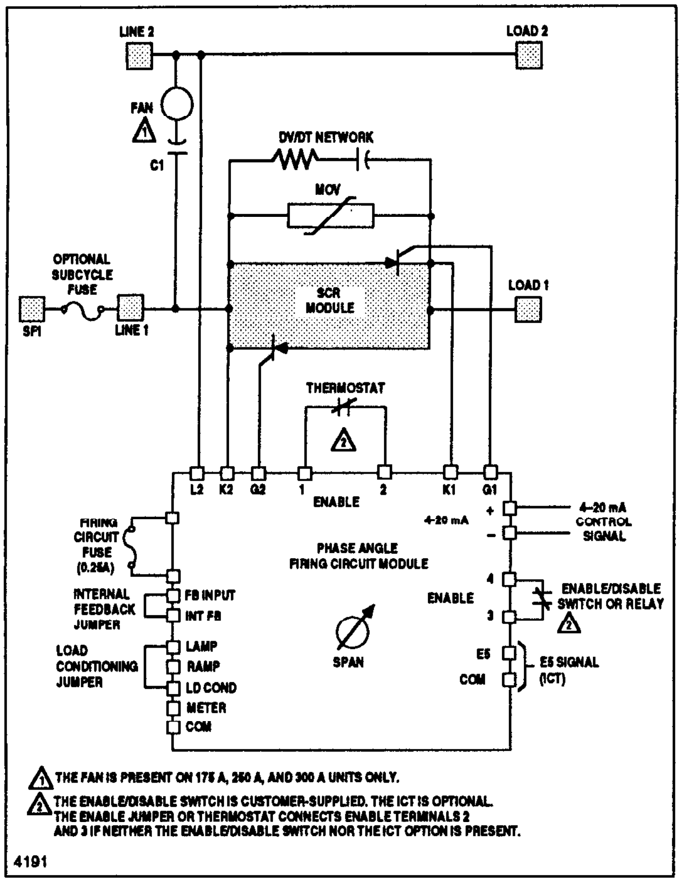

Figure 3–10. Functional diagram, standard model 664F power controller.

3.5.3 MOVs

A metal oxide varistor (MOV) also is connected across each SCR module to protect the SCRs from being damaged by high-voltage transients on the power line.

3.5.4 Optional Subcycle Fuses

The optional subcycle fuses protect the SCRs and diodes in the SCR modules by opening within one AC cycle if excessive current is drawn by the load. Subcycle fuses are available for all model 664 controllers rated at 70 A or more. (Subcycle fuse ratings are presented in table 3–1.)

Table 3–1. Subcycle Fuse Ratings

CONTINUOUS CURRENT	I^2T
70 A	2,400
90 A	4,000
125 A	7,700
175 A	16,000
250 A	40,000
300 A	63,000

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3.5.5 Optional Failed SCR Alarm Circuit

An optional failed SCR alarm circuit is available for each SCR module in all model 664 power controllers. The SCR alarm circuit operates a set of form C relay contacts if an SCR module short-circuits or if AC line power is lost to that SCR module. Each contact pair is rated for 3 A (resistive) at 120 VAC.

3.5.6 Firing Circuitry

3.5.6.1 General Description

The firing circuitry for the model 664F, 664G, and 664K controllers consists of ***phase angle control*** circuitry and ***SCR driver*** circuitry.

Both the phase angle control circuitry and SCR driver circuitry for the model 664F are located in the model 664F phase angle firing circuit module (figure 3–12).

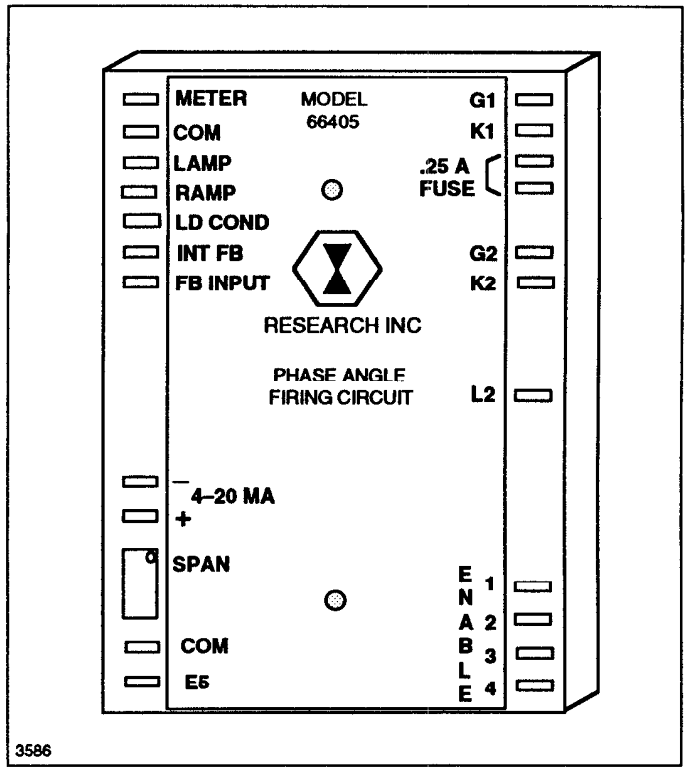


Figure 3–12. Model 664F phase angle firing circuit module.

The 664G/K phase angle control circuitry for the 664G/K is located in the phase angle control module. The 664G/K SCR driver circuitry is located in the SCR driver module (see figure 3–13).

The phase angle control modules for the 664G and 664K controllers are identical except the 664G phase angle control module has a DC elimination ("D-guard") circuit (see section 3.5.6.3), whereas the 664K phase angle control module does not.

The 664G and 664K SCR driver modules are identical.

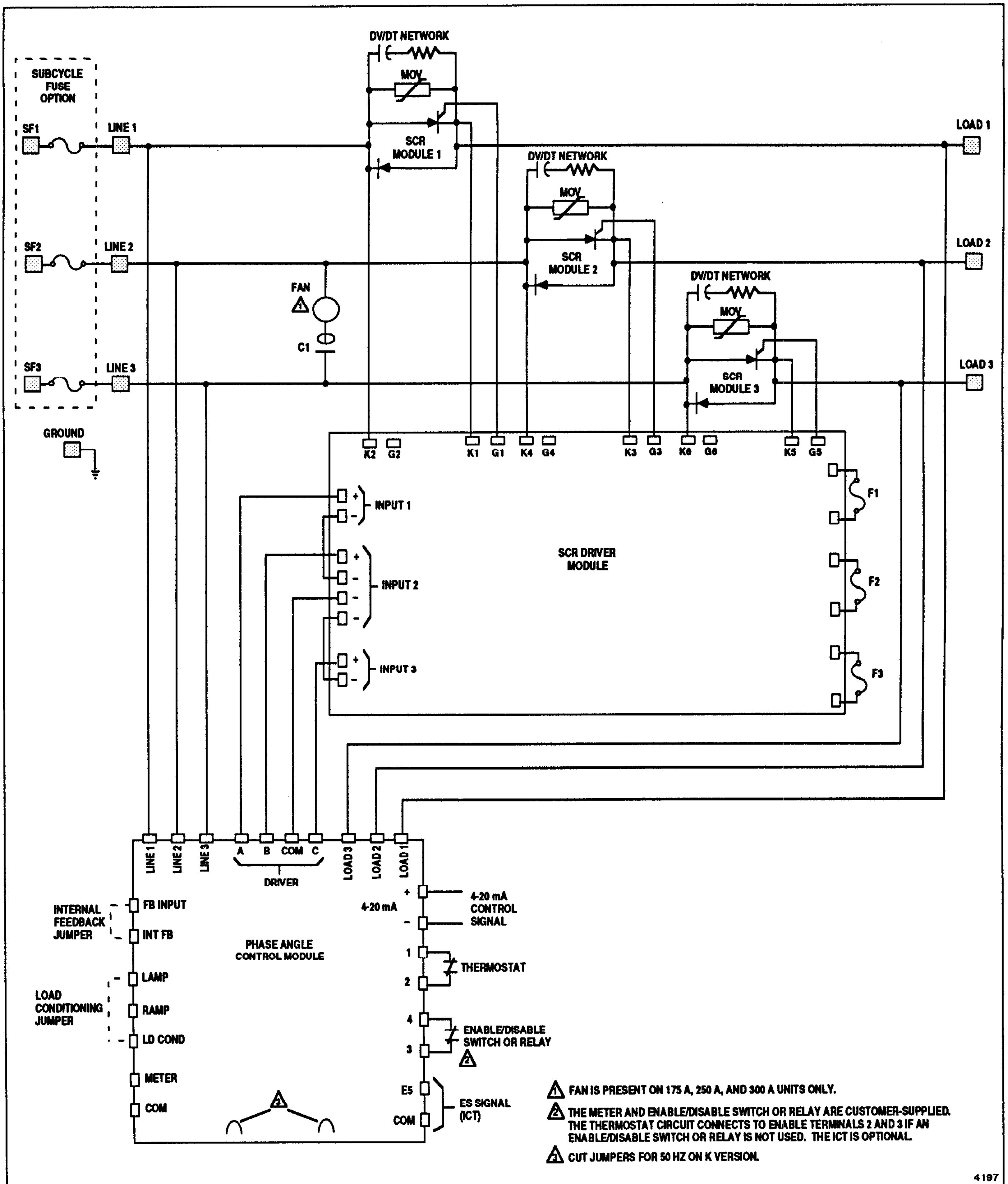


Figure 3–11. Functional diagram, standard model 664G and 664K controller.

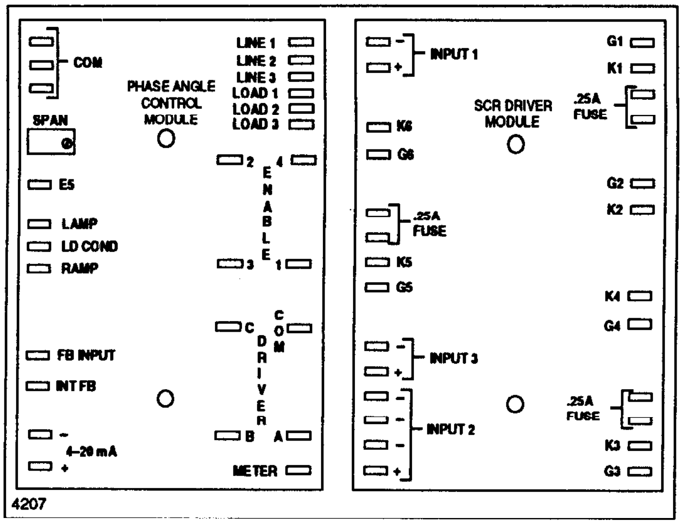


Figure 3–13. Model 664G and 664K phase-angle control module and SCR driver module.

3.5.6.2 Theory of Operation

The model 664F firing-circuit module (see figure 3–14) and model 664G/K phase angle control module (see figure 3–15) accept a milliampere control signal (typically 4–20 mA) through the modules' **4–20 MA +** and **–** terminals. The modules' control integrator and control comparator circuits generate control pulses that activate the SCR driver circuitry. For low output power, the control pulses occur late in the AC half-cycles so the SCRs conduct only briefly. For higher output power, the control pulses occur earlier in the AC half-cycles so the SCRs conduct longer. The firing circuitry is self-adjusting for line frequencies from 47 through 63 Hz.

The model 664F firing circuit module and 664G/K phase angle control module include an internal feedback circuit that monitors the average voltage across the power controller load terminals. An optical coupler isolates the internal feedback circuit from load voltage. The firing circuit **SPAN** potentiometer varies the gain of the internal feedback circuit to match the line

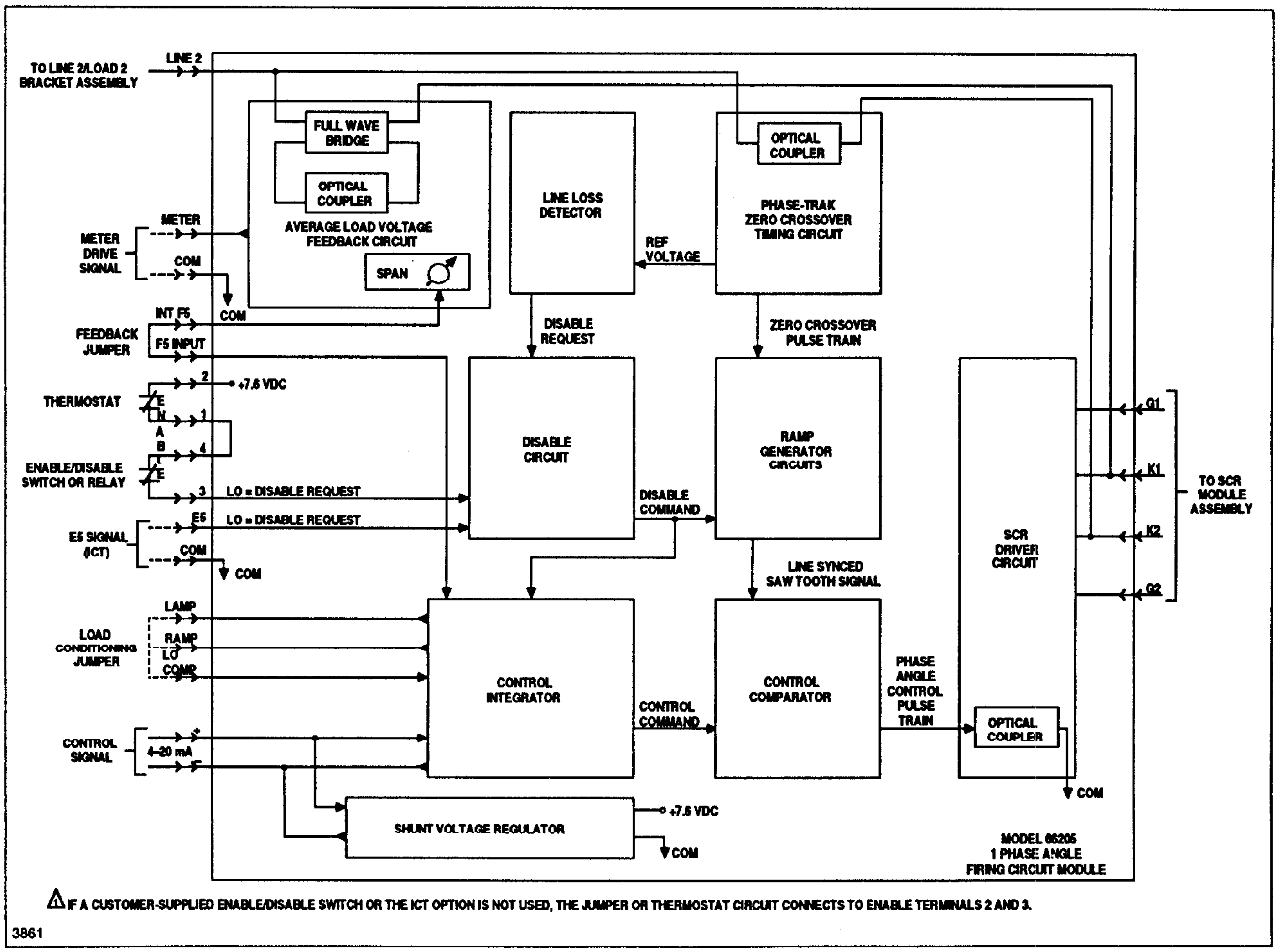


Figure 3–14. Model 664F firing circuit module functional diagram.

voltage in use. A summing junction at the input to the control integrator circuit compares the feedback signal with the control signal to determine the required SCR firing angle. As a result, when internal feedback is selected, the firing circuit **SPAN** potentiometer adjusts the control signal input span by varying the control signal value that produces full output.

The internal feedback circuit also provides a 0–100 microampere meter drive signal that indicates average load voltage. 100 microamperes corresponds to full output voltage, as determined by the line voltage for which the **SPAN** potentiometer is adjusted. The meter drive signal is available at the **METER** and **COM** terminals of the firing circuit module or phase angle control module.

A jumper wire on the firing circuit module or phase angle control module connects the internal feedback-signal terminal (**INT FB**) to the control circuit feedback input (terminal **FB INPUT**). If desired the internal feedback jumper can be deleted and an isolated external feedback signal can be connected to the **FB INPUT** and **COM** terminals. If the internal feedback jumper is removed, the average load voltage meter drive signal remains available at the **METER** terminal. The **SPAN** potentiometer then adjusts the meter drive signal span but has no effect on the control signal input span.

The control integrator circuit provides jumper-selectable load conditioning (fast, ramp, or lamp). The load conditioning configuration determines the controller's output response time for changes in the control signal and feedback signal. Ramp or lamp load conditioning is selected by connecting a jumper wire from the firing-circuit or phase angle control module's **LD COND** terminal to either the **RAMP** or **LAMP** terminal. Installing the **LD COND** jumper between the **RAMP** and **LAMP** terminals disables the ramp and lamp conditioning circuits, resulting in fast load conditioning. See section 2.7 for details regarding load conditioning configuration and operating characteristics.

In the model 664F firing circuit module, the control integrator generates a control command signal that is input to a control comparator. A sawtooth waveform from a ramp generator acts as the second input to the control comparator. The ramp generator is synchronized to the AC line by a zero crossover timing circuit, to provide one low-going ramp per AC half cycle. The control comparator outputs a control pulse to the SCR driver circuit each time the ramp generator signal drops below the control command signal.

In the model 664G and 664K phase angle control module, the control integrator generates a control command signal that is input to each of three control comparators (one control compara-

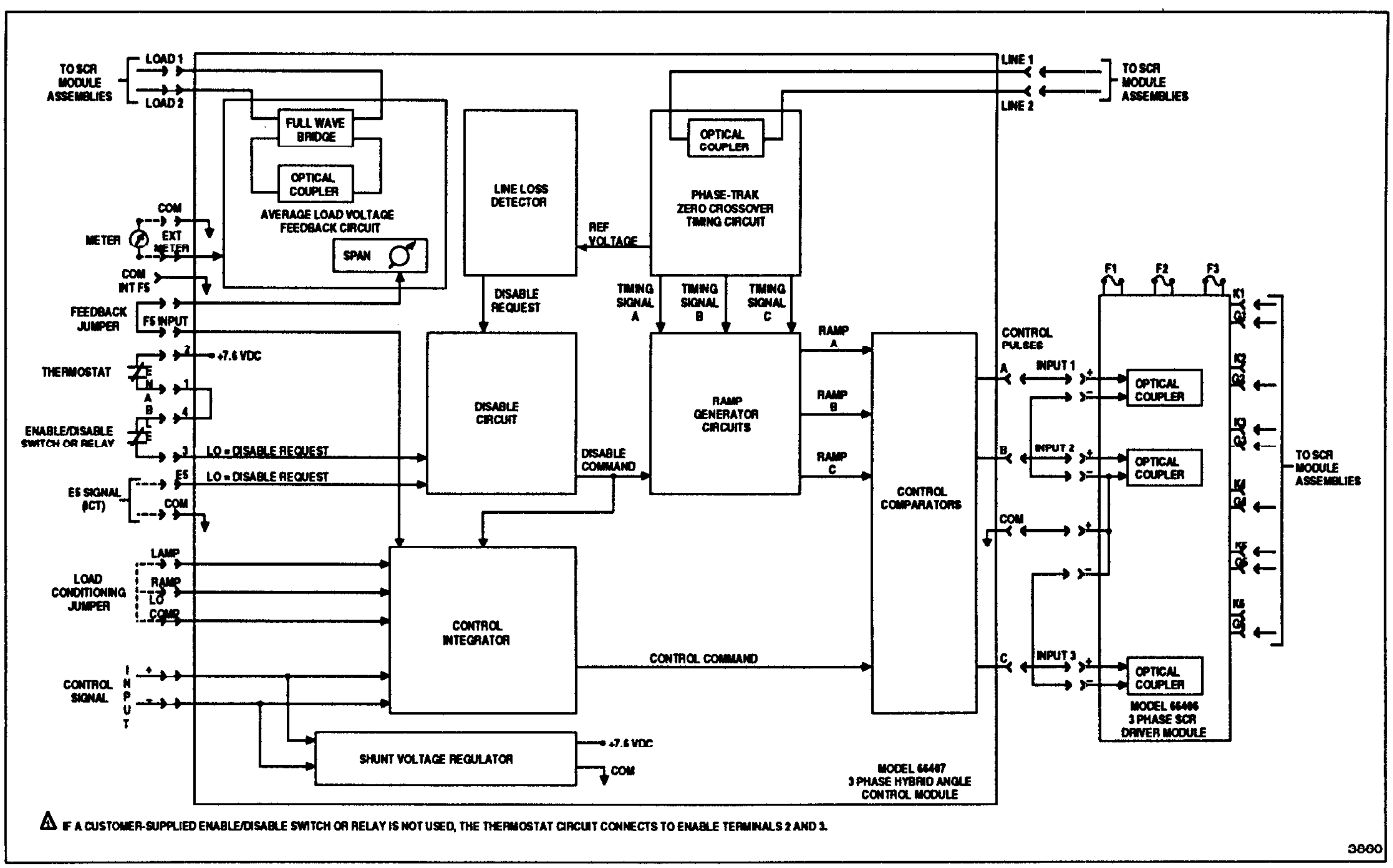


Figure 3–15. Model 664G and 664K firing circuit functional diagram.

tor for each AC phase). A sawtooth waveform from a ramp generator acts as the second input to each control comparator. A zero crossover timing circuit synchronizes the ramp generators so that each ramp generator provides one low-going ramp per cycle of its AC phase. When a ramp generator signal drops below the control command signal, the control comparator for that AC phase outputs a control pulse to the SCR driver module. The control pulse activates a gating circuit in the SCR driver module to fire the SCR for that AC phase.

3.5.6.3 Model 664G "D-Guard" Circuit

The DC elimination circuit (the "D-guard circuit") in the 664G (the 664F and 664K do not have the D-guard circuit) monitors DC voltage across each pair of load phases. The **A ADJ** and **B ADJ** signals from the DC elimination circuit adjust the bias for the phase A and phase B control comparators to eliminate DC voltage across any pair of load phases.

3.5.6.4 Enable/Disable Circuitry

The firing-circuit and phase-angle control modules also include enable/disable circuitry. **ENABLE** terminals **1/2/3/4** are used for connecting the controller thermostat and, if installed, a customer-supplied enable/disable switch or relay. The controller thermostat is factory-connected to **ENABLE** terminals **2** and **3**. If used, a customer-supplied enable/disable switch or relay is connected between **ENABLE** terminals **3** and **4**. The jumper or thermostat circuit then connects across **ENABLE** terminals **1** and **2**. **ENABLE** terminals **1/2/3/4** operate by transferring a 7.6 VDC signal (supplied by the control circuitry) from **ENABLE** terminal **2** to **ENABLE** terminal **3**. **ENABLE** terminals **1** and **4** are connected internally within the phase angle firing-circuit module and the phase angle control module. The firing circuit disable circuit is triggered if the 7.6 VDC to **ENABLE** terminal **3** is interrupted. When triggered, the disable circuit blocks the generation of control pulses by inhibiting operation of the ramp generator and control comparator. The disable circuit also discharges the control integrator to provide full load conditioning action when the power controller is enabled again.

The disable circuit also can be activated by connecting the **E5** terminal to the **COM** terminal on the firing-circuit or phase-angle control module. The **E5** and **COM** terminals typically are used as the connection points for the ICT option (see section 3.5.12.2). In addition, a line loss detector triggers the disable circuit if the AC line voltage to the controller is interrupted. The line loss detector provides a brief startup delay when line voltage is applied to the controller so the control circuit timing is stabilized before any control pulses are generated.

3.5.6.5 Control Signal Source Compliance

Operating power for the phase angle control circuits is derived from the 4–20 mA control signal through use of an internal shunt regulator. Because of the action of the shunt regulator, the converter's input impedance varies inversely with the level of the control signal, from 3000 ohms at 4 mA to 600 ohms at 20 mA. The control signal source compliance therefore must be at least 12 VDC.

3.5.6.6 SCR Driver Circuits

The SCR driver circuits in the 664F phase angle firing circuit module and the 664G/K SCR driver module provides gating signals for the controller SCR modules in response to low-level signals received from the phase angle control circuitry.

Operating power for the SCR driver circuitry in the 664F phase angle firing circuit module and the 664G/K SCR driver module is derived from the AC line through the SCR module cathode leads. An optical coupler isolates the control circuits from the SCR driver circuit.

3.5.7 Load Voltage Meter Drive Signal

The 664F phase angle firing circuit module and the 664G/K phase angle control modules provide a 0–100 microampere meter drive signal the level of which is proportional to the average load voltage. The signal is available at the modules' **METER** and **COM** terminals (see figure 3–12 for the 664F or figure 3–13 for the 664G/K) and can be used to drive an external meter.

3.5.8 Thermostat

A normally closed, nonlatching thermostat is included with all 175 A, 250 A, and 300 A controllers. It is optional on all other controllers. If the temperature of the thermostat exceeds approximately 180°F (82°C), the thermostat opens and disables the firing circuit. When the thermostat's temperature drops to approximately 140°F (60°C), it recloses and re-enables the firing circuit. If a thermostat is factory-installed, it is connected between **ENABLE** terminals **2** and **3** of the firing circuit module. If a thermostat is not factory-installed, a jumper is factory-connected between those terminals.

3.5.9 Enable/Disable Switch or Relay

Standard 664F, 664G, and 664K controllers can be turned on (enabled) and turned off (disabled) from a remote location by a switch or relay contact closure connected to terminals **3** and **4** of the firing circuit module. If the user wishes to use an enable/disable switch or relay, the thermostat or jumper connector connected to **ENABLE** terminal **3** is moved to **ENABLE** terminal **1**, and the enable/disable switch or relay is connected to **ENABLE** terminals **3** and **4** as described in section 2.6.

3.5.10 Cooling Fan

A cooling fan is standard on all 175 A, 250 A, and 300 A model 664 power controllers. The fan assembly is factory-configured to match the line voltage specified in the customer order but can be reconfigured for a different line voltage as described in section 2.7.2.

3.5.11 Firing Circuit Fuses

The firing circuit fuses protect circuitry in the firing circuit module (664F) and SCR driver module (664G and 664K) against damage if an SCR fails or an SCR gate circuit opens.

3.5.12 Current Module (Optional)

3.5.12.1 Introduction

An optional current module (figure 3–16), available for all controllers, offers instantaneous current trip (ICT), a load-current meter drive signal the level of which is proportional to the controller's output current, and either current feedback (IFB) or current limiting (CLA). To provide these features, the current module monitors load current by means of a current transformer for each AC phase. Interconnections with other modules are shown in figures 3–17, 3–18, 3–20, 3–21, 3–22, and 3–23.

3.5.12.2 Instantaneous Current Trip

Instantaneous current trip (ICT) is a resettable electronic alternative to subcycle fusing. If excessive current flows, the ICT

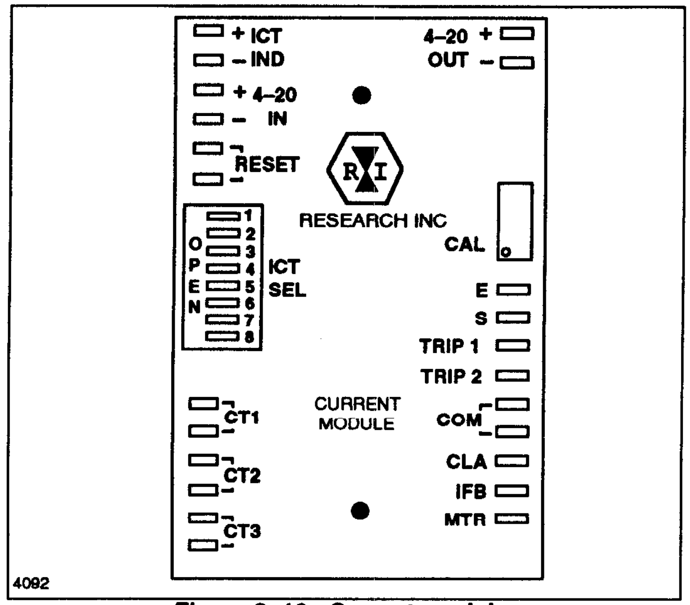


Figure 3–16. Current module.

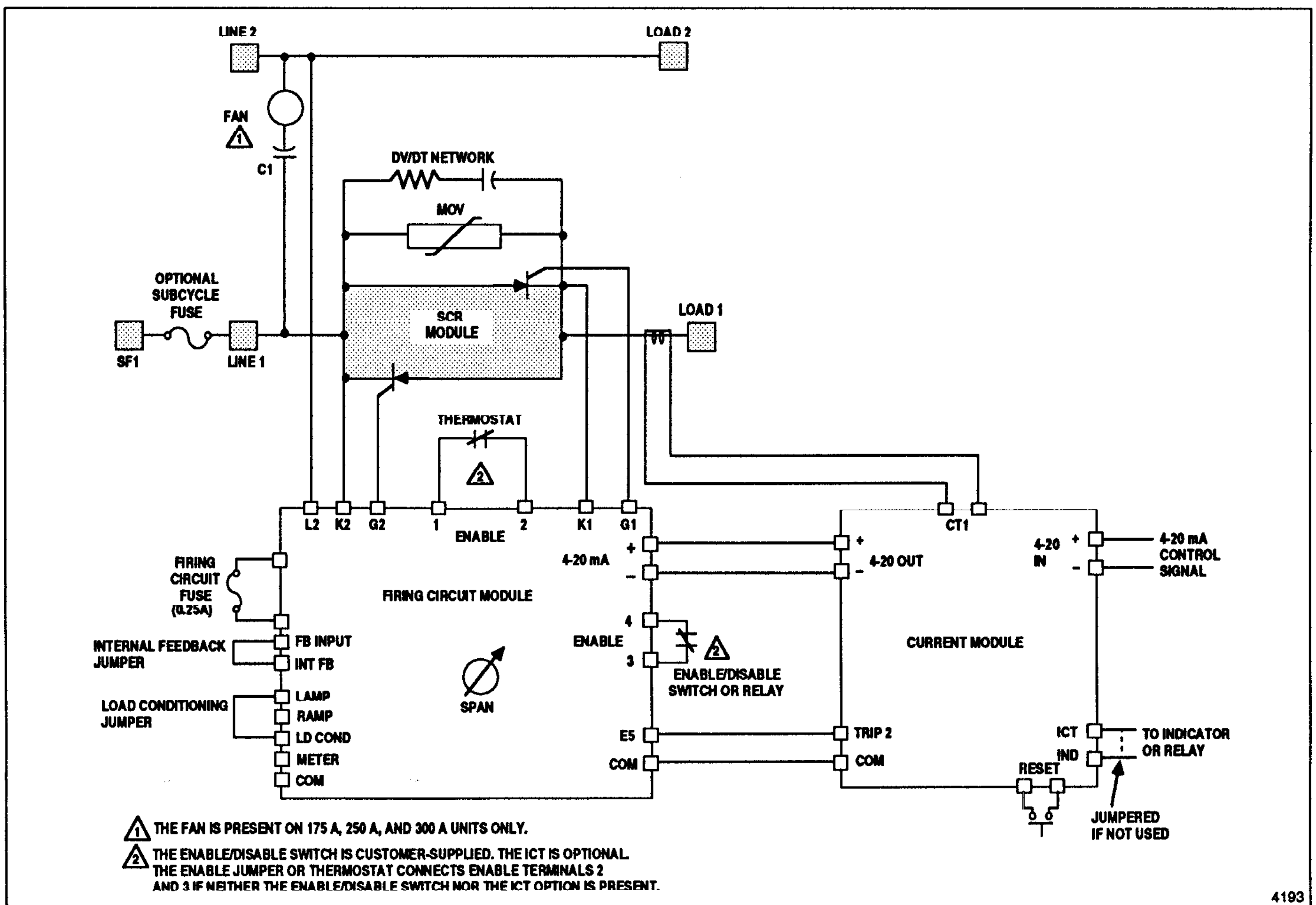


Figure 3–17. Functional diagram, standard model 664F power controller with current module.

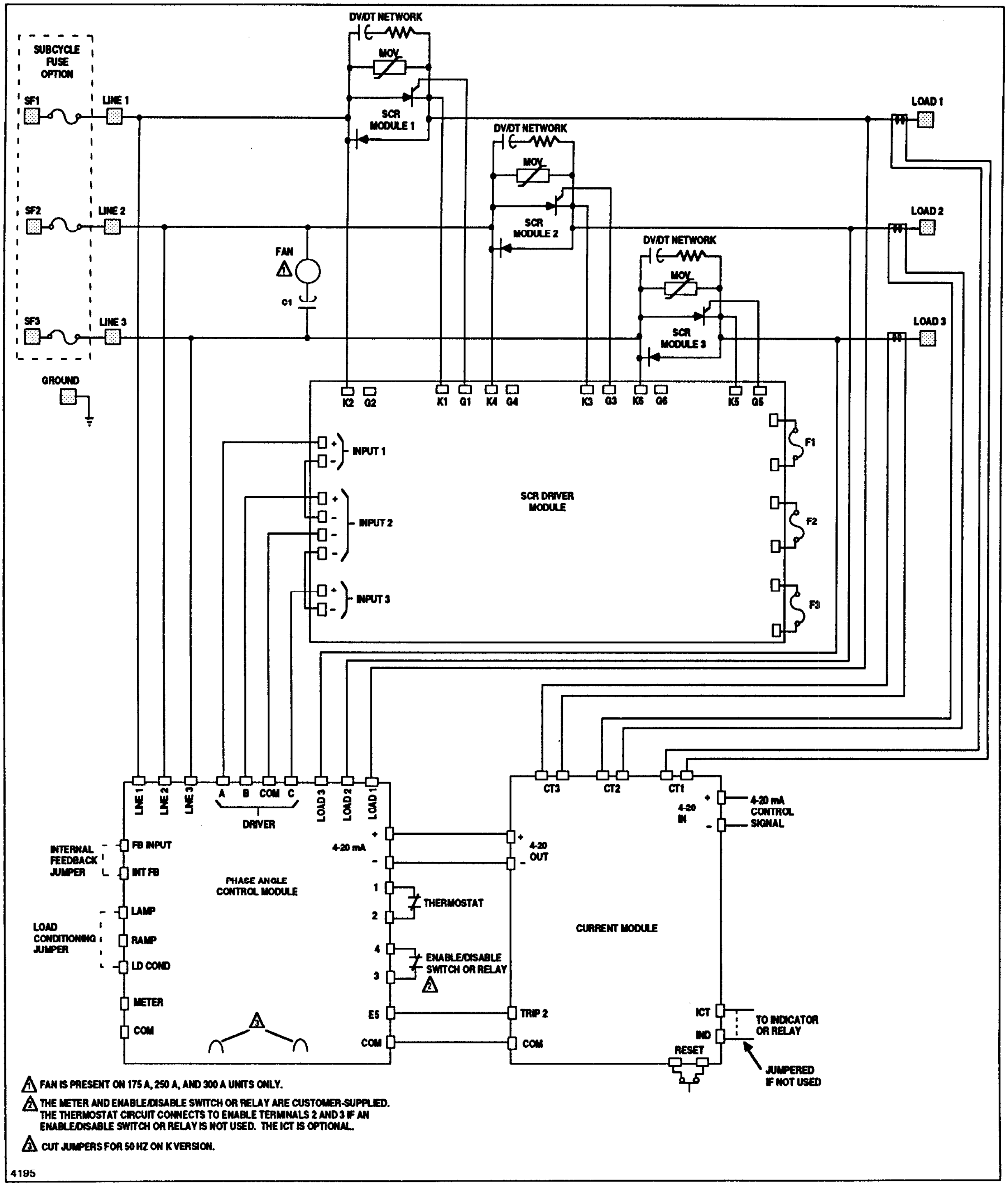


Figure 3–18. Functional diagram, standard model 664G and 664K power controller with current module.

circuit is activated and sends a signal to the firing circuitry that disables the controller within one AC cycle. Once disabled, the ICT circuit remains disabled until it is reset by closing a customer-supplied ICT reset switch or by interrupting the 4–20 mA control signal to the current module. While the ICT circuit is activated, an ICT indicator signal is also activated that can be used to operate a customer-supplied remote ICT indicator.

Instructions for using ICT are presented in section 2.12.

3.5.12.3 Current Feedback

Current feedback linearizes the relationship between the control signal and the power controller average total load current for the three phases. Current feedback also provides current regulation to maintain the selected load current level despite variations in line voltage and load impedance. When selected, current feedback replaces the power controller's standard feedback circuit (average load voltage feedback).

If current feedback is selected, the current module also provides a 1–100 microampere meter drive signal that is proportional to the power controller load current. Procedures for using current feedback are presented in section 2.10.2.

NOTE
When current feedback is selected, current limiting is not available. See section 3.5.12.4.

3.5.12.4 Current Limiting

Current limiting limits the power controller's average total load current for the three phases to a user-adjustable maximum value (50–125 percent of total rated current capacity). Current limiting is especially useful for limiting inrush current to loads having long inrush periods (more than several seconds). Current limiting operates in conjunction with the standard load conditioning circuit in the firing-circuit or phase angle control modules (see section 2.7) for model 664F, 664G, and 664K controllers.

Procedures for using current limiting are presented in section 2.10.3.

NOTE
When current limiting is selected:
1. **Current feedback is not available. See section 3.5.12.3.**
2. **The current module's meter drive signal is available but its range is determined by the current limiting setting. Consequently, the meter drive signal is 100 microamperes when the load current is 89 percent of the selected current limiting value.**

3.5.12.5 Load Current Meter-Drive Signal

If either current feedback or current limiting is selected, the current module provides a meter drive signal the level of which is proportional to the controller's average load current. The operating range of the meter drive signal is determined by the current module **CAL** potentiometer and whether current feedback or current limiting is selected. See section 2.9 for detailed utilization instructions.

3.5.13 Input Modules (Optional)

The standard firing-circuit and current modules accept only 4–20 mA control signals. The optional input module (figure 3–19) makes it possible to control the model 664 controllers with a 1000 ohm, one- or 10-turn (specified when the controller is ordered) potentiometer; a 0–20 mA signal; or a 0–5 VDC signal.

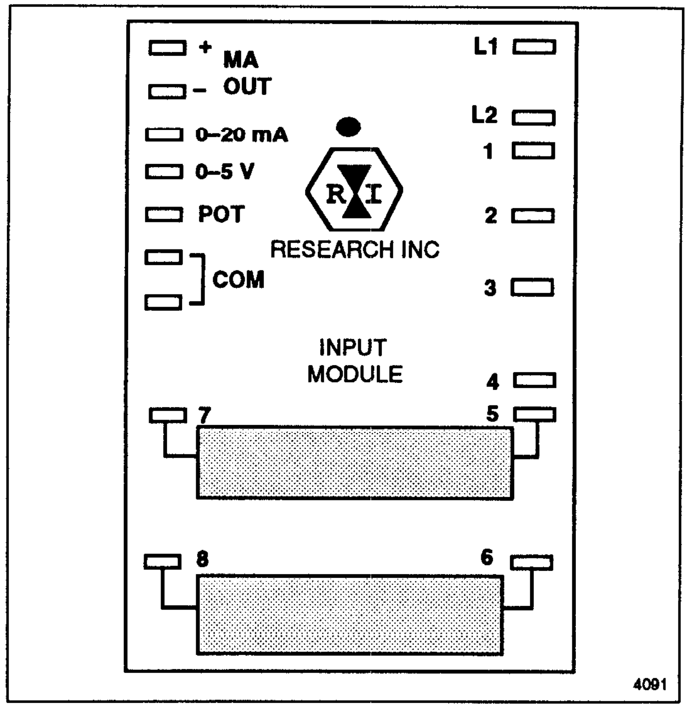


Figure 3–19. Input module.

The input module converts the potentiometer output or either the 0–20 mA or 0–5 VDC signal to a 4–20 mA signal, which is connected to the input terminals of the standard firing-circuit module or current module (whichever is used). See figures 3–20, 3–21, 3–22, and 3–23.

If a potentiometer is used, it is factory-installed on the controller's cover. The potentiometer's **CW** terminal is connected to the input module **POT** terminal; the **CCW** potentiometer terminal is connected to the input module **COM** terminal, and the potentiometer's wiper is connected to the input module **0–5V** terminal. All connections are made with push-on terminals. In most circumstances, if a 4–20 mA, 0–20 mA, or 0–5 VDC signal is being used, the pot wiper must be disconnected from the **0–5V** terminal.

Input module terminals **1**, **2**, **3**, and **4** are used to configure the input module for operation from different AC supply voltages. The configuration procedure is presented in section 2.13.1.

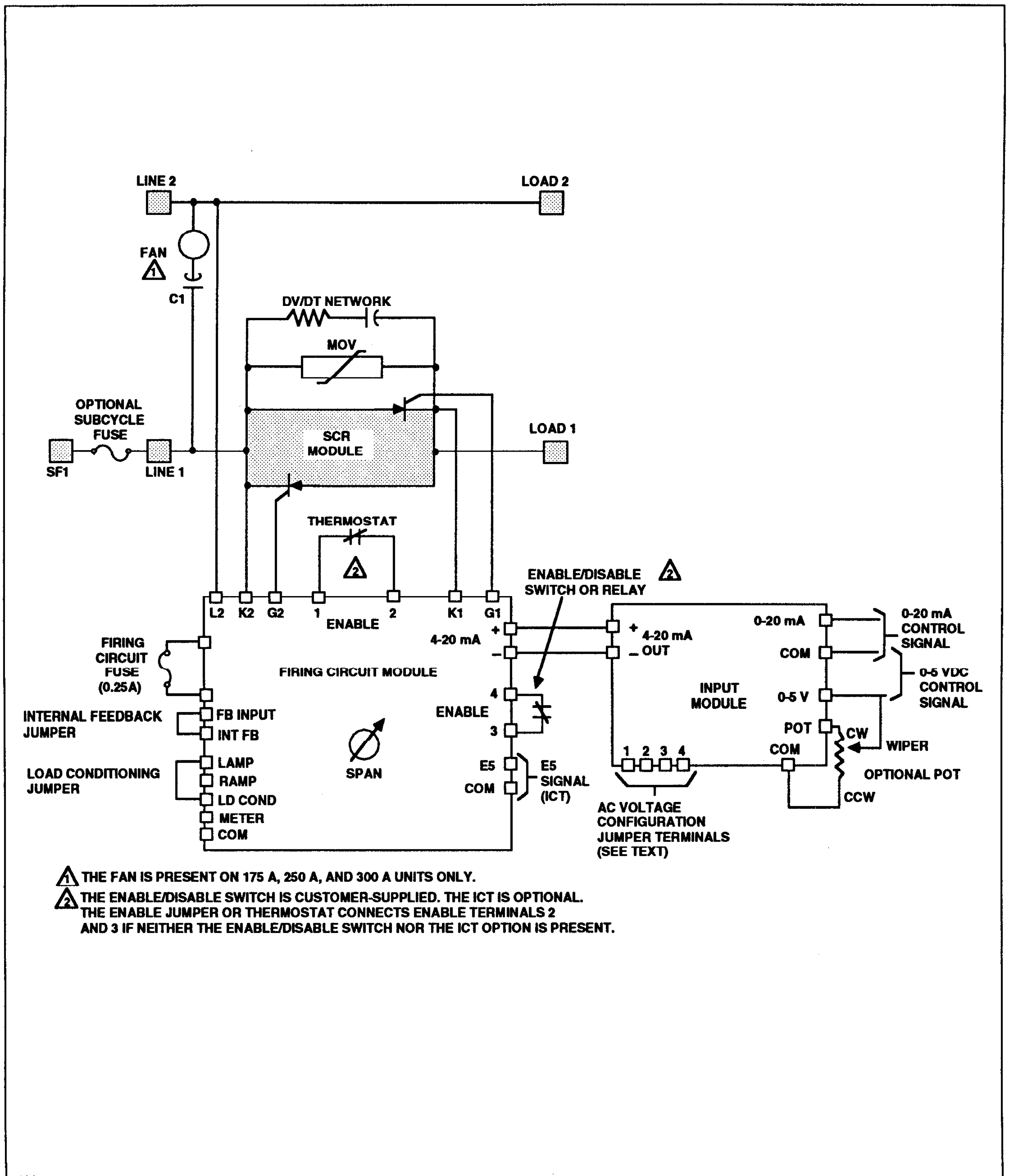


Figure 3–20. Functional diagram, standard model 664F power controller with input module.

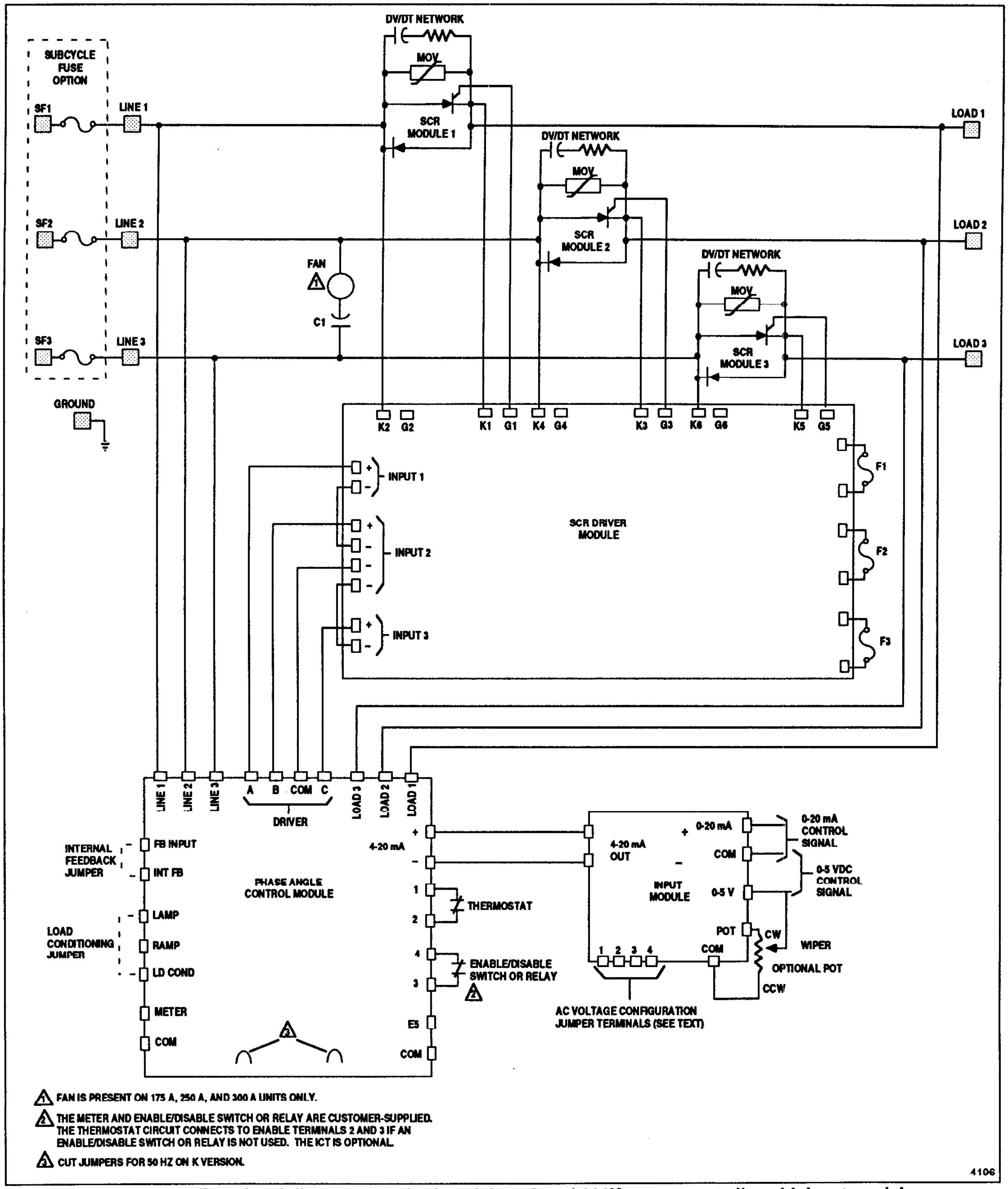
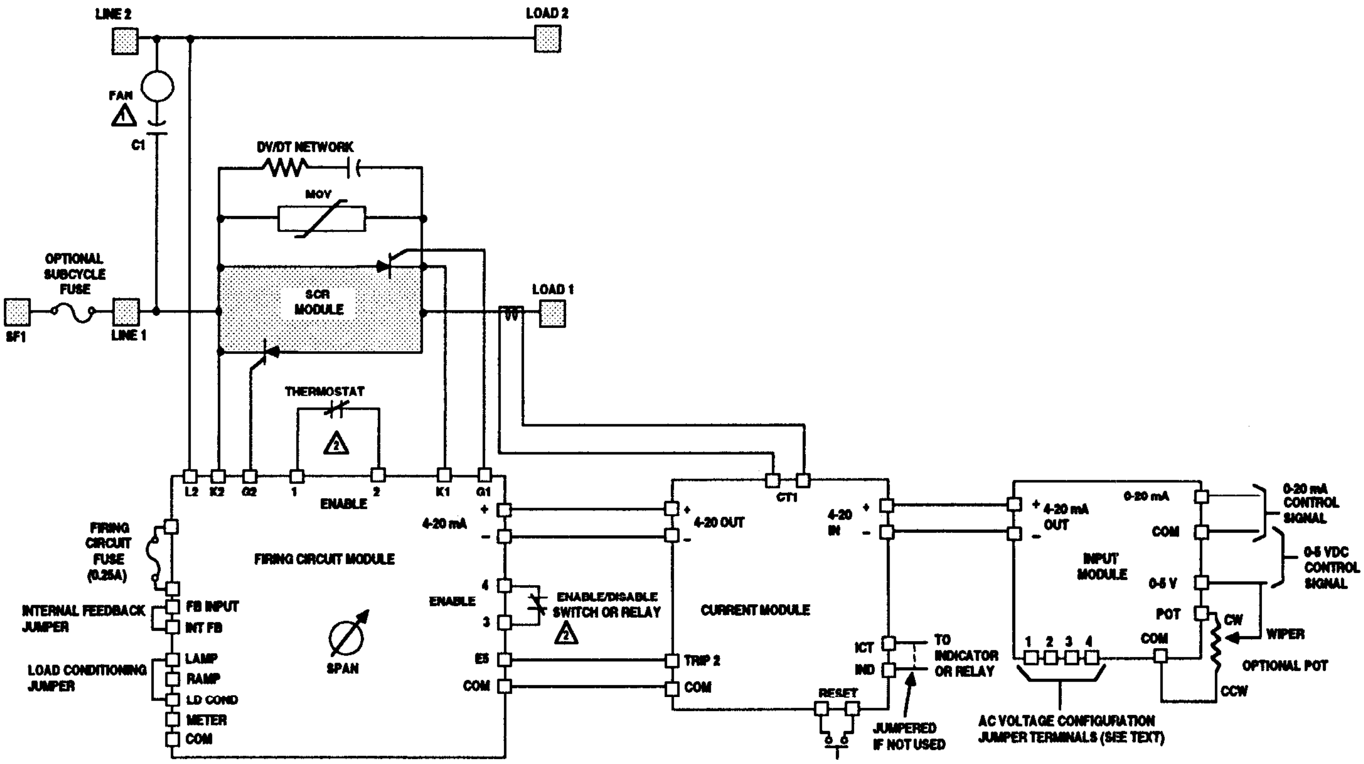


Figure 3–21. Functional diagram, standard model 664G and 664K power controller with input module.



⚠1 THE FAN IS PRESENT ON 175 A, 250 A, AND 300 A UNITS ONLY.

⚠2 THE ENABLE/DISABLE SWITCH IS CUSTOMER-SUPPLIED. THE ICT IS OPTIONAL. THE ENABLE JUMPER OR THERMOSTAT CONNECTS ENABLE TERMINALS 2 AND 3 IF NEITHER THE ENABLE/DISABLE SWITCH NOR THE ICT OPTION IS PRESENT.

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Figure 3–22. Functional diagram, standard model 664F power controller with current module and input module.

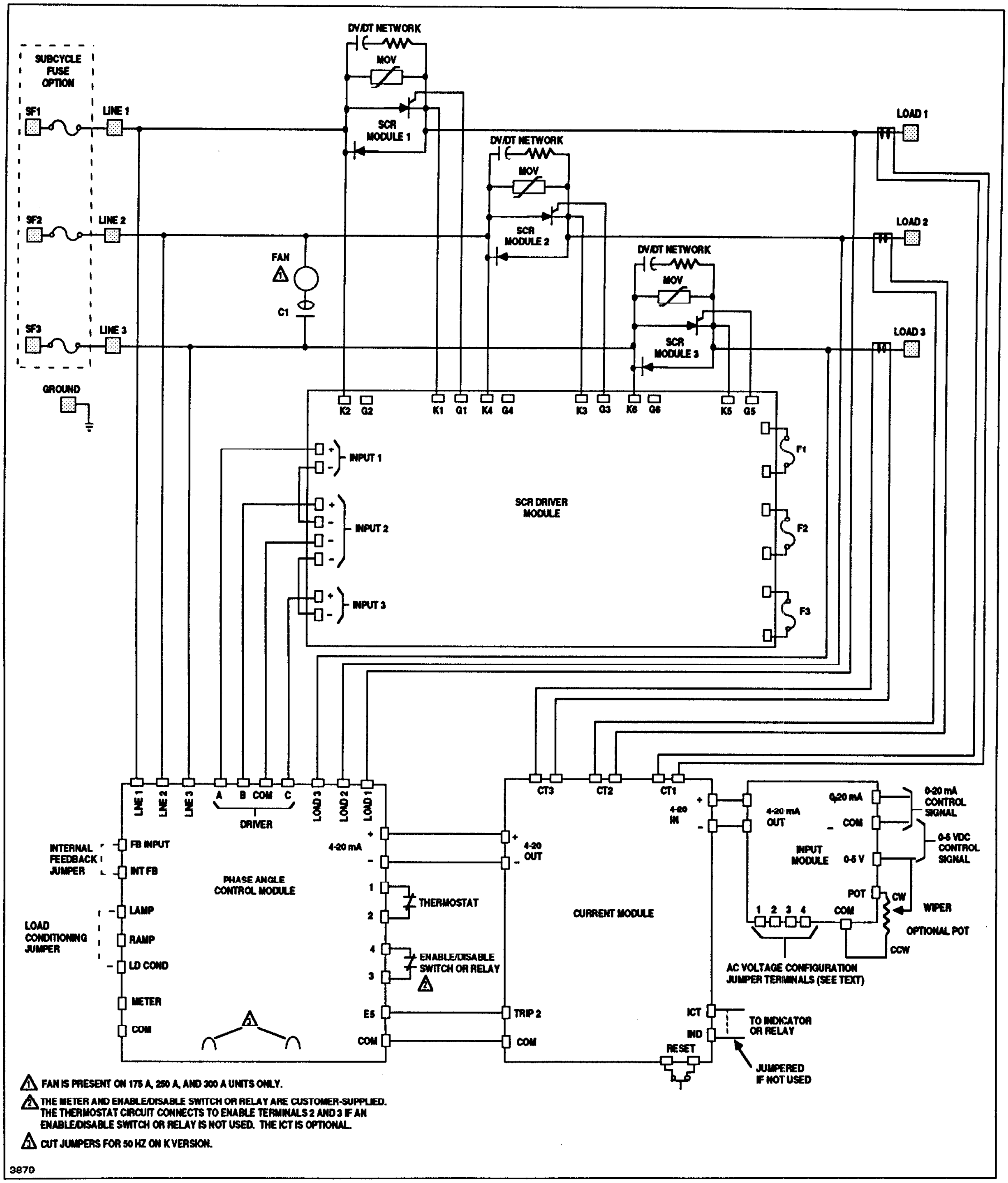


Figure 3–23. Functional diagram, standard model 664G and 664K power controller with current module and input module.

NOTES

SECTION 4.

OPERATION

4.1 NORMAL STARTUP

WARNING

To prevent personal injury, equipment damage, and operating problems, the model 664 power controller must be installed and configured as described in section 2, and you should read and understand all previous sections in this manual before attempting to operate the controller.

To turn on the controller:

1. Make sure line voltage is not applied to the controller's **LINE** terminals.
2. Ensure that the controller's cover is in place.
3. Set the control signal to its minimum value or set the control potentiometer (if used) to its most counterclockwise position.
4. Set the enable/disable switch (if used) to its enable position.
5. Apply AC line voltage to the controller's **LINE** terminals.

CAUTION

As long as line voltage is applied to the controller's LINE terminals, hazardous voltage remains at the Model 664 LOAD terminals even when the control signal is set to minimum or the firing circuit is disabled.

6. Gradually increase the level of the control signal or turn the control potentiometer knob clockwise from zero to the level desired. Increasing the control signal level or turning the potentiometer knob clockwise increases the controller's output level.

4.2 NORMAL SHUTDOWN

There are four ways to shut down the 664 controller normally:

1. Remove the line voltage from the controller's **LINE** terminals.
2. If the control potentiometer is in use, simply turn its knob fully counterclockwise.
3. If a control signal is used, decrease it to its minimum value.
4. If an enable/disable switch is in use, set it to its disable position.

4.3 AUTOMATIC SHUTDOWN

The 664 power controller will shut down automatically if:

1. It overheats to the temperature at which its thermostat opens.
2. The optional instantaneous current trip (ICT) circuit is installed and the controller's **LINE** current exceeds the ICT-circuit trip level.

4.4 RESTART FOLLOWING AUTOMATIC SHUTDOWN

If the controller was shut down automatically by action of the instantaneous current trip (ICT) circuit (if installed), you must press the **ICT RESET** switch to turn the controller back on again.

WARNING

If the controller shuts down automatically because overtemperature caused its thermostat to open, and if none of the four normal shutdown steps presented in section 4.2 was performed, the controller will turn on again automatically—*without warning*—when the thermostat's temperature falls to approximately 140°F (60°C).

NOTES

SECTION 5.

MAINTENANCE AND REPAIR

5.1 ROUTINE MAINTENANCE

The model 664F and 664G/K controllers require very little routine maintenance. The only moving part is the fan (present only on 175 A, 250 A, and 300 A controllers), and it is permanently lubricated. Remove dirt or dust accumulations frequently. Check for damaged wiring and loose connections occasionally and whenever any connections are changed. No other routine maintenance is required.

5.2 INTRODUCTION TO GENERAL CHECKOUT PROCEDURE

Use the general checkout procedure to check the controller for proper operation before placing it in operation following initial installation and as an aid to troubleshooting the controller for maintenance purposes.

Before you perform the general checkout procedure, the controller must be completely installed in its normal operating configuration. A multimeter providing AC voltmeter, DC ammeter, and ohmmeter functions is also required.

WARNING

1. Hazardous voltages are present at the controller's LINE and LOAD terminals and within the controller's chassis. Disabling firing circuit operation or setting the control signal to minimum does not eliminate these hazardous voltages.

2. Always remove AC line voltage from the controller before making contact with internal assemblies, line or load wiring, or any other areas where hazardous voltages may be present. Also remove AC line voltage from the controller before making connections, equipment changes, or resistance measurements.

5.3 GENERAL CHECKOUT PROCEDURE

5.3.1 Step 1—Set Up Controller for Checkout

Set up the controller for checkout as follows (see figure 5–1):

1. Set the control signal to minimum.
2. Set the enable/disable switch (if used) to enable.

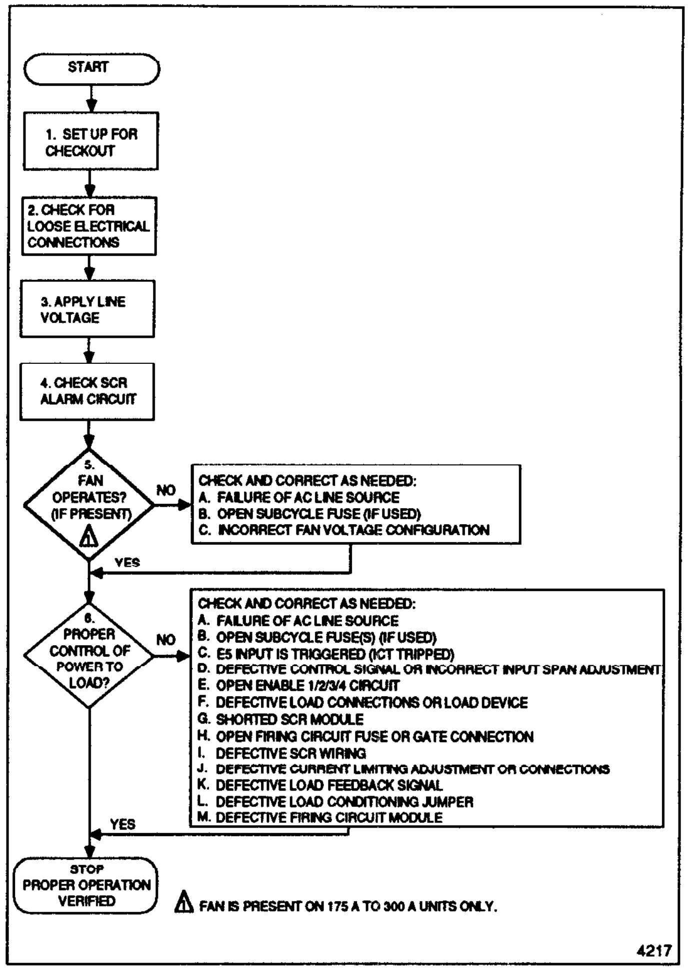


Figure 5–1. General checkout procedure, model 664F, 664G and 664K power controllers.

5.3.2 Step 2—Check for Loose Electrical Connections

1. Remove line voltage from the controller and check that all firing circuit and SCR module lugs are fully seated on their terminals.
2. Check that the line, load, and ground wiring is tightly fastened to the **LINE**, **LOAD**, and **GROUND** terminals.

5.3.3 Step 3—Apply AC Line Voltage to the Controller's LINE Terminals

Turn on the main power switch or circuit breaker to apply AC line voltage to the controller's **LINE** terminals.

5.3.4 Step 4—Check the Optional SCR Alarm Circuit

Check the optional SCR alarm circuit (if installed) as follows:

1. If an alarm indicator has been connected to the controller's SCR alarm circuit(s), check the indicator(s) to determine whether an SCR has shorted.
2. If an alarm indicator has not been connected to the controller's SCR alarm circuit(s), measure the resistance between each main circuit board's **N/O** and **COMMON** terminals with an ohmmeter. If the measured resistance is zero (or approximately zero) ohms, the SCR associated with that circuit board is OK. If the measured resistance is higher than approximately zero ohms, the SCR is defective and should be replaced (see section 5.5.1 for replacement procedure).

5.3.5 Step 5—Check Fan Operation (175–300 Amp Controllers Only)

On 175 A, 250 A, and 300 A controllers, check the operation of the fan. The fan should start when line voltage is applied to the controller. If the fan does not start or if it seems to run too slow or fast, check for the following:

1. Failure of the AC line source(s). Measure the voltage across the **LINE 1** and **LINE 2** terminals if a 664F controller and across the **LINE 2** and **LINE 3** terminals if a 664G/K controller. If the correct voltage is not present, check the AC line source for a tripped circuit breaker or other fault.
2. Open subcycle fuse(s) (if installed).

WARNING

1. Remove the line voltage from the controller before making resistance checks.

2. Inspect for damaged wiring or components before replacing the fuse.

Measure the resistance across the subcycle fuse(s). Replace any fuse found to be open (see section 5.5.4 for replacement procedure).

3. Incorrect fan voltage configuration. Measure the voltage across the fan leads. It should be approximately 120 VAC. If it is not approximately 120 VAC, check whether the correct voltage-configuration capacitor is installed on the fan assembly (see section 2.13.2).

5.3.6 Step 6—Check for Proper Control of Output to the Load

5.3.6.1 Introduction

Connect a load device across the controller **LOAD** terminals, as shown in figure 5–2 (for 664F) or 5–3 (for 664G/K).

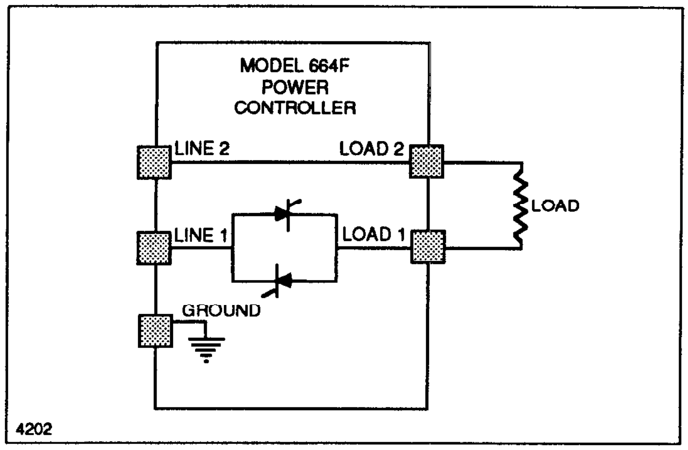


Figure 5–2. Load connections for 664F power controller.

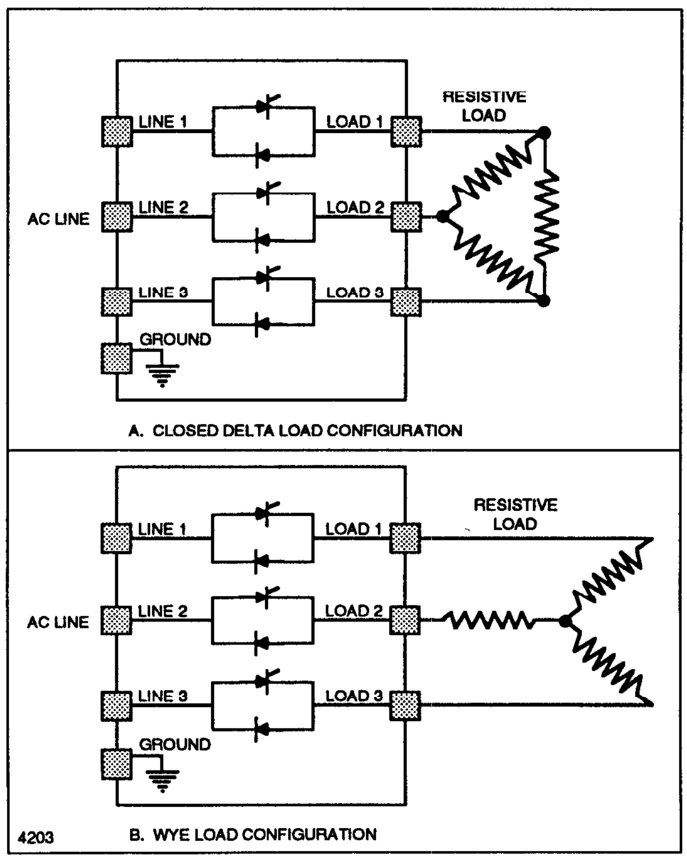


Figure 5–3. Load connections for 664G/K power controllers.

Vary the level of the control signal while monitoring the controller's output to the load. Measure the voltage across each pair of **LOAD** terminals with an AC voltmeter. Also observe the load device to ensure that power is being received properly.

The power to the load should vary smoothly across the full output range being used. If it does not, perform the checks described in the following subsections of section 5.3.6.

5.3.6.2 Step 6A—Check AC Line Source

Measure the voltage across the **LINE** terminals with an AC voltmeter. If the correct voltage is not present, check the AC line source for a tripped circuit breaker or other fault.

If the controller is a model 664G/K and its output level jumps suddenly as the level of the control signal is increased, the AC line connections may be out of sequence.

1. Remove line voltage from the controller.
2. Reverse any two connections to the **LINE** terminals.
3. Reapply line voltage.
4. If proper power control is achieved, retain the new connections. Otherwise, restore the connections as they were previously and continue with this checkout procedure.

5.3.6.3 Step 6B—Check Subcycle Fuse(s)

Measure the resistance across each subcycle fuse. Replace any fuse that is open (see section 5.5.4 for replacement procedure).

5.3.6.4 Step 6C—Check Whether the E5 Input is Triggered (ICT Tripped)

Measure the voltage between the **E5** and **COM** terminals of the phase angle firing circuit module (figure 3–12) or phase angle control module (figure 3–13) It should be approximately 6.5 to 7.6 volts. Shorting the **E5** terminal to **COM** triggers the firing circuit module's disable circuit.

If improper voltage is found at terminal **E5**, continue with this checkout procedure.

5.3.6.5 Step 6D—Check the Control Signal

1. Verify that a control signal of the correct polarity and level is reaching the firing circuit **INPUT** + and – terminals. To do so:
   A. Disconnect the sensor (thermocouple, etc.) or other normal control-signal source, and in its place connect a source that can provide a test signal of the proper type (voltage or current) and level.
   B. Using a milliammeter (see figure 5–4) verify that a 4–20 mA control signal of the proper level and polarity is reaching the firing circuit's **INPUT** – and + input terminals. Be sure to check for reversed control signal polarity and for open or intermittent connections caused by loose or damaged wiring.

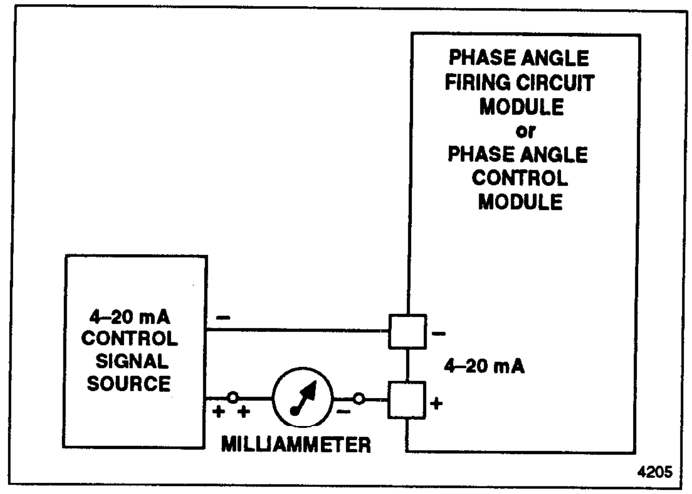


Figure 5–4. Control signal check.

Repair or replace the control signal source or wiring as needed.

NOTE

Be sure to reconnect the control-signal source, observing proper polarity, after you finish this step.

2. Verify that the control signal **SPAN** potentiometer is set correctly, as described in section 2.14.

5.3.6.6 Step 6E—Check the ENABLE 1/2/3/4 Circuit

Check whether the **ENABLE** terminal **1/2/3/4** circuit is open as follows:

1. Remove line voltage from the controller and disconnect one of the control signal leads from the **INPUT** + and – terminals of the firing circuit module (see figure 5–5A or 5–5B).
2. Check the **ENABLE** terminals **1**, **2**, **3**, and **4** circuit as follows:
   A. If only the **ENABLE 2** and **3** terminals are used (see figure 5–5A), check for an open **ENABLE** jumper, ICT circuit, or thermostat circuit by measuring the resistance between **ENABLE** terminals **2** and **3**.
   B. If all four **ENABLE** terminals are used (see figure 5–5B), check for an open circuit between **ENABLE** terminals **1** and **2** (**ENABLE** jumper or thermostat circuit) and between **ENABLE** terminals **3** and **4** (enable/disable switch or ICT option).
   C. Check all wiring terminations for tightness and good electrical contact.
   D. Check all wiring for continuity.
   E. Check the thermostat for proper operation. If the thermostat circuit is open and the controller was in

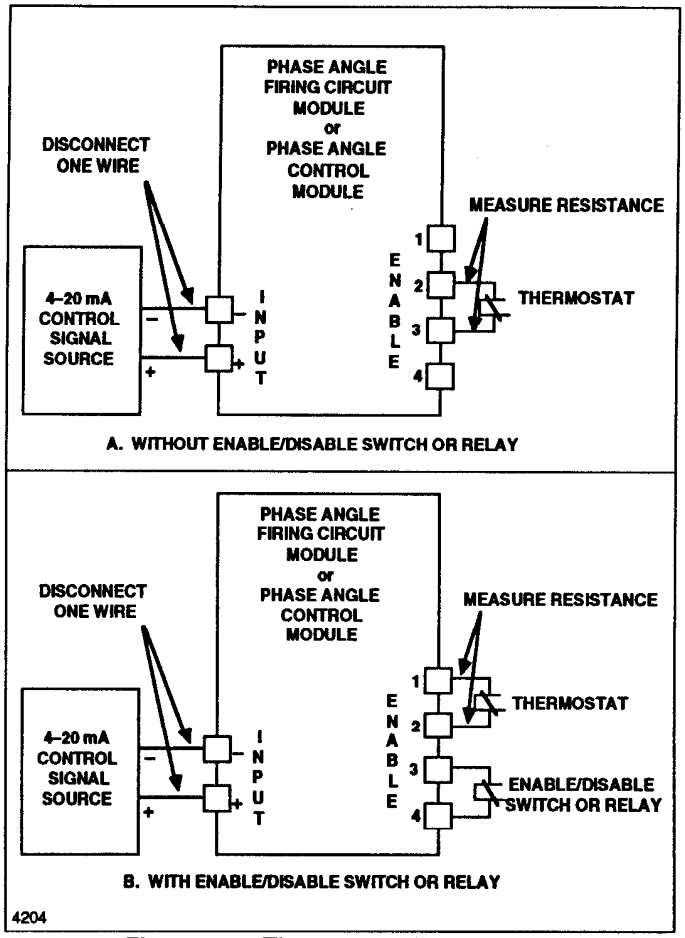


Figure 5–5. Thermostat circuit check.

operation recently, the heatsink may be overheated to the point the thermostat has opened. Allow sufficient time for the heatsink to cool to its normal operating temperature. If the thermostat is operating properly, it will reclose when its temperature reaches approximately 140°F (60°C). If the thermostat does not reclose properly, replace it (see section 5.5.5 for procedure).

If a malfunction is found in the ICT circuit, replace the current module (see section 5.5.6 for procedure).

If the customer-supplied enable/disable switch is open, replace it.

5.3.6.7 Step 6F—Check Load and Load Connections

Check the load and load connections as follows:

1. Remove the line voltage from the controller.
2. Disconnect the load's wiring from the controller's **LOAD** terminals.
3. Using an ohmmeter, check the load and the load wiring for defects or failure.

5.3.6.8 Step 6G—Check SCR Module

Check for a shorted SCR module as follows:

1. Remove line voltage from the controller.
2. Measure the resistance between the **LINE** terminal and **LOAD** terminal of each SCR module in both directions (i.e., measure the resistance once and then reverse the meter leads and measure the resistance again).

Replace any SCR module (see section 5.5.1 for replacement procedure) for which the resistance reads zero ohms in either measurement.

5.3.6.9 Step 6H—Check Firing Circuit Fuses and Gate Connections

Check for an open firing circuit fuse or open gate connection, as follows:

CAUTION

To ensure that ohmmeter current does not blow a fuse, do not set the ohmmeter to its lowest range.

1. Remove the line voltage from the controller.
2. Using an ohmmeter, measure the resistance across each firing circuit fuse. If a firing circuit fuse is open, also check for an open or intermittent gate connection to the SCR module. An open gate connection will cause the firing circuit fuse to blow. If a firing circuit fuse blows repeatedly and its SCR's gate connections have been verified, an SCR in the SCR module associated with that fuse has failed in the open condition. Replace that SCR module (see section 5.5.1 for replacement procedure).

5.3.6.10 Step 6I—Check SCR Wiring Continuity

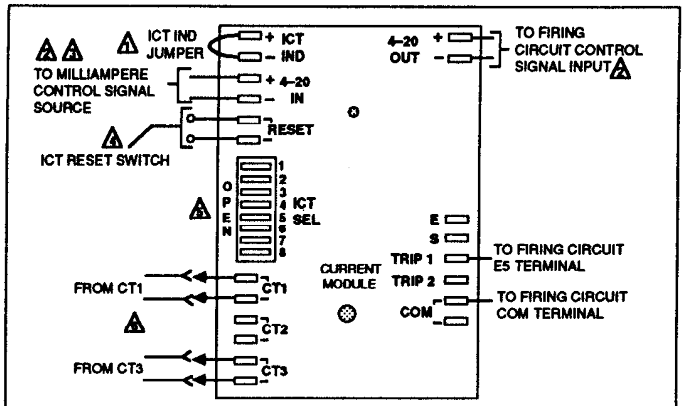
Check all wiring between the terminals of the phase angle firing circuit module or phase angle control module and the terminals of the controller's SCR module(s).

5.3.6.11 Step 6J—Check the Current Limiting Adjustment and Connections

If the current limiting feature of the optional current module (figure 5–6) is used, check whether the current limiting is correctly connected or adjusted. See section 2.10.3.

5.3.6.12 Step 6K—Check for Defective Load Feedback Signal

The phase angle firing circuit module or phase angle control module requires an isolated load feedback signal at the module's **FB INPUT** terminal. Either internal feedback or external feedback may be used (see figure 2–9). An optional current module is the most commonly used source for external feedback.



⚠ ICT IND JUMPER MAY BE REPLACED BY CUSTOMER-SUPPLIED REMOTE INDICATOR.
⚠ CONNECT + TO +, AND – TO –.
⚠ IF AN INPUT MODULE IS PRESENT, THE INPUT MODULE IS FACTORY CONNECTED TO THE CURRENT MODULE 4–20 mA IN TERMINALS. OTHERWISE, THE CUSTOMER-SUPPLIED MILLIAMPERE CONTROL SIGNAL CONNECTS TO THE CURRENT MODULE 4–20 IN TERMINALS.
⚠ ICT RESET SWITCH IS CUSTOMER-SUPPLIED.
⚠ ICT SEL SWITCH SETTINGS.
⚠ NO WIRING POLARITY IS REQUIRED FOR CURRENT TRANSFORMER CONNECTIONS (CT1, CT2 AND CT3) (DEPENDS ON NUMBER OF PHASES).
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Figure 5–6. Current module connections.

Verify correct load feedback as follows:

1. Ensure that a suitable feedback source is being used and that the feedback signal is correctly connected and adjusted, (see section 2.10).
2. If external feedback is used, reconfigure the feedback input from external to internal feedback as described in section 2.10. Be sure to verify correct control signal input span adjustment (section 2.14).

   If proper operation is restored by replacing external feedback with internal feedback, the external feedback source or wiring is defective and should be repaired or replaced. If current feedback is used, see section 2.10.
3. Using a meter, monitor the controller's output to the load. If possible use a meter that measures the same characteristic that is detected by the feedback circuit (i.e., either average load voltage or average load current). Also measure the feedback voltage across the firing circuit **FB INPUT** and **COM** terminals.

   The feedback signal should change proportionately with the measured power controller output as the control signal is varied. The feedback signal is nominally 0–4 VDC, but the feedback signal span value depends on the desired control signal input span (see section 2.10). A feedback circuit malfunction is clearly indicated if a large feedback signal occurs with little or no measured power-controller output to the load.

5.3.6.13 Step 6L—Check for Defective Load Conditioning Jumper

NOTE
When used, a current module's current limiting signal also connects to the LD COND terminal.

If the load conditioning jumper on the phase angle firing circuit module or phase angle control module (figure 2–8) is installed incorrectly or makes intermittent connection, the controller may operate erratically or may not provide the desired load conditioning action.

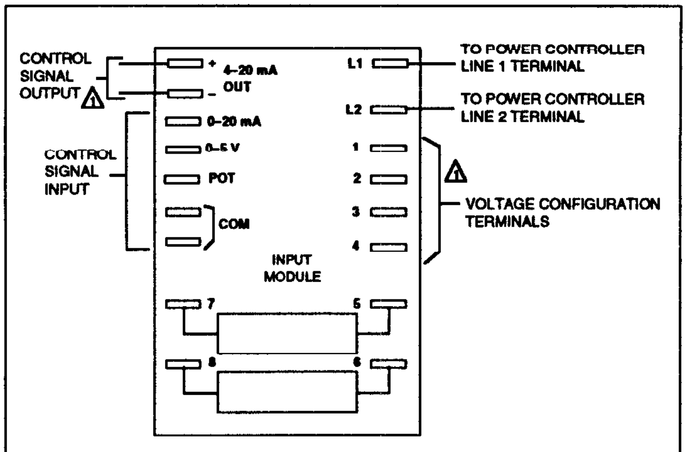
1. Verify that the load conditioning jumper is correctly installed. See section 2.7 for load conditioning configuration details.
2. Disconnect one of the control signal leads from the 4-20 mA terminals of the phase angle firing circuit module or phase angle control module. Using an ohmmeter, check for an open or intermittent load conditioning jumper connection. Repair or replace the load conditioning jumper as needed.

5.3.6.14 Step 6M—If the Control Problem Still Exists

If the power control problem still exists, replace the phase angle firing circuit module or phase angle control module (see section 5.5.3 for replacement procedure).

5.4 INPUT MODULE CHECKOUT PROCEDURE

The purpose of this checkout procedure is to determine the cause if the input module (figure 5–7) does not appear to operate properly.



⚠ CONTROL SIGNAL OUTPUT CONNECTS TO CURRENT MODULE IF A CURRENT CONTROL OPTION IS PRESET; OTHERWISE, CONTROL SIGNAL OUTPUT CONNECTS TO FIRING CIRCUIT CONTROL SIGNAL INPUT TERMINALS. IN ALL CASES, CONNECT + TO + AND – TO –.
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Figure 5–7. Input module electrical connections.

Before beginning the input module checkout procedure, confirm that the problem is not elsewhere, as follows:

1. Perform the general checkout procedure presented in section 5.3.
2. Check for reversed signal polarity at each control signal connection.

3. Check for loose or damaged wiring to and from the input module.

If necessary, repair or replace the control signal source and any connections to the input module as needed.

If the preceding steps do not isolate the problem, proceed with the input module checkout procedure as follows:

1. Check for correct input module line voltage configuration (see section 2.5.1).
2. Using an AC voltmeter, verify that line voltage is present at the input module's **L1**, **L2**, and (if a 664G/K) **L3** terminals (see figure 5–8).

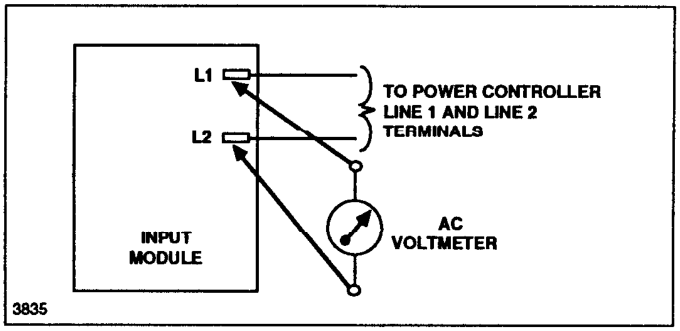

Figure 5–8. Input module line voltage verification.

3. Using a DC voltmeter or milliammeter (whichever is appropriate for the type of control signal being received), verify that the correct control signal is present at the input module terminals.
4. Using a milliammeter (see figure 5–9), verify that the correct 4–20 mA output signal is produced at the input module's **4–20 mA OUT** terminals when signal inputs from each of the signal input configurations shown in figure 5–10 is applied to the input terminals of the input module.

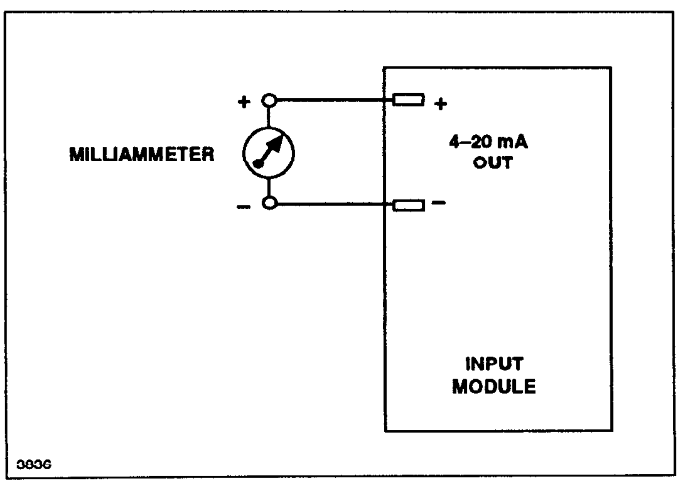

Figure 5–9. Input module 4–20 mA OUT signal verification.

If the input module does not produce the correct **4–20 mA OUT** signal when its input signal, line-voltage connections, and line voltage configuration have been verified, replace the input module (see section 5.5.7 for replacement procedure).

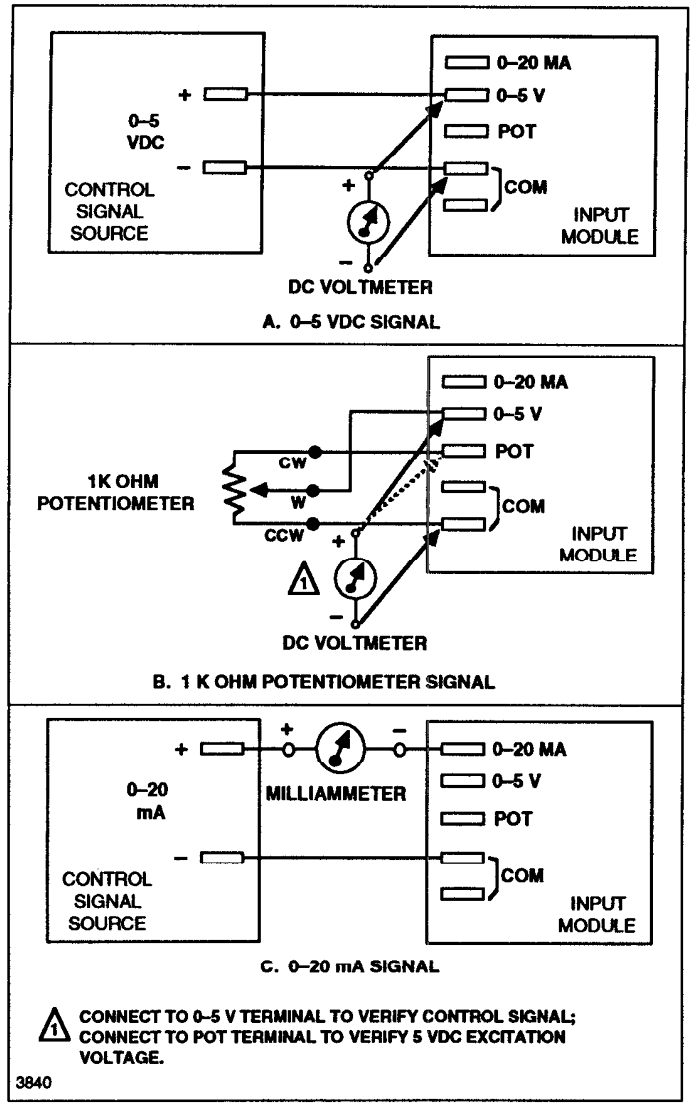

Figure 5–10. Input signal verification.

5.5 REPLACEMENT PROCEDURES

5.5.1 SCR Modules

To replace an SCR module (see table 5–1 for part number):

1. Remove line voltage from the controller.
2. Depending on the SCR module to be replaced, disconnect the firing-circuit leads from the SCR modules (see figures 5–11 and 5–12) as follows:
   A. Disconnect the SCR module's **K1**, **K3**, or **K5** lead from the **LOAD 1**, **LOAD 2**, or **LOAD 3** push-on terminal to which it is connected.

Table 5–1. Replacement SCR Modules

CONTINUOUS CURRENT RATING	664F PART NUMBER	664G & K PART NUMBER
35 A	KB062802-003	KB62790-003
50 A	KB062802-003	KB62790-003
70 A	KB062802-003	KB62790-003
90 A	KB062802-001	KB62790-001
125 A	KB062802-002	KB62790-002
175 A	KB062802-002	KB62790-002
250 A	KB062780-002	KB62781-002
300 A	KB062780-002	KB62781-002

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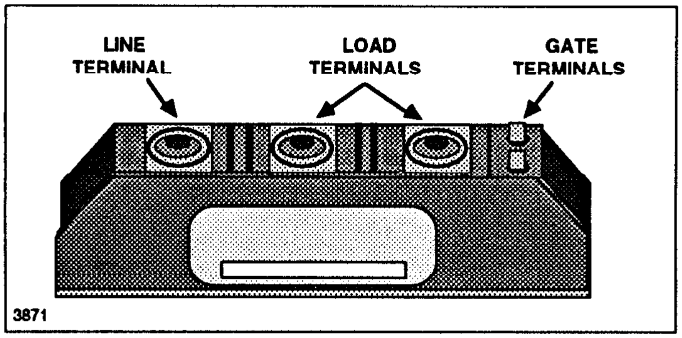

Figure 5–11. 35–175A SCR module containing two SCRs. SCR modules of the same ratings having only one SCR and a diode are identical except they have only one gate terminal.

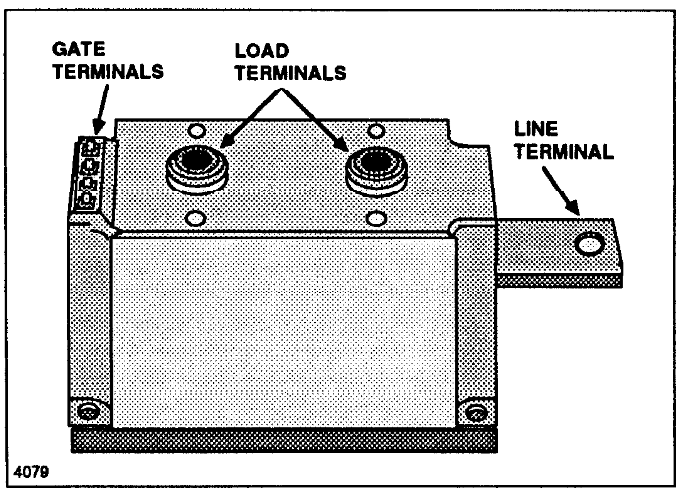

Figure 5–12. 250–300 A SCR module containing two SCRs. SCR modules of the same ratings having one SCR and one diode are identical except they have only two gate terminals instead of four.

B. Disconnect the SCR module's **K2**, **K4**, or **K6** lead from the **LINE 1**, **LINE 2**, or **LINE 3** push-on terminal to which it is connected.

C. Disconnect the firing circuit **G1** and **G2**, **G3** and **G4**), or **G5** and **G6** gate leads from SCR module terminals **G1** and **G2**, **G3** and **G4**, or **G5** and **G6** terminals to which they are connected.

3. Remove the SCR module's **LOAD 1** , **LOAD 2**, or **LOAD 3** connection.
4. Remove the SCR module's **LINE 1** , **LINE 2**, or **LINE 3** connection.
5. Remove the SCR module's mounting screws and associated spring washers.
6. Lift the SCR module off the heatsink.
7. Clean all traces of the previous heatsink thermal compound from the heatsink.
8. Apply a thin layer of heatsink thermal compound to the bottom of the replacement SCR module.
9. Install the replacement SCR module where the old one was located.
10. Replace the SCR module mounting screws:
    A. Be sure to install the conical spring washers as shown in figure 5–13.
    B. Torque the SCR module mounting screws for all SCR modules to 40–50 pound-inches (4.5–5.5 Newton-meters).

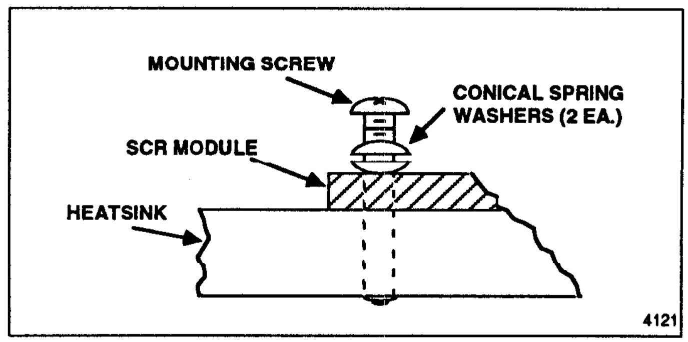

Figure 5–13. SCR module assembly mounting details. Be sure to install the two conical spring washers in series beneath mounting screw head as shown.

11. If the controller has an input module, reconnect the input module's **LINE 1** push-on terminal connection.
12. Depending on the SCR module replaced, reconnect the disconnected firing circuit gate leads to the SCR module as follows:
    A. Connect the **G1** lead to SCR module 1 terminal **G1**.
    B. Connect the **G2** lead to SCR module 1 terminal **G2**.
    C. Connect the **G3** lead to SCR module 2 terminal **G3**.
    D. Connect the **G4** lead to SCR module 2 terminal **G4**.
    E. Connect the **G5** lead to SCR module 3 terminal **G5**.
    F. Connect the **G6** lead to SCR module 3 terminal **G6**.
13. Depending on the SCR module replaced, reconnect the other disconnected firing-circuit leads to the SCR module as follows:

A. Connect the **K1** lead to a **LOAD 1** push-on terminal.
B. Connect the **K2** lead to a **LINE 1** push-on terminal.
C. Connect the **K3** lead to a **LOAD 2** push-on terminal.
D. Connect the **K4** lead to a **LINE 2** push-on terminal.
E. Connect the **K5** lead to a **LOAD 3** push-on terminal.
F. Connect the **K6** lead to a **LINE 3** push-on terminal.

14. Re-install the controller.

5.5.2 Firing Circuit Fuses

To replace a firing circuit fuse:

1. Remove line voltage from the controller.
2. Inspect the controller for damaged or loose SCR gate wiring before replacing the firing circuit fuse.
3. Remove the firing circuit fuse from its holder (see figure 5–14 for 664F or figure 5–15 for 664G/K) and install a replacement.

CAUTION

Replace the firing circuit fuse only with an AGC 1/4 A fast-acting fuse.

5.5.3 Phase Angle Firing Circuit Module or Phase Angle Control Module

To replace a phase angle firing circuit module or phase angle control module (see table 5–2 for part number):

1. Remove line voltage from the controller.

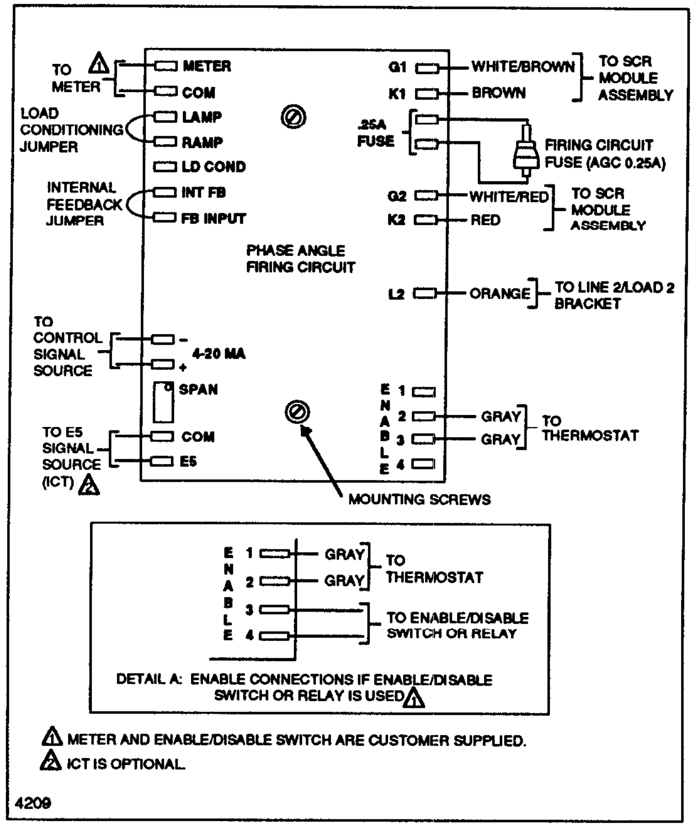

Figure 5–14. Model 664F phase angle firing circuit module connections.

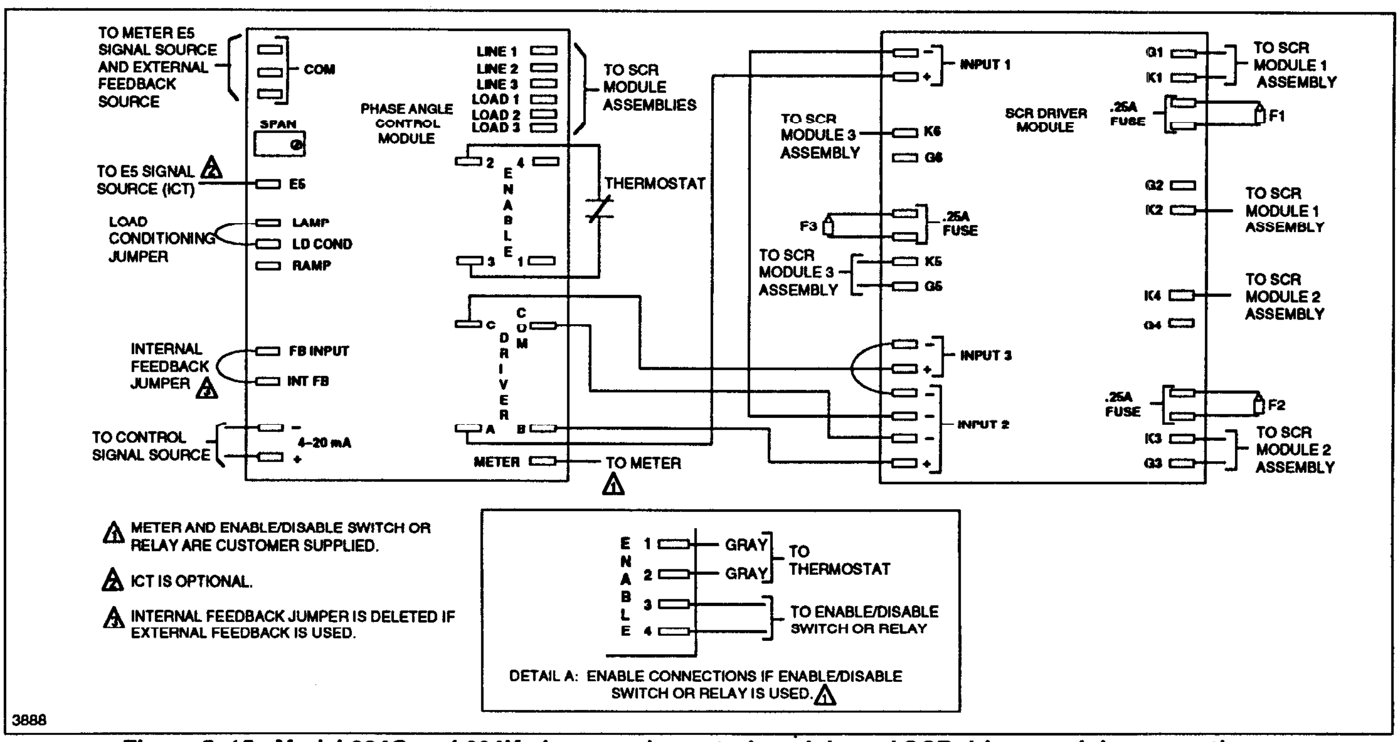

Figure 5–15. Model 664G and 664K phase angle control module and SCR driver module connections.

Table 5–2. Replacement Parts List

DESCRIPTION	PART NUMBER
Caution High Voltage Label	KA048319-000
Cover and Module Panel Mounting Screw (6-32 x 3/8 pan head screw with self-forming threads)	KB065023-001
Firing Circuit Fuse (AGC 1/4A)	KB062972-001
Model 664F Firing Circuit Module	OB070403-001
Model 664G Phase Angle Control Module	OC070395-001
Model 664K Phase Angle Control Module	OC073393-001
Firing Circuit and Option Module Mounting Hardware	
4-40 x 3/4 truss-head screw	KB065023-002
#4 flat washer	KA055029-002
Push-On Lug (for Firing Circuit and Line/Load Bracket Connections)	KB067427-001
SCR Driver Module	070398-001
SCR Driver Module Mounting Hardware	
#10 conical spring washer	KB055442-004
#10 flat washer	KB055310-027
Thermal compound	KA057842-000
Subcycle Fuse	See Table 5–3
Thermostat	KB070025-001
Mounting Bracket	
Bracket "A"	KB062775-001
Bracket "B"	KB062775-002
Fan	KC047118-001
Fan Capacitor	
208 VAC	KB062877-002
240 VAC (Requires both capacitors)	KB062865-001 KB062877-001
277 VAC	KB062877-001
380 VAC	KB062878-002
415 or 480 VAC	KB062878-001
600 VAC	KB062878-003
1 Turn 1K Potentiometer	KB067513-001
Knob	KA055844-002
10 Turn 1K Potentiometer	KB055769-004
Digital Dial	KA055819-000
Manual	664F/G/K
Schematic, 664F	OD070040-001
Schematic, 664G/K	OD070041-001
SCR Module	See Table 5–1

4200

2. Loosen the screws that secure the controller's cover plate.
3. Remove the cover plate and place it on its edge (see figure 5–16).
4. Note the locations of all push-on lugs on the module to be replaced (see figure 5–14 for 664F or figure 5–15 for 664G/K). Then disconnect them from the firing circuit module.

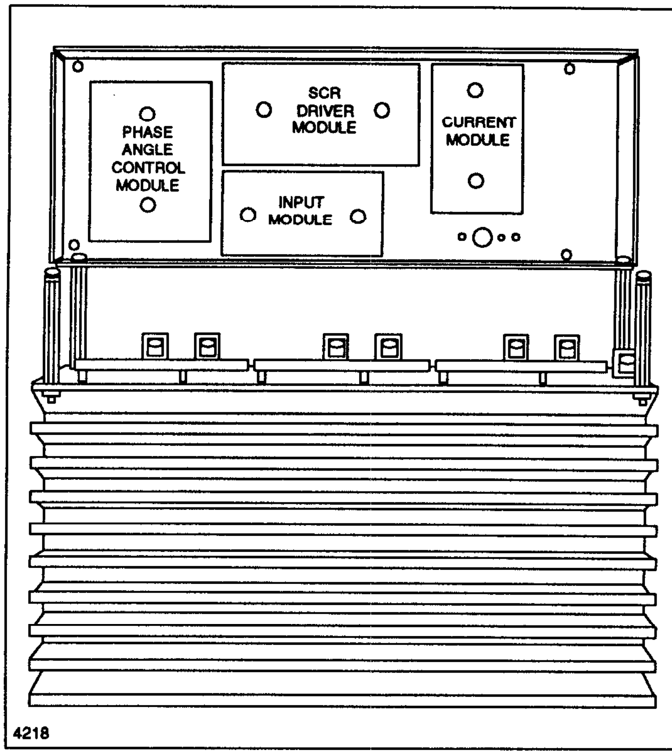

Figure 5–16. Model 664G/K controller with cover plate on edge for access to modules.

5. Remove the two module mounting screws and remove the module.
6. Install the replacement module and secure it in place with the mounting screws removed in step 5.
7. Replace all wiring push-on lugs removed in step 4.
8. Reconnect line voltage to the controller.
9. Set the control signal input **SPAN** potentiometer as described in section 2.14.
10. Replace the cover plate and secure it in place with the screws loosened in step 2.

5.5.4 Subcycle Fuse(s)

To replace a subcycle fuse (see table 5–3 for part number):

1. Remove line voltage from the controller.
2. Inspect all wiring and components for damage and replace if necessary.
3. Remove the subcycle fuse mounting screws and lift the fuse off its standoffs (see figures 2–5 and 2–6).
4. Install a replacement subcycle fuse.
5. Replace and tighten the fuse mounting screws.

5.5.5 Thermostat

To replace a thermostat (see table 5–2 for part number):

1. Remove line voltage from the controller.
2. Remove the perforated shield from the end of the heatsink near the thermostat.

Table 5–3. Replacement Subcycle Fuses

CONTINUOUS CURRENT RATING	PART NUMBER	
	500 V FUSES	600 V FUSES
70 A	KB057525-008	KB057519-008
90 A	KB057525-009	KB057519-009
125 A	KB057525-001	KB057519-010
175 A	KB057525-010	KB057519-011
250 A	KB057525-011	KB057519-012
300 A	KB057525-003	KB057519-007

4126

3. Remove the screws that secure the thermostat to the heatsink.
4. Lift the thermostat off the heatsink.
5. Pull the push-on terminals of the thermostat wires off the thermostat's terminal lugs.
6. Push the push-on terminals of the thermostat wires onto the replacement thermostat's terminal lugs.
7. Remove all traces of the previous thermal compound from the heatsink. Make certain the surface on which the thermostat will be mounted is clean and smooth.
8. Apply a thin layer of thermal compound to the bottom of the replacement thermostat.
9. Place the thermostat on the heatsink and tighten the mounting screws firmly.
10. Reinstall the perforated shield on the end of the heatsink.
11. Reapply line voltage to the controller.

5.5.6 Current Module

To replace the current module (see table 5–2) for part number):

1. Remove line voltage from the controller.
2. Loosen the screws that secure the controller's cover plate.
3. Remove the cover plate and place it on edge (see figure 5–16).
4. Note the settings of the **ICT SEL** switches and the locations of all push-on lugs on the current module (see figure 5–6). Then disconnect all wiring from the current module.
5. Remove the two module mounting screws and their washers.
6. Remove the current module from its mounting location.
7. Place the replacement module in the location from which the old current module was removed.
8. Reinstall the two module mounting screws and washers.
9. Reconnect all wiring disconnected in step 4.
10. Replace the cover plate and secure it in place with the screws loosened in step 2.
11. Reconnect line voltage to the controller.

5.5.7 Input Module

To replace the input module (see table 5–2 for part number):

1. Remove line voltage from the controller.
2. Loosen the screws that secure the controller's cover plate.
3. Remove the cover plate and place it on edge (see figure 5–16).
4. Note the locations of all push-on lugs on the input module. Then disconnect all wiring from the input module.
5. Remove the two module mounting screws and their washers.
6. Remove the input module from its mounting location.
7. Place the replacement module in the location from which the old current module was removed.
8. Reinstall the two module mounting screws and washers.
9. Reconnect all wiring disconnected in step 4 (see figure 5–7).

NOTE

Be sure to reinstall the input module line-voltage configuration jumper where it was connected previously.

10. Replace the cover plate and secure it in place with the screws loosened in step 2.
11. Reconnect line voltage to the controller.

5.6 REPLACEMENT PART NUMBERS

The part numbers for the most common field-replaceable parts are listed in tables 5–1, 5–2, and 5–3. To order any part by telephone, contact the Research, Inc. Customer Service department at 612-941-3300. Be sure to have a purchase order number when you call.

If you have technical questions about these or any other parts, or if you need technical assistance in solving a problem, contact the Research, Inc. Field Service department at 612-829-8317.

NOTES